Despite a small sample size (n = 24), the total suspended sediment load was moderately predicted by turbidity ($F_{1,22} = 17.34$, $p < 0.01$, $R^2 = 0.44$ on log-transformed variables; Fig. 3). The addition of the percentage of organic suspended sediments did not improve the ability of turbidity to predict the concentration of total suspended sediments ($t = -1.032$, $P = 0.31$). The percentage of organic suspended sediments was weakly correlated with turbidity ($R = 0.27$). In this study, the US EPA (1986) recommended maximum turbidity of 25 NTU was exceeded on 2 of 6 sampling events (Jan and Apr 2003) in the North and South Forks of Caspar Creek, and on 1 of 6 sampling events (Nov/Dec 2003) in Little Lost Man and Upper Prairie creeks.

Microbial respiration was greater in association with organic (mean = 0.39 mg O_2 consumed $min^{-1}L^{-1}$, SD = 0.10) than inorganic (mean = 0.21, SD = 0.23) suspended sediments (1-tailed *t* test, df = 23, $p < 0.01$). Per mg of organic sediments, respiration differed between high and low flow periods ($F_{1,16} = 7.28$, $P = 0.02$, $R_2 = 0.36$), but not among sites or the interaction of site and flow (all $P > 0.73$). Respiration was greater during periods of low flow (mean = 0.22 mg $O_2 min^{-1}$ mg organic sediments^{-1}, SD = 0.16) than high flow (mean = 0.08, SD = 0.10). In contrast, concentrations of chlorophyll *a* differed among sites ($F_{3,16} = 4.22$, $P = 0.48$), but not among flow categories or the site*flow interaction (all $P > 0.29$). Chlorophyll *a* concentration in suspended sediments was greatest in Upper Prairie Creek, where canopy coverage was least (Fig. 4). We observed a negative correlation between chlorophyll and respiration at the same site ($R = -0.48$, n = 24, Fig. 5).

MACROINVERTEBRATES

Characteristics of the suspended load were not detectably related to macroinvertebrate assemblages. Macroinvertebrate taxa that were collected from the study sites are listed in Appendix 1. Contrary to our hypothesis, biomass of filtering collectors was not related to either mass of organic suspended sediments ($R^2 = 0.00$, $P = 0.93$) or to percentage of organic suspended sediments ($R^2 = 0.05$, $P = 0.31$). Nor did data suggest relationships between mass or percentage of organic suspended sediments with biomass of scrapers, total collectors (gathering and filtering collectors), or the entire macroinvertebrate assemblage (all $R^2 < 0.10$, $p > 0.20$). Mass of the total suspended load (inorganic plus organic) also did not explain variation in biomass of macroinvertebrate assemblages.

Biomass of filtering collectors was modestly positively related to the chlorophyll concentration of the suspended load ($R^2 = 0.20$, $P < 0.03$), but not to microbial respiration ($R^2 = 0.01$, $P = 0.61$). Filtering collector biomass also differed among sites ($F_{3,16} = 15.92$, $P < 0.01$), flow periods ($F_{1,16} = 14.76$, $P < 0.01$), and the interaction of site and flow ($F_{3,16} = 13.46$, $P < 0.01$). During low flow periods, differences in filtering collector biomass among sites were slight (Fig. 6). During high flow periods, filtering collector biomass was substantially higher in Upper Prairie Creek than in the other three sites. Larvae of the caddisflies *Chimarra* (Philopotamidae) and *Hydropsyche* (Hydropsychidae) were the primary contributors of filtering collector biomass at all of the sites. Biomasses of scrapers, total collectors, and all macroinvertebrates were not affected by site, flow, or their interaction (all $P > 0.06$).

The percentage of drifting macroinvertebrates (drift/ benthic + drifting invertebrates), by mass, was modestly related to the suspended load of organic particles ($R^2 = 0.41$, $P < 0.01$; Fig. 7), but not to the total suspended load.

FISH

Gut fullness of juvenile salmonids was not detectably related to turbidity, mass of organic suspended sediments, or percentage of organic suspended sediments (all $R^2 < 0.03$, $P > 0.43$). Gut fullness did not differ between sites, flow, or with a site*flow interaction (all $P > 0.54$). An average of 9 diet samples (SD = 3) were analyzed from each site on each date, with the exception of the February 2003 sample from North Fork Caspar Creek, when no fish were captured. Fish from which diet samples were obtained ranged in fork length from 70 – 144 mm. Over all dates and sites, gut fullness averaged 3.6 mg of prey per gram of fish (SD = 3.5, range = 0.25 – 14.96, n = 206). Fish diets were dominated by non-feeding invertebrates (pupae and adults of aquatic origin, as well as terrestrial taxa), and filtering collectors were the least represented functional feeding group by biomass (Fig. 8). Filtering collectors did not comprise more than 3% of any diet sample. Macroinvertebrate taxa identified from salmonid gut contents are described in Appendix A.

Feeding activity of juvenile salmonids was not related to turbidity, total suspended sediment load, or suspended organic sediments (all $R^2 < 0.12$, $p > 0.10$). Nor did feeding rates of fish vary consistently among sites or dates. Averaged over all sites and dates, fish were observed to make 0.5 captures per fish per 3 minute observation (SD = 0.3, range = 0.07 - 1.07, n = 24). Total number of fish observed within 10 pools of each reach on each date averaged 72 (SD = 49, range = 2-186), but fewer than 10 fish per reach were detected in January 2003 in North Fork Caspar and Little Lost Man creeks, and in April 2003 in South Fork Caspar Creek. However, at least some feeding activity was observed at each site on each of the sampling dates, at turbidities ranging from 4 – 123 NTU (Table 2).

Length-weight relationships for coho salmon among sites differed between October and June. In October, slopes of ln-transformed length-weight regression lines differed among sites (site*length interaction, $F_{3,214} = 2.68$, $P = 0.05$; Fig. 8A.), indicating that the effect of site on fish growth differed with fish size. In June, both slopes (site* length interaction $F_{3,207} = 0.47$, $P = 0.70$) and intercepts ($F_{3,207} = 0.58$, $P = 0.62$) of the length-weight relationships were similar among sites (Fig. 8B).

FLUME EXPERIMENT

Prey capture by individual steelhead in lab feeding trials differed between high and low total suspended sediments ($F_{1,24} = 48.70$, $P < 0.01$), but not among levels of organic: inorganic ratios ($F_{2,24} = 2.40$, $P = 0.11$). The interaction of total suspended sediments and organic: inorganic ratios was also not significant ($F_{2,24} = 0.08$, $P = 0.92$). Steelhead consumed twice as many prey at low than at high suspended loads (Fig. 10A). While average prey consumption appeared to be lower at a fraction of 25% than at 50 or 75% organic suspended particles (Fig. 10B), suggesting a greater deleterious impact of inorganic than organic materials on feeding efficiency, the difference in means was insufficient to override individual variation.

DISCUSSION

The high variability in concentrations and percentages of organic seston that we observed among sampling dates and sites likely reflects sample sizes too small to reveal any patterns that may exist. Variability in both total and organic suspended loads was greater during periods of higher than lower flows (e.g., Fig. 2). This may be attributable to differences in seston concentrations and composition that have been observed between leading and trailing edges of individual storm events. Several studies have reported increases in seston concentration during the rising limb of a storm events, and that peak concentrations usually occur before peak discharge (e.g. Webster et al. 1990, Wallace et al. 1991). Our sampling was limited because of logistical constraints in sampling stream biota concurrently with suspended sediments, and an inability to sample or observe biota during large storms. Finer resolution of temporal variability in suspended load concentrations and composition is best accomplished with automated sampling devices such as ISCO samplers. As a separate part of this study, we analyzed the organic composition of ISCO-taken storm samples collected at the study sites by the US Forest Redwood Sciences Laboratory (North and South Forks of Caspar Creek) and Redwood National and State Parks (Little Lost Man and Upper Prairie creeks) personnel. Preliminary analysis of this larger dataset supported a finding that organic content was higher on early rising hydrograph limbs, as well as on late falling limbs. Organic materials also tended to be more abundant in water samples collected during early-season storms. On an annual cumulative basis, most organic flux occurred during a few days of high flow. By weight, the inorganic component of suspended sediment dominated the annual sediment flux in three of the catchments, but organics represented more than half the suspended sediment load in the most pristine old growth redwood stream (Upper Prairie Creek, unpublished data). This is consistent with a finding of Webster and Golladay (1984) that percent ash (i.e., inorganic fraction) was positively related with long-term forest disturbance. However, they also reported a higher mass of organic seston in summer than in winter, which they attributed to biological activity. This is contrary to our finding (from point samples) of higher organic loads in winter high flows. It is important to note that automated suspended load sampling is usually terminated at low flows, which have very low turbidity values, at times when essentially the only particles in suspension are organic. Excluding this seasonal difference will always give an annual bias to inorganic sediment in the suspended load. This is particularly true if all comparisons are on a mass per volume basis.

While automated sampling should be employed to better characterize temporal variability in both organic and inorganic components of the suspended load, monitoring programs and analytic procedures currently in place may require design modifications. For example, the USGS National Water Quality laboratory considers sediment concentrations of <10 mg/L to be below reliable analytical capabilities. Thus a larger volume of sampled water, or combining of filters, may be required to increase sediment volumes. Estimation of organic content requires that sediment samples be processed immediately or kept chilled and in the dark to reduce microbial respiration or photosynthesis. Size fractions chosen for particle size analysis should be standardized among laboratories to allow for site comparisons.

Because organic particles remain in suspension longer than similar-sized inorganic sediments, we expected that the ability of turbidity to predict suspended sediment concentrations would be improved by the addition of percent organics to the model. Although conclusions are limited by a small sample size, our data did not support this expectation. However, we also note that assessing the relative roles of inorganic vs. organic particles in contributing to turbidity or suspended sediment concentrations is problematic when done on a mass per volume basis. Such a comparison needs to be made on a volume per volume basis (e.g. number of particles in a given size range per volume of water). After roughly separating the organic from inorganic particles by decanting, number of particles per volume could be determined by running samples through a Coulter counter. To our knowledge, this has never been done. Until such analyses are conducted, it will be difficult to accurately evaluate the relative importance of the organic portion of the suspended load to stream biota.

Our finding of greater masses of organic and inorganic particles in larger (>1 - 1,000 µm) than smaller (0.7 – 1.0 µm) size classes is inconsistent with literature reports that the majority of seston is in the smallest size fractions. Sedell et al. (1978) found that > 70% of particulate organic matter in transport was in the size range of 0.45 – 53 µm. In setting the lower limit of our analyses at 0.7 µm, we likely missed the bulk of sedimentary particles, and conclusions regarding size-class partitioning are likely immaterial. In this study, separation of size classes for analysis was constrained by filter availability and small volumes of our water samples. A more meaningful separation would distinguish size classes based on ranges of sizes used by differing taxa of filtering collectors, or that differ in nutritional quality. Wallace et al. (2006) suggested a minimum of three size fractions: 0.45 – 250 µm, 250-500 µm, and 500 - 1000 µm. They added that, because particle-size distributions are strongly skewed toward smaller size fractions, larger quantities of water (i.e. > 1 L) need to be sampled to obtain accurate concentration estimates for seston particle sizes > 250 µm.

Seston particle size rather than quality serves as the basis of food selection for macroinvertebrates in the collector functional group, including both gathering collectors (e.g. Mattingly et al. 1981, Ward and Cummins 1978, Ward and Cummins 1979) and filtering collectors. Because of this, it is likely that concentrations of organic seston or its surrogate turbidity will predict the food supply and abundance of collectors (especially filtering collectors) only when the quality of the suspended material is taken into account. The correlation we observed between biomass of filtering collectors with chlorophyll *a* concentrations of suspended sediments and biomass of filtering collectors, but not with organic seston loads, is a case in point. Because macroinvertebrate abundance generally reflects variation in environmental conditions over periods of at least the previous several weeks or longer, it is also likely that relationships with suspended sediment composition would be best detected by time-integrated rather than point sampling.

Taxonomic richness and overall abundance of filtering collectors at our study sites, and in other small watersheds that we have sampled in coastal northern California, was quite low relative to other regions. Filter-feeders at our sites were limited to sparse populations of *Hydropsyche* (Trichoptera: Hydropsychidae), *Chimarra* (Trichoptera: Philopotamidae), *Tanytarsini* (Diptera: Chironomidae), and blackflies (Simuliidae). In other river systems, filter-feeders also include, among others, representatives of the trichopteran families Psychomiidae and Polycentropidae, representatives of other dipteran families including Dixidae and Culicidae, as well as bivalve mollusks and freshwater polychaetes. The filtering functional group plays an important role in stream ecology, particularly in tightening the spirals of particulate organic matter with an increase in efficiency to the entire ecosystem (Wallace et al. 1977). The seeming paucity of filtering collectors in northern California streams may reflect an overriding limitation from high suspended loads of inorganic sediments.

Results of our flume experiment also suggested that fish feeding may be more adversely affected by suspended inorganic than organic particles. However, a revised experimental design that compared relative roles of organic and inorganic particles on a volume per volume basis, as discussed above, would be required to strengthen this conclusion. Our field observations of salmonid feeding activity and analyses of gut fullness suggest that turbidity does not inhibit salmonid feeding to the extent often assumed, at least within the range of turbidities encountered. Similar findings have been recently reported (DeYoung 2007, White and Harvey 2007).

We suggest that a more complete understanding of stream biotic response to suspended sediments will require the development of a conceptual model that highlights the importance of, and link between, the suspended and deposited organic particulate resources. Both particle size partitioning among collector macroinvertebrate taxa and the quality of particles in different size ranges need to be incorporated in such a conceptual model. One contrast could be between: 1) the more immediate effect of the ratio of organic to inorganic particles in suspension (transport) and the size and quality of those organic particles on filtering collector populations; and 2) the effect of the ratio of the organic to inorganic particles deposited in the sediments (bed load), again by size and quality, on the gathering collectors. Over longer timeframes, but not during high flows, the amount of deposited organic particles in storage would exceed those in suspension. The longer residence time of organic particles in storage would be expected to provide a larger and better conditioned particle resource, which is utilized by gathering collectors. The organic particulates stored in the sediments would represent the largest year-round, utilizable food resource for macroinvertebrates, except for the period of leaf litter drop in the autumn. For open streams, and in the early spring and late autumn in those streams with a heavy deciduous riparian cover, an algal food base may exceed the stored particulate organic resource in importance. But, even in such streams, on an annual basis the sedimentary organics may dominate. The ubiquitous and abundant organic particulate food resource available to macroinvertebrates on and in the sediment, coupled with a lack of specialized feeding behaviors to harvest the fine particulate resource, likely explains the usual dominance by the gathering collector functional feeding group in stream invertebrate assemblages.

Future research should first establish the linkage between the quantity and quality of organic particles in transport and in storage in a stream with the macroinvertebrate taxa that are supported by this organic particulate resource. Establishing the relative importance of these taxa as food for salmonids can then provide the linkage between the quality and quality of the suspended load or turbidity with the abundance and growth of stream salmonids.

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TABLE 1. Characteristics of stream study sites.

Basin	**Caspar Creek**		**Redwood Creek**	
Site	North Fork	South Fork	Upper Prairie	Little Lost Man
Watershed area (km^2)	3.94	4.24	10.52	8.96
Stream gradient (%)	1.5	0.8	1.0	2.6
Elevation (m)	86-317	48-329	85-432	15-591
Dominant overstory riparian vegetation	2nd growth redwood	red alder	old- growth redwood, Douglas-fir forest	old- growth redwood forest
Canopy cover (%)	87	91	80	83
Dominant substrate	cobble, pebble	pebble	pebble, sand	cobble, pebble

TABLE 2. Discharge, turbidity, mass of total suspended sediments (TSS), and percent by mass of TSS comprised of organic particles on sampling dates in North Fork (NFC) and South Fork (SFC) Caspar Creek, and in Little Lost Man (LLM) and Upper Prairie (UPC) creeks.

Site	Date	Discharge (cfs)	Turbidity (NTU)	TSS (mg/L)	Percent Organic
NFC	10/26/02	0.10	4	6.54	5.35
NFC	02/15/03	7.42	123	17.35	13.96
NFC	04/19/03	27.1	80	15.45	13.70
NFC	06/09/03	7.70	16	15.86	0.56
NFC	8/21/03	0.32	5	3.81	1.35
NFC	11/20/03	0.42	6	2.03	0.01
SFC	10/25/02	0.04	4	8.71	3.06
SFC	01/08/03	4.14	104	31.47	26.70
SFC	05/16/03	21.3	46	24.70	19.58
SFC	06/27/03	3.90	18	22.09	2.05
SFC	08/03/03	0.30	5	2.79	1.69
SFC	11/03/03	0.39	2	9.03	0.03
LLM	10/20/03	0.02	4	10.02	9.06
LLM	01/08/03	28.30	9	6.82	5.14
LLM	5/06/03	31.20	8	7.79	3.46
LLM	06/27/03	4.00	7	11.21	1.02
LLM	08/17/03	1.01	5	1.86	0.76
LLM	11/28/03	22.00	30	27.10	6.78
UPC	10/28/02	2.10	4	5.07	3.19
UPC	01/08/03	16.50	6	3.49	3.19
UPC	04/01/03	41.80	10	5.64	5.46
UPC	06/16/03	10.46	5	12.45	7.92
UPC	08/15/03	6.54	6	6.3	4.64
UPC	12/10/03	41.84	53	55.6	10.11

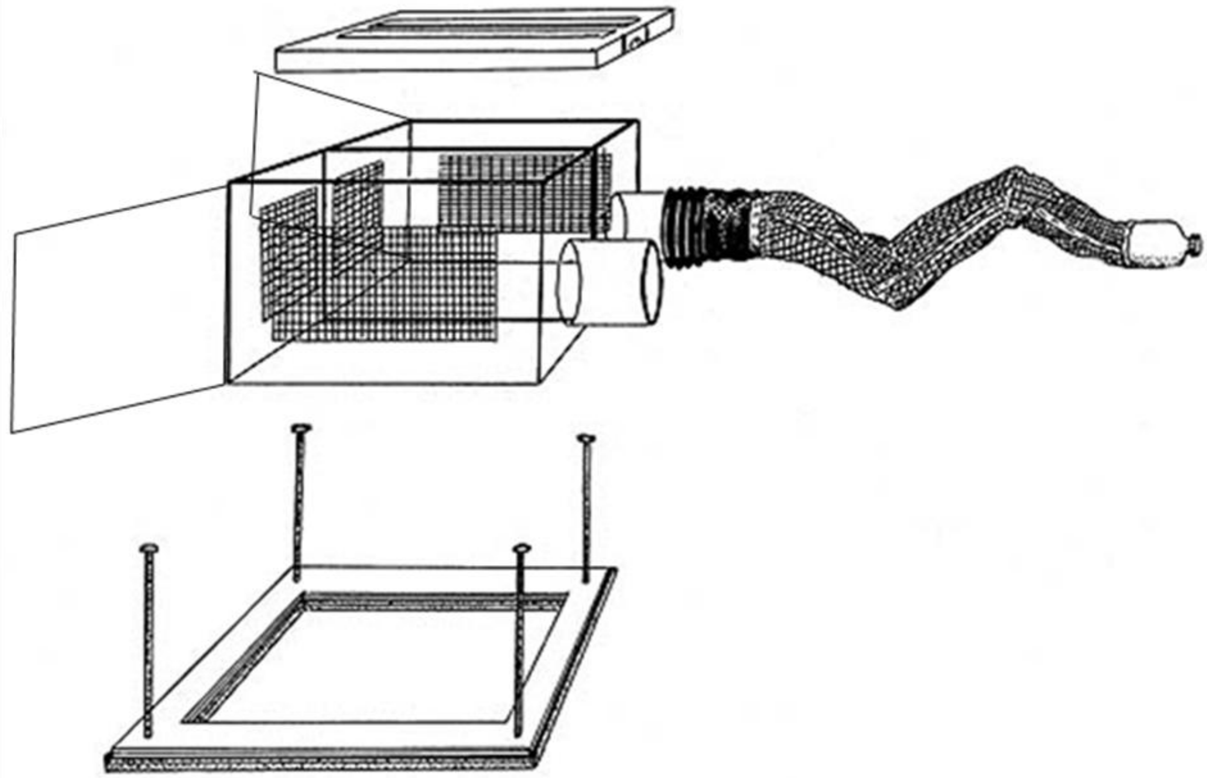

Figure 1. Drift-benthic partitioning sampler used in collecting aquatic macroinvertebrates. The sampler is divided with a central partition that allow for replicated comparison of drift and benthos collected from the same confined area. Panels of 250 µm mesh netting on the front, sides, and top allow flow to pass through the box. Wing flanges attached to the leading edge of the box ensure flow through the box. Drift nets positioned over the ports at the back of the box are 250 µm mesh wind-sock type, 0.75 µm in length. Samples retrieved from nets collect animals drifting from a known area of bottom during the sampling period; subsequent samples collected by disturbing bottom sediments into the nets sample animals that did not drift during the sampling period.

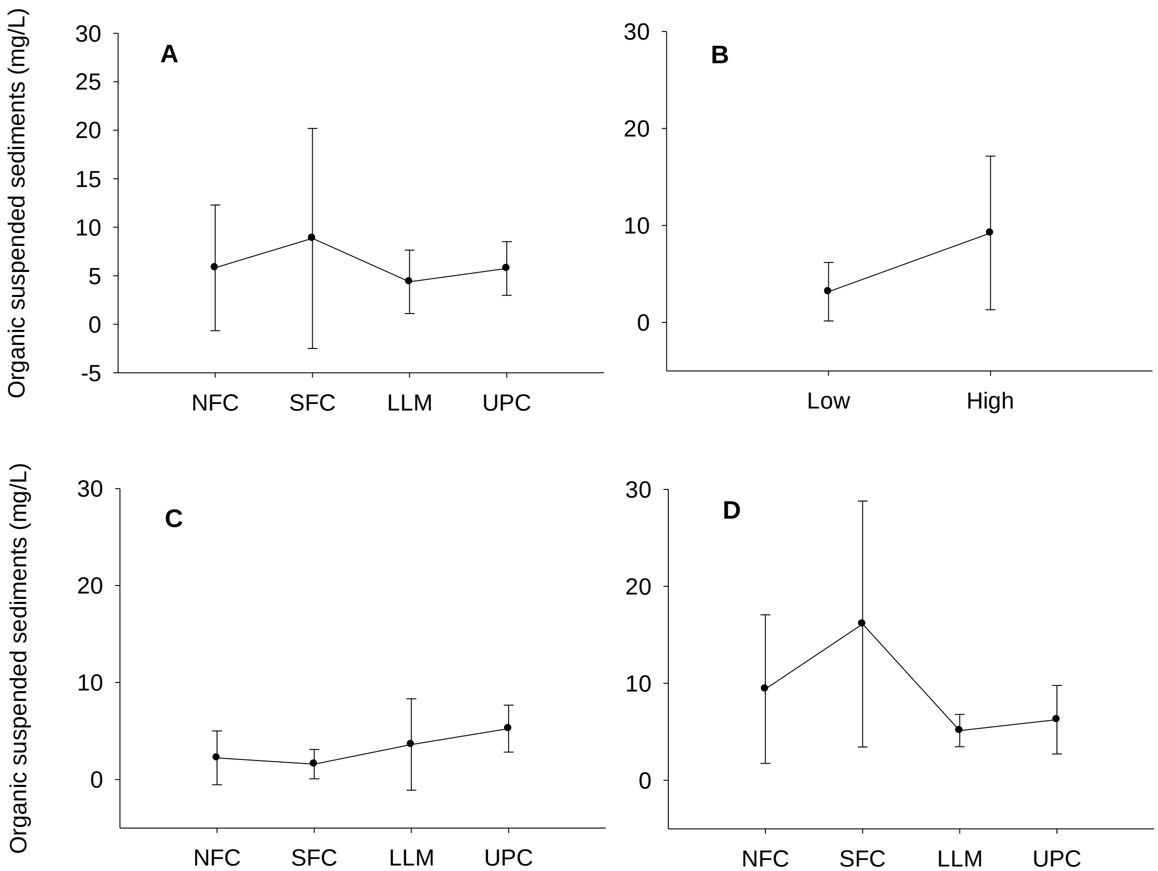

Figure 2. Mean concentration of organic suspended sediments: A) among sites (n = 6 samples per site), B) between low and high flows (n = 12 samples at each flow period), C) among sites during low flows (n = 3 samples at each site), and D) among sites during high flows (n = 3 samples at each site). Site abbreviations: LLM = Little Lost Man Creek; NFC=North Fork Caspar Creek; SFC = South Fork Caspar Creek; UPC = Upper Prairie Creek. Vertical lines represent standard deviation.

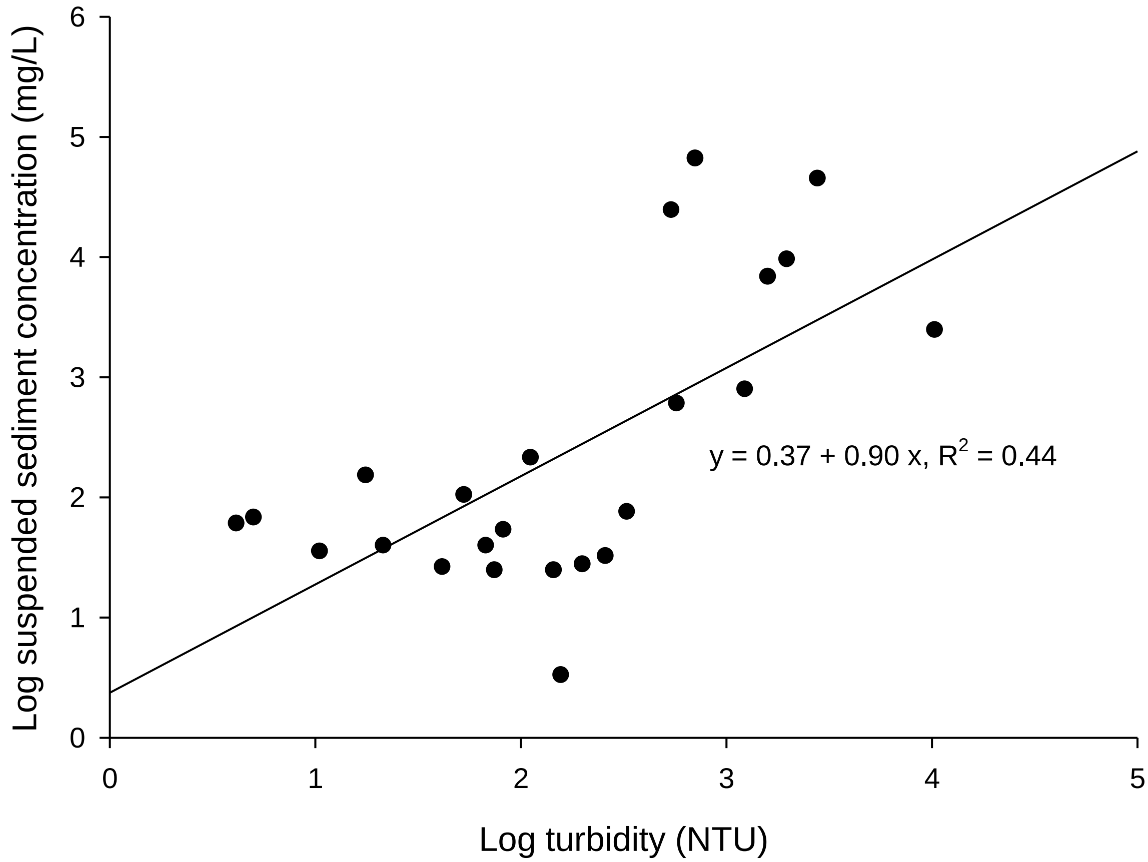

Figure 3. Relationship between turbidity and total suspended sediment concentration at the four study sites over six sampling dates.

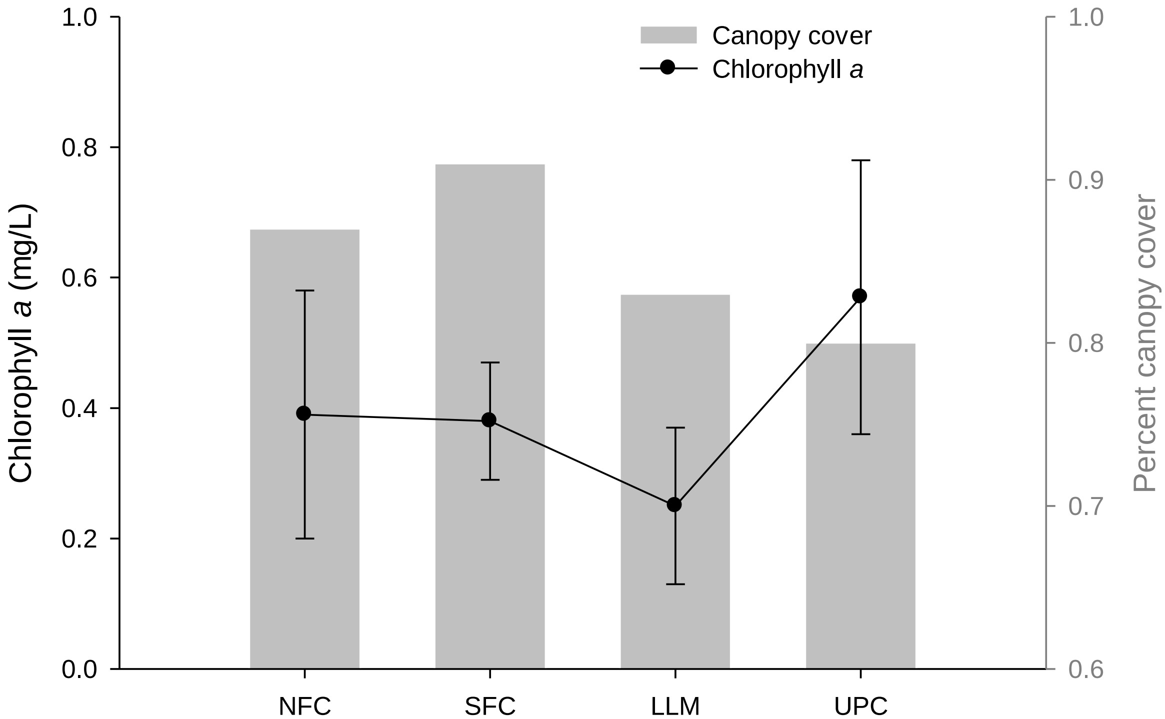

Figure 4. Concentration of chlorophyll *a* (closed circles, with vertical lines representing standard deviation) in samples of the total suspended load, and percentage of canopy cover (vertical bars) in each of the four sites (NFS= North Fork Caspar Creek, SFC = South Fork Caspar Creek, LLM = Little Lost Man Creek, and UPC = Upper Prairie Creek). Chlorophyll *a* concentrations were averaged over 6 sampling dates between October 2002 and December 2003.

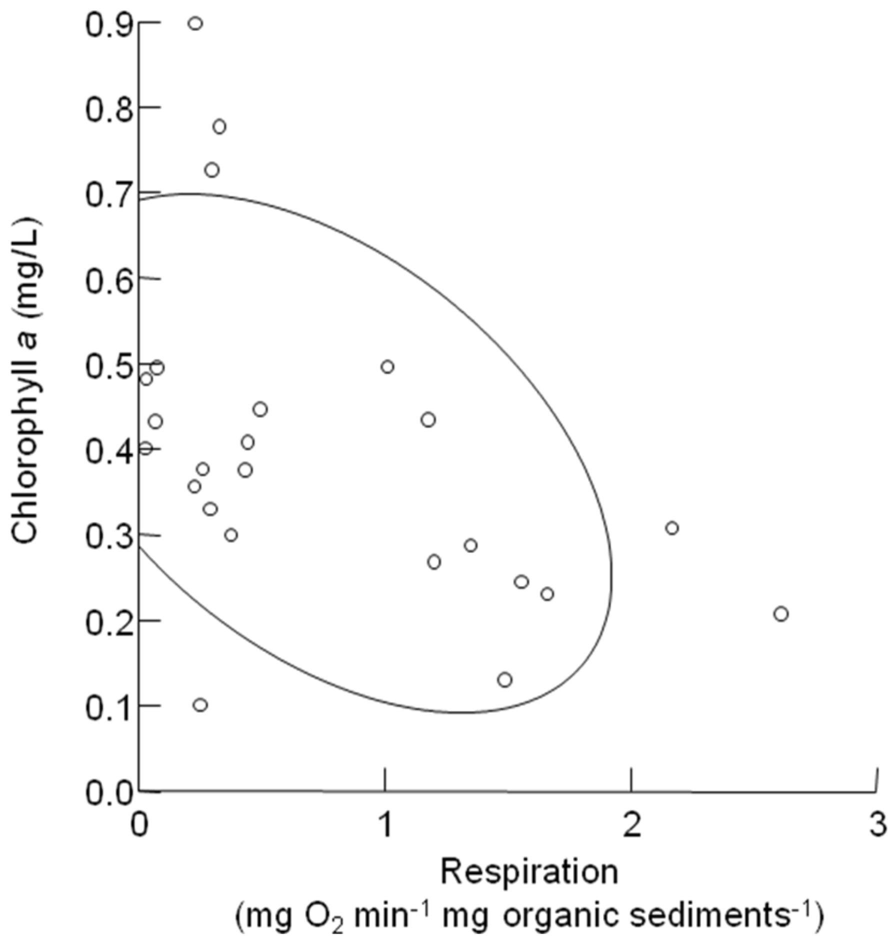

Figure 5. Relationship between respiration, as mg O_2 consumed per mg of suspended organic sediments, and chlorophyll (mg/L) in the four study sites on six sampling dates ($R = -0.48$, $n = 24$). The ellipse is drawn centered on means of chlorophyll and respiration, with its size and orientation representing unbiased standard deviations with a probability of 0.68.

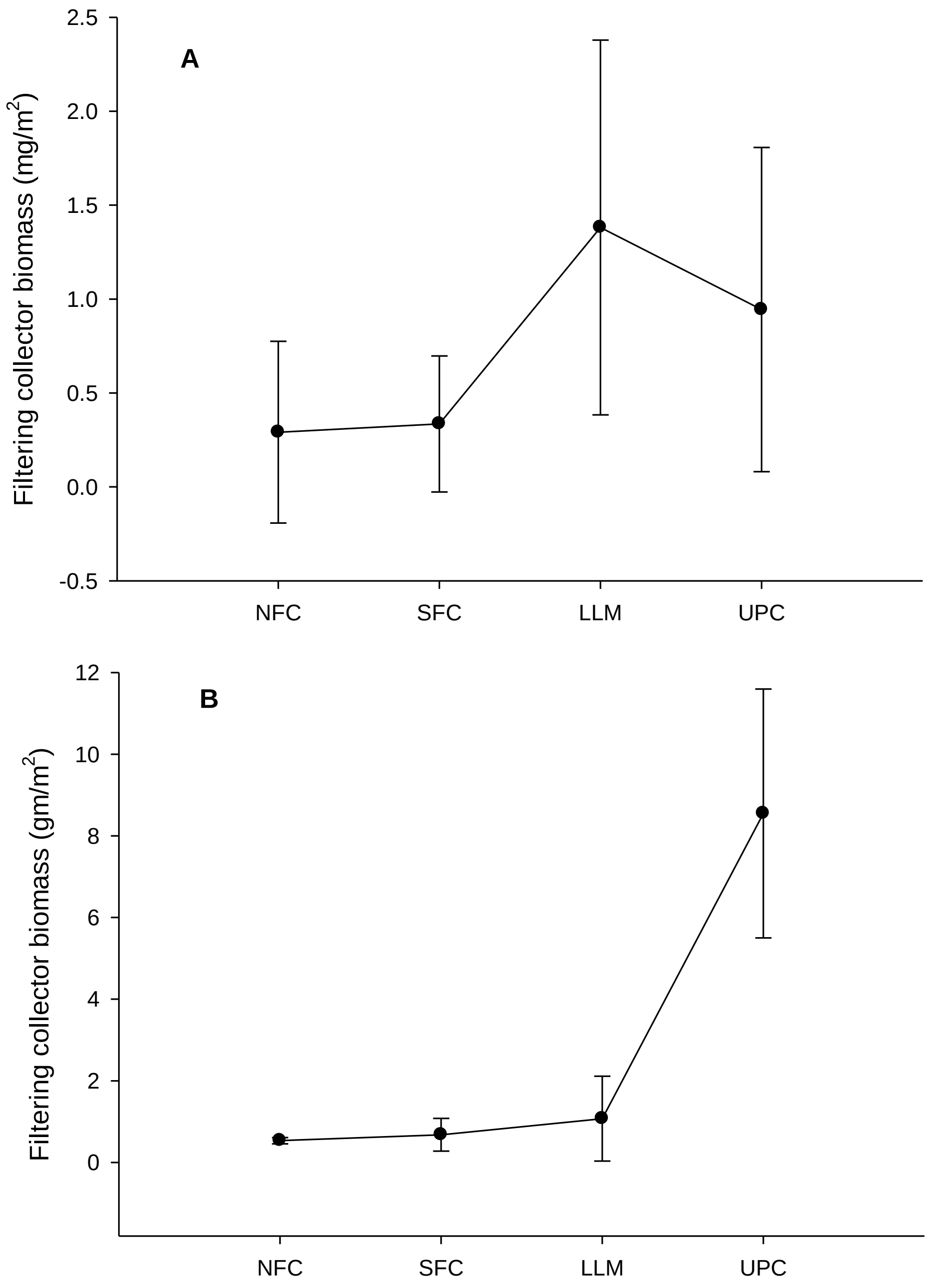

Figure. 6. Biomass of invertebrate filtering collectors among sites during A) low flow periods, and B) high flow periods. Sites are abbreviated as: Little North Fork Caspar Creek (NFC), South Fork Caspar Creek (SFC), Lost Man Creek (LLM), and Upper Prairie Creek (UPC). Biomass during each flow period was estimated from 4 samples on each of 3 dates at a site. Vertical lines represent 1 standard error.

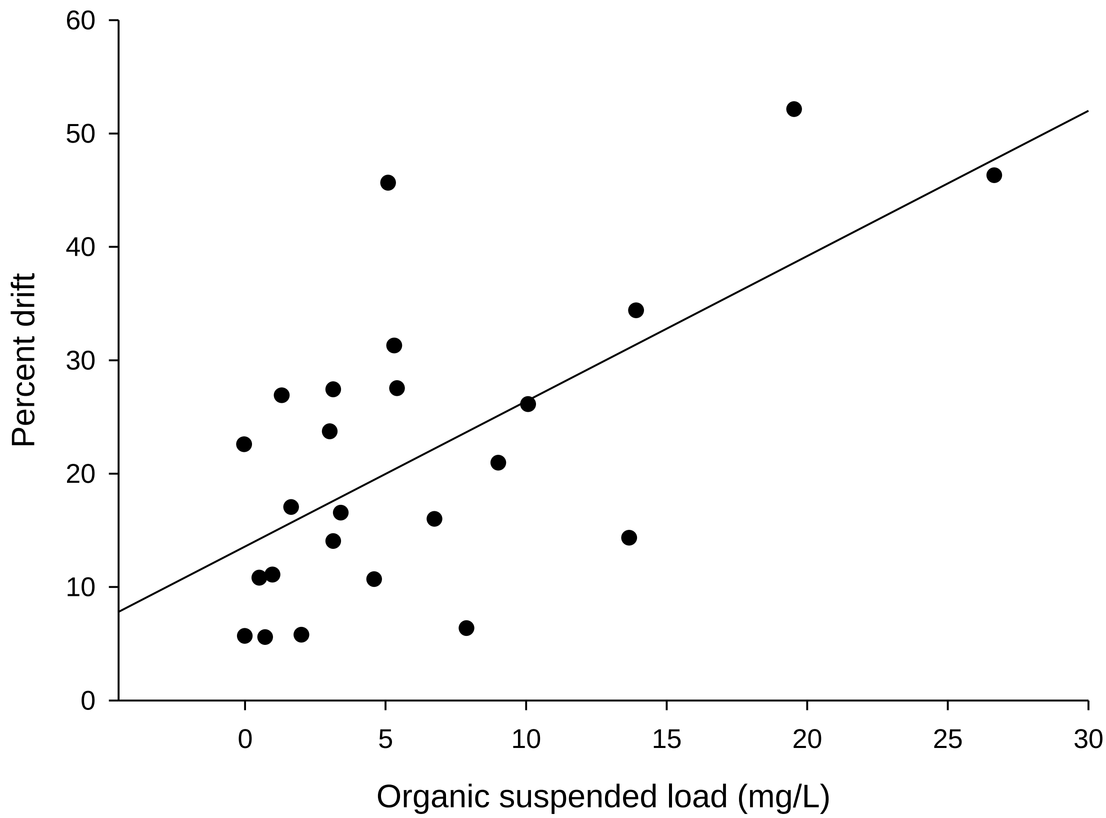

Figure 7. Relationship between concentration of the organic suspended load and the percent of invertebrates collected that were captured in the drift. Percent drift was arcsine transformed.

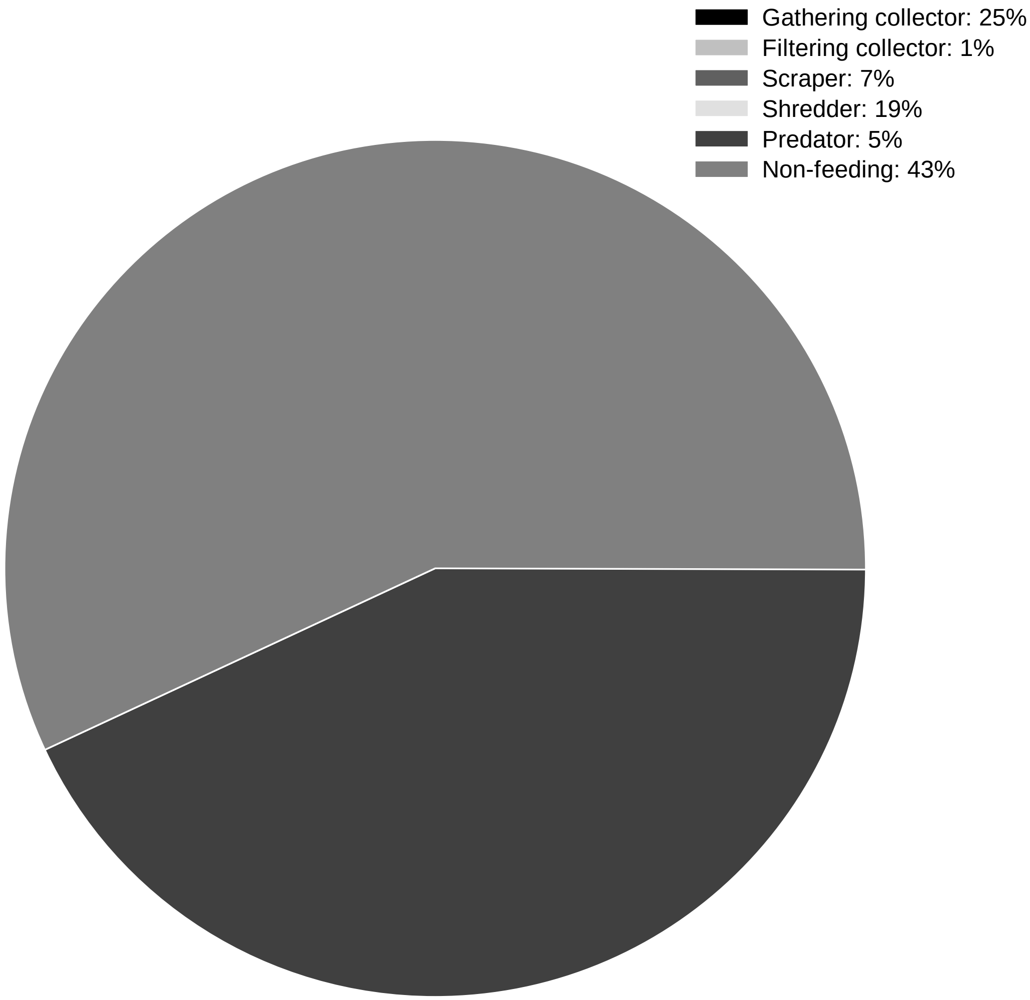

Figure 8. Representation of macroinvertebrate functional feeding groups within the diets of steelhead and coho salmon, averaged among creeks and dates (n = 206 diets analyzed). The non-feeding category includes pupae and adults of aquatic origin, together with all terrestrial taxa.

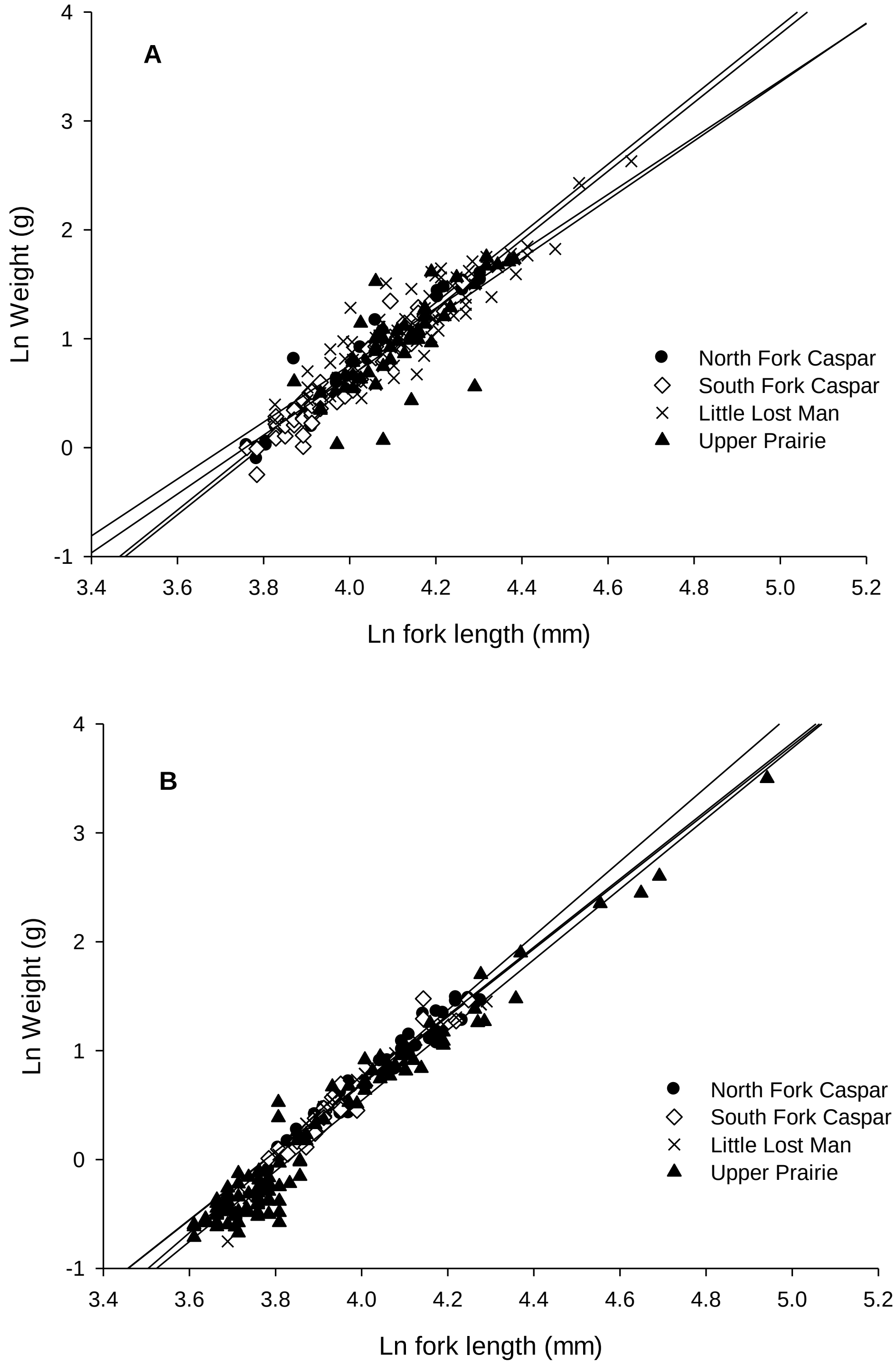

Figure 9. Length-weight relationships for coho salmon from the four study sites in A) October 2002 and B) June 2003.

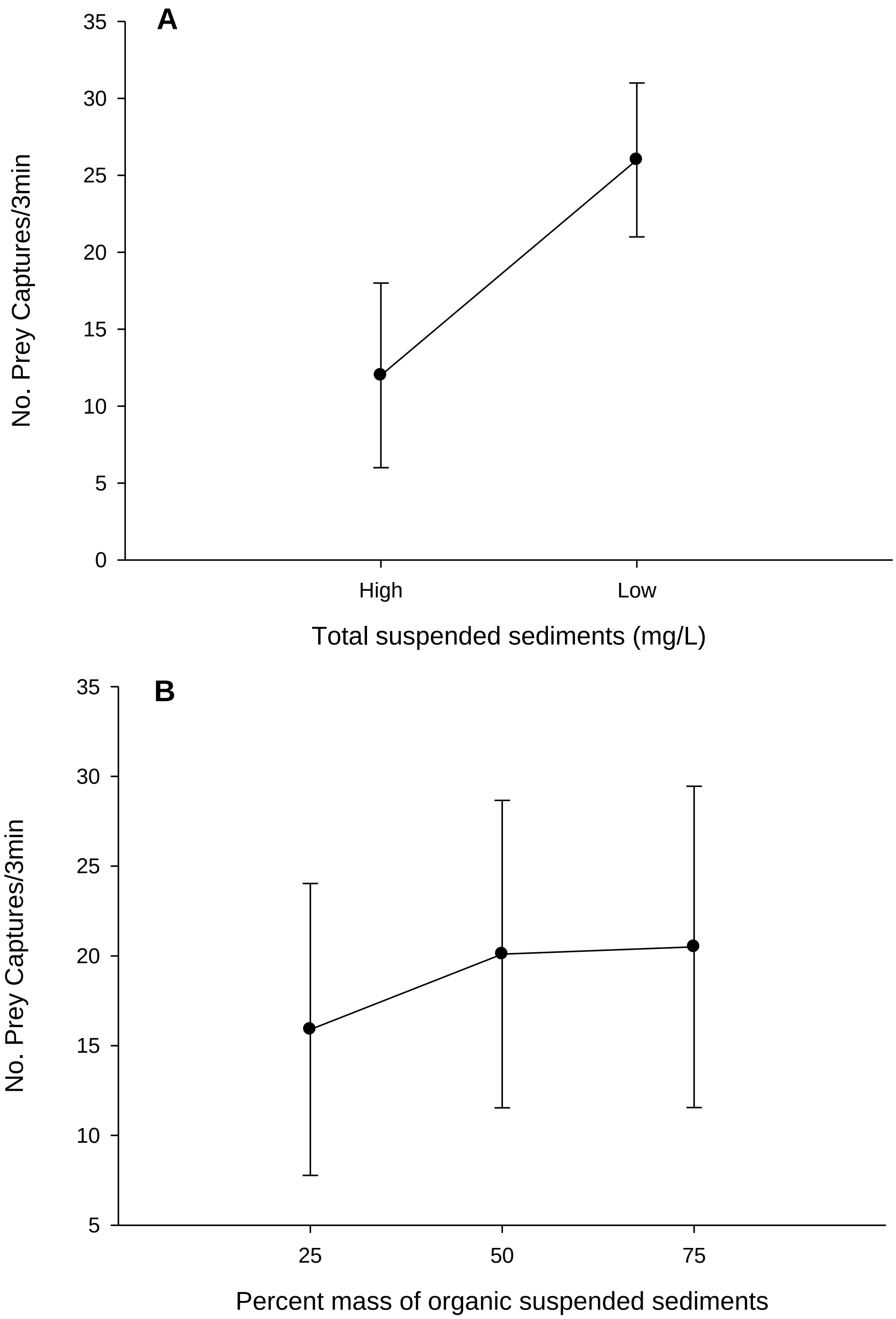

Figure 10. Average number of prey captures by solitary steelhead in 3 minute lab feeding trials at A) high and low suspended sediment concentrations, and B) under varying percentages by mass of organic suspended sediments. Vertical lines represent 1 standard deviation, n = 5 trials at each combination of suspended sediment concentrations and organic percentages.

Appendix A. Macroinvertebrate taxa collected from drift-benthos (x) and salmonid diet samples (d) from study reaches October 2002 to December 2003.

Taxa	NF Caspar	SF Caspar	Little Lost Man	Upper Prairie
Collembolla (springtails)	x,d	x,d	x,d	x,d
Isotomidae		x		
Porduridae	x,d	x,d	x	x
Pordura	x	x		x
Crustacea				
Amphipoda	d	x,d	x	d
Gammeridae	d	x	x	d
Gammarus	d	x	x	d
Copepoda		x		
Diplopoda		d		
Isopoda		d		
Odonata (dragonflies)				
Zygoptera				
Lestidae				d
Anisoptera				
Libellulidae				d
Ephemeroptera (Mayflies)				
Ameletidae	x,d	x	x,d	x
Ameletus	x,d	x	x,d	x
Baetidae	x,d	x,d	x,d	x,d
Baetis	x,d	x,d	x,d	x,d
Procoelon	x,d	x	x	
Ephemerellidae	d	x,d	x,d	x,d
Caudatella				x
Drunella		x,d	x	x

Taxa	NF Caspar	SF Caspar	Little Lost Man	Upper Prairie
Ephemerella				x
Serratella			x	
Timpanoga	x			
Heptagenaiidae	x,d	x,d	x,d	x,d
Cinygmula	x,d	x	x	x,d
Epeorus	x,d	x,d	x,d	x,d
Heptagenia		x,d		
Ironodes		d		
Nixe	d	x,d	d	x,d
Rithrogena			x,d	x,d
Stenonema	x	x	x	
Leptophlebiidae	x,d	x,d	x,d	x,d
Leptophlebia	x,d	x,d	x,d	x,d
Paraleptophlebia	x,d	x,d	x	d
Polymetrarcidae		d		
Tricorythidae		d		
Plecoptera (stoneflies)				
Capniidae	x,d	x,d	x,d	x,d
Capnia	x,d	x,d	x	x
Isocapnia			x	
Chloroperlidae	x,d	x,d	x	x
Haploperla		x		
Isoperla		x		
Kathoperla		x	x	
Paraperla	x,d			
Leuctridae	x,d	x,d	x,d	x,d
Perlomyia	x,d			

Taxa	NF Caspar	SF Caspar	Little Lost Man	Upper Prairie
Nemouridae	d	x,d	x,d	d
Peltoperlidae		x		x,d
Perlidae		x,d		x,d
Calineuria		x		
Hesperoperla				d
Perlodidae		x	x	x
Pteronarcydae	d	x		
Taeniopterygidae	d			
Hemiptera (true bugs)				
Corixidae	d			
Mesovellidae				d
Homoptera				
Aphidae				d
Trichoptera (caddisflies)				
Brachycentridae			x,d	x,d
Amiocentrus			x	x
Micrasema			d	x,d
Calamoceratidae	x	x,d	d	d
Heteroplecton	x	x	d	d
Glossosomatidae	x,d		x,d	x,d
Glossosoma	x,d		x,d	x,d
Hydropsychidae	d	x	d	x,d
Homoplectra				x
Hydropsyche			d	x,d
Lepidostomatidae	x,d	x,d	x,d	x,d
Lepidostoma	x,d	x,d	x,d	x,d
Leptoceridae				d

Taxa	NF Caspar	SF Caspar	Little Lost Man	Upper Prairie
Mystacides				d
Limnephilidae	d	x,d	d	x,d
Allocosmoecus	d	x		x
Dicosmoecus		x,d	d	d
Ecclisomyia		x		
Hydatophylax	d	x,d		x,d
Odontoceridae	d	x	x,d	x
Parthina		x,d		
Philipotamidae	x,d	x,d	x,d	x,d
Chimarra	x,d	x,d	x,d	x,d
Rhyacophilidae		x,d	x,d	x,d
Rhyacophila		x	x	
Sericostomatidae		x,d		x,d
Gumaga		x		x,d
Uenoidae				x,d
Neothremma				x,d
Lepidoptera				d
Thysanoptera	d	d	d	d
Megaloptera				
Calopterygidae		d		
Corydalidae	d		d	
Sialidae	x,d	x		x,d
Sialis	x,d	x		x,d
Coleoptera (beetles)				
Elmidae	x,d	x,d	x,d	x,d
Cleptelmis	x,d	x,d	x,d	x,d
Lara	x,d			x,d

Taxa	NF Caspar	SF Caspar	Little Lost Man	Upper Prairie
Narpus	x			
Hydraenidae				d
Psephenidae	x		x,d	x,d
Psephenus	x		x,d	x,d
Staphylinidae	d		x	
Stenus			x	
Hymenoptera				
Formicidae (ants)	d	d		
Vespidae (wasps)				d
Diptera (flies)				
Athericidae			x	
Blephariceridae		d	x	
Blepharicera			x	
Ceratopogonidae	x,d	x,d	x,d	x,d
Bezia	x,d	x,d	x	x,d
Chironomidae	x,d	x,d	x,d	x,d
Chironomini	x	x	x,d	x,d
Tanytarsini	x	x,d		x,d
Orthocladiinae	x,d	x	x,d	x,d
Tanypodinae	x,d	d	d	x,d
Culicidae	d			
Deuterophlebiidae		d		
Dixidae	x,d	d	x,d	x,d
Pelecorhynchidae	d			
Psychodidae		x	d	x
Psychomyidae	d			
Simuliidae	d	x,d	x	x,d

Taxa	**NF Caspar**	**SF Caspar**	**Little Lost Man**	**Upper Prairie**
Stratiomyidae	x,d	d	x	
Syrphidae		d		
Tabanidae		d		
Tipulidae	x,d	x,d	x,d	x,d
Arachnida	d	d		d
Hydracarina	x,d	x,d	x,d	x,d
Gastropoda				
Pleuroceridae				x
Juga			x	x
Chilopoda		d	d	d
Oligochaeta	x	x	x	X

Appendix B. Regression coefficients (a, b) used in estimation of biomass (W) from length (L) measurements of invertebrate taxa using the formula $W=aL^b$, based on unpublished data of Cummins and Wilzbach.

Coefficient a	Coefficient b	Invertebrate taxa	Life stage
0.001230	3.5800	Ephemeroptera	Adult
0.001849	3.4570	Ephemeroptera	Larvae
0.002809	3.0360	Plecoptera	Adult
0.004303	3.0610	Plecoptera	Larvae
0.017650	2.9030	Trichoptera	Adult
0.002299	3.0790	Trichoptera	Larvae
0.037140	2.3660	Diptera	Adult
0.001135	2.7508	Diptera	Larvae
0.000115	3.4780	Diptera	Pupae
0.002581	2.9930	Collembola	Adult
0.004303	3.0610	Isopoda	Adult
0.003300	2.3200	Diplopoda	Adult
0.003300	2.3200	Chilopoda	Adult
0.004303	3.0610	Amphipoda	Adult
0.004303	3.0610	Megaloptera	Larvae

Coefficient a	Coefficient b	Invertebrate taxa	Life stage
0.017650	2.9030	Lepidoptera	Adult
0.047360	2.6810	Coleoptera	Adult
0.001453	3.6110	Coleoptera	Larvae
0.085350	0.2160	Coleoptera (terrestrial)	Adult
0.044780	2.9290	Araneae	Adult
0.020838	2.4070	Hymenoptera	Adult
0.020838	2.4070	Hymenoptera	Larvae
0.039726	2.7610	Acari	Adult
0.049887	2.2700	Hemiptera	Adult
0.049887	2.2700	Hemiptera	Larvae
0.036589	2.6960	Homoptera	Adult
0.036589	2.6960	Homoptera	Larvae
0.002809	3.0360	Thysanoptera	Adult
0.001135	2.7508	Pulmonata	Adult
0.287200	1.0000	Hirudinea	Adult
0.003300	2.3200	Oligochaeta	Adult

Note: *The following is an excerpt from Brandow et. al. 2006, pages 19, 20 and 21, with additional statistics included in italics in Tables 1, 2, and 3. For each average WLPZ canopy and "n" (the number of segments sampled for each average), statistics on variance (Var.), standard deviation (S.D.), median, first quartile (1stQ) and third quartile (3rdQ) are included.*

II. Results

WLPZ segments were located in 187 of the 281 THPs included in the MCR sample. The regional distribution was 110 WLPZ segments on the Coast (CDF Region 1), 49 in the Inland North area (Region 2) and 28 WLPZ segments in the Inland South area (CDF Region 4.)

WLPZ Percent Total Canopy

Average percent total canopy cover in WLPZs was higher in the Coast than in the Inland areas. Looking at Class I and II watercourses together, average percentages for the Coast are in the mid to low eighties, and are around seventy for both Inland North and Inland South. In Table 1, below, the column for overall average includes all WLPZ results within each Region. The next two columns to the right split the overall sample into WLPZ segments with no harvest in this entry (the current THP) and WLPZ segments with harvest as part of this entry.

Class I & II WLPZs	Overall	No Harvest	Harvest
Coast (Region 1)	84% n = 110 Var. = 106.71 S.D .= 10.3 Ave. = 84.0 Median = 86 1stQ = 78 3rdQ = 92	86% n = 55 Var. = 102.50 S.D .= 10.1 Ave. = 86.0 Median = 88 1stQ = 80 3rdQ = 94	82% n = 55 Var. = 104.90 S.D .= 10.2 Ave. = 82.1 Median = 84 1stQ = 77 3rdQ = 88
Inland North (Region 2)	68% n = 49 Var. = 187.71 S.D .= 13.7 Ave. = 67.8 Median = 68 1stQ = 60 3rdQ = 76	72% n = 12 Var. = 296.82 S.D .= 17.2 Ave. = 71.5 Median = 66 1stQ = 58 3rdQ = 82	67% n = 37 Var. = 153.53 S.D .= 12.4 Ave. = 66.6 Median = 68 1stQ = 60 3rdQ = 76
Inland South (Region 4)	73% n = 28	69% n = 15	77% n = 13

Table 1. Average percent total canopy in WLPZs by Region for Class I and Class II watercourses combined. The number of segments included in each average equals “n.”

Results for Class I watercourses alone are similar (Table 2). Note that the number of WLPZ segments (n) represented in some of these averages is very small. Consequently, the 10 percent difference between average percent canopy for harvested and unharvested WLPZs in the Inland South area is probably not meaningful.

Class I WLPZs	Overall	No Harvest	Harvest
Coast (Region 1)	84% n = 29 Var. = 0.61 S.D .= 7.8 Ave. = 83.6 Median = 84 1stQ = 78 3rdQ = 90	83% n = 14 Var. = 89.61 S.D .= 9.5 Ave. = 83.1 Median = 83.5 1stQ = 76 3rdQ = 91.5	84% n = 15 Var. = 37.41 S.D .= 6.1 Ave. = 84.1 Median = 86 1stQ = 80 3rdQ = 89
Inland North (Region 2)	69% n = 18 Var. = 148.71 S.D .= 12.2 Ave. = 69.3 Median = 69 1stQ = 60 3rdQ = 77	74% n = 3 Var. = 329.33 S.D .= 18.1 Ave. = 74.7 Median = 72 1stQ = 65 3rdQ = 83	68% n = 15 Var. = 126.21 S.D .= 11.2 Ave. = 68.3 Median = 68 1stQ = 60 3rdQ = 76
Inland South (Region 3)	71% n = 5	65% n = 2	75% n = 3

Table 2. Average percent total canopy in WLPZs by Region for Class I watercourses. The number of segments included in each average equals "n."

The percent total canopy results for WLPZs along Class II watercourses are also similar to both the combined and Class I results (Table 3).

Class II WLPZs	Overall	No Harvest	Harvest
Coast (Region 1)	84% n = 81 Var. = 124.10 S.D .= 11.1 Ave. = 84.2 Median = 86 1stQ = 80 3rdQ = 94	87% n = 41 Var. = 105.17 S.D .= 10.3 Ave. = 87.0 Median = 90 1stQ = 82 3rdQ = 94	81% n = 40 Var. = 129.54 S.D .= 11.4 Ave. = 81.3 Median = 83 1stQ = 75.5 3rdQ = 88
Inland North (Region 2)	67% n = 31 Var. = Var. 213.82 S.D .= 14.6 Ave. = 66.9 Median = 68 1stQ = 59 3rdQ = 76	70% n = 9 Var. = 320.78 S.D .= 17.9 Ave. = 70.4 Median = 62 1stQ = 58 3rdQ = 78	65% n = 22 Var. = 175.69 S.D .= 13.3 Ave. = 65.4 Median = 69 1stQ = 62 3rdQ = 75.5
Inland South (Region 3)	73% n = 23	70% n = 13	78% n = 10

Table 3. Average percent total canopy in WLPZs by Region for Class II watercourses. The number of segments included in each average equals “n.”

The MCR percent total canopy results for WLPZs are strikingly similar to the findings of the Hillslope Monitoring Program, which used similar canopy measurement techniques, but was based on a completely different random sample of THPs. The importance of this will be covered in more depth in the WLPZ discussion section.

MONITORING STUDY GROUP
CALIFORNIA STATE BOARD OF FORESTRY AND FIRE PROTECTION

Modified Completion Report MONITORING PROGRAM

Implementation and Effectiveness of Forest Practice Rules related to Water Quality Protection

MONITORING RESULTS FROM 2001 THROUGH 2004

Ruben Grijalva
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State of California

July 2006
SACRAMENTO, CALIFORNIA

ABSTRACT

The California Forest Practice Rules (FPRs) (Title 14, California Code of Regulations) are designed in large part to protect water quality and aquatic habitat in forested watersheds during and after silviculture activities (Figure 1). The critical questions then become: 1) At what rate are the water quality related FPRs being properly implemented?, and 2) When properly implemented, how effective are these FPRS in protecting water quality by retaining canopy and groundcover in watercourse and lake protection zones (WLPZs), by preventing erosion, by preventing sediment transport, and/or by preventing sediment transport to stream channels? The Modified Completion Report (MCR) program focused on answering these two basic questions using forensic monitoring data collected on a random selection of 281 Timber Harvesting Plans (THPs) and randomly selected sites within those THPs. The data were collected in the field primarily by the California Department of Forestry and Fire Protection's (CDF's) Forest Practice Inspectors and were analyzed by CDF's watershed staff in Sacramento, California. Overall, the MCR monitoring study found that: 1) The rate of compliance with FPRs designed to protect water quality and aquatic habitat is generally high, and 2) FPRs are highly effective in preventing erosion, sedimentation and sediment transport to channels when properly implemented. There are specific areas where improvements in implementation and/or effectiveness could be made, and these are enumerated with specific recommendations at the end of this report. The findings of the MCR monitoring project are comparable to the findings of the earlier Hillslope Monitoring Program (HMP) project (Cafferata and Munn 2002).

KEY TERMS: water quality, aquatic habitat, forestry, monitoring, streams, California Forest Practice Rules (FPRs) (Title 14, California Code of Regulations), Timber Harvesting Plans (THPs) watercourse and lake protection zones (WLPZs), roads, watercourse crossings, WLPZ canopy, groundcover, erosion, sediment transport, and sediment transport to channels.

Figure 1. A small watercourse or stream in a forest in California.

CALIFORNIA DEPARTMENT OF FORESTRY AND FIRE PROTECTION

Modified Completion Report
MONITORING PROGRAM: MONITORING RESULTS FROM 2001 THROUGH 2004

July 2006

by Clay A. Brandow, Peter H. Cafferata and John R. Munn
California Department of Forestry and Fire Protection

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The Monitoring Study Group (MSG) is a standing committee of the BOF made up of members of the public, resource agencies (both state and federal), three universities, and the timber industry. The agencies listed above make up the MSG; the names listed above are the current primary representatives for these agencies at MSG meetings. The MSG chair is appointed by the Board of Forestry and Fire Protection (BOF) and the group is staffed by CDF. Each agency and organization is responsible for determining the appropriate person(s) to serve as a representative on the MSG (i.e., the BOF does not make formal appointments to the MSG).

Modified Completion Report

Executive Summary

A key objective of California's Forest Practice Rules (FPRs) is to protect the beneficial uses of water (Figure 2). To determine whether this is being accomplished, the Board of Forestry and Fire Protection and the California Department of Forestry and Fire Protection (BOF/CDF) have established a long-term monitoring program, which includes a number of monitoring projects that are briefly described at the end of this Executive Summary. The Modified Completion Report (MCR) project is a major component of this long-term program. This report:

- Describes MCR monitoring conducted from 2001 through 2004,
- Summarizes and analyzes the MCR monitoring results, and
- Makes findings and recommendations based on those results.

The purpose of the MCR project has been to determine the adequacy of both implementation and effectiveness of the Forest Practice Rules (FPRs) that are used to protect water quality and riparian/aquatic habitat.

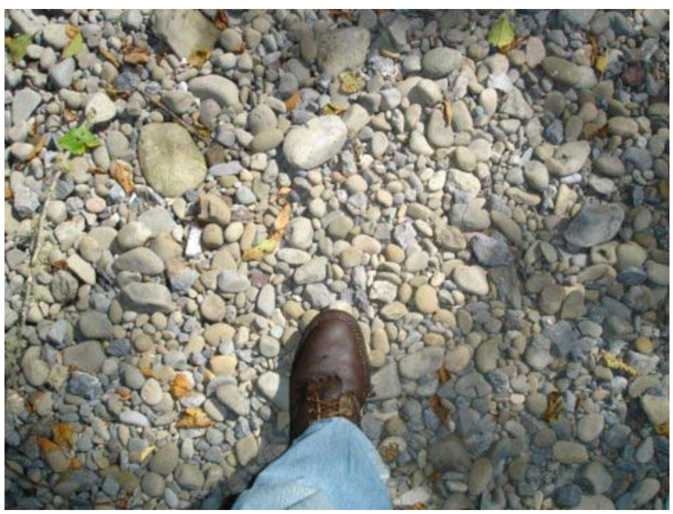

Figure 2. Substrate of a watercourse or stream in a forested watershed on the California coast. Reaches with clean gravel are an important habitat component of many forested streams. A key objective of the water quality related FPRs is to prevent transport of excessive fine sediment (e.g., sand and silt) to watercourse channels.

MCR monitoring is an extension of the normal timber harvest inspections and Completion Reports that CDF is required to conduct on timber harvesting plans (THPs) by the California Forest Practice Act and the FPRs. MCR data was collected by CDF Forest Practice Inspectors on a random sample of THPs at the time of plan completion and/or during the erosion control maintenance period.

Based on the findings of CDF's earlier Hillslope Monitoring Program (HMP) project (Cafferata and Munn 2002), the MCR project has focused on the following landscape features:

1) Watercourse and Lake Protection, including:
   - WLPZ Percent Total Canopy
   - WLPZ Groundcover and Erosion Features
2) Roads, and
3) Watercourse Crossings

Although the MCR project used a different random sample of THPs than the HMP (1996-2001) and was performed by CDF Inspectors instead of a third-party contractor, the results of these two studies are comparable. Furthermore, the MCR and HMP watercourse crossing effectiveness results compare well with findings of other California studies, such as the USDA Forest Service's Best Management Practices Effectiveness Program (BMPEP) (USFS 2004).

The *MCR Monitoring Procedures and Methods* are included in Appendix A of this report and are found on-line at:

http://www.bof.fire.ca.gov/board/msg_archives.asp

In both the MCR and the HMP studies, effectiveness of erosion control measures is based on the assumption that if soil is kept on site and out of stream systems, then water quality and riparian and aquatic habitat are protected from the effects of increased sedimentation.

Like HMP monitoring, MCR monitoring found that: 1) The rate of compliance with the FPRs designed to protect water quality and aquatic habitat is generally high, and 2) the FPRs are highly effective in preventing erosion, sedimentation and sediment transport to channels when properly implemented.

In most cases, Watercourse and Lake Protection Zone (WLPZ) canopy and groundcover exceeded Forest Practice Rule (FPR) standards. For Class I and Class II WLPZs, average total percent canopy was 84% for the Coast area (Region 1), 68% for the Inland North area (Region 2) and 73% for the Inland South area (Region 4).   With rare exceptions, WLPZ groundcover exceeds 70%, patches of bare soil in WLPZs exceeding the FPR standards are rare, and erosion features within WLPZs related to current operations are uncommon. Moreover, in most cases, actual WLPZ widths were found to meet or exceed FPR standards and/or widths prescribed in the applicable THP.

There are rare instance were WLPZ canopy and groundcover do not meet FPR standards, either naturally or as a result of harvesting operations. Detection, and where possible, prevention or abatement of these rare occurrences is an important key to water quality protection. Because these occurrences are rare, rapid ocular inspection of as many high-risk WLPZs as possible is the recommended method of detection for enforcement purposes, saving the more rigorous and time consuming measurement method and procedures to follow up on observed problems and document possible WLPZ violations.

When properly implemented, road-related FPRs were found to be highly effective in preventing erosion, sedimentation and sediment transport to channels. Overall implementation of road-related rules was found to meet or exceed required standards 82% of the time, was marginally acceptable 14% of the time, and departed from the FPRs 4% of the time. Road-related rules most frequently cited for poor implementation were waterbreak spacing and the size, number and location of drainage structures.

This low rate of non-compliance is important because erosion and sedimentation was found to be much more likely at road-related features where the FPRs are not properly implemented. Additionally, erosion, sedimentation and sediment transport is much more likely at road-related features where there was a departure from the applicable FPRs. For example, when there is a departure from the rule, the chance of erosion is about 1 in 2, the chance of sediment transport is about 1 in 3, and the chance of sediment transport to a channel 1 in 10. But where the FPR implementation is acceptable or better, the chance of erosion is about 1 in 20, and the chance of sediment transport or sediment transport to a channel is equal to or less than 1 in 100. In addition, more than half of the departures from the FPRs are concentrated in the worst six percent of all road segments. Finding and fixing the drainage and discharge problems on these few bad segments would have the greatest impact on improving road-related water quality problems for the least cost.

Watercourse crossings present a higher risk of discharge into streams than roads, because while some roads are close to streams, all watercourse crossings straddle watercourses. Overall, 64% of watercourse crossings had acceptable implementation of all applicable FPRs, while 19% had at least one feature with marginally acceptable implementation and 17% had at least one departure from the FPRs. Common deficiencies included diversion potential, fill slope erosion, culvert plugging, and scour at the outlet.

All these topics and more are covered in detail in the full report. Findings and recommendations can be found at the end of the report.

MCR Project Context: Brief Synopsis of BOF/CDF Long Term Monitoring Program

The BOF/CDF *Long Term Monitoring Program* (LTMP) has had three main components from 1996 through 2004. These are: 1) Modified Completion Report (MCR) Monitoring, 2) the Hillslope Monitoring Program (HMP), and 3) Cooperative Instream Monitoring Projects (CIMPs). An additional component, the *Interagency Mitigation Monitoring Program* (IMMP), will build on the HMP and the MCR projects and is currently being designed by an interagency team.

HMP monitoring was conducted from 1996 through 2002. MCR monitoring was conducted from 2001 through 2004. CDF plans to revise and re-start MCR monitoring in 2006. CIMPs began in 1997 and are ongoing. IMMP monitoring will begin as soon as the monitoring study design is completed.

MCR monitoring is an extension of the normal timber harvest inspections and Completion Reports that CDF is required to do on THPs under the California Forest Practice Act and the Forest Practice Rules (FPRs). MCRs are done by CDF Forest Practice Inspectors on a random sample of THPs at the time of THP completion and/or during the erosion control maintenance period. MCR used a different random sample of THPs than the HMP, but the results are comparable. The MCR random sample analyzed in this report included 281 plans, all THPs. The HMP random sample analyzed in Cafferata and Munn (2002) included 300 plans, of which 295 were THPs and five were Non-Industrial Timber Management Plan – Notices of Timber Operations (NTMP-NTOs). Plan submission dates in the two random samples ranged from 1993 to 2002 for the MCR random sample analyzed in this report and from 1991 to 2000 for the HMP random sample analyzed in Cafferata and Munn (2002).

HMP monitoring assessed a random sample of completed THPs that had over-wintered from one to four years, using an outside contractor. The objective of the HMP was to evaluate the implementation and effectiveness of Forest Practice Rules and special THP provisions specifically designed to protect water quality and riparian and aquatic habitat.

The CIMPs measure water quality and aquatic habitat parameters in selected basins. The objectives are two-fold: 1) to establish baselines and trends, and 2) to gage the effects of all activities in a watershed on the beneficial uses of water. It is often difficult to establish cause and effect (i.e., link current management practices to instream conditions), and instream monitoring is not specific to the impacts of timber management alone. Instream monitoring is important in establishing whether overall efforts to protect the beneficial uses of water are succeeding or failing, and can address cumulative watershed impacts.

The IMMP is being developed to provide information regarding forestry-related practices at high-risk sites where practices have been designed to protect water quality. The IMMP will use multi-agency teams composed of representatives from CDF, California Department of Fish and Game (CDFG), California Geological Survey (CGS), and the Regional Water Quality Control Boards (RWQCBs). It is anticipated that this team approach will provide a balance of interests for all the Review Team agencies and provide greater public confidence in the monitoring results.

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*Indicates individuals who collected data on one or more THPs randomly selected for MCR Monitoring.

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*Indicates individuals who assisted in the collection of MCR data on one or more randomly selected THPs.

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List of Abbreviations

BMPs	Best Management Practices
BOF	California State Board of Forestry and Fire Protection
CDF	California Department of Forestry and Fire Protection
CDFG	California Department of Fish and Game
CDPR	California Department of Parks and Recreation
CFA	California Forestry Association
CGS	California Geological Survey
CIMP	Cooperative Instream Monitoring Project
CLFA	California Licensed Foresters Association
CPSS	Certified Professional Soil Scientist
CSES	Critical Sites Erosion Study
EEZ	Equipment Exclusion Zone
EHR	Erosion Hazard Rating
ELZ	Equipment Limitation Zone
ESU	Evolutionarily Significant Unit
PA	Forest Practice Act
FPRs	Forest Practice Rules (Rules)
HMP	Hillslope Monitoring Program
LTMP	Long-Term Monitoring Program
LTO	Licensed Timber Operator
LWD	Large Woody Debris
MAA	Management Agency Agreement
MCR	Modified Completion Report
MSG	Monitoring Study Group
NMFS	National Marine Fisheries Service
NPS	Non-point Source
NTMP	Non-industrial Timber Management Plan
NCRWQCB	North Coast Regional Water Quality Control Board
NTO	NTMP Notice of Timber Operations
PE	Professional Engineer
PG	Professional Geologist
PH	Professional Hydrologist
PHI	Preharvest Inspection
PMP	Pilot Monitoring Program
QA/QC	Quality Assurance/ Quality Control
RCD	Resource Conservation District
RPF	Registered Professional Forester
Rules	Forest Practice Rules (FPRs)
RWQCB	California Regional Water Quality Control Board
SMZ	Streamside Management Zone
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
THP	Timber Harvesting Plan
UCCE	University of California Cooperative Extension
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Department of Agriculture, Forest Service
WLPZ	Watercourse and Lake Protection Zone

Introduction

The purpose of the Modified Completion Report (MCR) project has been to determine the adequacy of the implementation and effectiveness of California's Forest Practice Rules (FPRs) used to protect water quality and riparian/aquatic habitat. This has been done using information collected by CDF Forest Practice Inspectors during Timber Harvesting Plan (THP) completion report inspections and erosion control maintenance inspections. The MCR data was collected from January 2001 to July 2004. Based on the findings of CDF's earlier Hillslope Monitoring Program (Cafferata and Munn 2002), the MCR project has focused on the following landscape features:

1) Watercourse and Lake Protection Zones, including:
- **WLPZ Percent Total Canopy**
- **WLPZ Groundcover and Erosion Features**

2) Roads, and
3) Watercourse Crossings

Background Information

California's modern Z'berg-Nejedly Forest Practice Act (FPA) was adopted in 1973, with full field implementation occurring in 1975. During the subsequent three decades, a variety of monitoring projects have examined the implementation and effectiveness of California's Forest Practice Rules in protecting water quality. These monitoring efforts are in addition to the California Department of Forestry and Fire Protection (CDF) Forest Practice compliance inspection program that has been in place for over 30 years. Under the FPA, Timber Harvesting Plans (THPs) must be submitted to CDF for review and approval prior to conducting commercial timber harvesting on non-federal timberlands. The THPs are then reviewed for compliance with the FPA and the Forest Practice Rules adopted by the Board of Forestry and Fire Protection (BOF), and for conformity with other state and federal regulations protecting watersheds and wildlife. Multi-disciplinary teams composed of representatives of CDF, the Department of Fish and Game (CDFG), Regional Water Quality Control Boards (RWQCBs), and the California Geological Survey (CGS), conduct Preharvest Inspections (PHIs) of THP areas to determine whether the proposed timber operations comply with requirements of the FPA and the FPRs. During PHIs, additional mitigation measures beyond the standard rules are often recommended based upon site-specific conditions. This report focuses on water quality issues, but the added THP mitigation also relates to habitat protection, public safety, and the protection of other public trust resources. Additional inspections during active timber operations and the post-harvest period when logging is completed ensure compliance with the Act, the FPRs, and specific provisions of the THP.

The State Water Resources Control Board (SWRCB) certified the Forest Practice Rules and review process as Best Management Practices (BMPs) under Section 208 of the Federal Clean Water Act in 1984, with a condition that a monitoring and assessment program be implemented. Initially, a one-year qualitative assessment of forest practices was undertaken in 1986 by a team of four resource professionals (Johnson 1993). The team audited 100 THPs distributed across the state and produced the final “208 Report” (California SWRCB 1987). This report indicated that the Rules were generally were effective when properly implemented on terrain that was not overly sensitive and that poor FPR implementation was the most common cause of observed water quality impacts. The team recommended several changes to the FPRs based on their observations.

The Critical Sites Erosion Study (CSES) was an additional water quality monitoring project in the 1980’s related to timber operations conducted within watersheds throughout northern California. The CSES project determined site characteristics on THPs that can be used to identify area susceptible to large erosion events and identified management factors that have contributed to erosion events. This project collected data during 1985 and 1986 on management and site factors associated with existing large erosion events on a random sample of 314 THPs covering over 60,000 acres (Durgin and others 1989, Lewis and Rice 1989, Rice and Lewis 1991).

In 1988, the BOF, CDF, and the SWRCB entered into a Management Agency Agreement (MAA) that required improvements in the FPRs for protection of water quality based on needs described in the “208 Report.” At this point, the SWRCB approved final certification of the FPRs as Best Management Practices. The U.S. EPA, however, withheld certification until the conditions of the MAA were satisfied, one of which was to develop a long-term monitoring program (LTMP).

In response to the MAA conditions, the BOF formed an interagency task force in 1989, later known as the Monitoring Study Group (MSG). The primary purpose of the MSG was to develop a long-term monitoring program that could test the implementation and effectiveness of the FPRs in protecting water quality. From 1989 to 1999, the MSG was an “ad hoc” committee of the BOF that met periodically to: 1) develop the long-term monitoring program, and 2) provide guidance to CDF in implementing monitoring programs. With public input, the MSG developed a LTMP with both implementation and effectiveness monitoring components, and conducted a pilot project to develop appropriate techniques for both hillslope and instream monitoring that was conducted from 1993 to 1995 (Rae 1995, Tuttle 1995, Spittler 1995, Lee 1997).

The primary goal of the MSG’s LTMP has been to provide timely information on the implementation and effectiveness of forest practices related to water quality for use by forest managers, agencies, and the public. Both CDF and the BOF placed initial emphasis on hillslope monitoring because it can provide a more immediate, cost effective and direct feedback on impacts from current timber operations when compared to instream monitoring (particularly channel monitoring which involves coarse sediment parameters) (Reid and Furniss 1999). As stated in Robben and Dent (2002), it is usually easier to identify a sediment source and quantify the volume of sediment it produced, compared to measuring sediment in the watercourse and tracing it to the source.

Two state-sponsored hillslope monitoring programs have been conducted from 1996 through 2004: first the Hillslope Monitoring Program (HMP) and then the Modified Completion Report (MCR) Monitoring Program. The HMP ran from 1996 to 2002, with data collection by highly qualified independent contractors. Interim and final reports were prepared by CDF (BOF 1999, Cafferata and Munn 2002). The first phase of the Modified Completion Report (MCR) monitoring program, which is the subject of this report, was implemented from 2001 to 2004 as a more cost-effective approach than the HMP, utilizing CDF Forest Practice Inspectors to collect onsite monitoring data as part of required Work Completion Reports.

Complementing these hillslope (onsite) monitoring efforts are several cooperative instream monitoring projects located throughout California. These include:

- Caspar Creek (CDF and USFS-Pacific Southwest Research Station)
- Garcia River (CDF, NCRWQCB, MCRCD, MRC, Maillard Ranch, The Conservation Fund)
- Wages Creek (CDF, Hawthorne Timber Company/Campbell Timberland Management)
- Judd Creek (CDF, Sierra Pacific Industries)
- Little Creek (CDF, Cal Poly San Luis Obispo, Sierra Pacific Industries)

The Caspar Creek project is a paired watershed study that has measured hydrologic changes, erosion impacts, sediment production, cumulative effects, and biological impacts from logging and road construction in second-growth redwood/Douglas-fir forests since 1962.[1] The Judd Creek and Wages Creek studies were developed to test the effectiveness of the FPRs and the THP review process in protecting water quality at the THP scale in Tehama and Mendocino Counties, respectively. The Garcia River project is designed to determine if sediment and turbidity conditions are improving for anadromous salmonids at five tributary stations (Barber and Birkas 2005). The Little Creek project is evaluating the effects of selective timber harvesting and will determine if current highly regulated practices in the Santa Cruz Mountains are adequately protecting the beneficial uses of water from adverse sediment-related impacts.

In addition to hillslope and instream monitoring efforts, numerous monitoring projects have been supported, or are currently being supported, by CDF that provide critical information related to monitoring techniques and/or answer key questions regarding forest practice implementation and effectiveness.[2] Examples of these projects include:

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[1] Caspar Creek published papers are found at: http://www.fs.fed.us/psw/topics/water/caspar/caspubs.shtml

[2] MSG reports and supported reports are found at: http://www.bof.fire.ca.gov/board/msg_supportedreports.asp

- Testing Indices of Cold Water Fish Habitat (Knoop 1993)
- V-Star Tests in Varying Geology (Lisle 1993, Lisle and Hilton 1999)
- Erodible Watershed Index (McKittrick 1994)
- Evaluation of Road Stream Crossings (Flanagan and others 1998)
- Sediment Storage and Transport in the South Fork Noyo River Watershed, Jackson Demonstration State Forest (Koehler and others 2001)
- Central Sierra Nevada Sediment Study (MacDonald and others 2004, Coe 2006)
- Sediment Composition as an Indicator of Stream Health (Madej 2005, Madej and others, in press)

Summary of Other Related Studies

Several monitoring-related studies have been completed in California over the past decade that are related to the monitoring work described in this report. A brief description of these related projects is given below, and a comparison of the results of these study results to those of MCR results is presented in the appropriate section of this report -- WLPZ and Groundcover Monitoring, Road Monitoring or Watercourse Crossing Monitoring.

BOF/CDF Hillslope Monitoring Program (HMP)
The HMP conducted a statewide evaluation of the implementation and effectiveness of California's Forest Practice Rules (FPRs) from 1996 through 2002 using an annual, random sample of 50 completed THPs and NTMPs that had over-wintered from one to four years. Detailed information was collected from sampled plans in the summer months. This included data on: (1) randomly located road, skid trail, and watercourse and lake protection zone (WLPZ) segments, as well as randomly located landings and watercourse crossings; and (2) large erosion events (e.g., mass wasting features) where they were encountered. Winter documentation of fine sediment delivery to streams was not undertaken by this program. The monitoring work was done by highly qualified independent contractors who acted as third party auditors (Ice and others 2004). A report of interim findings was prepared (California State BOF 1999), and a final report based on 300 plans was completed in 2002 (Cafferata and Munn 2002). Data revealed that implementation rates of the FPRs related to water quality were high, averaging 94%, and that individual practices required by the rules were effective in preventing hillslope erosion when properly implemented. WLPZs were found to retain high levels of post-harvest canopy and surface cover as required by the FPRs, and these high levels were found to be effective in preventing harvesting related erosion. In those instances where erosion sites were identified, they were nearly always associated with inadequate implementation of the appropriate rule required by the FPRs. Roads and associated watercourse crossings were found to have the highest frequency of problems. These conclusions were generally similar to those reached in an earlier audit of 100 THPs (California SWRCB 1987).

USFS Best Management Practices Evaluation Program (BMPEP)
Water quality monitoring data collected from 1992 through 2002 on National Forest lands located in California was reported in 2004, fulfilling monitoring commitments to the SWRCB (USFS 2004). Twenty-nine different on-site monitoring protocols were used to evaluate BMP implementation and effectiveness. Altogether, there were approximately 3,900 random evaluations made for the 18 National Forests, with the most occurring on the Klamath and the least on the Los Padres. Most of the observations were for engineering and timber-related BMPs. Both implementation and effectiveness for a BMP were rated at the same time following 1-2 overwintering periods. If impacts to water quality were found, the observer estimated the magnitude, duration, and extent of impacts. A statistically significant relationship between BMP implementation and effectiveness was found for 16 of the 29 BMP protocols. In general, the results show that while some improvements are necessary, the program performed reasonably well in protecting water quality on National Forest lands in California. BMP implementation and effectiveness were relatively high for most activities and elevated effects on water quality were relatively infrequent, particularly in recent years. For all activities combined, BMPs were implemented 85% of the time, and were effective at 92% of the sites at which they were implemented. Effects classified as elevated were typically caused by lack of or inadequate BMP implementation and most elevated effects were related to engineering practices. Roads, and in particular stream crossings, were found to be the most problematic.

Colorado State University (CSU) Sierra Nevada Sediment Study
Dr. Lee MacDonald and graduate student Drew Coe measured sediment production rates on the Eldorado National Forest and on Sierra Pacific Industries timberlands in the Central Sierra Nevada (Coe and MacDonald 2001, 2002; MacDonald and others 2004; Coe 2006). Approximately 150 sediment fences were installed in the summers of 1999 and 2000. Field investigations focused on (1) quantifying sediment production and sediment delivery from timber harvest, roads, wild and prescribed fires, off-road vehicles, and undisturbed areas; (2) quantifying the year-to-year variability in sediment production; and (3) determining the effect of key site variables (MacDonald and others 2004). MacDonald and others (2004) found that roads, high-severity wildfires, OHV trails, and certain skid trails on granitic soils were the dominant sediment sources. The mean road sediment production rate was 0.9 kg/m^2, 0.1 kg/m^2 from skid trails, 0.4 kg/m^2 from ORV trails, 1.1 kg/m^2 from high severity burn sites, and 0.001 kg/m^2 from minimally disturbed sites. Native surface roads produced 10-50 times more sediment than rocked roads and most sediment delivery related to roads occurred at or near stream crossings. Additionally, they found that sediment production rates were highly variable between sites within a year as well as between years. Multivariate analyses indicated that the dominant controls on road sediment production included road contributing area (A), road gradient (S), annual erosivity (E_A), and road surfacing (rock vs. native surface; T). An empirical model containing these variables explained 54% of the variability in annual road sediment production.

USFS-PSW Research Station and CDF—Caspar Creek Watershed Study
Suspended sediment and bedload have been measured at the North and South Forks of Caspar Creek for more than 40 years (Ziemer 1998, Lewis and others 2001,

Keppeler and others 2003). Caspar Creek is a small coastal watershed situated between the Noyo and Big River drainages in western Mendocino County. The Caspar Creek data set is unique in California, since it is the only forested experimental watershed currently in operation with a continuous, long-term flow and sediment record (Ziemer and Ryan 2000). Results show that improved forestry practices after 1974 have significantly reduced sediment yields. Selection logging conducted prior to the implementation of the modern FPRs in the South Fork of Caspar Creek produced from 2.4 to 3.7 times more suspended sediment than clearcutting in the North Fork under the modern FPRs (Lewis 1998). In the North Fork of Caspar Creek following clearcut harvesting of almost half the watershed in three years under the modern FPRs, suspended sediment monitoring showed that annual sediment loads increased 123-269% in the tributaries. At main-stem stations, however, increased loads were detected only in small storms and there was little effect on annual sediment loads. Most of the suspended sediment measured at the North Fork weir resulted from one large landslide that occurred in January 1995. Road rehabilitation work was conducted during the summer of 1998 on three miles of road that had had been constructed along the South Fork in 1967. A total of 33 watercourse crossings were abandoned, removing a total of approximately 28,500 cubic yards of fill material. Surveys of the abandoned crossings have shown that downcutting following large winter storm events resulted in 854 cubic yards of sediment production, or three percent of the total amount of sediment removed, with an average loss of approximately 26 cubic yards per crossing. Over 70% of this material came from three crossings, or 9% of the abandoned crossings surveyed (Cafferata and Munn 2002).

Klein—Sanctuary Forest Stream Crossing Excavations in the Upper Mattole River Basin, 2002-2003

The Sanctuary Forest, Inc. is implementing an erosion control and prevention program to reduce long-term sediment yield in the upper Mattole River watershed, with the focus on decommissioning unneeded forest roads that pose sedimentation risks. Klein (2003) conducted a monitoring project to determine volumes of erosion following road removal at excavated crossings and impacts to water quality. Erosional void dimensions were measured at 18 excavated crossings. Both channel scour and bank slumps were documented for each crossing. Survey work was not conducted prior to the onset of winter rains, so channel scour was estimated by making field measurements of scarp heights and top widths at geometric transition points within the excavation. Most of the erosion was found in the excavated channel areas, but erosion was also documented above crossings where culverts had been located. The total sediment delivery for the first winter was 279 yds^3, with an average of 15.5 yds^3 per crossing. Sediment yield for individual crossings ranged from over 50 yds^3 to less than 2 yds^3. Four crossings (approximately 22% of the excavated crossings) produced roughly half the total sediment volume. In general, channel scour strongly dominated sediment yield. Bank slumps were relatively minor except at one removed crossing.

Modified Completion Report (MCR) Study Design

Overview

Under the FPA, Public Resources Code (PRC) Section 4586 requires that within six months of the receipt of the Work Completion Report specified in PRC Section 4585, the director shall determine, by inspection, whether the work described in the report has been properly completed in conformity with the rules and regulations. If so, a report of satisfactory completion is issued. If not, the director shall take such corrective action as he or she determines appropriate. MCR is a slight modification to this process. MCR adds a monitoring step, which is designed to collect data on the implementation and effectiveness of the FPRs designed to protect water quality.

The initial MCR monitoring design was a simple check list used in the late 1990's by CDF inspectors during the Work Completion Report inspection that is required on all THPs. This approach had several deficiencies. First, even though the check list forms were to be turned-in for all THPs undergoing Work Completion Report inspections, in practice forms were turned-in for only a small, non-random fraction of the completed THPs. Since the sample was not random, it was not possible to tell whether this was a representative sample of all THPs. Second, the check list only included categories for deficient implementation or effectiveness of listed FPRs. This implied that absence of a check mark always meant no deficiency, which was not always true. And third, because the check list instructions did not include criteria for site selection, it was not possible to determine what bias might have been introduced by the choice of sampling locations.

To solve these problems the MCR protocols were revised to include:

1) Random selection of THPs for monitoring to ensure a representative sample,
2) Forms that required a mark or an entry for each question to indicate whether it had been answered or deemed not applicable, and
3) Criteria for random selection of monitoring sites within each THP.

Random Selection of THPs

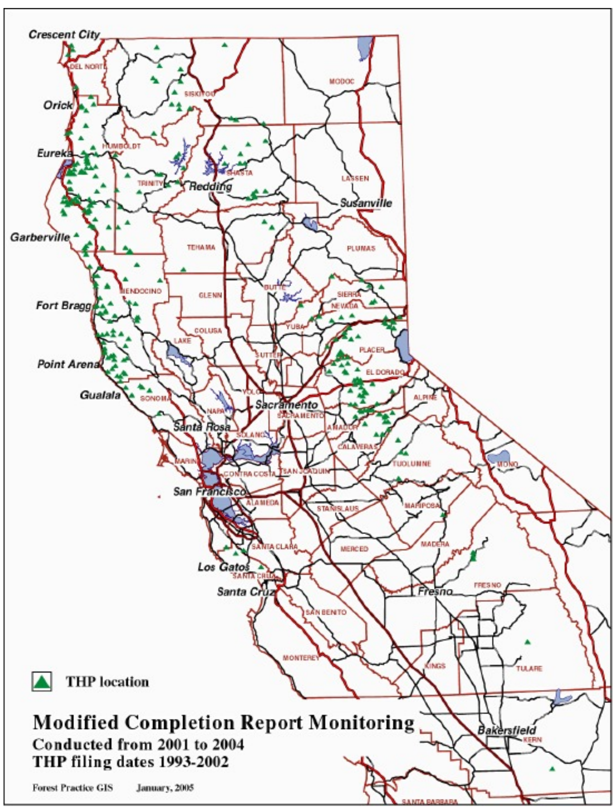
The MCR monitoring was performed on a random sample of completed THPs. The initial target sample size was 25% of all THPs undergoing Work Completion Report inspections. This percentage was subject to change based on staffing levels and workload, and the sample size was revised downward from 25% to 12.5% on February 25, 2002. A 12.5% sample represented about 125 THPs in 2002.

To obtain a random sample, pick-lists of randomly selected THP numbers were generated and distributed to Forest Practice Inspectors. One list was generated for THPs dated 1990 through 1999; and separate, annual lists were generated for THPs approved in 2000, 2001, 2002, and 2003. There were no THPs with a filing date of 2004 or later in this sample, because no plans filed in 2004 were completed by July 1, 2004. To avoid confusion, the same list of numbers was used for all three CDF

Regions. This does not affect the randomness of the sample because each region assigns its own, consecutive THP numbers, starting with 001, annually. If the THP number for a completed plan matched one of the numbers on the random list for a given year, then that THP was selected for monitoring.

A program used to produce lists of random THP numbers was written by State Forests Research Coordinator Tim Robards of CDF in collaboration with CDF watershed scientist Clay Brandow. In this approach, each number from 1 to 1000 is individually compared to a randomly generated number that gives a one in "X" chance of selection. For example, to get a 12.5% sample, "X" equals 8, and each THP number has an independently determined one-in-eight chance of being selected. This provides a random, 12.5% sample of completed THPs regardless of the number of THPs approved in any given year.

The MCR project has not yet included Non-Industrial Timber Management Plan (NTMP) Notices of Timber Operations (NTO), while the Hillslope Monitoring Program did include some NTMPs. Neither the MCR random sample nor the HMP random sample included harvesting operations conducted under Exemption or Emergency Notices.



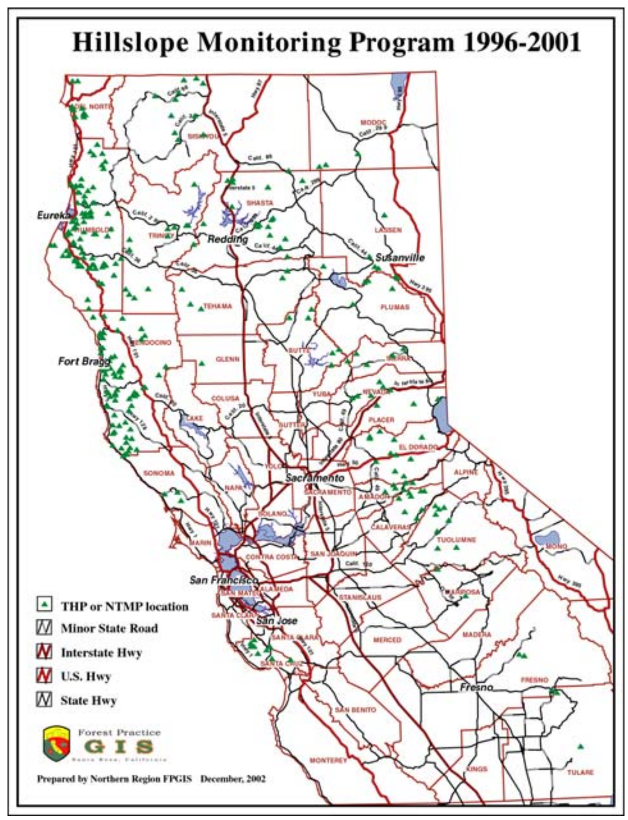


Figure 3. General locations of THPs randomly selected for MCR monitoring from 2001 to 2004 on the left, compared to the general locations of THPs randomly selected for HMP monitoring from 1996-2001 on the right.

Plotting the locations of THPs selected for MCR monitoring from 2001 to 2004 produces a statewide pattern of sampling sites that is remarkably similar to a plot of THP and NTMP sample sites selected for the HMP from 1996 through 2001 (See Figures 3 & 4).

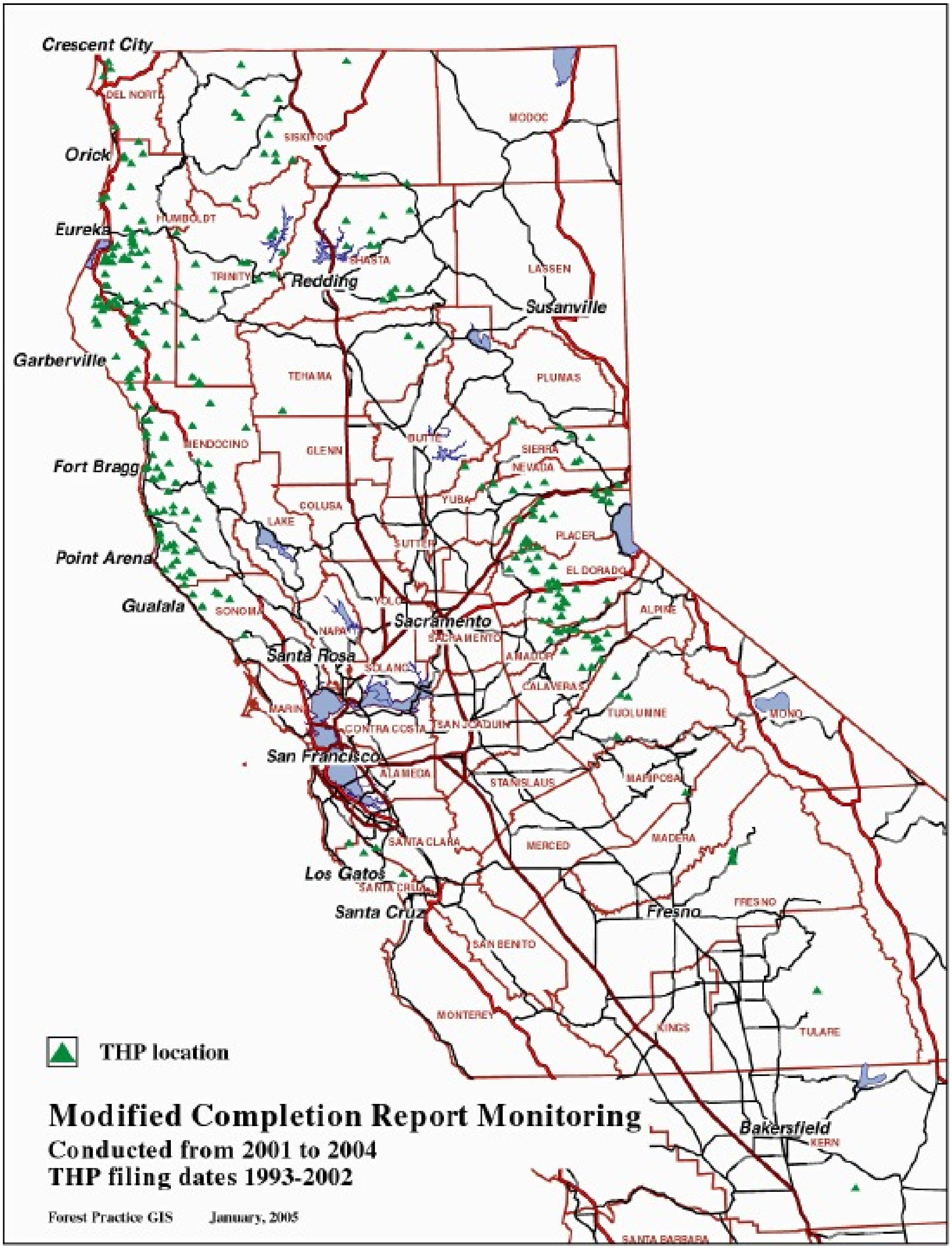


Figure 4. General locations of THPs randomly selected for MCR Monitoring from 2001 to 2004. This is simply an enlargement of the map of MCR THP distribution shown on the left in Figure 3.

The similarity of geographic patterns is the expected outcome, since MCR and HMP monitoring used independent, random samples of roughly equal size of THPs completed California. This similarity of geographic patterns is further evidence that both random samples are representative of the whole population.

Data Collection

Most of the MCR monitoring data was collected by CDF Forest Practice Inspectors, with some assistance from other CDF staff. On a small number of the THPs, monitoring assistance was provided by Regional Water Quality Control Board staff, California Department of Fish and Game staff, or landowner representatives (generally the Registered Professional Foresters (RPFs) who prepared and/or administered the THP).

Data was collected on paper forms. To avoid ambiguities from blanks in the data, responses such as "N/A" (for "not applicable") were required for all entries that might otherwise be left empty Despite training on filling out the data collection forms, blanks were still a problem. This has required some interpretation of the meaning of items left blank for subsequent data analyses. For future monitoring efforts, a solution to this problem is to use electronic data loggers that will not allow field observers to complete the form without all of the required entries.

The methods and procedures used in data collection for this report are documented in Modified Completion Report Monitoring Procedures and Methods (rev.4/9/03), which is listed in this report as Appendix A. An electronic copy of the *Modified Completion Report Monitoring Procedures and Methods (rev.4/9/03)* is available on line at:

http://www.bof.fire.ca.gov/board/msg_archives.asp

Implementation and Effectiveness Evaluations

All four sites (WLPZ segment, road segment, and two watercourse crossings) were evaluated for implementation at the time of the final Work Completion Report inspection(s). The sample road segment and watercourse crossings drainage structures were to be evaluated a second time for effectiveness during the post-completion erosion control maintenance inspection(s), after at least one over-wintering period. In some cases, the implementation evaluation was done after one or more over-wintering period(s) and the effectiveness evaluation was done on the same visit. In other cases, the effectiveness inspections were not done for lack of a second visit. Consequently, the subset of THPs with roads and crossings rated for effectiveness is smaller than the sub-set of the THPs with roads and crossings rated for implementation.

Effectiveness information recorded included erosion features present (if any), source and cause of erosion features, impact to water quality, and adequacy of road and crossing design and construction.

Between November 2000 and June 2003, field training sessions on MCR data collection were conducted on THPs located in several CDF units located around the state. Seventy-five individuals took part in the training. Most of these were CDF inspectors, but some RWQCB staff were also present.

Quality Assurance/Quality Control (QA/QC)

Quality assurance consists of actions to ensure adherence to data collection and analysis procedures, while quality control is associated with actions to maintain data collection and analysis consistent with study goals through checks of accuracy and precision. The quality assurance program was composed of three components: 1) qualifications and practical experience of CDF Forest Practice Inspectors, 2) a detailed field training program, and 3) protocols provided in the *Modified Completion Methods and Procedures* document (See Appendix A).

The quality control program consisted of self-evaluation of the data collection forms for completeness in the field and a second evaluation of the forms by watershed staff at CDF Headquarters. Questions were resolved through direct communication between the Forest Practice Inspectors and watershed staff.

To ensure completeness of THP samples, lists of recently completed THPs subject to MCR Monitoring were generated quarterly using the Forest Practice System (FPS) data base and the MCR random pick-lists. These lists of THP numbers were checked against lists of MCR monitoring reports received in Sacramento, and responsible Forest Practice Inspectors were contacted about missing reports.

Regional Distribution of Monitored THPs

CDF has four Administrative Regions, three of which are included in this monitoring and will be referred in this report by short, descriptive names:

1) North Coast Region 1 is referred to as **"Coast"**,
2) Cascade Region 2 is referred to as **"Inland North"**
3) Central Sierra Region 4 is referred to as **"Inland South"**

Southern Region 3, which includes southern California and the eastern slope of the Sierra Nevada south of the Carson River, is arid, except at the highest elevations, which are for the most part federal lands. The region contains very little private or state forest lands and generates very few THPs. Consequently, Southern Region 3 was not included in this study. Also, in some portions of the of the report, notably the section on roads, the combined areas of Inland North and Inland South are referred in the aggregate as simply **"Inland."**

All of the 281 plans selected for MCR monitoring were THPs, while the 300 plans selected and analyzed for the HMP included 295 THPs and 5 NTMPs.

The distribution of plans by CDF Administrative Region was somewhat different for the MCR project than in the HMP. For MCR Monitoring, percentages of Coast (R-1), Inland North (R-2) and Inland South (R-4) plans were 52%, 27% and 21%, respectively (see Figure 5). For the HMP, the percentages of Coast (R-1), Inland North (R-2) and Inland South (R-4) plans were 62%, 26% and 13%, respectively (see Figure 6). Simplifying the comparison by combining the inland categories gives a Coast vs. Inland ratio of about 50/50 for the MCR sample of THPs and about 60/40 for Hillslope Monitoring Program sample.

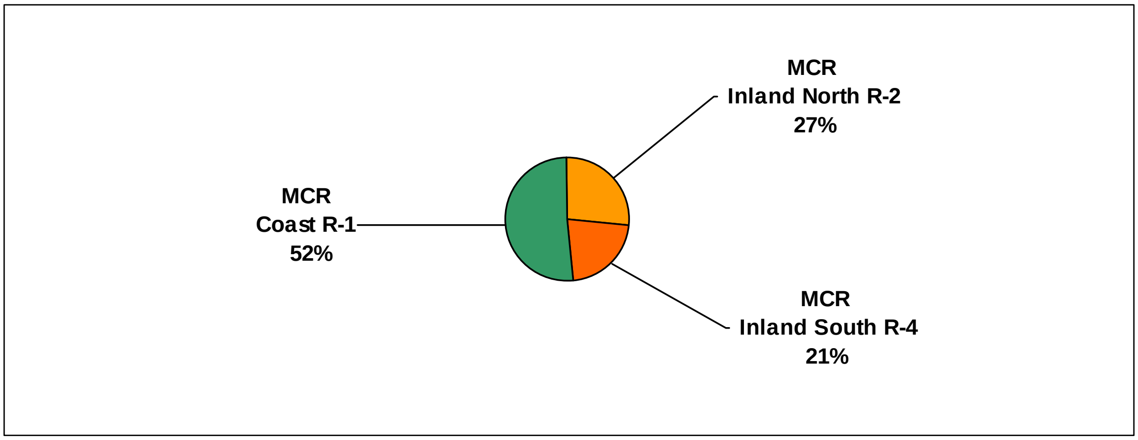


Figure 5. Distribution of MCR Monitoring Randomly Sampled THPs by Region.

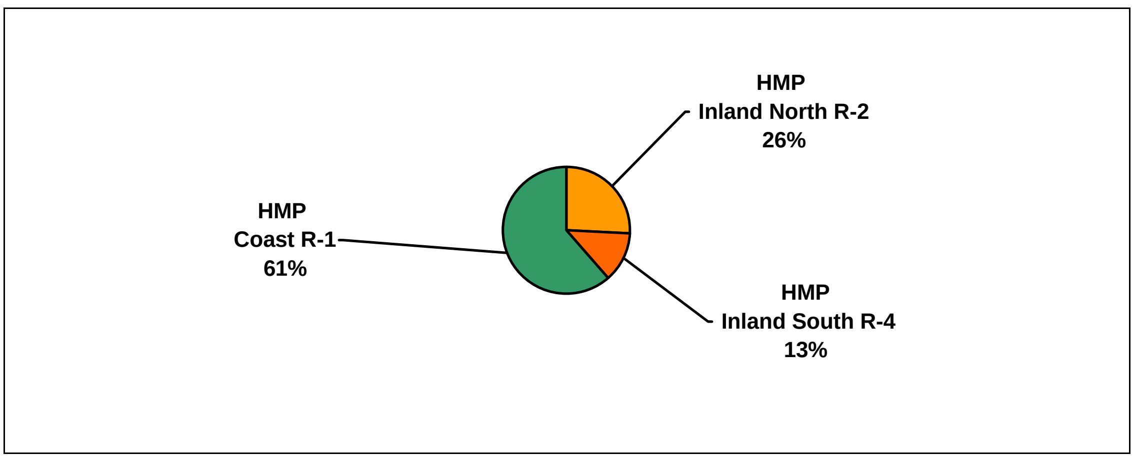


Figure 6. Distribution of HMP Randomly Sampled THPs by Region.

General locations of THPs randomly selected for MCR monitoring are shown plotted on the map of CDF Administration Regions below in Figure 7. Note the clustering; this clustering is representative of the clustering in the population of all THPs completed from 2001 through 2004. A similar pattern of clustering was observed in the HMP random sample (1999-2001).

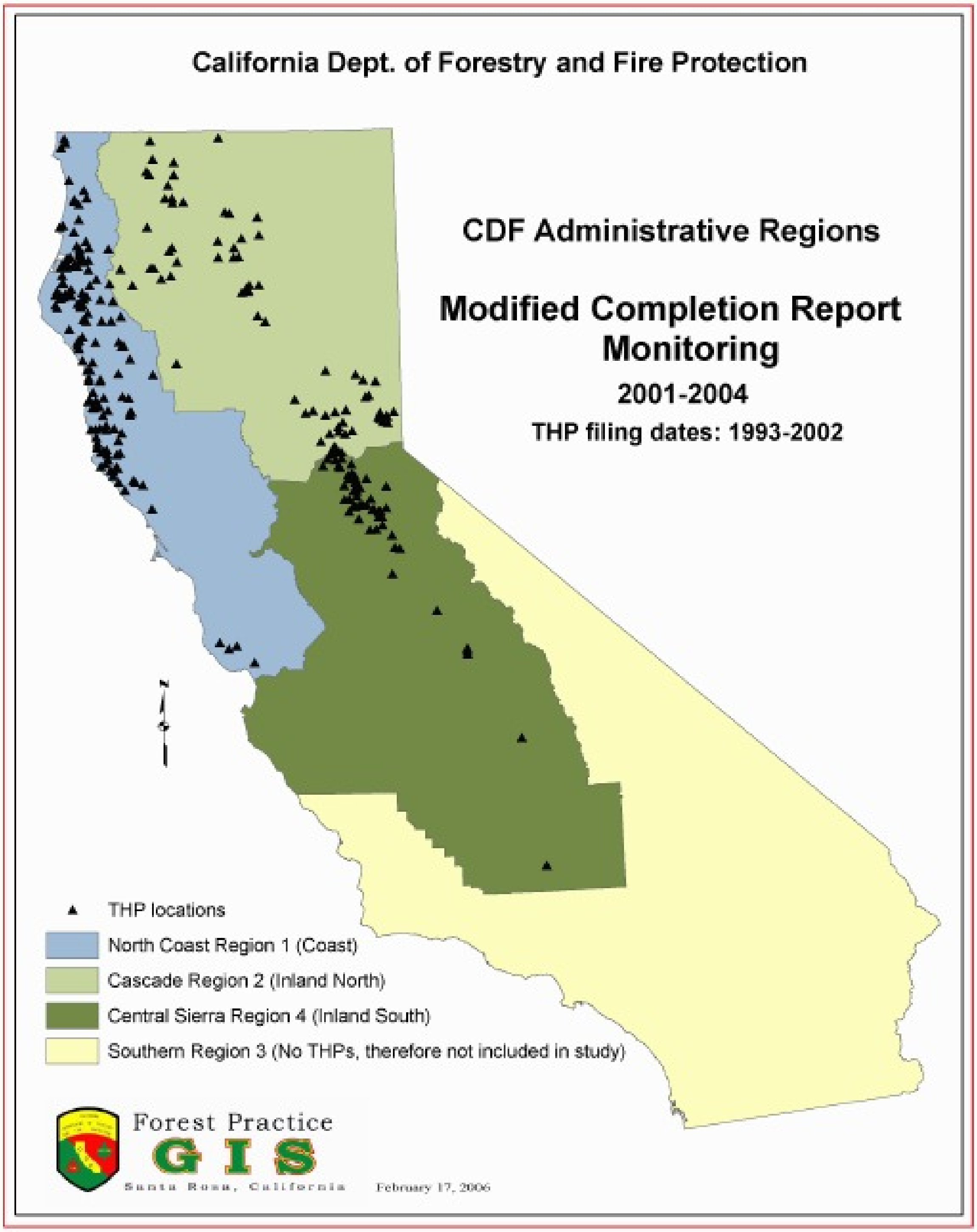


Figure 7. General locations of THPs randomly selected for MCR Monitoring from 2001 to 2004 by CDF Administrative Region.

Random Site Selection within Randomly Selected THPs

Up to four monitoring sites were located on each THP. These included:

1) A 200 foot WLPZ segment along a Class I or Class II watercourse,
2) A 1000 foot road segment, and
3) Two crossings of Class I, Class II or Class III watercourses.

For THPs that lacked one or more of these sites, forms were turned-in with the notation: "Not applicable to this THP."

Methods of random site selection for WLPZ segments, road segments, and watercourse crossings within a selected THP are described elsewhere in this report under the methods section for each of these features.

The use of randomly selected sampling sites within the THP allowed inspectors to focus in detail on whether the FPRs applicable to that site were: 1) properly implemented, and 2) effective in protecting water quality by preventing erosion, sediment transport, and discharge into channels.

MCR Monitoring:
WLPZ Canopy and Groundcover

I. Methods

Monitoring Timelines and WPLZ Selection

A 200-foot long WLPZ segment was randomly selected for MCR monitoring from each of the randomly selected THPs with one or more WLPZs. This was not possible in some cases, because Class I or Class II watercourses were not present on all of the randomly selected THPs. Within the WLPZ, sample segment zone width and percent total canopy were measured (Figure 8), and groundcover conditions were observed. Also, where they existed within the WLPZ segment, three additional items were observed and recorded: 1) erosion features, 2) untreated patches of bare mineral soil, and 3) timber harvesting that occurred on this entry.

Figure 8. Pete Cafferata, CDF, making canopy cover measurements using a sighting tube.

Selecting the 200-foot WLPZ segment began with the inspector delineating all of the Class I and Class II WLPZs on the THP map(s). Then a scale was used to mark 200 foot segments along all of the delineated WLPZs. Each of these segments was given a number. Then a random number between 1 and the maximum number of segments was identified using a random number table or a pocket calculator random number generator, and the segment number corresponding to the identified random number was selected for sampling. Where both sides of the creek were harvested, a coin flip was used to determine which side of the stream to monitor. Random selection of WLPZ reaches was used to capture a representative sample of WLPZ conditions. This is different than the objective of WPLZ enforcement inspections. For enforcement purposes, segments are selected for canopy measurement based on apparent violations. Therefore, enforcement data represents worst-case post-harvest WLPZ conditions, while MCR measurements represent average WLPZ conditions for the study period.

The MCR procedures used for WLPZ canopy measurement were modified from Preharvest Inspection (PHI) and enforcement action procedures developed by Robards (1999). In both procedures, canopy is determined using a sighting tube, but the number of observations for the MCR procedure is 50, as compared to 100 for the enforcement procedure. Average WLPZ width for the MCR was determined by pacing within the segment sampled for canopy cover, and groundcover was estimated by ocular observation. Additionally, fresh erosion features in the MCR sample segment (i.e. gullies, rills, or areas of sediment deposition) were noted. The advantages to using similar WLPZ canopy/surface cover sampling methods for PHIs, enforcement, and MCR sampling included continuity of techniques, reduced training needs, and data comparability.

Sampling Procedures

The following sampling procedures apply to both Class I and Class II WLPZs. The target sample size for canopy measurements was 50 sighting tube points, regardless of the size of the sampled area. The distance (D) between points was calculated using the following formula, where width and length refer to the width and length of the sampled WLPZ segment:

$$D = \sqrt{\frac{\textit{width x length}}{50}}$$

Since the standard MCR sample length is 200 feet, this equation can be simplified to:

$$D = 2\sqrt{\textit{width}}$$

When applied to standard widths of 50, 75, 100 and 150 feet, D is 14, 17, 20 and 28 feet, respectively. For convenience, the WLPZ width stated in the THP was used to determine D for field measurements, even if the actual WLPZ width flagged on the ground was found to be different during subsequent field work.

WLPZ transects were started at the watercourse transition line at one end of the WLPZ segment. From there, the first sample point was located on a line perpendicular to the watercourse at a distance that was calculated using a random number between zero and one times the measurement interval distance D. From the first sample point, the distance D was paced perpendicular to the stream to reach the next sample point, and so on until the next point would exit the flagged WLPZ. The WLPZ transect was then turned 90º for distance D to start of a new line perpendicular to the stream. This procedure was repeated until 50 sample points were measured, whether this completed the final line or not. The resulting measurement pattern is similar to what is shown in Figure 9.

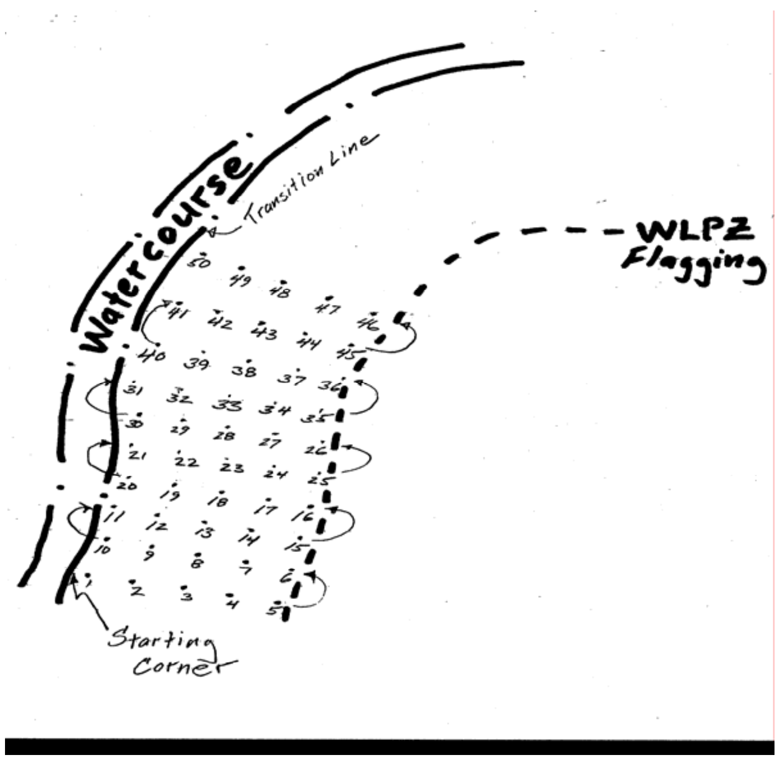


Figure 9. Typical pattern of canopy sighting and groundcover observation points within a typical randomly sampled WLPZ segment.

At each sample point, the inspector recorded total canopy as either a hit or miss, using a sighting tube (shown in Figure 10) as follows: (1) the sighting tube was leveled in front of one eye using the horizontal and vertical bubbles, (2) the dot in the center of the tube was lined up with circle in the center of the tube, and (3) the dot was evaluated as to whether it intercepted an object above the observer, such as needles, a leaf or a tree branch. Hits were recorded as “+” in the hit column and misses were recorded as “-” in the miss column on the WLPZ data form. When deciduous trees were encountered without leaves in the winter, it was assumed that leaf cover would be present in the summer months.

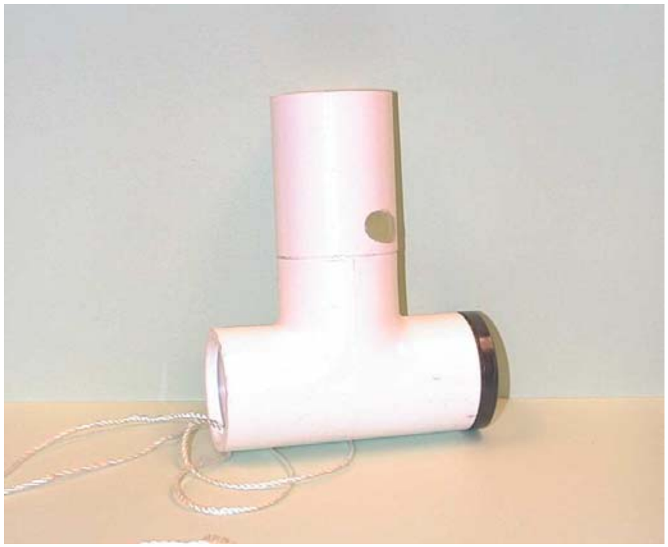


Figure 10. Example of a sighting tube used for making WLPZ canopy measurements.

The proportion of the ground surface covered with duff, litter, gravel larger than ¾ inch, and other protective material was also estimated and recorded at each sample point. In addition, the presence of erosion features or sediment deposition encountered during the transect was documented in association with the nearest sample point, along with information about feature type (i.e., gully, rilling, or areas of sediment deposition) and the feature's approximate size (width, depth, and length) in feet. Each erosion feature was recorded only one time, even if it was observed at more than one location, and a check box for "No erosion features observed in the sample WLPZ segment" was included on the data form to ensure that absence of recorded erosion features was not an oversight.

Following completion of the WLPZ transect, an overall assessment of conditions in the WLPZ segment was made, including whether or not there had been harvesting (yes or no), and if there had been harvesting how much canopy was removed, using three categories: <10%, 10-30%, and 30-50%.

An example of a completed form is included in the Modified Completion Report Methods and Procedures (see Appendix A).

II. Results

WLPZ segments were located in 187 of the 281 THPs included in the MCR sample. The regional distribution was 110 WLPZ segments on the Coast (CDF Region 1), 49 in the Inland North area (Region 2) and 28 WLPZ segments in the Inland South area (CDF Region 4.)

WLPZ Percent Total Canopy

Average percent total canopy cover in WLPZs was higher in the Coast than in the Inland areas. Looking at Class I and II watercourses together, average percentages for the Coast are in the mid to low eighties, and are around seventy for both Inland North and Inland South. In Table 1, below, the column for overall average includes all WLPZ results within each Region. The next two columns to the right split the overall sample into WLPZ segments with no harvest in this entry (the current THP) and WLPZ segments with harvest as part of this entry.

Class I & II WLPZs	Overall	No Harvest	Harvest
Coast (Region 1)	84% n = 110	86% n = 55	82% n = 55
Inland North (Region 2)	68% n = 49	72% n = 12	67% n = 37
Inland South (Region 4)	73% n = 28	69% n = 15	77% n = 13

Table 1. Average percent total canopy in WLPZs by Region for Class I and Class II watercourses combined. The number of segments included in each average equals "n."

Results for Class I watercourses alone are similar (Table 2). Note that the number of WLPZ segments (n) represented in some of these averages is very small. Consequently, the 10 percent difference between average percent canopy for harvested and unharvested WLPZs in the Inland South area is probably not meaningful.

Class I WLPZs	Overall	No Harvest	Harvest
Coast (Region 1)	84% n = 29	83% n = 14	84% n = 15
Inland North (Region 2)	69% n = 18	74% n = 3	68% n = 15
Inland South (Region 3)	71% n = 5	65% n = 2	75% n = 3

Table 2. Average percent total canopy in WLPZs by Region for Class I watercourses. The number of segments included in each average equals “n.”

The percent total canopy results for WLPZs along Class II watercourses are also similar to both the combined and Class I results (Table 3).

Class II WLPZs	Overall	No Harvest	Harvest
Coast (Region 1)	84% n = 81	87% n = 41	81% n = 40
Inland North (Region 2)	67% n = 31	70% n = 9	65% n = 22
Inland South (Region 3)	73% n = 23	70% n = 13	78% n = 10

Table 3. Average percent total canopy in WLPZs by Region for Class II watercourses. The number of segments included in each average equals “n.”

The MCR percent total canopy results for WLPZs are strikingly similar to the findings of the Hillslope Monitoring Program, which used similar canopy measurement techniques, but was based on a completely different random sample of THPs. The importance of this will be covered in more depth in the WLPZ discussion section.

WLPZ Erosion Features

Of the 187 WLPZs sampled, 19 (~10 percent) had one or more erosion features. Of the 19 WLPZs with erosion features, only 2 (or about one percent) had erosion features related to current timber operations. Of the two WLPZ segments with erosion features related to current timber operations, one involved sediment deposition from erosion on a landing upslope, and the other was a gully that resulted from soil with less than 70% groundcover. In the first case, the WLPZ functioned as it should to intercept sediment originating from upslope erosion. In the second case, removal of groundcover as part of the timber operation led to erosion and sediment production, based on field observation.

The causes of the 17 WLPZ erosion features not related to current timber operations were described as follows:

- 6 inner gorge erosion sites,
- 2 streambank failures,
- 1 sediment deposition from a scarp,
- 4 originated from old skid trails/roads,
- 1 gully from a county road,
- 1 eroding cow trail, and
- 1 breached irrigation ditch.

Inner gorge erosion, streambank failures and scarps are natural features of the California landscape, and are common on California's north coast. County roads, cow trails, and irrigation ditches are land management features related to uses other than timber harvesting. Skid trails and skid roads from past timber operations reflect past practices that are not generally permitted under current FPRs.

Other WLPZ Results

Other WLPZ information collected as part of the MCR inspections included WLPZ length, width, canopy removal, understory canopy, and groundcover. Blanks have been interpreted as missing data and were not included in the calculation of average values. In some cases, however, data points with a value of zero may have been left blank.

The average total length of Class I WLPZ in the sampled THPs was 1,309 feet on the Coast (Region 1) and 1,770 feet in the Inland areas (Regions 2&4). The average total length of Class II WLPZ in the sampled THPs was 3,369 feet on the Coast and 3,396 feet Inland.

For all Regions, actual WLPZ widths as paced were equal (within ±5 feet) to the width prescribed in the THP 58% of the time, greater than prescribed 35% of the time, and less than prescribed 7% of time.

The average prescribed WLPZ widths for Class I streams were 129 feet, 92 feet and 75 feet for the Coast, Inland North and Inland South, respectively. WLPZ widths measured on the ground were generally wider than prescribed widths. The average actual widths for Class I streams were 145 feet, 94 feet and 94 feet for the Coast, Inland North and Inland South, respectively. On Class II watercourses, the average prescribed WLPZ widths were 85 feet, 64 feet and 63 feet for the Coast, Inland North and Inland South, respectively. Again, the actual widths were wider than the prescribed widths on average. The average measured widths were 93 feet, 69 feet and 67 feet for the Coast, Inland North and Inland South, respectively.

Canopy removal by current timber operations within sampled WLPZ segments was extremely variable. For Class I watercourses in all Regions, 18 WLPZ segments had no canopy removal, 19 had less than 10% of the canopy removed, 12 had 10% to 30% of the canopy removed, and none had more than 30% canopy removal. For Class II watercourses in all Regions, 64 WLPZ segments had no canopy removal, 44 had less than 10% removed, 25 had 10% to 30% removed, and none had more than 30% canopy removal.

Total canopy has two components: understory canopy and overstory canopy. Based on ocular estimates, the remaining understory canopy in Class I WLPZs was 50% or greater 92% of the time, and the remaining overstory canopy was 50% or greater 96% of the time. Likewise for Class II WLPZs, remaining understory canopy was 50% or greater 91% of the time, and remaining overstory was 50% or greater 92% of the time.

The “Threatened and Impaired Watershed Rule Package Requirements (T&I Standards)” for overstory canopy came into effect on July 1, 2000. They only apply to Class I watercourses in specific watersheds in THPs filed after mid-year 2000. To the question “Does this Class I watercourse meet the T&I standards?” inspectors answered 25 WLPZs did meet the standards, 6 did not, and in 10 the standards were not applicable. There were 11 instances of apparent missing data were the question was not answered.

Regarding WLPZ groundcover, both live and dead, 70% groundcover is a threshold at which surface erosion is normally prevented. Class I WLPZ percent groundcover was equal to or greater than 70% on average 93%, 81%, and 60% of the time for the Coast, Inland North and Inland South, respectively. Similarly, Class II WLPZ percent groundcover was equal to or greater than 70% on average, 93%, 90%, and 71% of the time for the Coast, Inland North and Inland South, respectively. Untreated patches of bare mineral soil equal to or greater than 800 square-feet, or greater than a threshold specified in the THP, were reported in only one Class I WLPZ, which was located on the Coast, and in three Class II WLPZs, one of which was on the Coast and two of which were in the Inland South.

III. Discussion

The MCR results for percent WLPZ total canopy are strikingly similar to the earlier findings of the Hillslope Monitoring Program (Cafferata and Munn 2002), which used similar canopy measurement techniques but was based on a completely different random sample of THPs. Comparisons of these results for Class I watercourses are shown in Table 4 and Figure 11, and Class II watercourse comparisons are shown in Table 5 and Figure 12. Such similarity of results from two independent studies indicates that these averages are a true representation of the current status of WLPZ total canopy cover on recently completed THPs in California.

Table 4. Comparison of MCR (2001-2004) and Hillslope Monitoring Program (1999-2001) results for average percent WLPZ total canopy by Region for Class I watercourses. The number of segments represented in each average equals "n."

Class I WLPZ Comparison	MCR Monitoring (2001-2004) Class I WLPZ percent total canopy	HMP (1999-2001) Class I WLPZ percent total canopy
Coast (Region 1)	84% n = 29	83% n = 27
Inland North (Region 2)	69% n = 18	61% n = 17
Inland South (Region 4)	71% n = 5	67% n = 13
Inland (Regions 2&4 combined)	69% n = 23	64% n = 30

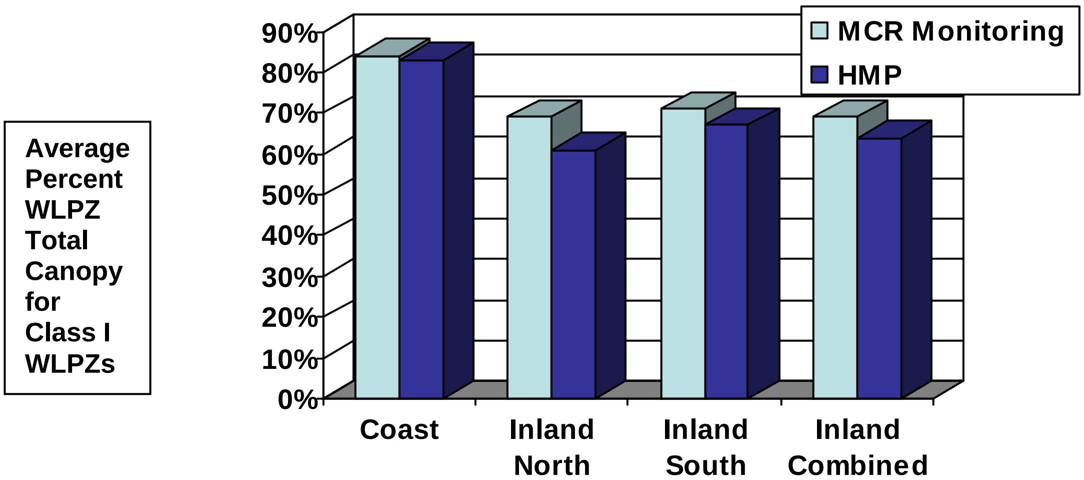


Figure 11. Graphic comparison of MCR (2001-2004) and Hillslope Monitoring Program (1999-2001) results for average percent WLPZ total canopy by Region for Class I watercourses.

Table 5. Comparison of MCR (2001-2004) and Hillslope Monitoring Program (1999-2001) results for average percent WLPZ canopy by Region for Class **II** watercourses. Number of segments represented in each average equals "n."

Class II WLPZ Comparison	MCR Monitoring (2001-2004) Class II WLPZ percent total canopy	HMP (1999-2001) Class II WLPZ percent total canopy
Coast (Region 1)	84% n = 81	80% n = 109
Inland North (Region 2)	67% n = 31	62% n = 46
Inland South (Region 4)	73% n = 23	74% n = 19
Inland (Regions 2&4 combined)	70% n = 54	66% n = 65

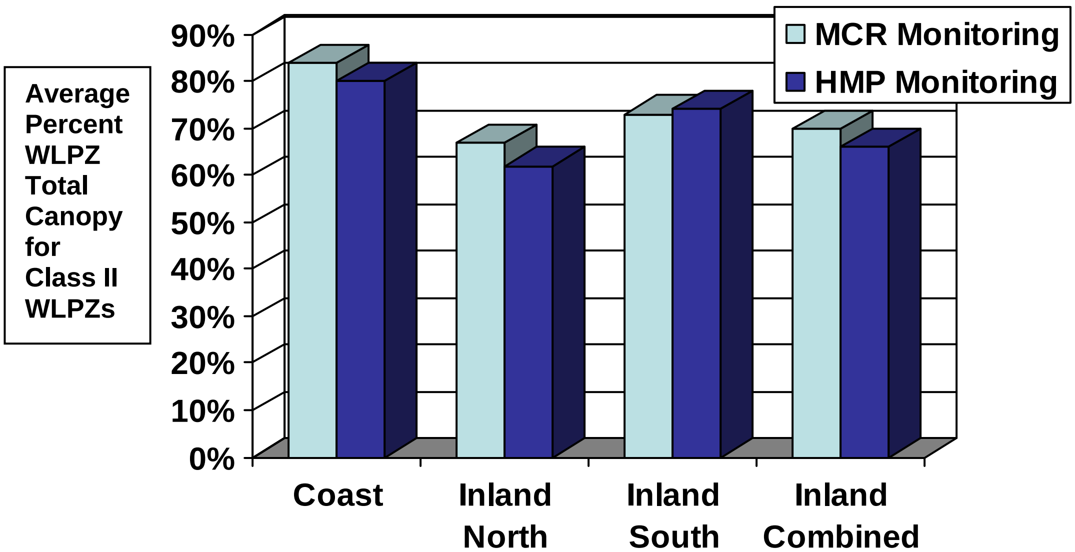


Figure 12. Graphic comparison of MCR (2001-2004) and Hillslope Monitoring Program (1999-2001) results for average percent WLPZ total canopy by Region for Class II watercourses.

Both the MCR and HMP results for percent WLPZ canopy indicate that the FPR standards are generally being met; however, there are rare instances of WLPZs with harvesting done under a current THP that do not meet FPR standards, which are potentially citable violations. Consequently for enforcement purposes, the best strategy to detect such infrequent violations is do quick ocular assessments of as many WLPZs as possible, and reserve more accurate but time-consuming canopy measuring techniques for WLPZs that appear to be probable violations. This observation will be reflected in the recommendations at the conclusion on this report.

Also, as in the HMP, MCR observations of WLPZ groundcover and erosion indicate that WLPZs function well to prevent erosion and sediment transport from current timber operations, assuming they have adequate groundcover and are free of significant patches of bare soil, which was generally found to be the case.

MCR Monitoring:
Roads

I. Methods

Road Segment Selection and Monitoring Timelines

The procedure for randomly selecting a road segment on a THP is described in detail in the *Modified Completion Report Monitoring Procedures and Methods* (see Appendix A). Briefly, a single 1,000-foot long road segment was selected for monitoring on each THP selected for MCR Monitoring (Figure 13). The basic concept is that results from randomly selected segments when aggregated provide unbiased estimates of hillslope erosion, sediment transport off the road prism, and sediment transport to channels.

Figure 13. Pete Cafferata, CDF, recording road observations at a rolling dip. Orange box on his right hip is a hip-chain which meters-out string for tracking distances of specific road-related features along a 1000-foot sample segment.

The initial study design included visiting each road segment twice: first during the Work Completion Report inspection to evaluate implementation, and then during the erosion control maintenance period to evaluate effectiveness after at least one overwintering period. In practice, most of the randomly selected road segments had been through at least one overwintering period prior to the Work Completion Report inspection, therefore most of the evaluations of implementation and effectiveness were done on the first visit.

Segments of roughly equal length (approximately 500 to 1,000 feet) were marked along all of the roads shown on the 1:24,000 scale THP road map. Each segment was then assigned a number. Using either a random number table or function on a calculator, a random number was generated between 1 and the highest numbered segment. The mid-point of the road segment matching the random number was used as the starting point for the 1,000-foot road segment. Direction from the starting point was decided by a coin flip, assuming a 1,000- foot sample road segment could be obtained in either direction.

Not all of the randomly sampled THPs had a single, 1,000-foot long road segment that was suitable for sampling. In these cases, where possible, a sample segment shorter than 1000-feet was monitored. On randomly selected THPs without roads suitable for monitoring (e.g., all of the roads used in the THP were either public roads or residential driveways), no road monitoring was done.

The location of the starting point was marked in the field, often by writing a message such as "Begin MCR Road Sample Segment" and noting the date on flagging attached to a nearby permanent object or vegetation. The *hip-chain* string would then be attached to the starting point and the counter set to zero. While walking the sample road segment, each road-related feature was evaluated and its distance from the start point recorded using the *hip-chain*, until reaching approximately 1,000 feet from the starting point or the end of the road, whichever came first.

Both the procedure and the form used for evaluating road segments were similar to those used in the HMP. Specific methods and the road form are available in the *Modified Completion Report Monitoring Procedures and Methods* (Appendix A). In short, the beginning and ending distances from the segment starting point of all road-related features (e.g., inside ditches, cut banks, waterbreaks, cross drains, etc.) were recorded, regardless of whether or not they presented a water quality problem. Consecutive numbers were assigned to each recorded feature, which, in combination with the THP and segment number, became a unique identifier for that feature. Then codes were recorded to indicate the type of feature and any associated drainage problems, erosion causes, erosion source areas, and sediment production. The dimensions of erosion features were also to be recorded, but this was not done consistently.

The rule numbers used in MCR monitoring were based on the California Forest Practice Rules (CDF 2000) (see Table 6). Unfortunately, the numbering of the FPRs tends to change from year to year with each new version of the rule book. Also, because the road-related rules are located in several sections of the book and because there is often more than one FPR from more one section of the book that covers a road-related feature or issue, the road-related rules tend to be complex. The roads discussion section describes what is being done to remedy this situation.

The California Forest Practice Rules for 2006, with the complete wording of each rule, is available in hardcopy from CDF Headquarters in Sacramento and on-line at http://www.fire.ca.gov/php/rsrc-mgt_forestpractice.php.

Table 6. Summary of road-related Forest Practice Rules that were available for selection for the implementation and effectiveness evaluations for each sample road segment.

Modified Completion Report **Road FPR Pick List (Column C)** Revised 8-11-00		
Type	Rule No.	Description
Waterbreaks	914.6(c) 934.6(c) 954.6(c)	Waterbreak spacing according to standards.
	914.6 (f) 934.6 (f) 954.6 (f)	Where waterbreaks don't work--other erosion controls.
	914.6(g) 914.6(g) 954.6(g)	Waterbreaks constructed with a depth of at least 6 inches cut into firm roadbed.
Roads	923.1(a) 943.1(a) 963.1(a)	Road shown on THP map correctly.
	923.1(a) 943.1(a) 963.1(a)	If landing on road >1/4 ac or required substantial excavation-shown on map.
	923.1(c) 943.1(c) 963.1(c)	Logging roads and landings shall be planned and located, when feasible, to avoid unstable areas.
	923.1(d) 943.1(d) 963.1(d)	For slopes >65% or 50% within 100 feet of WLPZ, soil treated to minimize erosion.
	923.1(e) 943.1(e) 963.1(e)	New logging roads shall not exceed a grade of 15%, except that for 500-foot pitches with max. 20% grades.
	923.1(f) 943.1(f) 963.1(f)	Adequate numbers of drainage facilities provided to minimize erosion.

Type	Rule No.	Description
Roads (continued)	923.1(g) 943.1(g) 963.1(g)	New roads shall be single lane with turnouts, and constructed with balanced cut and fills where feasible.
	923.1(h) 943.1(h) 963.1(h)	Road construction shall be planned to stay out of WLPZs.
	923.1(h) 943.1(h) 963.1(h)	If logging roads will be used from the period of October 15 to May 1, hauling shall not occur when saturated soil conditions exist on the road.
	923.2(b) 943.2(b) 963.2(b)	Sidecast minimized for slopes >65% for distances >100 feet.
	923.2(c) 943.2(c) 963.2(c)	Compacted fill on roads with >50% sideslopes.
	923.2(d) 943.2(d) 963.2(d)	Fills constructed with insloping approaches, etc.
	923.2(e) 943.2(e) 963.2(e)	Breaks in grade above/below throughfill.
	923.2(f) 943.2(f) 963.2(f)	On 35% sideslopes remove organic layer of soil prior to placing fill.
	923.2(g) 943.2(g) 963.2(g)	Proper placement of excess material to avoid polluting streams.
	923.2(h) 943.2(h) 963.2(h)	Drainage structures of sufficient size, number and location to carry runoff water.
	923.2(h) 943.2(h) 963.2(h)	Drainage structures of sufficient size, number and location to minimize erosion.
	923.2(i) 943.2(i) 963.2(i)	Trash racks, etc. installed where appropriate.
	923.2(j) 943.2(j) 963.2(j)	No wood debris in road fills.

Type	Rule No.	Description
Roads (continued)	923.2(k) 943.2(k) 963.2(k)	No overhanging banks.
	923.2(l) 943.2(l) 963.2(l)	Fell trees >12" dbh with >25% of roots exposed by road.
	923.2(m) 943.2(m) 963.2(m)	Sidecast extending >20 ft treated to avoid erosion.
	923.2(o) 943.2(o) 963.2(o)	Discharge onto erodible fill prevented waterbreaks installed to discharge into cover.
	923.2(p) 943.2(p) 963.2(p)	Waterbreaks installed according to standards in FPR 914.6 [934.6, 954.6].
	923.2(q) 943.2(q) 963.2(q)	Drainage facilities in place and functional by October 15, except waterbreaks on roads in use until rains begin to produce overland flow.
	923.2(s) 943.2(s) 963.2(s)	Completed road construction shall be drained by outsloping, waterbreaks, and/or cross-draining by October15.
	923.2(t) 943.2(t) 963.2(t)	Winter roads surfaced where necessary.
	923.2(u) 943.2(u) 963.2(u)	Slash and other debris from road construction placed so as not to discharge into Class I and II streams.
	923.2(v) 943.2(v) 963.2(v)	Road construction activities in the WLPZ, except for stream crossings or specified in the THP, shall be prohibited.
	923.4(a) 943.4(a) 963.4(a)	Road maintenance completed during erosion control period.
	923.4(b) 943.4(b) 963.4(b)	Upon completion of timber operations, temporary roads and associated landing shall be abandoned properly FPR 923.8).
	923.4(c) 943.4(c) 963.4(c)	Waterbreaks maintained to minimize erosion. Erosion controls maintained during maintenance period.

Type	Rule No.	Description
Roads (continued)	923.4(d) 943.4(d) 963.4(d)	Watercourse crossings facilities and drainage structures shall be kept open.
	923.4(e) 943.4(e) 963.4(e)	Roadside berm removed or breached, except where needed for erosion control.
	923.4(f) 943.4(f) 963.4(f)	50-year flow design minimum for drainage structures.
	923.4(g) 943.4(g) 963.4(g)	Temporary roads blocked by start of winter.
	923.4(h) 943.4(h) 963.4(h)	Prevent excessive loss of road surface.
	923.4(i) 943.4(i) 963.4(i)	Soil stabilization where needed to prevent discharge.
	923.4(j) 943.4(j) 963.4(j)	Drainage ditches maintained to allow flow of water.
	923.4(k) 943.4(k) 963.4(k)	Prevent discharge from cuts, fills and sidecast. slopes.
	923.4(l) 943.4(l) 963.4(l)	Maintain trash racks.
	923.4(m) 943.4(m) 963.4(m)	Maintain drainage structures to prevent discharge.
	923.4(n) 943.4(n) 963.4(n)	Maintain drainage structures to prevent diversions.
	923.4(o) 943.4(o) 963.4(o)	Use heavy of equipment, road maintenance in WLPZ is prohibited during the wet season, except in emergencies.
	923.6 943.6 963.6	Wet spots rocked or otherwise treated.

II. Results

Two-hundred and forty-four (244) road segments were rated for implementation of FPRs related to water quality protection. Most of these segments were approximately 1,000 feet long. Some segments were shorter, commonly on plans without a single 1,000 foot long segment, and a few were longer. Using an average length of 1,000 feet, 244 segments equates to approximately 46 miles of road, which is about the distance from Sacramento to Stockton or from San Francisco to San Jose.

Implementation

In this random sample of road segments, a total of 1,991 road features were evaluated for implementation of the FPRs, which gives an average of 43 features per mile of road. Of these 1,991 features, there were 83 departures from the FPRs, or about 1.8 departures per mile of road. It is important to note that these departures tend to be clustered on short sections of bad road. For example, just five road segments out of the total of 244 segments account for 33 of the departures. In other words, the worst 2% of the road mileage accounted for 40% of the departures. This finding has important implications for both road managers and regulators that will be discussed more fully in roads discussion section.

As shown below in Figure 14, of the 1,991 implementation evaluations, 4% were rated as departures from the FPRs, 14% were rated as marginally acceptable, 76% were rated as acceptable, and 6% were rated as exceeding the FPR requirements (greater than acceptable implementation).

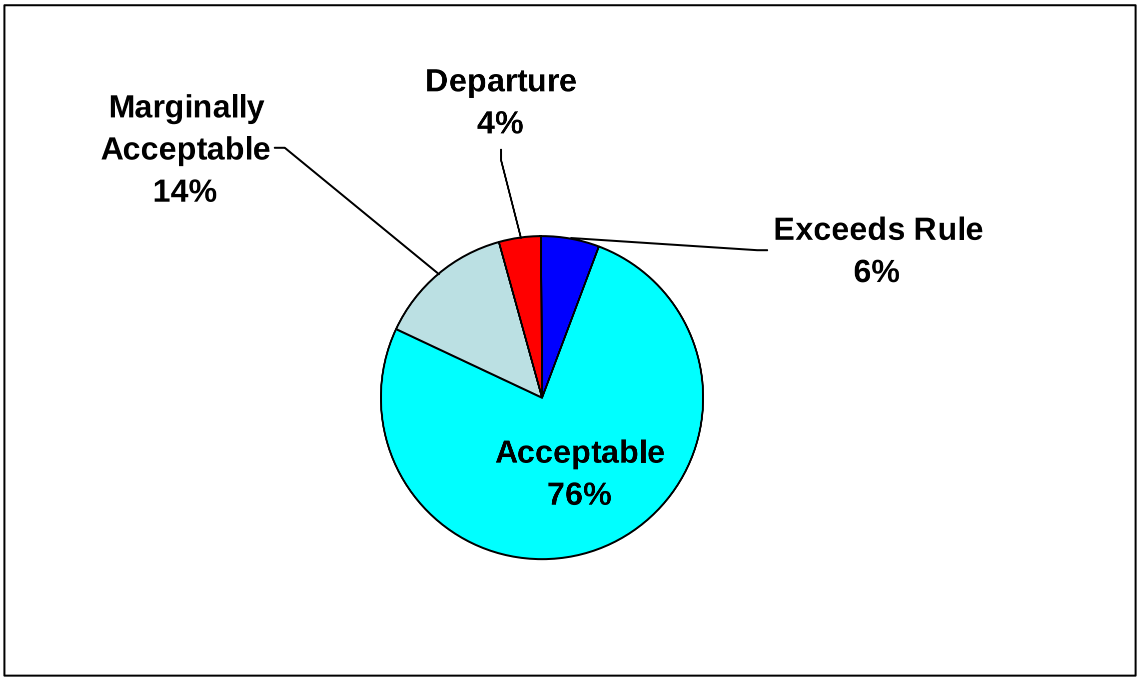


Figure 14. Overall road-related features rated for implementation (n = 1,991).

The Coast (CDF Region 1) accounted for 1,285 of the total 1,991 road features rated for implementation, and 706 were Inland (CDF Regions 2 &4). On the Coast, 2% of the evaluated road features were rated as departures from the FPRs, 15% were rated as marginally acceptable, 76% were rated as acceptable, and 7% were rated as exceeding the FPR requirements (Figure 15).

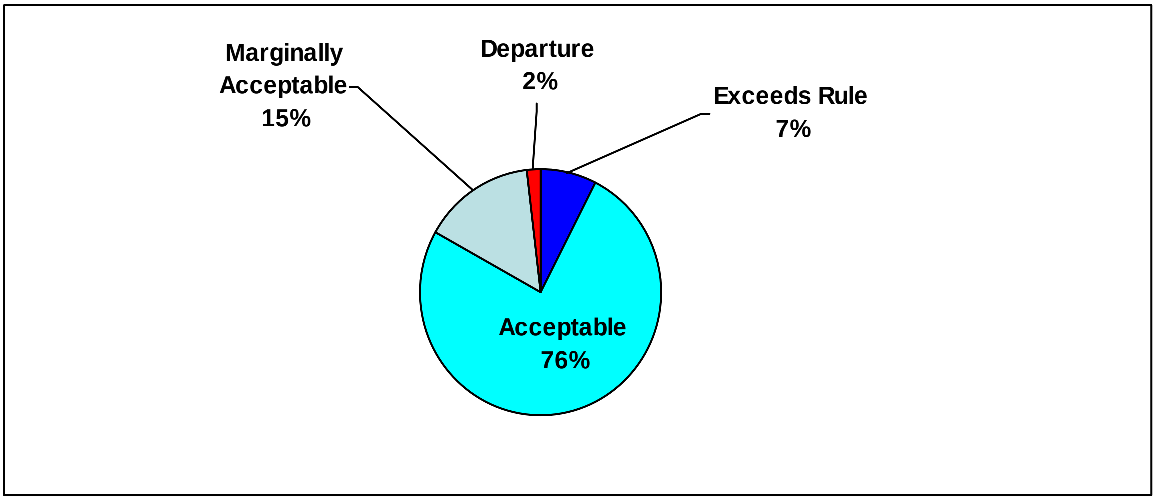


Figure 15. Coast (CDF Region 1) road-related features rated for implementation (n = 1,285).

Inland, 8% of the evaluated road features were rated as departures from the FPRs, 11% were rated as marginally acceptable, 78% were rated as acceptable, and 3% were rated as exceeding the rule (Figure 16).

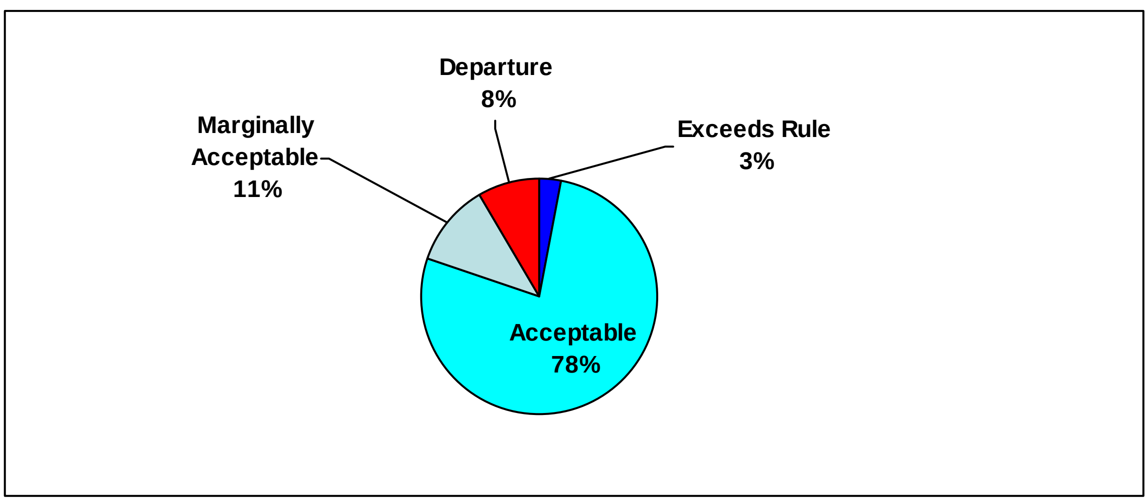


Figure 16. Inland (Regions 2 & 4) road-related features rated for implementation (n = 706).

There is a notable difference between the departure rates of 2% and 8% for coastal and inland regions, respectively. Combining the departure and marginally acceptable ratings for the coast region and also for the inland regions gives much closer results of 17% and 18%. Therefore, it is possible that the difference in departure rates could be an artifact of where inspectors conducting the MCR evaluations in the different regions choose to draw the line between departures vs. marginally acceptable implementations of FPRs. Determining whether this difference is real or not would require having personnel conducting the MCR inspections work and/or train across regions.

Assuming that departure rates for the Coast and Inland regions have been consistently evaluated, there are greater opportunities for improved implementation Inland, where the worst 6% of road segments account for three-quarters of the observed departures. Consequently, preventing departures on the worst 6% of the road mileage would hypothetically reduce the inland departure rate from 8% to a much more acceptable 2%, as shown in Figure 17, below.

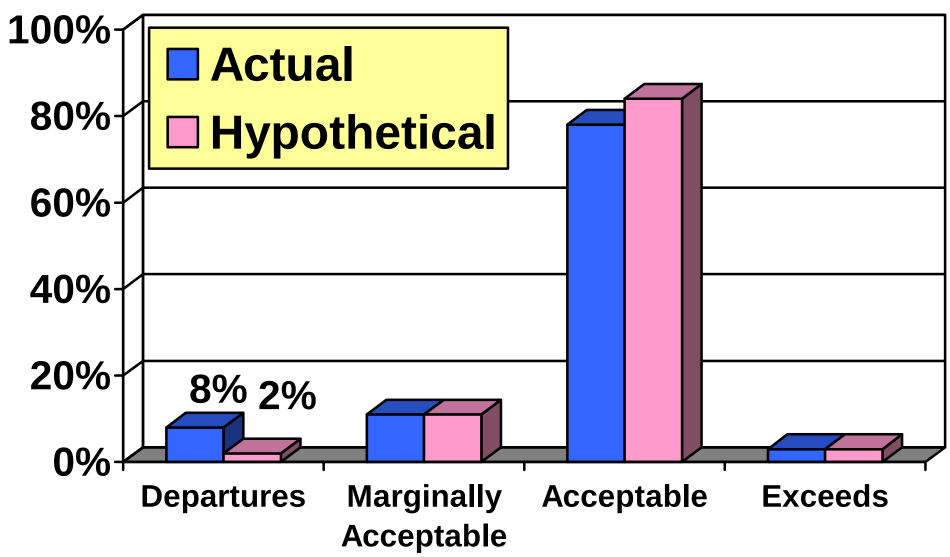


Figure 17. Inland (CDF Regions 2 & 4) hypothetical exercise: What would happen to the departure rate if we found and fixed the worst 6% of all road segments? Answer, the departure rate would hypothetically drop significantly from 8% to 2%.

On the Coast, the departure rate is already a relatively low 2%, and fixing the worst 6% of the road mileage brings the departure rate down to 1% (Figure 18).

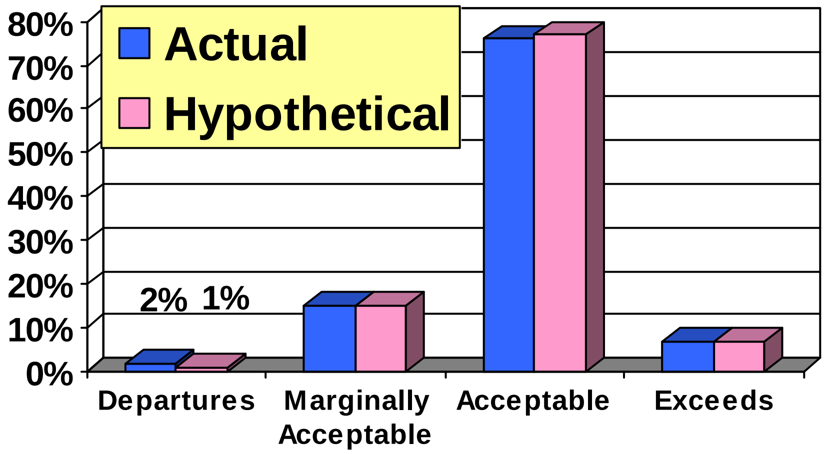


Figure 18. Coast (CDF Region 1) hypothetical exercise: What would happen to the departure rate if we found and fixed the worst 6% of all road segments? Answer, the departure rate would hypothetically drop slightly from 2% to 1%.

Figure 19. Example of road segment built to drain properly in wet weather. Note the two functional dips and their spacing.

The monitoring results demonstrate that most road features are implemented properly (figure 19), since 96% of the road features were rated marginally acceptable or above, as shown in Figure 14 presented earlier. However, there is still room for improvement, and these improvements can and should be focused on areas where it is possible to further reduce the impacts of roads on water quality.

When looking at specific types of features related to observed departures from the FPRs, there is very a definite pattern. Overall, 95% of the observed road-related departures involve FPRs directly related to providing proper drainage. Some of the remaining five percent of departures may also be directly or indirectly affected by drainage. Figure 20, shown below, groups the 95% of departures that are definitively related to drainage into five major categories, and a list of these departures by specific FPR is provided at the end of this section.

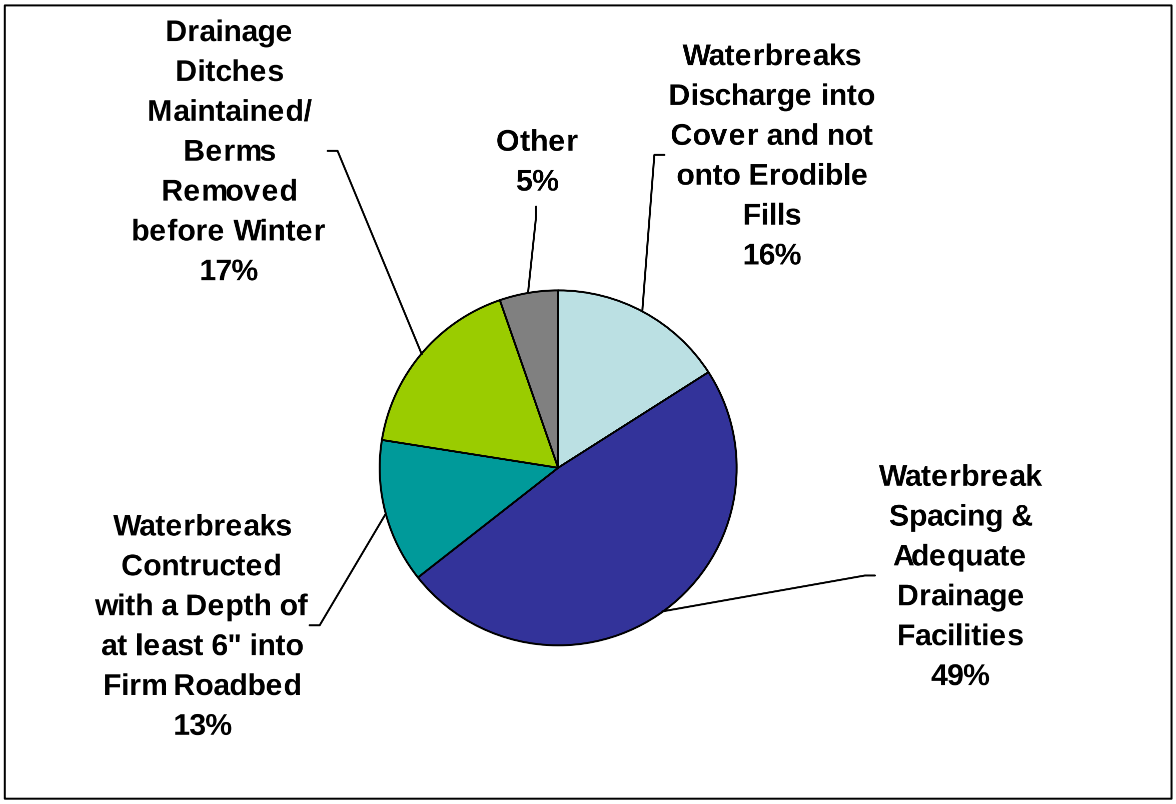


Figure 20. Departures from the road-related FPRs – percentages by category.

As demonstrated in Figure 20, the waterbreak spacing and adequate drainage category accounts for about half of the departures; drainage ditches maintained/ berms removed before winter category accounts for 17%. The waterbreaks discharge into cover and not onto erodible fills category accounts for 16%. The waterbreaks constructed with a depth of at least six inches into firm roadbed category accounts for 13%, and the catch-all category of "other" accounts for only 5% of the departures.

Effectiveness

A total of 130 out of the 244 sampled road segments were rated for FPR effectiveness, which (assuming an average segment length of 1,000 feet, as described above) equates to about 24 miles of sampled roads. These 130 road segments included 1,147 road-related features that were evaluated and rated for effectiveness and are subsets of the 244 road segments and 1,991 features rated for implementation, respectively.

All road segments rated for effectiveness had been through at least one wet season. An important caveat is that selection of road segments rated for effectiveness was not completely random, but neither was it systematic. At the time the monitoring study was designed, it was thought that all road segments in the sample would eventually be rated for effectiveness. This topic is discussed further in the discussion section.

As shown in Figure 21, below, evidence of erosion was found on 109 of the 1,147 road-related features rated for effectiveness. Sediment transport was found associated with 36 of the 109 erosion features, and 9 of those 36 features had evidence of sediment transport to a watercourse channel.

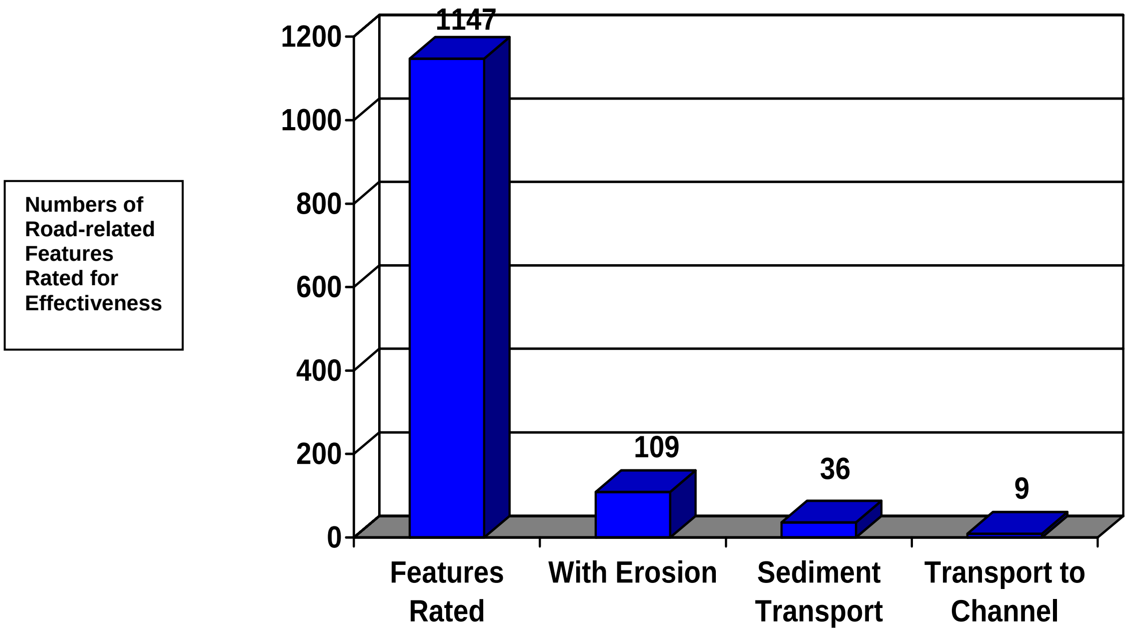


Figure 21. Road-related features rated for effectiveness, comparing the total features rated to the number with evidence of erosion, sediment transport and transport to channel.

When calculated as a percentage of the total features rated, 9.5% of the road features evaluated for effectiveness had erosion, 3.1% showed signs of sediment transport, and 0.8% showed evidence of sediment transport to a channel, as shown in Figure 22.

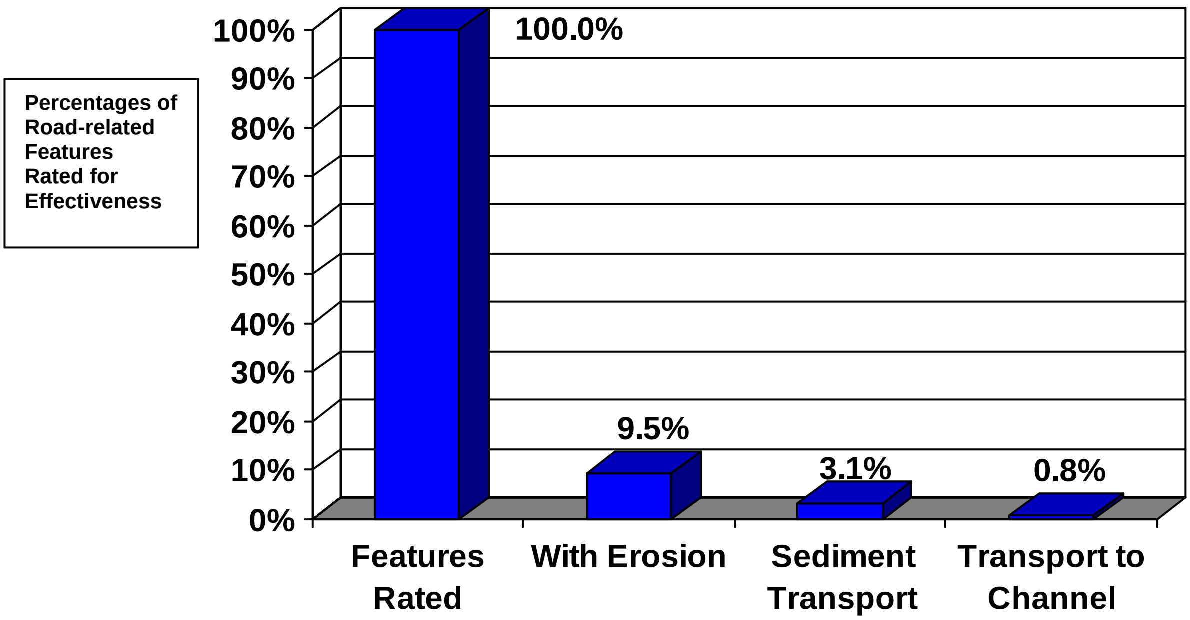


Figure 22. Road-related features rated for effectiveness as percentages, comparing the total features rated to the number with evidence of erosion, sediment transport and transport to channel.

Dividing the data into regions yields 639 road-related features rated for effectiveness on the Coast (CDF Region 1) and 508 Inland (CDF Regions 2 & 4). Of these, 35 and 74 had evidence of erosion, 9 and 27 showed evidence of sediment transport, and 4 and 5 had evidence of transport to a channel for the coast and inland regions, respectively, as shown in Figure 23.

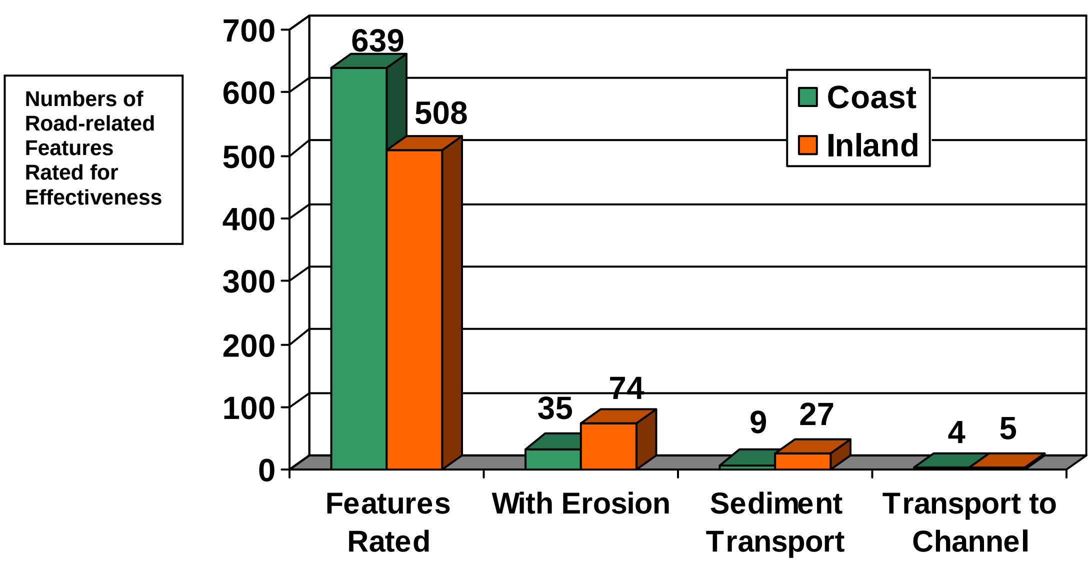


Figure 23. Coast vs. Inland road-related features rated for effectiveness, comparing the total features rated to the number of features with evidence of erosion, sediment transport and transport to channel.

Expressing these results as percentages, as shown in Figure 24, allows an easier comparison between regions. Erosion was found on 5.5% of the road-related features on the Coast versus a much higher 14.5% Inland. Evidence of sediment transport was observed on 1.4% of road-related features on the Coast and on 5.3% Inland. Evidence of sediment transport to channels was found on 0.6% of the road-related features on the Coast and 0.9% Inland.

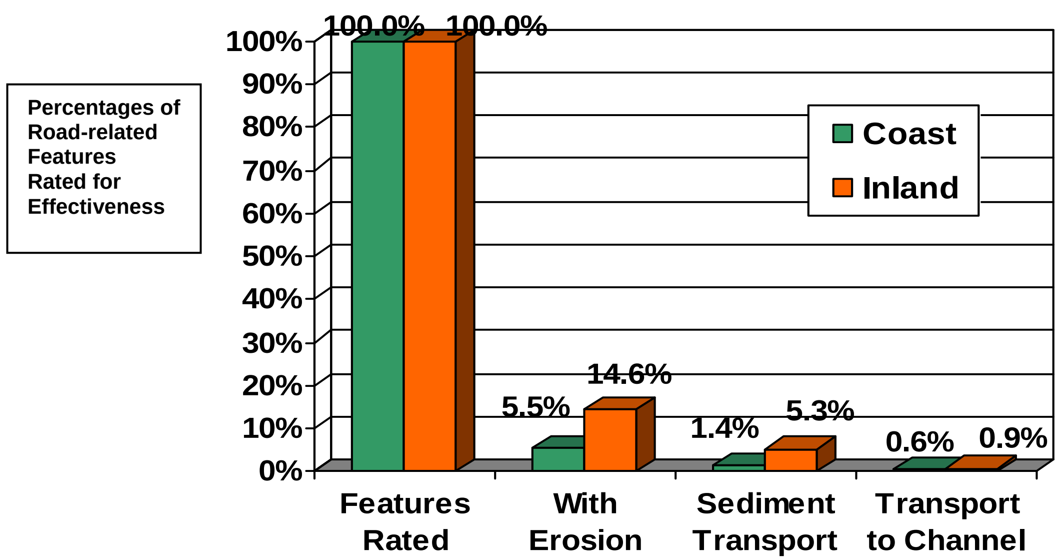


Figure 24. Coast vs. Inland road-related features rated for effectiveness as percentages, comparing the total features rated to the percentage of features with evidence of erosion, sediment transport and transport to channel.

Inland road-related features show signs of erosion and sediment transport more frequently than road-related features on the Coast; however, the percentage of road-related features showing evidence of sediment transport to channels is about the same on the Coast and Inland. One possible explanation for this is that timberlands on the Coast generally get more rainfall than timberlands in Inland and consequently develop denser networks of natural channels, which put road-related features closer to more channels.

Implementation vs. Effectiveness

Better implementation of the road-related FPRs resulted in greater effectiveness in preventing erosion, sediment transport, and sediment transport to channels. While properly implemented road FPRs occasionally failed to prevent erosion, sediment transport, and discharge, improperly implemented FPRs failed at a much higher rate.

Of the 1,147 road-related features that were evaluated for both implementation and effectiveness, 5% had implementation that exceeded the FPR, 78% had acceptable implementation, 12% had marginally acceptable implementation, and 5% were departures from the rule (unacceptable implementation). The effectiveness of each of these implementation categories in preventing erosion, sediment transport and sediment transport to channel is shown in Table 7, below.

Road-related Features Implementation Rating	Effectiveness Problems		
	Erosion	Sediment Transport	Transport to Channel
Exceeds Rule/THP requirement n = 57	2%	0%	0%
Acceptable n = 893	5%	1%	1%
Marginally Acceptable n = 142	23%	9%	1%
Departures n = 55	53%	35%	11%

Table 7. FPR effectiveness: road-related feature implementation ratings vs. percent of features with effectiveness problems.

The results shown in Table 7 demonstrate that the FPRs were very effective in preventing erosion and sediment transport related to roads. When implementation exceeded the rule requirements, erosion was found only 2% of the time, and no evidence of sediment transport or sediment transport to a channel was observed. With acceptable implementation of the FPRs, erosion was found 5% of the time, and evidence of sediment transport or sediment transport to a channel was observed only 1% of the time. However, when implementation of the FPRs was marginally acceptable, erosion was found 23% of the time, sediment transport was seen at 9% of the evaluated features, but evidence of sediment transport to a channel was still observed only 1 percent of the time. When implementation was rated as departing from the FPRs, erosion was found at more than half of the road-related features, sediment transport was seen 35% of the time, and evidence of sediment transport to channels was found at 11% of the evaluated sites, which indicates a noticeable reduction in water quality protection.

In summary for roads, when there is a departure from the rule, the chance of erosion is about 1 in 2, the chance sediment transport is about 1 in 3, and the chance of sediment transport to a channel 1 in 10. But where the FPR implementation is acceptable or better, the chance of erosion is about 1 in 20, and the chance of sediment transport or sediment transport to a channel is equal to or less than 1 in 100.

Sediment transport to a channel can lead to water quality impacts. Evidence of transport to channels was seen on 9 road-related features out 1,147 rated for effectiveness, which is about 0.8 percent. Implementation ratings for these nine road-related features included three rated as acceptable, one rated as marginally acceptable and five rated as departures from the rule. Two of three features rated as acceptable and the one feature rated as marginally acceptable were located at watercourse crossings in the sampled road segments. The remaining feature rated as acceptable involved a road drainage site impacted by a high-intensity storm. Of the five features rated as departures, two involved discharges onto erodible material or failure to discharge into cover. The other three departures were related to inadequate numbers of drainage facilities/structures or inadequate spacing.

III. Discussion

The FPRs related to roads were found to be properly implemented 96% of the time and, when properly implemented, effectively prevented erosion from most road features. Where erosion did occur, proper rule implementation prevented nearly all road-related sediment transport and discharge into channels. The infrequent departures from the road rules were associated with most of the road-related erosion, sediment transport, and sediment deposition in channels. Departures with potential to impact water quality were generally related to inadequate drainage and failure to discharge onto non-erodible sites. From a management and regulatory standpoint, it is useful to note that departures with potential to impact water quality occur on only 5% to 6% of road segments, or about one mile out of every twenty miles of THP roads. As a result, finding and fixing drainage problems on the worst 5% of all road segments would produce the greatest reduction in road-related water quality impacts for the least amount of money.

The MCR road results compare reasonably well with earlier monitoring work conducted in California on non-federal timberlands. In the HMP, Cafferata and Munn (2002) reported that 93.2% of the road rules evaluated for implementation were rated as acceptable. Where there was sediment transport to watercourse channels documented, erosion features were usually caused by a drainage feature deficiency, and the FPRs rated at these problem sites were nearly always found to be out of compliance. Most of the identified road problems were related to inadequate size, number, and location of drainage structures; inadequate waterbreak spacing; and lack of cover at waterbreak discharge points. Approximately 15% of the inventoried erosion features delivered sediment to watercourse channels, compared to 11% percent sediment delivery at rule departure sites in the MCR. Only 5.5% of the drainage structures evaluated along the road transects in the HMP were found to have problems.

The FPRs do not apply to federal lands, but the USFS has an analogous set of road-related BMPs. The USFS (2004) reported that from 1992 through 2002 on California National Forests, BMPs for road surface, drainage, and slope protection were implemented at 85% of the 284 sites evaluated. At the 40 sites where these BMPs were not implemented, consistency of drainage structure repair with road management objectives was the criterion for which both minor and major departures were most common. BMPs were effective 90% of the time that they were implemented. At the sites where effectiveness objectives were not met, minor departures were most frequently associated with rilling on road surfaces and fillslopes. Sediment discharges to stream management zones (SMZs) or stream channels were the most common type of major departures. Effects were classified as elevated at less than 5% of the sites. Inadequate BMP implementation caused the elevated effects at all but one of these sites.

In their current form, the road-related FPRs are complicated and not organized well in the Forest Practice Rule Book. A Road Rules Committee of the Board of Forestry and Fire Protection is currently working on ways to revise and streamline these rules. This has the potential to further improve the effectiveness of road-related FPRs by making them easier to implement and enforce and also has the potential to make the rules easier to monitor in future MCR efforts.

The form used for data collection by this MCR monitoring study needs to be revised for future MCR monitoring. The current form was modeled after the form used in the HMP, where most of the observations were made by one team of observers (a single contractor) working closely together in the field. In contrast, the MCR observations were made by multiple observers (CDF Forest Practice Inspectors), and the complexity of the form caused inconsistencies in data collection from multiple observers working at various, disparate locations. Therefore, the data collection form should be simplified to focus on factors related to drainage spacing and adequacy, discharge into groundcover, and percent road grade between drainage structures that this study and others have found to be most closely associated with erosion and sediment transport. A revised road form for future MCR monitoring is currently being developed and will be available for field testing later in 2006.

MCR Monitoring:
Watercourse Crossings

I. Methods

Monitoring Timelines and Site Selection

The first two permanent or abandoned crossings on Class I, II, or III watercourses encountered along the randomly located 1000-foot road transect (as described in the Road Section of this report) were selected for MCR monitoring (Figure 25). Inspectors were instructed to sample the first crossing that was available and to not be concerned whether these features were distributed throughout the THP area or whether similar types of crossings were being evaluated.

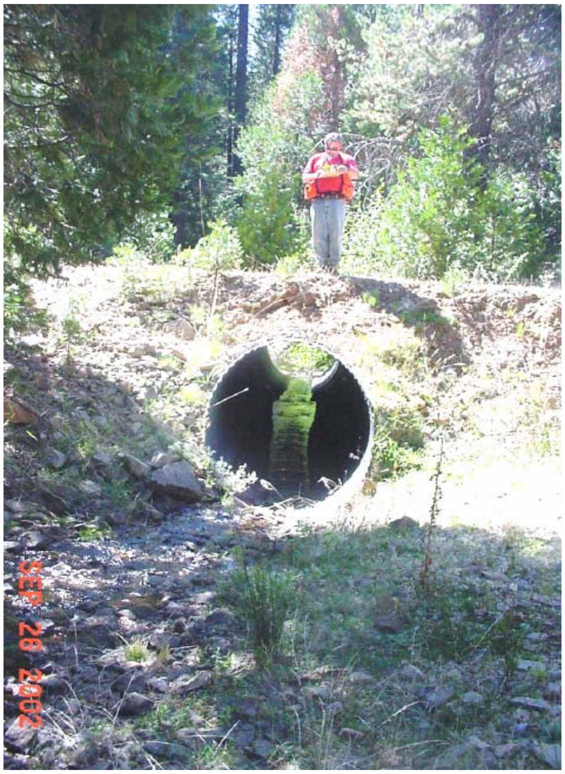


Figure 25. Clay Brandow, CDF, rating implementation and effectiveness for a Modified Completion Report watercourse crossing in the central Sierra Nevada Mountains.

If no crossings were noted within the 1000-foot road transect, then inspectors selected the closest watercourse crossings shown on the THP map relative to the randomly chosen road transect. If there were no watercourse crossings associated with roads, then the nearest skid trail crossings were evaluated. If there were no watercourse crossings within the THP, this information was recorded at the beginning of the

Watercourse Crossing form package.

The area to be included in the watercourse crossing evaluation was determined by inspecting the road prism in both directions from the crossing and identifying the points where drainage from the road surface, cuts, and fills was no longer transported to the crossing. The evaluation also included the drainage structures on the road immediately upslope from the crossing that should route water away from the crossing (e.g., “cut-off” waterbar). The road length for evaluation was located between these points.

The *MCR Methods and Procedures* guidelines specified that each of the selected crossings was to be rated on two separate occasions:

1) During field inspection of the THP Work Completion Report, CDF’s Forest Practice Inspector recorded site information on the MCR field form and rated implementation of applicable Forest Practice Rules for the selected watercourse crossing; and

2) The Inspector was asked to use the same form to rate rule effectiveness after at least one over-wintering period during the Erosion Control Maintenance Period.[3]

Watercourse Crossing Site Information

The following site information was included on the Watercourse Crossing Implementation Form:

- watercourse class (i.e., I, II, III, or IV – see glossary for definitions),
- road type (i.e., permanent, seasonal, temporary, or abandoned),
- crossing type (i.e., culvert, ford, bridge, etc.),
- crossing status (i.e., existing or abandoned),
- culvert diameter (if appropriate), and
- installation date (i.e., installed prior to the THP or newly installed as part of THP).

The crossing site information and implementation field form is displayed in Appendix A.

Watercourse Crossing Forest Practice Rule Implementation Rating

Following completion of the site information portion of the form, the Inspector rated implementation of 27 FPR requirements for roads and crossings found in 14 CCR § 923 [943, 963] and three Rule requirements for skid trails and crossings (referred to as tractor roads in the FPRs) found in 14 CCR § 914 [934, 954] using one of the following five implementation codes:

[3] This did not occur on a majority of the evaluated sites. Data on a second time period effectiveness evaluation is provided in the watercourse crossing results section.

D - Departure
MA - Marginally Acceptable
A - Acceptable
ER - Exceeds Rule/THP Requirements
N/A - Not Applicable

Watercourse Crossing Effectiveness Rating

The Watercourse Crossing Effectiveness Form was patterned after the crossing form (E09) developed by the USFS as part of their Best Management Practices (BMP) Evaluation Program (USFS 1992; USFS 2004), as well as a simplified version of the field forms developed for the BOF's Hillslope Monitoring Program (Cafferata and Munn 2002). Features rated for effectiveness were included within the following major categories: fill slopes, road surface drainage to the crossing, culvert design/ configuration, non-culverted crossings, and removed/abandoned crossings. In most cases, the effectiveness rating was selected from a description that generally can be summarized by one of the following four categories: not applicable (N/A), not a problem ("none" or "slight"), a minor problem, or a major problem. The Watercourse Crossing Effectiveness Form is displayed in Appendix A, and the following is a description of the rating criteria used for the 27 different crossing features.

FILL SLOPES

Gullies: Gullies were defined as being greater than 6 inches deep. The major problem category was checked if the gullies were significant and appeared to be enlarging.

Cracks: Cracks on fill slopes were assessed to determine whether they appeared to be stabilized or were widening, threatening the integrity of the fill.

Slope Failures: Slope failures were defined as movement of soil in blocks, rather than by rills, gullies or sheet erosion. The Inspector estimated whether fill slope failure(s) at the crossing site totaled between 0 and 1 cubic yard (minor problem), or greater than one cubic yard (major problem).

ROAD SURFACE DRAINING TO THE CROSSING

Gullies: Gullies on the road surface draining towards the crossing were rated as a major problem if they appeared to be enlarging or depositing sediment into a watercourse channel.

Cutoff Drainage Structure: Cutoff drainage structures were evaluated to determine if they were preventing water from reaching the crossing location. The major problem category was selected when water was reaching the crossing.

Inside Ditch Condition: When an inside ditch was present, its condition was evaluated to determine how functional it was in routing water to the culvert inlet. The major problem category was picked if the ditch was blocked with sediment or debris.

Ponding: The road surface was inspected for evidence of surface water ponding. A major problem was defined as ponding that threatened the integrity of the fill material.

Rutting (from vehicles): When vehicle ruts were present, the major problem category was selected if they impaired road drainage.

CULVERT DESIGN/CONFIGURATION

Crossing Failure: The Inspector determined whether the crossing had failed (yes/no) and recorded an estimate of cubic yards of fill lost at failure sites.[4]

Scour at Inlet and Outlet: The total amount of scour that had occurred and was likely to occur in the next two years at both the inlet and outlet of the culvert was estimated. The presence of significant scour, which may have undercut the fill material, was used to identify major problems.

Diversion Potential: Diversion of streamflow at crossings can transport large amounts of sediment to stream channels. The amount and direction of road surface slope at the crossing was used to determine whether the stream would be diverted down the roadway if flow exceeded the culvert capacity or the culvert was plugged with wood or sediment.

Plugging: The inlet and outlet of the culvert were inspected to determine the presence of debris (i.e., small wood, soil or rock) and, if debris was present, the degree of blockage. The major problem category was selected if more than 30% of the pipe opening was obstructed.

Alignment: The channel configuration was evaluated at the culvert inlet to determine if the pipe was properly aligned with the channel. A major problem was indicated by the presence of a considerable angle for the channel approach.

Degree of Corrosion: For steel pipes, the competency of the metal was evaluated. The major problem category was assigned if the pipe could be easily punctured.

Crushed Inlet/Outlet: The Inspector determined if the pipe inlet or outlet had been deformed. Less than 30% blockage by crushing was defined as a minor problem, and greater than 30% was a major problem.

Pipe Length: Pipe length was evaluated to determine if it was appropriate for the fill placed at the crossing, or whether insufficient culvert length was causing significant erosion problems.

Gradient: Improper culvert gradient was indicated when the pipe inlet was set too low

[4] This data was frequently not recorded.

or too high in the fill causing debris accumulation, unless this was intended for fish passage and the remaining culvert area provided sufficient flow capacity.

Piping: The crossing fill was inspected to determine if streamflow was passing beneath or around the culvert, without being routed through the pipe.

NON-CULVERT CROSSINGS (e.g., Rocked Ford)

Armoring: The amount and size of applied rock and cobbles at the crossing were observed to determine if minor or major downcutting was occurring at the crossing site.

Scour at Outlet: The total amount of scour that had occurred and was likely to occur in the next two years was observed at the crossing outlet. The presence of noticeable scour was used to indicate a major problem.

Diversion Potential: The watercourse crossing and approaches were examined to determine if they would prevent diversion of stream overflow down the road if the drainage structure became blocked. A major problem was indicated if water had or would flow down the road instead of being directed off the road surface.

REMOVED OR ABANDONED CROSSINGS

Bank Stabilization: Bank cuts were evaluated to determine if cover prevented transport of exposed surface soil to a watercourse. The major problem category was selected when less than 50% of the banks had effective cover.

Gullies: Gullies were defined as being greater than 6 inches deep. The major problem category was used when large gullies were present and appeared to be enlarging.

Slope Failure: The volume of fill slope failure(s) at the crossing was estimated and ratings were assigned based on totals of less than 1 cubic yard (slight), greater than 1 cubic yard without channel entry (minor), or greater than 1 cubic yard and deposition into a stream channel (major).

Channel Configuration: The restored channel configuration was examined at abandoned and removed crossings to determine if it was wider than the natural channel and as close as feasible to the natural watercourse grade and orientation. Small differences from natural channel width, grade, or orientation were rated as a minor problem, while a major problem was assigned when there were significant differences from natural channel width, grade, or orientation.

Excavated Material: The channel was observed to determine if banks had been sloped back and stabilized to prevent slumping and minimize sediment input into the channel. A minor problem was defined as having less than 1 cubic yard of excavated material transported to the channel, and a major problem was identified when greater than 1 cubic yard of material had entered the channel.

Maintenance Free Drainage: The abandonment procedure was evaluated to determine if it was providing permanent, maintenance free drainage, or if minor/major problems were noted.

II. Watercourse Crossing Results

General Results

A total of 357 watercourse crossings were rated for implementation from 2001 through 2004, and 289 of these crossings were rated for effectiveness (Table 8.) Of these crossings, 63% were located on the Coast (CDF Region 1), 25% were in Inland North (CDF Region 2), and 12% were in Inland South (CDF Region 4). The intention was to rate all 357 watercourse crossings for effectiveness; however, 68 had not been rated for effectiveness by July 2004 when MCR data collection was suspended due to budget uncertainties.

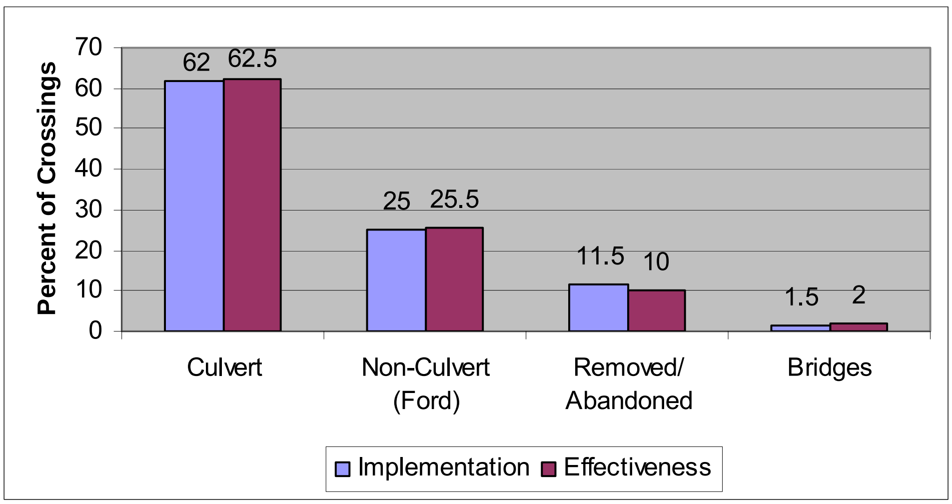


Figure 26. Distribution of watercourse crossing types for both the implementation and effectiveness evaluations.

Watercourse Crossing Type	Implementation	Effectiveness
Culvert	221	181
Non-culvert (ford)	89	74
Removed/Abandoned	41	29
Bridge	6	5
Total	**357**	**289**

Table 8. Distribution of watercourse crossing types rated for implementation and effectiveness from 2001 through 2004.

The proportions of crossing types were very similar in both implementation and effectiveness data sets (Figure 26, Table 8). For the implementation ratings, approximately 62% of the crossings were culverts, 25% were non-culverted crossings (mainly fords), 11.5% were removed or abandoned crossings, and 1.5% were bridges. Of the crossings rated for implementation, 59% were located in Class III watercourses, 34% were in Class II watercourses, 4% were in Class I's, and 1% were in Class IV watercourses (with missing data on 2%) (Figure 27). Nearly all the non-culverted crossings were in Class III watercourses, while the proportions of crossings with culverts were nearly the same in Class II and III watercourses. Bridges were almost entirely associated with Class I watercourses, and removed/abandoned crossings were mostly found in Class II and III watercourses (Table 9).

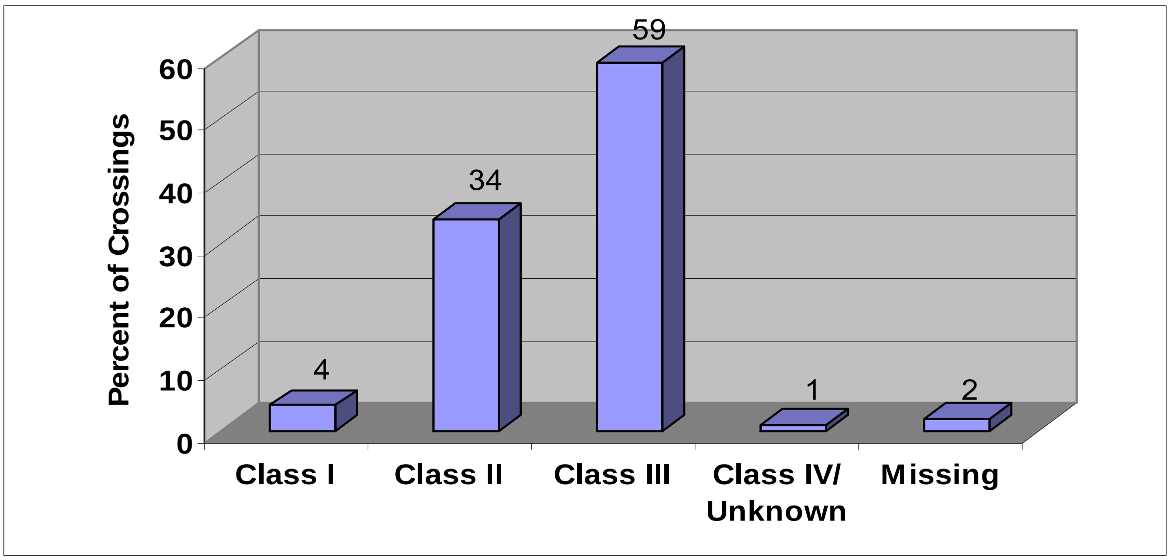


Figure 27. Percentages of the sampled watercourse classes.

Watercourse Class	Bridge	Culvert	Non-Culvert (Ford)	Removed/ Abandoned	Total
I	5	6	0	4	15
II	1	94	8	17	120
III	0	112	79	20	211
IV	0	4	0	0	4
Missing Data	0	5	2	0	7
Total	**6**	**221**	**89**	**41**	**357**

Table 9. Watercourse classes summarized by watercourse crossing types.

Almost three-quarters (74%) of the crossings with culverts were found on seasonal roads, and about a quarter (24%) were on permanent roads (Table 10). Similarly, 83% of the non-culverted crossings were associated with seasonal roads. Removed or abandoned crossings were approximately equally distributed between seasonal roads and skid trails, and were found to a lesser degree on temporary roads. Bridges were found on permanent and seasonal roads.

Road Type	Bridge	Culvert	Non-Culvert (Ford)	Removed/ Abandoned	Total
Permanent	2	54	3	0	59
Seasonal	4	163	74	17	258
Temporary	0	2	3	8	13
Skid Road	0	2	7	14	23
Combined Categories	0	0	2	0	2
Missing Data	0	0	0	2	2
Total	**6**	**221**	**89**	**41**	**357**

Table 10. Distribution of watercourse crossing types summarized by road type.

For crossings with culverts, 67% had pre-existing culverts and 33% of the crossings had new pipes installed as part of the THP. Roughly half the non-culverted and removed/abandoned crossings (46% and 51% respectively) were new, and one-third (33%) of the evaluated bridges were classified as being installed as part of the plan (Table 11).

Crossing Status	Bridge	Culvert	Non-Culvert (Ford)	Removed/ Abandoned	Total
Existing	4	149	48	16	217
New	2	72	41	21	136
Missing Data	0	0	0	4	4
Total	**6**	**221**	**89**	**41**	**357**

Table 11. Crossing types installed as part of the plan or prior to the plan date.

The distribution of pipe sizes for crossings with culverts is displayed in Figure 28. This diagram shows that approximately 41% of the pipes were 18 inches in diameter, 21% were 24 inches, 12% were 36 inches, and 7% were 48 inches or larger. Figure 29 illustrates that the majority of the Class III watercourses had 18 inch diameter pipes, while Class II watercourses had a more equal distribution of 18, 24, and 36 inch pipes. Class I watercourses had 48 inch and larger CMPs installed, while Class IV's had 24 inch and smaller diameter pipes.

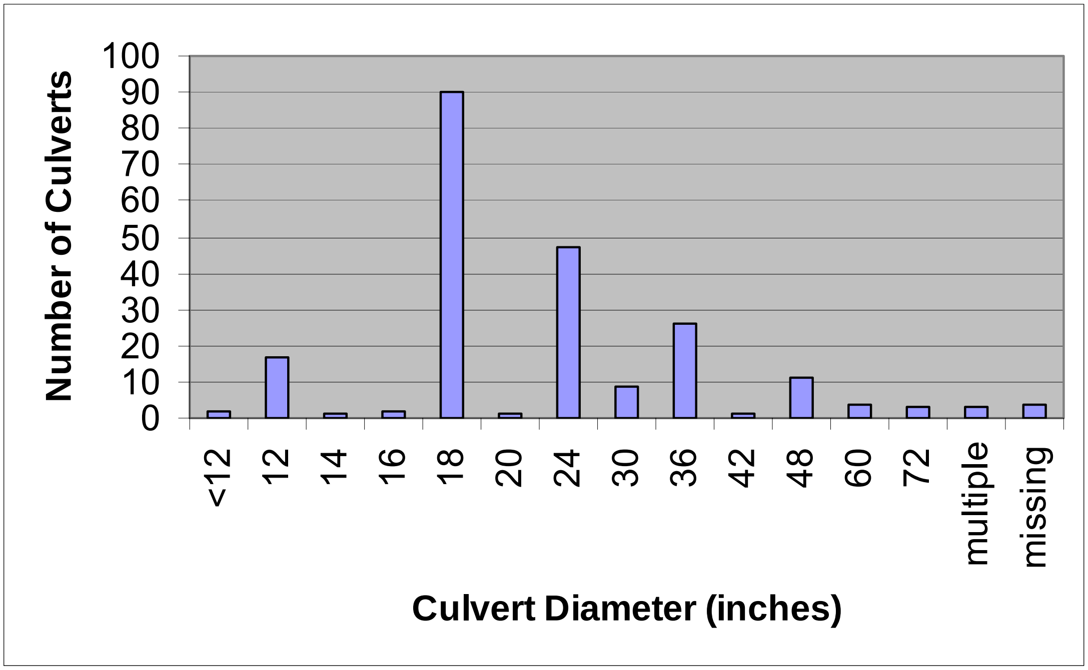


Figure 28. Culvert size distribution for watercourse crossings with pipes.

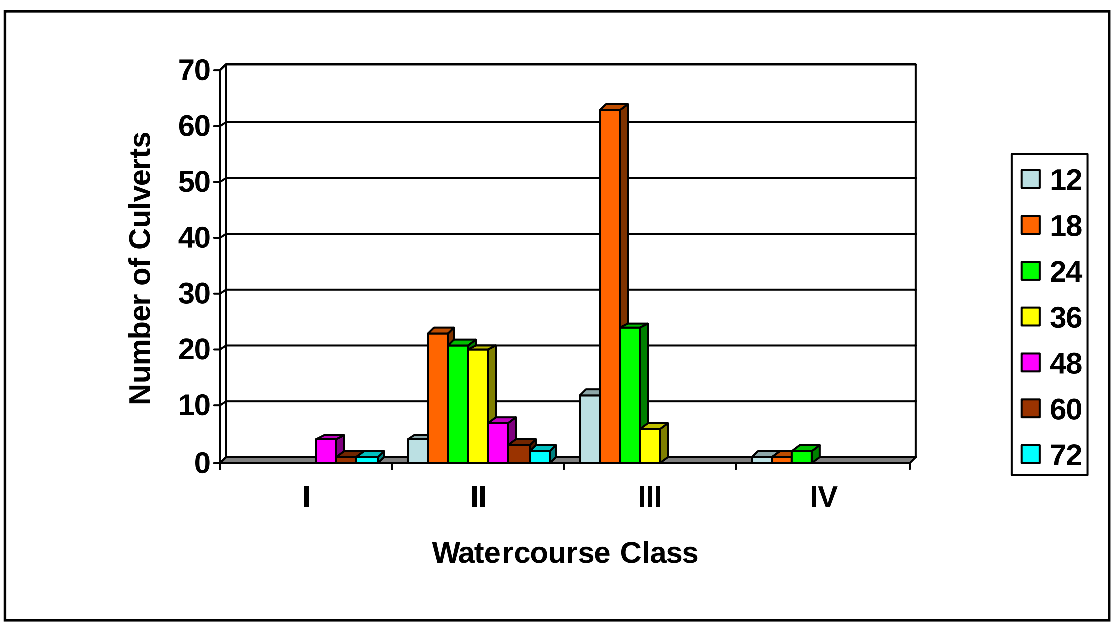


Figure 29. Distribution of culvert diameter categories (inches) by watercourse classes.

Approximately 80% of the watercourse crossings rated for implementation were also rated for effectiveness. These effectiveness ratings occurred at three different times, depending on the crossing being monitored (Table 12). About three-quarters (76%) of the effectiveness ratings were done on or about the same day as implementation ratings. Effectiveness ratings were made during a second field visit 13% of time, which usually took place one to two years later. In addition, 11% of the crossings had effectiveness evaluations conducted both when the initial implementation rating was done and a second time one to two years later. Therefore, almost 25% of the time, watercourse crossings were rated for effectiveness one to two years following an initial implementation rating.

Effectiveness Rating	Bridge	Culvert	Non-Culvert (Ford)	Removed/ Abandoned	Total	Percent
Only at time of Implementation	4	136	60	19	219	**76%**
Only at second visit	0	26	6	6	38	**13%**
Second rating at second visit	1	19	8	4	32	**11%**
Total	**5**	**181**	**74**	**29**	**89**	**100%**

Table 12. Distribution of effectiveness rating time periods for different watercourse crossing types.

Watercourse Crossing Implementation Results

Implementation of FPR requirements was rated using the following compliance categories: Departure (D), Marginally Acceptable (MA), Acceptable (A), Exceeds Rule/THP Requirement (ER), and Not Applicable (NA). These criteria were applied to 30 individual rule requirements, including 27 road rules found in 14 CCR § 923 [943, 963] and three rules related to skid trails found in 14 CCR § 914 [934, 954]. Implementation data is presented below in Table 13 for all the crossing types combined; and separately for existing culverts, new culverts, non-culverted crossings and removed/abandoned crossings (combined), and bridges.[5]

[5] Note that the numbers of crossings included for each crossing type for implementation are slightly different than those presented in the previous section due to minor adjustments made when compiling data with hand counts.

Rule Number	Rule Description	Total Obs. (w/out NA)	Departure (%)	Departure plus Marginally Acceptable (%)
923.3(d)(1) 943.3(d)(1) 963.3(d)(1)	Removed crossings—fills excavated to adequately reform channel	91	7.4	21.3
923.4(n) 943.4(n) 963.4(n)	Crossing/approaches maintained to prevent diversion	246	6.9	18.7
923.2(i) 943.2(i) 963.2(i)	Where needed, trash racks installed to minimize blockage	65	6.2	23.1
923.8 943.8 963.8	Abandoned crossings—maintenance-free drainage	35	5.7	14.3
923.8 943.8 963.8	Abandoned crossings—minimizes concentration of runoff	35	5.7	8.6
923.8(b) 943.8(b) 963.8(b)	Abandoned crossings—stabilization of cuts/fills appropriate	35	5.7	8.6
923.8(c) 943.8(c) 963.8(c)	Abandoned crossings—grading of road for dispersal of flow	36	5.6	11.1
923.4(m) 943.4(m) 963.4(m)	Inlet/outlet structures, etc. repaired/replaced/installed	130	5.4	19.2
923.3(f) 943.3(f) 963.3(f)	Crossings/fills built/maintained to prevent diversion	301	5.0	18.3
923.4(l) 943.4(l) 963.4(l)	Drainage structure/trash rack maintained/repaired as needed	127	4.7	11.0

Table 13. Forest Practice Rule requirements for all watercourse crossing types with at least four percent departures based on at least 30 observations where implementation could be rated (i.e., excludes N/A observations).

The number of observations available for analysis is not the same for each rule requirement because many requirements were not applicable at all crossing sites. There are also different numbers of observations for each crossing type, which leads to large differences in numbers of observations among rule and crossing type combinations. As a result, the following discussion of combined crossing types has been limited to those rules with as least 30 observations to include results from both active and abandoned/removed crossings, and discussion of results for individual crossings types is limited to rules that are applied on at least 20% of the applicable sites.

All Crossing Types

Twenty-five specific FPRs related to watercourse crossings were observed and rated for implementation at 30 or more crossings. Ten of these 25 FPRs had departure rates of 4% or higher, as shown in Table 13, and most of these had departure rates between 5% and 7%.[6] Five of these ten FPR requirements relate to removed or abandoned crossings. When crossings with marginally acceptable ratings are included, the proportion of sites with implementation problems ranges from about 9% to 23%.

The FPR requirement with the highest overall departure rate was 14 CCR § 923 [943, 963], which requires removed crossings to have fills excavated to form a channel that is as close as feasible to the natural watercourse grade and orientation and is wider than the natural channel.[7] The FPRs requiring crossings to be constructed or maintained to prevent diversion potential, 14 CCR § 923.4 [943.4, 963.4] (n) and § 923.3 [943.4, 963.4] (f), had departure rates of 6.9 and 5.0%, respectively. A complete list of the implementation ratings for all the watercourse crossing Forest Practice Rule requirements is shown in Table 14, beginning on the next page. For watercourse crossings with implementation evaluations, 64% had all the crossing rules rated as meeting or exceeding Forest Practice Rule requirements; 19% had one or more marginally acceptable ratings, but no departures; and 17% had one or more departures ratings (Figure 30).

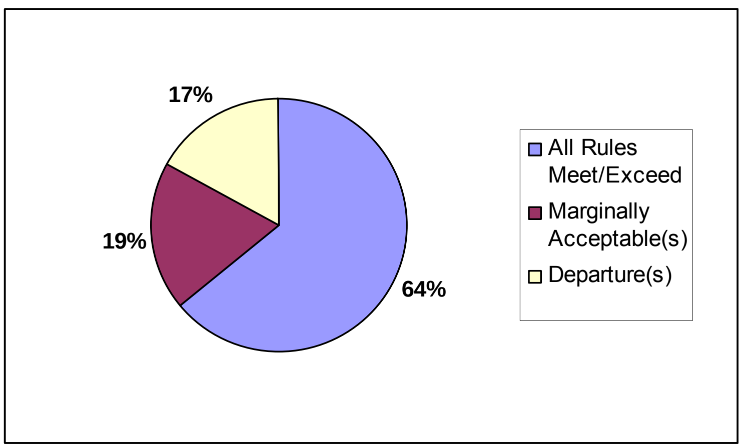


Figure 30. Percentages of watercourse crossings rated for Forest Practice Rule implementation having different implementation codes.

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[6] The minimum value of 30 observations (where the Forest Practice Inspector assigned a rating of D, MA, A, or ER) is similar to the value used in the earlier Hillslope Monitoring Program final report (Cafferata and Munn 2002), and represents nearly 10% of the possible implementation ratings available for each rule requirement.

[7] As shown in Table 14, 14 CCR § 923.3(a) has the overall highest rate of departure at 9.6%, but this rule only applies to new permanent crossings and temporary crossings within the WLPZ. Since it was rated as a departure for 18 existing culverts, it was concluded that spurious data was recorded for this requirement and it is not included.

Table 14. All Forest Practice Rule requirements rated for implementation (NA = Not Applicable).

Rule Number	Rule Description	Total Obs. (w/o NA)	Departure (%)	Departure + Marginally Acceptable (%)
923.2(d)(C) 943.2(d)(C) 963.2(d)(C)	Fills across channels built to minimize erosion	262	1.9	9.9
923.2(h) 943.2(h) 963.2(h)	Size, number, location of structures installed to carry runoff	287	2.4	8.0
923.2(h) 943.2(h) 963.2(h)	Size, number, location of structures installed to minimize erosion	285	2.8	8.4
923.2(h) 943.2(h) 963.2(h)	Size, number, location of structures installed to maintain or restore the natural drainage pattern	287	2.4	7.7
923.2(i) 943.2(i) 963.2(i)	Where needed, trash racks installed to minimize blockage	65	6.2	23.1
923.2(o) 943.2(o) 963.2(o)	No discharge onto fill unless energy dissipators installed	255	2.4	14.1
923.3(a) 943.3(a) 963.3(a)	Permanent new crossings shown on THP map	188	9.6	11.7
923.3(c) 943.3(c) 963.3(c)	Unrestricted passage of fish allowed	21	4.8	4.8
923.3(d)(1) 943.3(d)(1) 963.3(d)(1)	Removed crossings—fills excavated to adequately reform channel	94	7.4	21.3
923.3(d)(2) 943.3(d)(2) 963.3(d)(2)	Removed crossings-- cut bank sloped back to prevent slumping and minimize soil erosion	95	3.2	11.6
923.3(d)(2) 943.3(d)(2) 963.3(d)(2)	Where needed, stabilizing treatment applied	200	2.0	10.0
923.3(f) 943.3(f) 963.3(f)	Crossings/fills built/maintained to prevent diversion	301	5.0	18.3
923.4(c) 943.4(c) 963.4(c)	Waterbreaks maintained as specified in 14 CCR 914.6	240	3.8	14.2
923.4(d) 943.4(d) 963.4(d)	Crossing open to unrestricted passage of water	316	3.5	12.3
923.4(d) 943.4(d) 963.4(d)	Trash racks installed where needed at inlets	125	3.2	12.0
923.4(f) 943.4(f) 963.4(f)	50-year flood flow requirement met or removed	228	2.2	7.5

Table 14 (continued.) All Forest Practice Rule requirements rated for implementation (NA = Not Applicable).

Rule Number	Rule Description	Total Obs. (w/o NA)	Departure (%)	Departure + Marginally Acceptable (%)
923.4(l) 943.4(l) 963.4(l)	Drainage structure/trash rack maintained/repaired as needed	127	4.7	11.0
923.4(m) 943.4(m) 963.4(m)	Inlet/outlet structures, etc. repaired/replaced/installed	130	5.4	19.2
923.4(n) 943.4(n) 963.4(n)	Crossing/approaches maintained to prevent diversion	246	6.9	18.7
923.8 943.8 963.8	Abandoned crossings—maintenance-free drainage	35	5.7	14.3
923.8 943.8 963.8	Abandoned crossings—minimizes concentration of runoff	35	5.7	8.6
923.8(b) 943.8(b) 963.8(b)	Abandoned crossings—stabilization of cuts/fills appropriate	35	5.7	8.6
923.8(c) 943.8(c) 963.8(c)	Abandoned crossings—grading of road for dispersal of flow	36	5.6	11.1
923.8(d) 943.8(d) 963.8(d)	Abandoned crossings—pulling/shaping of fills appropriate	31	3.2	9.7
923.8(e) 943.8(e) 963.8(e)	Abandoned crossings—fills excavated to reform channel	35	2.9	20.0
923.8(e) 943.8(e) 963.8(e)	Abandoned crossings—cutbanks sloped back	30	3.3	6.7
923.8(e) 943.8(e) 963.8(e)	Abandon crossings—removal not feasible but diversion potential addressed	12	0.0	16.7
914.8(b) 934.8(b) 954.8(b)	Drainage structure used where water present during life of crossing	6	0.0	0.0
914.8(c) 934.8(c) 954.8(c)	Unrestricted fish passage in Class I watercourses	1	0.0	0.0
914.8(d) 934.8(d) 954.8(d)	Skid road crossing fill removed and banks sloped properly	23	4.3	8.7

Existing Culverts

Nineteen FPRs related to existing culverts were rated. These 19 FPRs do not include FPRs related to removed/ abandoned culverts and skid road culverts. Sixteen of these 19 FPRs were observed at 30 or more existing watercourse crossings. Nine of the 16 FPRs with 30 or more observations had departure rates of 4% or more, as shown in Table 15. For existing culverts, the FPR rule with the highest departure rate was 14 CCR § 923.4 [943.4, 963.4] (n), which requires crossings and their approaches to be maintained to avoid diversion of flow should the pipe become plugged. Other FPRs with high departure rates include FPRs requiring: 1) installation/maintenance of trash racks to minimize blockage (where required), 2) repair and replacement of crossing inlet and outlet structures, 3) maintenance of crossing openings for unrestricted passage of water, 4) waterbreak maintenance, and 5) culvert sizing for the required flood flow recurrence interval or removal of undersized culverts by the start of the winter period.

Table 15. Watercourse crossing related Forest Practice Rule requirements for existing culverts with at least four percent departures based on at least 30 observations (i.e., 20% of sample size) where implementation could be rated (i.e., excludes N/A observations).

Rule Number	Rule Description	Departure (%)	Departure plus Marginally Acceptable (%)
923.4(n) 943.4(n) 963.4(n)	Crossing/approaches maintained to avoid diversion	12.4	27.8
923.2(i) 943.2(i) 963.2(i)	Where needed, trash racks installed to minimize blockage	11.4	37.1
923.4(l) 943.4(l) 963.4(l)	Drainage structure/trash rack maintained/repaired as needed	7.5	17.9
923.4(m) 943.4(m) 963.4(m)	Inlet/outlet structures, etc. repaired/replaced/installed	7.2	23.2
923.4(d) 943.4(d) 963.4(d)	Trash racks installed where needed at inlets	6.8	27.3
923.4(d) 943.4(d) 963.4(d)	Crossing open to unrestricted passage of water	6.5	17.4
923.4(c) 943.4(c) 963.4(c)	Waterbreaks maintained as specified in 14 CCR 914.6	6.3	22.1
923.3(f) 943.3(f) 963.3(f)	Crossings/fills built/maintained to prevent diversion	6.1	23.5
923.4(f) 943.4(f) 963.4(f)	Crossing meets 50-yr flood flow requirement or is removed by first day of the winter period	4.4	13.3

New Culverts

For culverts installed as part of the THP, only one rule requirement was found with greater than a 4% departure rate. 14 CCR § 923.3 [943.3, 963.3] (f), which requires crossings and associated fills to be constructed and maintained to prevent diversion, had a departure rate of 4.1% and a departure plus marginally acceptable rate of 13.7%.

Non-Culvert Crossings and Removed/Abandoned Crossings

Non-culvert crossings and removed/abandoned crossings were combined for rating FPR implementation because, in many cases, rules related to crossing removal were also rated for existing non-culvert crossings. This occurred since some removed crossings are fords that are drivable with four-wheel drive vehicles—and hence were considered existing crossings. Thirty FPR requirements were applicable to this combined category.

Of 20 FPRs with at least 26 observations (i.e., 20 percent of the sample size), 13 FPRs had a departure rate of 4% or higher, as shown in Table 16 (next page). The rule with the highest departure rate was 14 CCR § 923.2 [943.2, 963.2] (h), which requires the installation of drainage structures that are of sufficient size, number and location to carry runoff water in a manner that minimizes erosion, ensures proper functioning, and maintains or restores the natural drainage pattern. Additional FPRs with at least 4% departure rates specify that: 1) fills across channels must be constructed in a manner that minimizes erosion, 2) drainage structures do not discharge water onto fill without energy dissipators, and 3) crossings/approaches must be built and maintained to prevent diversion.

The removal and abandonment rule requirement with the highest overall departure rate was 14 CCR § 923.3 [943.3, 963.3] (d)(1), which specifies that fills for removed crossings must be excavated to form a channel that is as close as feasible to the natural watercourse grade and orientation and is wider than the natural channel. 14 CCR § 923.3 [943.3, 963.3] (d)(2), requiring removed crossings to have cut banks that are sloped back from the channel and stabilized to prevent slumping and minimize soil erosion, had a slightly lower departure rate. Other rule requirements with at least 4% departure rates were: 14 CCR § 923.8 [943.8, 963.8], which requires, among other items, that abandoned crossings provide permanent maintenance-free drainage and minimize the concentration of runoff; 14 CCR § 923.8 [943.8, 963.8] (b), which states that exposed soil on cut and fill slopes of abandoned crossings must be stabilized; and 14 CCR § 923.8 [943.8, 963.8] (c), requiring abandoned crossings to be graded and shaped in a manner that disperses water flow.

Bridges

No departures were assigned to the few bridges evaluated as part of the MCR monitoring work, and there was only one marginally acceptable rating. The FPR requirement 14 CCR § 923.4 [943.4, 963.4] (c), which specifies that waterbreaks on roads are to be maintained as specified under 14 CCR § 914.6 [934.6, 954.6], was cited once as being marginally acceptable for the road segments draining to the bridge.

Table 16. Forest Practice Rule requirements for non-culvert and removed/abandoned crossings with at least four percent departures based on at least 26 observations (i.e., 20% of sample size).

Rule Number	Rule Description	Percent Departure	% Departure plus Marginally Acceptable
923.2(h) 943.2(h) 963.2(h)	Size, number, location of structures minimizes erosion	8.8	20.6
923.3(d)(1) 943.3(d)(1) 963.3(d)(1)	Removed crossings—fills excavated to reform a channel similar to the natural channel grade, but wider	7.5	26.9
923.2(h) 943.3(h) 963.3(h)	Size, number, location of drainage structures sufficient to carry runoff	6.5	13.0
923.8 943.8 963.8	Abandoned crossings—maintenance-free drainage	5.7	14.3
923.8 943.8 963.8	Abandoned crossings—minimizes concentration of runoff	5.7	8.6
923.8(b) 943.8(b) 963.8(b)	Abandoned crossings—stabilization of cuts/fills	5.7	8.6
923.3(d)(1) 943.3(d)(1)	Fills across channels built to minimize erosion	5.6	22.2
923.8(c) 943.8(c) 963.8(c)	Abandoned crossings—grading of road for dispersal of flow	5.6	11.1
923.3(d)(2) 943.3(d)(2) 963.3(d)(2)	Removed crossings—cut bank slope	4.8	17.7
923.2(o) 943.2(o) 963.2(o)	No discharge on fill without energy dissipators	4.6	23.1
923.3(f) 943.3(f) 963.3(f)	Crossings/fills built/maintained to prevent diversion	4.4	15.4
923.2(h) 943.2(h) 963.2(h)	Size, number, location of structures installed to maintain or restore the natural drainage pattern	4.3	13.0
923.4(n) 943.4(n) 963.4(n)	Crossing/approaches maintained to prevent diversion	4.0	16.0

Watercourse Crossing Effectiveness Results

Watercourse crossing effectiveness was evaluated by applying one of the following four ratings to 27 crossing-related parameters: not applicable (N/A), not a problem (usually "none" or "slight"), a minor problem, or a major problem.[8] Examples of crossings rated for effectiveness are shown in Figures 31 and 32. On nearly 25 percent of the 289 crossings rated for effectiveness, this evaluation was conducted one or more years after the implementation ratings were made. The rest of the crossings with effectiveness ratings were evaluated for implementation and effectiveness at the same, or nearly the same, time. Table 17 shows the percentage of major and minor problems when all crossing types are combined. The percentage of crossings with major and minor problems for different combinations of crossing types, crossing features, and problem types is displayed in Table 18.

Figure 31. Example of an existing culvert with scour at the outlet for a central Sierra Nevada THP included in the MCR sample.

Figure 32. Example of an existing culvert that is partially plugged with sediment on a central Sierra Nevada THP included in the MCR sample.

[8] For rutting, N/A was not provided on the field form. For culvert-related piping, the minor category was not provided as an option. The N/A option was not provided for any of the effectiveness parameters on the initial field form provided at the beginning of the MCR monitoring program.

Table 17. Watercourse crossing effectiveness ratings (excludes NA ratings).

Crossing Feature	Problem Type	Total # (w/out NA)	Major Only (%)	Major + Minor (%)
Fill Slopes	Gullies	253	1.2	11.5
	Cracks	253	0.0	2.4
	Slope Failure	254	1.2	5.1
Road Surface Draining		0	0.0	0.0
To Crossing	Gullies	272	0.4	6.3
	Cutoff Drainage Structure	225	4.0	24.9
	Inside Ditch Condition	119	0.8	18.5
	Ponding	261	0.0	12.6
	Rutting	248	0.8	16.5
Culvert Crossing	Scour at Inlet	182	1.1	15.9
	Scour at outlet	182	1.1	33.5
	Diversion Potential	179	10.6	35.2
	Plugging	182	5.5	17.6
	Alignment	180	1.7	5.6
	Degree of Corrosion	169	1.8	7.7
	Crushing	181	0.6	5.0
	Pipe length	182	0.0	4.9
	Gradient	182	2.7	8.2
	Piping	180	2.2	2.2
Non-Culverted Crossing	Armoring	58	1.7	32.8
	Scour at outlet	71	0.0	43.7
	Diversion Potential	73	5.5	23.3
Abandoned/Removed	Bank stabilization	36	0.0	22.2
	Gullies	36	0.0	8.3
	Slope Failure	16	0.0	0.0
	Channel Configuration	38	7.9	28.9
	Excavated Material	33	0.0	12.1
	Maintenance Free Drainage	45	0.0	17.8

Table 18. Modified Completion Report—Watercourse Crossing Effectiveness Ratings (% major, % minor, % major + minor) [excludes NA ratings].

Crossing Feature	Problem Type	Existing Culverts	New Culverts	Non-Culvert	Removed/Abandoned	Bridge
Fill Slopes	Gullies	2.6/ 8.7/ 11.3	0/ 10.0/ 10.0	0/17.2/ 17.2	NA	0/ 0/ 0
	Cracks	0/ 2.4/ 2.4	0/ 3.9/ 3.9	0/ 1.8/ 1.8	NA	0/ 0/ 0
	Slope Failure	1.6/ 3.2/ 4.8	1.9/ 1.9/ 3.8	0/ 8.8/ 8.8	NA	0/ 0/ 0
Road Surface Draining to Crossing	Gullies	0.8/ 4.9/ 5.7	0/ 0/ 0	0/ 10.7/ 10.7	0/ 11.1/ 11.1	0/ 0/ 0
	Cutoff Drainage Structure	6.5/ 27.8/ 34.3	2.1/ 23.4/ 25.5	2.0/ 12.0/ 14.0	0/ 0/ 0	0/ 0/ 0
	Inside Ditch Condition	1.4/ 20.3/ 21.7	0/ 8.0/ 8.0	0/ 26.7/ 26.7	0/ 0/ 0	0/ 25.0/ 25.0
	Ponding	0/ 13.5/ 13.5	0/ 18.0/18.0	0/ 9.4/ 9.4	0/ 6.3/ 6.3	0/ 0/ 0
Culvert	Scour at Inlet	1.6/ 16.3/ 17.8	0/ 11.3/ 11.3	NA	NA	NA
	Scour at outlet	1.6/ 36.4/ 38.0	0/ 22.6/ 22.6	NA	NA	NA
	Diversion Potential	11.9/ 26.2/ 38.1	7.5/ 20.8/ 28.3	NA	NA	NA
	Plugging	7.8/ 14.0/ 21.7	0/ 7.5/ 7.5	NA	NA	NA
	Alignment	1.6/ 4.7/ 6.3	1.9/ 1.9/ 3.8	NA	NA	NA
	Degree of Corrosion	2.4/ 8.1/ 10.6	0/ 0/ 0	NA	NA	NA
	Crushing	0.8/ 5.5/ 6.3	0/ 1.9/ 1.9	NA	NA	NA
	Pipe length	0/ 5.4/ 5.4	0/ 3.8/ 3.8	NA	NA	NA
	Gradient	3.8/ 7.7/ 11.5	0/ 0/ 0	NA	NA	NA
	Piping	3.1/ 0/ 3.1	0/ 0/ 0	NA	NA	NA
Non-Culverted Crossing	Armoring	NA	NA	1.8/ 32.1/ 33.9	0/ 0/ 0	NA
	Scour at outlet	NA	NA	0/ 42.6/ 42.6	0/ 66.7/ 66.7	NA
	Diversion Potential	NA	NA	4.3/ 18.6/ 22.9	33.3/ 0/ 33.3	NA
Removed/Abandoned	Bank stabilization	NA	NA	0/ 21.4/ 21.4	0/ 22.7/ 22.7	NA
	Gullies	NA	NA	0/ 6.3/ 6.3	0/ 10.0/ 10.0	NA
	Slope Failure	NA	NA	0/ 0/ 0	0/ 0/ 0	NA
	Channel Configuration	NA	NA	12.5/ 37.5/ 50.0	4.5/ 9.1/ 13.6	NA
	Excavated Material	NA	NA	0/ 33.3/ 33.3	0/ 0/ 0	NA
	Maintenance Free Drainage	NA	NA	0/ 21.7/ 21.7	0/ 13.6/ 13.6	NA

All Crossing Types

When all crossing types are combined, major problems were found a total of 76 times on 53 crossings. The most frequently cited effectiveness problems were associated with culvert diversion potential (19), followed by culvert plugging (10), and road cutoff drainage structure function (9) (see Figure 33). Other parameters identified as having major problems four or more times included: culvert gradient, culvert piping, and non-culvert crossing diversion potential. Overall, 18% of the crossings evaluated for effectiveness had one or more major problems.

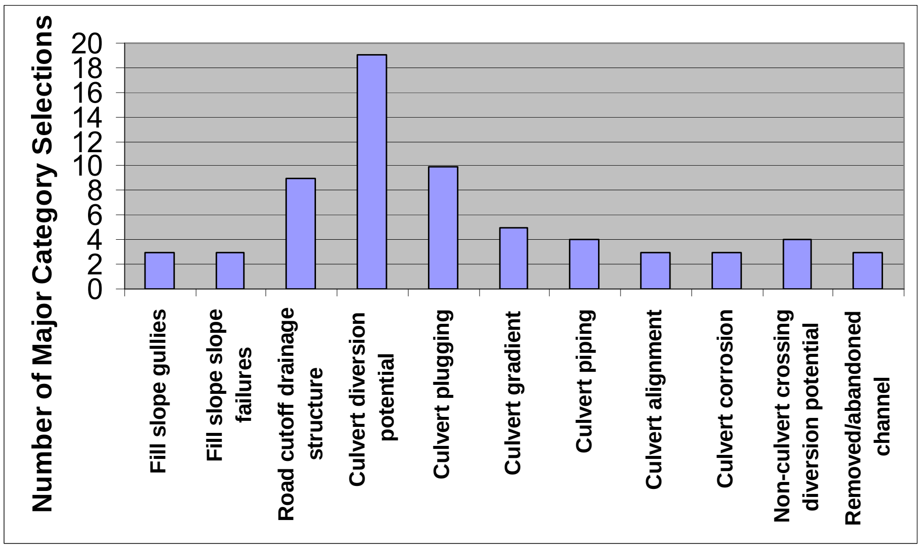

Figure 33. Major problem effectiveness categories for all crossing types.

When the major and minor problem categories were combined, the most frequently cited feature remained culvert diversion (63 selections), but secondary parameters were somewhat different. They included: culvert scour at the outlet (61), road cut-off waterbar function (56), road rutting (41), road ponding (33), culvert plugging (32), and non-culvert crossing scour at the outlet (31).

For new and existing culverts, 10.6% had a major diversion problem, 5.5% had a major plugging concern, 4.0% had a cutoff drainage structure problem, 2.7% had a significant gradient issue, and 2.2% had a major piping concern. For non-culverted crossings, 5.5% had a major diversion potential problem (Table 17).

Existing Culverts

For existing culverts, 11.9% of the pipes had a major problem with diversion potential, while 7.8% had a major problem with inlet or outlet plugging, as shown in Table 18. Road cut-off drainage structures were identified as a major problem for 6.5% of the crossings, and approximately 3% of the road fills at crossings had significant gullying present. For combined major and minor effectiveness ratings, the following features were selected greater than 30% of the time: culvert scour at the outlet (38.0%), culvert diversion potential (38.1%), and road cutoff drainage structure (34.3%). Culvert plugging and road inside ditch condition were selected more than 20% of the time for both effectiveness ratings.

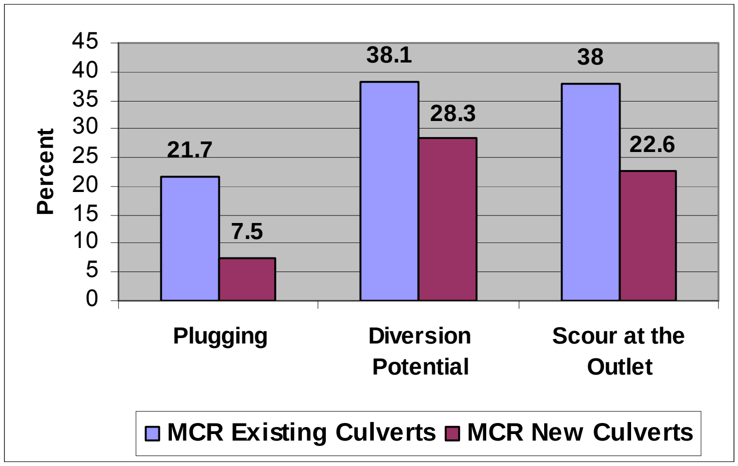

Figure 34. Comparison of three culvert effectiveness categories for new culverts installed as part of the THP vs. existing culverts installed before the plan. Data shown is for both major and minor effectiveness categories combined.

New Culverts

The percentage of major and minor problems was smaller for new culverts that were installed as part of the most recent THP, when compared to existing culverts. This can be attributed to improved practices and/or fewer overwintering periods with stressing storm events (Figure 34). As displayed in Table 18, 7.5% of the new culverts had significant diversion potential, 2.1% had major problems with road cutoff drainage structures, and 1.9% had major problems with culvert alignment and fill slope failures. For combined major and minor effectiveness ratings, the following features were found to have problems more than 20% of the time: culvert diversion potential (28.3%), culvert scour at the outlet (22.6%), and road cutoff drainage structures (25.5%).

Non-Culvert and Removed/Abandoned Crossings

There were major diversion potential problems on 4.3% of the non-culvert crossings and minor problems on an additional 18.6%, for a combined total of 22.9%. For both removed/abandoned crossings and non-culvert crossing types, channel configuration following crossing removal had the highest percentage of problems, with 7.9% of the crossings rated as having a major problem and 21.0% receiving a minor problem, for a combined rating of 28.9%.

Bridges

None of the five bridges rated for effectiveness had any major problems identified. The condition of the road inside ditch was selected once as a minor problem.

III. Discussion

Watercourse crossing implementation ratings are generally similar to findings from the earlier HMP (Cafferata and Munn 2002). For example, the departure rates in the HMP for 14 CCR § 923.3 [943.3, 963.3] (f) [requiring construction to prevent diversion] were 5.5% major departures and 14.6% major plus minor departures, respectively; which are similar to the 5.0% and 18.3% rates for departure and departure plus marginally acceptable ratings in the MCR work.[9] Additionally, abandonment rules 14 CCR § 923.8 [943.8, 963.8], 923.8 [943.8, 963.8] (b), and 923.8 [943.8, 963.8] (c) in the HMP had major departure rates of 4.6%, 4.8%, and 4.8%, respectively, while the MCR monitoring results for these rules had departure rates of 5.7%, 5.7%, and 5.6%. The FPRs 14 CCR § 923.3 [943.1, 963.1] (d)(1), 923.4 [943.4, 963.4] (l), and 923.4 [943.4, 963.4] (n) were also listed as having relatively high departure rates in both monitoring programs. In addition, in the final HMP data set (1996 through 2002), one or more major rule departures were found for 19.5% of the watercourse crossings, compared to 17% of crossings with departures in the MCR work.

Similarly, MCR watercourse crossing effectiveness results compare well with the findings of previous watercourse crossing studies in California, both with studies done on private and state lands (HMP) and studies done on federal National Forest System (NFS) lands (Figure 35). For example, the HMP (Cafferata and Munn 2002) reported that 9.0% of culverted crossings had major diversion potential problems, which compares well with the 10.6% rate reported in this study based on analysis of MCR data (see Figure 36 for an example of a crossing without diversion potential). Both the HMP and MCR monitoring sampled sites on private and state lands in California, and as such are directly comparable. The USFS (2004) BMP Evaluation Program sampled federal (NFS) lands in California and found major diversion problems on 8.9% of culverted crossings, which is also compares well with both the HMP (9.0%) and MCR (10.6%) results. For culvert plugging, the HMP and USFS BMP documents reported problems on 8.6% and 3.0% of crossings, respectively, while the rate is 5.5% based on the MCR data. Data for scour at the outlet of a culvert is less consistent between these three recent monitoring programs, probably due to differing instructions and definitions.[10] A more detailed comparison of the HMP and MCR crossing effectiveness data is provided in Table 19.

[9] FPR 14 CCR § 923.3(f) is referred to in Cafferata and Munn (2002) as 923.3(e).

[10] For example, in the HMP major scour at the outlet was defined as extending more than two channel widths below the pipe outlet, or scour that is undercutting the crossing fill, while in MCR monitoring, it was simply defined as “major scour, maybe undercutting fill material.”

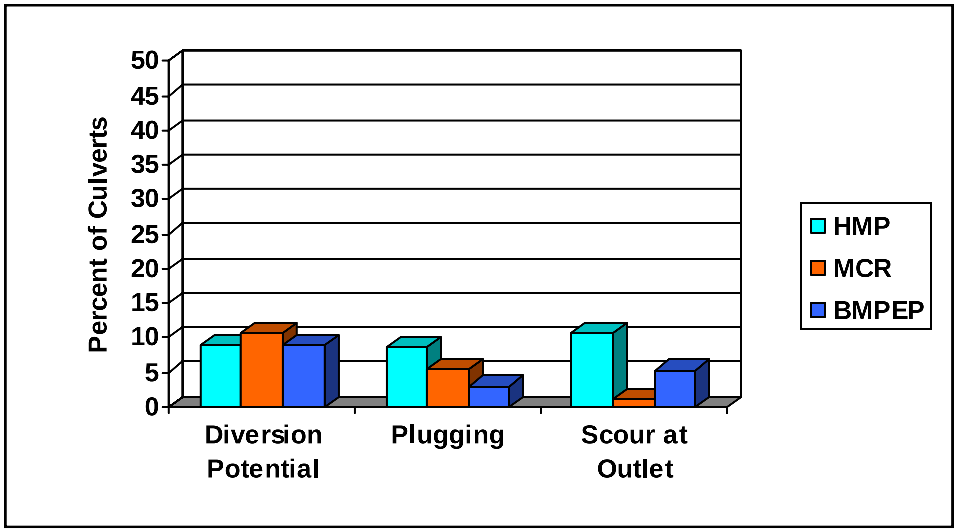

Figure 35. Comparison of three Modified Completion Report (MCR) culvert crossing effectiveness categories to results from the Hillslope Monitoring Program (HMP) and USFS BMP Evaluation Program. Ratings are for major effectiveness categories for the HMP and MCR programs.

Table 19. Comparison of MCR and HMP crossing effectiveness data for selected categories.

Monitoring Program	Culvert Plugging	Culvert Diversion Potential	Culvert Scour At the Outlet	Removed/Abandoned Channel Configuration
MCR Problems				
Major	5.5 %	10.6%	1.1%	7.9%
Minor	12.1%	24.6%	32.4%	21.0%
Total	17.6%	35.2%	33.5%	28.9%
HMP Problems				
Major	8.6%	9.0%	10.7%	3.6%
Minor	14.9%	18.5%	22%	14.3%
Total	23.5%	27.5%	32.7%	17.9%

Figure 36. John Munn, CDF, at a culverted watercourse crossing in a forested watershed on the North Coast of California without diversion potential. Munn is standing in the critical dip.

Conclusions and Recommendations

Overall Findings and Recommendations

Findings: Overall, the Modified Completion Report monitoring work found that:

1) The rate of compliance with FPRs designed to protect water quality and aquatic habitat is generally high, and
2) FPRs are highly effective in preventing erosion, sedimentation and sediment transport to channels when properly implemented.

Recommendations: The Forest Practice Program should continue to emphasize education, licensing, inspection and enforcement to ensure proper implementation of the FPRs designed to protect water quality. Since departures from the FPRs were found to be rare, the best inspection strategy is to have the inspectors focus on THPs and locations where their experience and previous plan review indicate that problems are most likely to occur. After a quick prioritization, inspectors should visually observe as much ground as possible to maximize detection of departures from FPRs, which are important but uncommon occurrences.

Because straightforward, clearly stated rules are more likely to be properly implemented, they are more likely to protect water quality. They are also easier to inspect, enforce and monitor. Therefore, the BOF should avoid unnecessary complexity and ambiguous language when revising or adding to the existing FPRs.

MCR monitoring should be revised according the specific recommendations for WLPZs, roads and watercourse crossings, which are outlined below.

Watercourse and Lake Protection Zones (WLPZs) Findings and Recommendations

Findings: With few exceptions, Watercourse and Lake Protection Zone (WLPZ) canopy and groundcover met Forest Practice Rule (FPR) standards. Patches of bare soil in WLPZs exceeding the FPR standards are rare, erosion features within WLPZs related to current operations are uncommon, and there are few instances where WLPZ canopy standards are not being met. Prevention, detection and abatement of these rare occurrences is an important key to improving water quality protection.

Recommendations: The Forest Practice Program should emphasize prevention, detection and abatement of WLPZ problems through rapid ocular inspections of WLPZs. The use of time-consuming canopy and ground cover measuring techniques should be reserved for enforcement where a rapid inspection has detected WLPZ canopy and/or groundcover conditions that may not meet minimum standards set by the FPRs or special provisions of the THP.

To provide more time for rapid ocular inspections, WPLZ trend monitoring conducted by Forest Practice Inspectors, such as with MCR inspections, should use the smallest random sample size that will produce repeatable and reliable results.   As a starting point, a WLPZ sample size of 5 percent of all THPs undergoing Work Completion Report Inspections is recommended. This may then be adjusted up or down annually based on an analysis of the prior year's data.

The current MCR data collection methods and procedures for WLPZs work well and, with some minor revisions to the WLPZ form, are suitable for use in the next phase of MCR Monitoring.

Road Findings and Recommendations

Findings: Properly implemented Forest Practice Rules are highly effective in preventing road erosion and sediment transport from roads to channels. Erosion and sedimentation is more likely to occur at road-related features where the implementation of the applicable FPR(s) is only marginally acceptable. Erosion and sediment transport are much more likely at road-related features where there was a departure from the applicable FPR(s) (See Table 7 on page 40).   For example, at sites where there is a departure from the rule, the chance of erosion is about 1 in 2, the chance sediment transport is about 1 in 3, and the chance of sediment transport to a channel 1 in 10.   In comparison, where FPR implementation is acceptable or better, the chance of erosion is about 1 in 20, and the chance of sediment transport to a channel is 1 in 100 or less.

Drainage problems (including drainage feature spacing, design, construction and maintenance) and failure to discharge into non-erodible cover are the most frequent types of departures from the road-related FPRs. Specifically, the following four categories of FPRs accounted for 95% of the departures: waterbreak spacing [49%], drainage ditches maintained/berms removed [17%], waterbreak discharge into cover [16%], and waterbreaks constructed to appropriate depth [13%]. These departures from the rules are also the most frequent causes of road-related erosion and sediment transport to channels.

Departure rates for the road-related features were 2% for the Coast (Region 1) and 8% for the Inland Area (Regions 2 &4). Most of these departures are clustered in a few poorly built and/or poorly maintained road segments. For example, just 6% of the sampled road segments, which would represent about sixth-tenths of a mile in 10 road miles, accounted for half the departures on Coast THPs and about three-quarters of the departures on Inland THPs.

The current MCR data collection methods and procedures for roads were found to be cumbersome, and both implementation and enforcement could be improved by focusing on two items critical to water quality protection: 1) the spacing and adequacy of the drainage features and, 2) discharge of road drainage into cover or non-erodible sites. These results are based on drainage spacing evaluations conducted during field inspections. No secondary analysis of drainage spacing could be conducted because FPR drainage spacing requirements are based on the Erosion Hazard Rating (EHR) and the road grade between drainage features, but these two pieces of data were not recorded on the MCR road form.

Recommendations: The Forest Practice Program should continue to emphasize proper implementation of the road-related FPRs through education and enforcement. Streamlining and consolidating the road-related rules to make them easier to understand, implement and enforce is expected to improve FPR effectiveness in protecting water quality.

Finding and fixing the worst 6% of THP road segments would yield the largest improvement in THP road-related water quality protection. The Forest Practice Program should encourage landowners, Registered Professional Foresters (RPFs) and Licensed Timber Operators (LTOs) to find and repair these problem sites. A standard, recommended methodology for finding and fixing the worst 6% of THP road segments may prove useful and could be developed by a subcommittee of the BOF, such as the MSG.

In addition, the current MCR data collection procedures should be revised to account for the types of water quality problems most commonly found on roads. Focus should be placed on: 1) the spacing and adequacy of drainage features and, 2) discharge of road drainage into cover or non-erodible sites. To allow a secondary check of appropriate drainage spacing according to the FPRs, the data collected for each road segment should also include the grade between drainage features (as measured in the field with a clinometer) and the Erosion Hazard Rating (EHR) assigned to the portion of the THP that includes the road segment.

Watercourse Crossing Findings and Recommendations

Findings: A total of 357 watercourse crossings were rated for FPR implementation. Approximately 62% of these were culverts, 25% were fords, 11% were removed or abandoned crossings, and 2% were bridges. Almost 60% of the crossings were in Class III watercourses, and close to 75% were associated with seasonal roads.

Ten FPR requirements (out of 30 rated) were found to have departure rates of 4% or higher. Five of these ten FPRs related to removed or abandoned crossings. The one rule with the highest departure rate (7.4%) requires fills to be excavated to form a channel that is similar to the natural watercourse grade and orientation and is wider than the natural channel.

For crossings with implementation evaluations, 64% had all the crossing rules rated as meeting or exceeding the FPRs; 19% had one or more marginally acceptable ratings, but no departures; and 17% had one or more departure rating(s). This compares well with the earlier HMP results, which had 19.5% of the crossings with one or more major departures.

Out of the twenty-seven items rated on each of the 289 crossings evaluated for crossing effectiveness, major problems were found a total of 76 times on 53 crossings (i.e., 18% of the crossings had significant effectiveness problems). For all new and existing culverts, 10.6% had a major diversion problem, 5.5% had a major plugging concern, and 4.0% had a major cutoff drainage structure problem. The percentage of major and minor problems was smaller for new culverts installed as part of the current THP when compared to existing culverts.

Recommendations: The Forest Practice Program should re-emphasize, through both education and enforcement, proper implementation of five aspects of culvert design, installation and maintenance included in the FPRs:

1. Proper design for passage of wood and sediment, as well as 100-years flood flows (Cafferata and others 2004),
2. Installation of functional critical dips at culvert crossings (Weaver and Hagans 1994),
3. Installation and maintenance of cutoff-drainage structures designed to prevent direct discharge to watercourse channels and erosion of crossing fills (Figure 37),
4. Proper maintenance to prevent plugging from wood and sediment, and
5. The complete excavation of fills at removed crossings to form a channel that is similar to the natural watercourse grade and orientation and is wider than the natural channel.

Figure 37. Pete Cafferata, CDF, points to the outlet of a uniquely-designed 3-rail cutoff-drainage structure on the approach to a watercourse crossing located in a forested watershed on the North Coast of California. Features like this, commonly a rolling dip without the rails, are used to prevent direct discharge of road runoff into watercourse channels.

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Glossary

Abandonment – Leaving a logging road reasonably impassable to standard production four-wheel-drive highway vehicles, and leaving a logging road and landings, in a condition which provides for long-term functioning of erosion controls with little or no continuing maintenance (14 CCR § 895.1).

Alternative practice – Prescriptions for the protection of watercourses and lakes that may be developed by the RPF or proposed by the Director of CDF on a site-specific basis provided that several conditions are complied with and the alternative prescriptions will achieve compliance with the standards set forth in 14 CCR § 916.3 (936.3, 956.3) and § 916.4(b) [(936.4(b), 956.4(b)]. 14 CCR § 916.6 (936.6, 956.6) More general alternative practices are permitted under 14 § CCR 897(e).

Beneficial uses of water - As described in the Porter-Cologne Water Quality Control Act, beneficial uses of water include, but are not limited to: domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish and wildlife, and other aquatic resources or preserves. In Water Quality Control Plans, the beneficial uses designated for a given body of water typically include: domestic, municipal, agricultural, and industrial supply; industrial process; water contact recreation and non-water contact recreation; hydropower generation; navigation; groundwater recharge; fish spawning, rearing, and migration; aquatic habitat for warm-water species; aquatic habitat for coldwater species; and aquatic habitat for rare, threatened, and/or endangered species (Lee 1997).

Best management practice (BMP) - A practice or set of practices that is the most effective means of preventing or reducing the generation of nonpoint source pollution from a particular type of land use (e.g., silviculture) that is feasible, given environmental, economic, institutional, and technical constraints. Application of BMPs is intended to achieve compliance with applicable water quality requirements (Lee 1997).

Canopy - the foliage, branches, and trunks of vegetation that blocks a view of the sky along a vertical projection. The Forest Practice Rules define canopy as "the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody species" (14 CCR § 895.1).

Critical dip – a dip over or near a culverted watercourse crossing designed to minimize the loss of road fill and the subsequent discharge of sediment into the affected watercourse in the event the culvert plugs.

Cutbank/sidecast sloughing – Shallow, surficial sliding associated with either the cutbank or fill material along a forest road or skid trail, with smaller dimensions than would be associated with mass failures.

Exception – A non-standard practice for limitations on tractor operations, 14 CCR § 914.2(f)(3) [934.2(f)(3), 954.2(f)(3)].

Gully - Erosion channels deeper than 6 inches (no limitation on length or width). Gully dimensions were estimated.

In-lieu practice – These practices apply to FPR sections for watercourse protection where provision is made for site-specific practices to be proposed by the RPF, approved by the Director and included in the THP in lieu of a stated Rule. The RPF must reference the standard Rule, explain and describe each proposed practice, how it differs from the standard practice, indicate the specific locations where it will be applied, and explain and justify how the protection provided by the proposed practice is at least equal to the protection provided by the standard Rule 14 CCR § 916.1 [936.1, 956.1].

Mass failure – Downslope movement of soil and subsurface material that occurs when its internal strength is exceeded by the combination of gravitational and other forces. Mass erosion processes include slow moving, deep-seated earthflows and rotational failures, as well as rapid, shallow movements on hillslopes (debris slides) and in downstream channels (debris torrents).

Non-standard practice - A practice other than a standard practice, but allowable by the FPR as an alternative practice, in-lieu practice, waiver, exclusion, or exemption (Lee 1997).

Permanent road – A road which is planed and constructed to be part of a permanent all-season transportation facility. These roads have a surface which is suitable for the hauling of forest products throughout the entire winter period and have drainage structures, if any, at watercourse crossings which will accommodate the 50-year flow. Normally they are maintained during the winter period (14 CCR 895.1). After July 1, 2000, watercourse crossings associated with permanent roads have been required to accommodate the estimated 100-year flood flow, including debris and sediment loads.

Process - The procedures through which the FPRs/BMPs are administered and implemented, including: (a) THP preparation, information content, review and approval by RPFs, Review Team agencies, and CDF decision-makers, and (b) the timber operations completion, oversight, and inspection by LTOs, RPFs, and CDF inspectors (Lee 1997).

Quality assurance - The steps taken to ensure that a product (i.e., monitoring data) meets specified objectives or standards. This can include: specification of the objectives for the program and for data (i.e., precision, accuracy, completeness, representativeness, comparability, and repeatability), minimum personnel qualifications (i.e., education, training, experience), training programs, reference materials (i.e., protocols, instructions, guidelines, forms) for use in the field, laboratory, office, and data management system (Lee 1997).

Quality control - The steps taken to ensure that products which do not meet specified objectives or standards (i.e., data errors and omissions, analytical errors) are detected and either eliminated or corrected (Lee 1997).

Repeatability – The degree of agreement between measurements or values of a monitoring parameter made under the same conditions by different observers (Lee 1997).

Rill - Small surface erosion channels that (1) are greater than 2 inches deep at the upslope end when found singly or greater than 1 inch deep where there are two or more, and (2) are longer than 20 feet if on a road surface or of any length when located on a cut bank, fill slope, cross drain ditch, or cross drain outlet. Dimensions were not recorded.

Rules - Those Rules that are related to protection of the quality and beneficial uses of water and have been certified by the SWRCB as BMPs for protecting the quality and beneficial uses of water to a degree that achieves compliance with applicable water quality requirements (Lee 1997). Forest Practice Rules are included in Title 14 of the California Code of Regulations (14 CCR).

Seasonal road – A road which is planned and constructed as part of a permanent transportation facility where: 1) commercial hauling may be discontinued during the winter period, or 2) the landowner desires continuation of access for fire control, forest management activities, Christmas tree growing, or for occasional or incidental use for harvesting of minor forest products, or similar activities. These roads have a surface adequate for hauling of forest products in the non-winter period; and have drainage structures, if any, at watercourse crossings which will accommodate the fifty-year flood flow. Some maintenance usually is required (14 CCR § 895.1). After July 1, 2000, all permanent watercourse crossings have been required to accommodate the estimated 100-year flood flow, including debris and sediment loads.

Standard practice - A practice prescribed or proscribed by the Rules (Lee 1997).

Surface cover – The cover of litter, downed woody material (including slash, living vegetation in contact with the ground, and loose rocks (excluding rock outcrops) that resist erosion by raindrop impact and surface flow (14 CCR § 895.1).

Temporary road – A road that is to be used only during the timber operation. These roads have a surface adequate for seasonal logging use and have drainage structures, if any, adequate to carry the anticipated flow of water during the period of use (14 CCR § 895.1).

Waterbreak – A ditch, dike, or dip, or a combination thereof, constructed diagonally across logging roads, tractor roads and firebreaks so that water flow is effectively diverted. Waterbreaks are synonymous with waterbars (14 CCR § 895.1).

Watercourse – Any well-defined channel with distinguishable bed and bank showing evidence of having contained flowing water indicated by deposit of rock, sand, gravel or soil including but not limited to , streams as defined in PRC 4528(f). Watercourse also includes manmade watercourses (14 CCR § 895.1).

Watercourse class - Classification of watercourses into one four groups (Classes I, II, III and IV) is based characteristics or key indicators of beneficial uses as described in 14 CCR § 916.5 (936.5, 956.5).

- Class I watercourses include: 1) Domestic supplies, including springs, on site and/or within 100 feet of downstream of the operations area and/or, 2) Fish always or seasonally present onsite, includes habitat to sustain fish migration and spawning.
- Class II watercourses include: 1) Fish always or seasonally present offsite within 1000 feet downstream and/or 2) Aquatic habitat for nonfish aquatic species. Excludes Class III waters that are tributary to Class I waters.
- Class III watercourses include: 1) No aquatic life present, watercourse showing evidence of being capable of sediment transport to Class I and II waters under normal high water flow conditions after completion of timber operations.
- Class IV watercourses include: Manmade watercourses, usually downstream, established domestic, agricultural, hydroelectric supply, or other beneficial uses.

Rill - Small surface erosion channels that (1) are greater than 2 inches deep at the upslope end when found singly or greater than 1 inch deep where there are two or more, and (2) are longer than 20 feet if on a road surface or of any length when located on a cut bank, fill slope, cross drain ditch, or cross drain outlet. Dimensions were not recorded.

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Appendix A:

Modified Completion Report Methods and Procedures

(revised April 9, 2003)

An electronic copy of the *Modified Completion Report Monitoring Procedures and Methods (rev.4/9/03)* is available on line at:

http://www.bof.fire.ca.gov/board/msg_archives.asp

MONITORING STUDY GROUP
CALIFORNIA STATE BOARD OF FORESTRY AND FIRE PROTECTION

HILLSLOPE MONITORING PROGRAM

MONITORING RESULTS FROM 1996 THROUGH 2001

Andrea E. Tuttle
Director
Department of Forestry and Fire Protection

Mary D. Nichols
Secretary for Resources
The Resources Agency

Gray Davis
Governor
State of California

DECEMBER 2002
SACRAMENTO, CALIFORNIA
BOARD OF FORESTRY AND FIRE PROTECTION

HILLSLOPE MONITORING PROGRAM: MONITORING RESULTS FROM 1996 THROUGH 2001

December 2002

by Peter H. Cafferata and John R. Munn
California Department of Forestry and Fire Protection

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The Monitoring Study Group (MSG) is made up of members of the public, resource agencies (both state and federal), and the timber industry. The agencies listed above make up the MSG; the names listed above are the primary representatives for these agencies at MSG meetings. The MSG chair is appointed by the Board of Forestry and Fire Protection (BOF) and the group is staffed by CDF. Each agency and organization is responsible for determining the appropriate person to serve as a representative on the MSG (i.e., the BOF does not make formal appointments to the MSG).

Executive Summary

The Hillslope Monitoring Program has been evaluating the implementation and effectiveness of California forest practices since 1996. This project began with field inspection of 50 timber harvesting plans (THPs) in Humboldt and Mendocino Counties in 1996, and has continued with a statewide random sample of 50 plans in subsequent years. Non-industrial timber management plans (NTMPs) were added in 2001.

As part of the Program, detailed information has been collected during summer months on THPs that have gone through one to four winters after harvesting was completed. Site characteristics, erosion problems, and Forest Practice Rule (FPR) implementation were recorded for randomly located landings, watercourse crossings and for randomly selected road, skid trail, and watercourse protection zone segments. Data was also collected at the site of large erosion events that were identified in the THP or located while conducting the field work. Some information was recorded on non-standard practices and additional mitigation measures when they were applied at the study sites and transects. Observations of fine sediment transport during winter storms were not included in this program because of logistic and safety concerns. Additionally, evaluation of the THP review and inspection process was not included as part of the Hillslope Monitoring Program.

This report is based on the 295 THPs and 5 NTMPs sampled through 2001. About 63 percent of these plans were on large ownerships and 37 percent were classified as smaller ownerships (non-industrial timberlands and other types of ownerships). The Coast Forest Practice District contained 61 percent of the plans, while the Northern and Southern Districts had 26 and 13 percent, respectively. The monitoring data was collected and entered into an extensive database by experienced independent contractors who acted as third party auditors. An interim report of study findings was prepared for the California State Board of Forestry and Fire Protection in June 1999. This report updates the interim findings and offers several recommendations. Analysis completed on the data set to date has primarily been composed of frequency counts and has been limited by time and access to database analysts. Additional data analysis will be conducted in the future.

Implementation and effectiveness of the Forest Practice Rules were rated by the field team as conditions requiring application of the Rules were encountered on the study sites and transects, and as part of an overall evaluation following completion of the inspection. In both cases, implementation of the Rules applicable to a given subject area was rated as either exceeding the requirements of the Forest Practice Rules, meeting the requirements, minor departure from requirements, major departure from requirements, not applicable, could not determine, or could not evaluate (with a description of why). At erosion problem points, the source and cause of the feature was recorded, along with whether sediment had been transported to a watercourse.

Results to date show that implementation rates of the Forest Practice Rules related to water quality are high and that individual practices required by the Rules are effective in preventing hillslope erosion features when properly implemented. Overall implementation ratings were greater than 90 percent for landings and for road, skid trail, and watercourse protection zone transects. Watercourse crossings had the lowest overall implementation ratings at 86 percent. Implementation of applicable Rules at problem points was nearly always found to be less than that required by the FPRs. These results, however, do not allow us to draw conclusions about whether the existing Rules are providing properly functioning habitat for aquatic species, since evaluating the biological significance of the current Rules was not part of the project.

To focus on areas where improvement in Rule implementation would provide the greatest benefit to water quality and where educational efforts are required, a list of 20 FPR requirements with the highest percentage of major departures is provided in the report. Three of these Rule requirements relate to roads, three to both roads and crossings, one to both roads and landings, one to skid trails, one to landings, ten to watercourse crossings, and one to watercourse protection zones.

Watercourse crossing problems are caused by a number of factors, including inherent uncertainties in determining and implementing site specific construction and abandonment needs, improper maintenance, the finite expected life of culverts, and high risk location for sediment delivery when stream discharge exceeds design discharge. The majority of the evaluated crossings were existing structures that were in place prior to the development of the THP, and frequent problems related to adequate design, construction, and maintenance were found. Crossings with culverts installed as part of the plan evaluated had a significantly lower rate of problem points per crossing, when compared to existing culverted crossings. Common problems included culvert plugging, stream diversion potential, fill slope erosion, scour at the outlet, and ineffective road surface cutoff waterbreaks.

The other main problem area identified by this program is erosion from roads caused by improper design, construction, and maintenance of drainage structures. Nearly half the road transects had one or more rills present and approximately 25 percent had at least one gully. Evidence of sediment transport to at least the high flow channel of a watercourse was found on 12.6 percent and 24.5 percent of the rill and gully features, respectively, with high percentages of delivery to Class III watercourses. These erosion features were usually caused by a drainage feature deficiency, and the FPRs rated at these problem sites were nearly always found to be out of compliance. Most of the identified road problems were related to inadequate size, number, and location of drainage structures; inadequate waterbreak spacing; and lack of cover at waterbreak discharge points. About six percent of the drainage structures evaluated along the road transects were found to have problems.

In contrast, watercourse protection zones were found to retain high levels of post-harvest canopy and surface cover, and to prevent harvesting related erosion. Mean total canopy exceeded FPR requirements in all three Forest Practice Districts and was approximately 80 percent in the Coast Forest Practice District for both Class I and II watercourses. Surface cover exceeded 75 percent for all watercourse types in the three districts. WLPZ width requirements were generally met, with major Rule departures recorded only about one percent of the time. The frequency of erosion events related to current operations in watercourse protection zones was very low for Class I, II, and III watercourses. Similarly, landings and skid trails were not found to be producing substantial impacts to water quality. Erosion problems on landing surfaces, cut slopes, and fill slopes were relatively rare. Rill and gully erosion features on skid trails were much less frequent than found on road transects, and sediment delivery to watercourses was also considerably lower.

Preliminary results on the use of non-standard practices and additional mitigation measures indicate the need for more thorough THP inspection to ensure proper implementation. A more focused monitoring approach, however, is needed to adequately examine the implementation and effectiveness of these practices. To date, the emphasis of the Hillslope Monitoring Program has been on evaluating the adequacy of standard Forest Practice Rules, and relatively little data has been collected for non-standard practices.

Ten recommendations are provided based on study findings to date. Six of these relate to training needs for CDF Forest Practice Inspectors, RPFs, Licensed Timber Operators, and personnel from other reviewing agencies (e.g., CDFG, CGS, and the Regional Water Quality Control Boards). Since watercourse crossings were found to be a significant problem area, voluntary, cooperative road management plans are recommended to effectively locate, prioritize, and schedule improvement work for high risk crossing structures. The results of this study also indicate a need to revise the Hillslope Monitoring Program to adequately sample additional mitigation measures and non-standard practices that are frequently added to THPs. Study revisions are also needed to monitor changes in the Forest Practice Rules that have occurred since July 1, 2000. Finally, it is recommended that the BOF and CDF continue to support the implementation and funding of instream monitoring projects designed to monitor compliance with Regional Water Quality Control Board Basin Plan standards.

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We would like to thank all the landowners that granted access for the Hillslope Monitoring Program from 1996 through 2001. Large landowners participating were: Barnum Timber Company, Coombs Tree Farms, Congaree River Limited Partnership, Crane Mills, Eel River Sawmills, Fruit Growers Supply Company, Georgia-Pacific Corporation, Gualala Redwoods Company, Hawthorne Timber Company, J.H. Baxter Company, LaTour Demonstration State Forest, Louisiana Pacific Corporation, Mountain Home Demonstration State Forest, Miller-Rellim Company, Mendocino Redwood Company, Pacific Lumber Company, Pacific Gas and Electric Company, Red River Forest (managed by W.M. Beaty and Associates), Richard Padula, Roseburg Resources Company, Shasta Forest (managed by W.M. Beaty and Associates), Sierra Pacific Industries, Siller Brothers, Inc., Simpson Resource Company, Soper-Wheeler Company, Stimson Lumber Company, Strategic Timber Trust, Timber Products Company, and Wetsel-Oviatt Lumber Company. Small landowners who participated are too numerous to thank individually, but their cooperation is deeply appreciated. In addition to providing access to their properties, many of these landowners (both small and large) assisted our field teams by providing maps, gate combinations, keys, and other help in locating the sites.

Roger Poff, Cliff Kennedy, and Joe Hiss collected data on more than 90 percent of the THPs and NTMPs monitored and provided helpful comments and suggestions throughout the project. Natural Resources Management Corporation (NRM) collected field data in Humboldt County on 25 THPs in 1996.

Clay Brandow of CDF assisted in many aspects of the project, including the laborious task of screening THPs and NTMPs in Santa Rosa, Redding, and Fresno.

CDF's State Forests Research Coordinator Tim Robards provided very valuable assistance with database queries for the current report and his efforts are greatly appreciated. We would also like to thank Dr. Don Warner, California State University, Sacramento, for his valuable assistance with the Hillslope Monitoring Program database over the entire six year period. Don developed the database, modified it as requested, maintained it, and queried it for report generation. CDF's Forest Practice Database Coordinator Shana Jones queried the Forest Practice Database for the basic pool of THPs and NTMPs to randomly sample.

CDF Deputy Director for Resource Management Ross Johnson recognized the importance of the Hillslope Monitoring Program and provided the funding for individual contracts to collect the field data and enter the data in the database from 1996 through 2001. Individuals representing the various state and federal agencies making up the Monitoring Study Group helped design the study and supplied valuable guidance and oversight for the Hillslope Monitoring Program throughout the six year period. CDF Secretaries and Office Technicians in Santa Rosa, Redding, and Fresno provided assistance with screening potential THPs and NTMPs and copying the appropriate sections of the THP/NTMP files for field work.

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List of Abbreviations

ACL	Associated California Loggers
BMPs	Best management practices
BOF	California State Board of Forestry and Fire Protection
CDF	California Department of Forestry and Fire Protection
CDFG	California Department of Fish and Game
CDPR	California Department of Parks and Recreation
CFA	California Forestry Association
CGS	California Geological Survey
CLFA	California Licensed Foresters Association
CPSS	Certified Professional Soil Scientist
CSES	Critical Sites Erosion Study
EEZ	Equipment exclusion zone
EHR	Erosion hazard rating
ELZ	Equipment limitation zone
ESU	Evolutionarily significant unit
FLOC	Forest Landowners of California
FPA	Forest Practice Act
FPRs	Forest Practice Rules
HMP	Hillslope Monitoring Program
LTMP	Long-Term Monitoring Program
LTO	Licensed Timber Operator
LWD	Large woody debris
MAA	Management Agency Agreement
MCR	Modified Completion Report
MSG	Monitoring Study Group
NMFS	National Marine Fisheries Service
NTMP	Nonindustrial Timber Management Plan
NCRWQCB	North Coast Regional Water Quality Control Board
NTO	NTMP Notice of Timber Operations
PHI	Pre-Harvest Inspection
PMP	Pilot Monitoring Program
QA/QC	quality assurance/ quality control
RCD	Resource Conservation District
RG	Registered Geologist
RPF	Registered Professional Forester
Rules	Forest Practice Rules
RWQCB	California Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
THP	Timber Harvesting Plan
UCCE	University of California Cooperative Extension
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Department of Agriculture, Forest Service
WLPZ	Watercourse and lake protection zone

Introduction

Monitoring the impacts of forestry related activities on water quality is an important issue for California. Aquatic species continue to be listed as threatened or impaired by state and federal agencies, such as the state listing of coho salmon in August 2002. The Regional Water Quality Control Boards are considering how to address a legislatively mandated expiration of waivers on January 1, 2003, for silvicultural activities under the Clean Water Act. The listing of numerous North Coast watersheds as impaired waterbodies under Section 303(d) of the Clean Water Act and the implementation of Total Maximum Daily Load (TMDL) requirements are significant issues to numerous landowners. Additionally, debate continues on the appropriate protection measures needed along small headwater streams for adequate water quality protection. Scientifically credible monitoring data is needed to help resolve these issues and to reach sound conclusions regarding the impacts of current timber operations on water quality.

The purpose of the Hillslope Monitoring Program is to determine if California's Forest Practice Rules are adequately protecting beneficial uses of water associated with commercial timber operations on nonfederal lands in California. In June 1999, the California State Board of Forestry and Fire Protection's Monitoring Study Group presented an interim report documenting preliminary findings from its Hillslope Monitoring Program (CSBOF 1999). Additional data collected over the past three years is now sufficient for the preparation of a second report on the project. Hillslope monitoring will continue in the future, with refined protocols for improved tests of individual practice effectiveness. Continued monitoring is also needed to evaluate changes in the California Forest Practice Rules, the issues raised above, and the changing expectations of resource agencies and California's citizens.

The Hillslope Monitoring Program is not the only approach used in California to determine impacts of timber operations to water quality. Other efforts to evaluate how well California's Forest Practice Rules are implemented and how effective they are in protecting water quality include: 1) extensive inspection, enforcement, and monitoring by California Department of Forestry and Fire Protection Forest Practice Inspectors, and 2) research conducted as part of detailed watershed studies, such as the Caspar Creek watershed study. Each approach has its advantages and disadvantages. The Hillslope Monitoring Program described in this report complements these efforts, and when combined with the results from other monitoring efforts, conclusions can be reached regarding Rule implementation and effectiveness (Ice et al. 2002).

Specific objectives of the Hillslope Monitoring Program are: 1) implementation monitoring to determine if the Forest Practice Rules (FPRs) related to water quality are properly implemented, and 2) effectiveness monitoring to determine if the FPRs affecting water quality are effective in meeting their intent when properly implemented. Both implementation and effectiveness monitoring are necessary to differentiate between water quality problems created by non-compliance with a FPR, versus problems with the practice itself. The goal of effectiveness monitoring is to provide information on where, when, and in what situations problems occur under proper implementation (Tuttle 1995). Determining which Rules have the poorest implementation and effectiveness and the highest frequency of violations both provides input to the BOF on needed Rule changes and identifies training needs for: (1) CDF's Forest Practice Inspectors; (2) Registered Professional Foresters (RPFs) submitting THPs; and (3) Licensed Timber Operators (LTOs).

Background Information

California's modern Forest Practice Act (FPA) was adopted in 1973, with full field implementation occurring in 1975, and many monitoring efforts have taken place over the past two decades to learn more about the implementation and effectiveness of California's Forest Practice Rules in protecting water quality. These monitoring efforts complement the California Department of Forestry and Fire Protection (CDF) Forest Practice compliance inspection program that has been in place for over 25 years.

Under the FPA, Timber Harvesting Plans (THPs) must be submitted to CDF and approved for commercial timber harvesting on all non-federal timberlands. THPs are reviewed for compliance with the FPA and the Forest Practice Rules adopted by the Board of Forestry and Fire Protection (BOF), as well as other state and federal regulations protecting watersheds and wildlife. CDF, along with the Department of Fish and Game, Regional Water Quality Control Boards, and the California Geological Survey, conducts Pre-Harvest Inspections (PHIs) of proposed harvest areas to determine if plans are in compliance with the Act and FPRs. During PHIs, additional mitigation measures beyond the standard rules are often recommended based upon site-specific conditions. This report focuses on water quality issues, but the added THP mitigation also relates to habitat protection, public safety, and numerous other public trust resources. CDF also conducts inspections during active timber operations and the post-harvest period when logging is completed to assess compliance with the Act, the FPRs, and the specific provisions of the THP.

The State Water Resources Control Board (SWRCB) certified the Forest Practice Rules and review process as Best Management Practices under Section 208 of the Federal Clean Water Act in 1984, with a condition that a monitoring and assessment program be implemented. Initially, a one-year qualitative assessment of forest practices was undertaken in 1986 by a team of four resource professionals (Johnson 1993) that audited 100 THPs distributed across the state and produced the final "208 Report" (CSWRCB 1987). The team found that the Rules generally were effective when properly implemented on terrain that was not overly sensitive, and that poor Rule implementation was the most common cause of observed water quality impacts. They recommended several changes to the FPRs based on their observations.

Additional water quality monitoring projects in the 1980's related to the Forest Practice Rules include the Critical Sites Erosion Study (CSES), conducted within watersheds throughout northern California, and the North Fork phase of the Caspar Creek watershed study, located near Fort Bragg. Objectives of the CSES project were to determine site characteristics on THPs that could be used to identify potential large erosion features, and to identify management factors which may have been responsible for erosion events. This project collected data during 1985 and 1986 on management and site factors associated with existing mass wasting events on a random sample of 314 THPs covering over 60,000 acres (Durgin et al. 1989; Lewis and Rice 1989, Rice and Lewis 1991). A brief summary of the Caspar Creek watershed study findings is included in the following section under Summary of Related Studies.

In 1988, the Board of Forestry, CDF, and the SWRCB entered into a Management Agency Agreement (MAA) that required the BOF to improve forest practice regulations for protection of water quality based on needs described in the “208 Report.” At this point, the SWRCB approved final certification of the FPRs as Best Management Practices. The U.S. EPA, however, withheld certification until the conditions of the MAA were satisfied, one of which was to develop a long-term monitoring program (LTMP).

In response to the MAA conditions, the BOF formed an interagency task force, later known as the Monitoring Study Group (MSG), in 1989 to develop this long-term monitoring program that could test the implementation and effectiveness of FPRs in protecting water quality. With public input, the MSG developed a LTMP with both implementation and effectiveness monitoring components, and conducted a pilot project to develop appropriate techniques for both hillslope and instream monitoring (CSBOF 1993). CDF has funded this monitoring program since 1990.

From 1989 to 1999, the MSG was an “ad hoc” committee which met periodically to: 1) develop the long-term monitoring program, and 2) provide guidance to CDF in implementing the program. The MSG was designated as an Advisory Committee to the Board of Forestry and Fire Protection in January 2000. The MSG continues to refine the long-term monitoring program testing the effectiveness of California’s Forest Practice Rules and provide oversight to CDF in implementing the program.

The primary goal of the MSG’s monitoring program has been to provide timely information on the implementation and effectiveness of forest practices related to water quality for use by forest managers, agencies, and the public. CDF and BOF chose to place more initial emphasis on hillslope monitoring for the Long-Term Monitoring Program because it can provide a more immediate, cost effective and direct feedback loop to resource managers on impacts from current timber operations when compared to instream monitoring (particularly channel monitoring which involves coarse sediment parameters) (Reid and Furniss 1999). As stated in Robben and Dent (2002), it is usually easier to identify a sediment source and quantify the volume of sediment it produced, when compared to measuring sediment in the watercourse and tracing it to the source.

The components of the Long-Term Monitoring Program are described in the MSG’s Strategic Plan (CSBOF 2000) adopted by the BOF in 2000. This program is robust—utilizing a combination of approaches to generate information on Forest Practice Rule implementation and effectiveness related to water quality. The major components of the program include: 1) continuation of the Hillslope Monitoring Program, 2) use of CDF Forest Practice Inspectors to collect hillslope monitoring data on a random sample of completed THPs as part of a Modified Completion Report (MCR), 3) development of scientifically credible monitoring plans for cooperative watershed monitoring projects in selected basins to provide instream monitoring data, and 4) development and/or funding of selected monitoring projects that can answer key questions about forest practice implementation and effectiveness.

To date, considerable information has been collected by projects conducted as part of each of these components of the Long-Term Monitoring Program. A summary of what has been learned so far as part of the Modified Completion Report monitoring process is included in the following section of this report. One cooperative instream monitoring project has been started in the Garcia River watershed. The first phase of the project provided a watershed assessment and instream monitoring plan (Euphrat et al. 1998). The second phase was implementation of the instream monitoring plan to document baseline habitat conditions, which will allow examination of long-term trends to determine if instream conditions are improving. A final report documenting baseline measurements made in 1998 and 1999 for parameters such as water temperature, canopy and shading, gravel composition and permeability, large wood loading, sediment source areas, fish surveys, channel cross sections, and thalweg profiles was produced in 2001 (Maahs and Barber 2001). In 2002/2003, smaller scale cooperative instream monitoring projects are planned in Mendocino County with Campbell Timberland Management/ Hawthorne Timber Company, and in the Sierra Nevada/Cascade province with Sierra Pacific Industries.

Additionally, numerous monitoring projects have been supported, or are currently being supported, by CDF that provide critical information related to monitoring techniques and/or answer key questions regarding forest practice implementation and effectiveness. Examples of these projects include:

- Testing Indices of Cold Water Fish Habitat—Knoop (1993)
- V-Star Tests in Varying Geology— Lisle (1993), Lisle and Hilton (1999)
- Erodible Watershed Index--McKittrick (1994)
- Evaluation of Road Stream Crossings (Flanagan et al. 1998)
- Sediment Storage and Transport in the South Fork Noyo River Watershed, Jackson Demonstration State Forest (Koehler et al. 2001)
- Sediment Composition as an Indicator of Stream Health (Dr. Mary Ann Madej, USGS, and Dr. Peggy Wilzbach, HSU; in progress)
- Central Sierra Nevada Sediment Study (Dr. Lee MacDonald, CSU; in progress)
- Caspar Creek Watershed Study—Ziemer 1998, Lewis et al. 2001 (Dr. Robert Ziemer, USFS-PSW (retired), Dr. Thomas Lisle, USFS-PSW, in progress)

Final reports for completed projects, as well as other earlier monitoring reports and papers, detailed information on the Modified Completion Report monitoring process, the MSG Strategic Plan, and agendas for upcoming MSG meetings are available online at:
http://www.fire.ca.gov/bof/board/msg_geninfo.html

Over 100 papers and reports documenting findings from the Caspar Creek Watershed Study are available online at:
http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

Summary of Other Related Studies

Several recently completed and ongoing monitoring efforts are related to the hillslope monitoring work reported on in this document. Many of the findings in these studies are similar to and support results described in this Hillslope Monitoring Program report.

Colorado State University, Department of Earth Resources— Central Sierra Nevada Sediment Study. Dr. Lee MacDonald and Drew Coe, Colorado State University, Fort Collins, CO (MacDonald and Coe 2001; Coe and MacDonald 2001; Coe and MacDonald 2002)

The objective of this research is to quantify natural and anthropogenic hillslope erosion rates for use in a spatially-explicit cumulative watershed effects model. Study sites are on the Eldorado National Forest and Sierra Pacific Industries land in the Central Sierra Nevada. Approximately 150 sediment fences were installed in the summers of 1999 and 2000 to measure sediment production and sediment delivery to the stream network (Figure 1). Silt fences were installed in areas subjected to different management activities, including undisturbed sites, across three geologic types (volcanic, granitic, and metamorphic) and different elevation zones. Sediment production rates were measured for three winter periods (hydrologic years 2000 through 2002). The first winter was the wettest of the three years, while the second winter was drier and colder. The third winter was intermediate in terms of total precipitation and the duration of snow cover.

Data analysis is currently nearing completion, although several progress reports and presentations have described some of the initial key findings. The results have shown that native surface roads are the primary anthropogenic source of sediment. High rates of sediment production have also been documented for high severity wildfires and areas used for off-highway vehicles. Most harvest units and areas burned at low severity produced relatively little sediment. Overall, there was a large degree of variability between sites within a given management category as well as between years. For example, sediment production rates in the first year were 3 to 11 times higher than the sediment production rates for the second winter, and this is due in large part to the lower amounts of precipitation and more consistent snow cover.

Data from the first winter showed that, on average, native-surface roads generated approximately seven times as much sediment as harvest units and landings. These results led to a greater focus on sediment production from native surface roads. Data from the next two winters indicated that recently-graded native surface roads produced twice as much sediment as comparable segments that had not been graded. Road surface area, slope, annual precipitation, elevation, and grading (i.e., recently graded vs. ungraded) were the primary controls on road sediment production. The product of road surface area and road gradient was the single best predictor of road surface erosion, and this explained from 40 to 65% of the variability within a given year. Rocked roads produced only 2-4% as much sediment as comparable native surface roads. Relative to the other factors, soil type was not an important control on sediment production from the native surface roads. However, the limited data suggest that erosion rates from harvest units on granitic soils can be as much as an order of magnitude larger than the erosion rates from harvest units on volcanic soils.

A survey of 285 road segments as defined by specific drainage outlets (e.g., waterbar, rolling dip, or culvert) indicated that approximately 18% of the segments (20% of the total surveyed length) had gullies or sediment plumes that reached to within 10 m (33 ft) of a stream channel. Road crossings accounted for 58% of the road segments that were connected to the stream network.

Overall, the highest sediment production rates were often associated with insloped road segments located downslope of areas with shallow, impermeable bedrock. Because the product of area and slope was a dominant control on road segment sediment production, the older roads with inadequate drainage produced much more sediment per unit area than roads that followed current drainage specifications. Hence the best means to reduce erosion rates from native surface roads is to alter the road surface by rocking, decreasing the product of area and slope by improving and maintaining road drainage, and avoiding areas with shallow bedrock that increase sideslope drainage and increase ditch runoff. Areas with shallow bedrock also appear to facilitate the generation of extended gullies that can link roads to the stream network. These segments, together with road crossings, account for nearly all of the road-derived sediment that is being delivered to the stream network.

Figure 1. Example of one of 147 sediment fences installed to measure sediment production rates in the central Sierra Nevada Mountains (photo by Drew Coe used with permission).

US Forest Service—Pacific Southwest Region—Best Management Practice Evaluation Program. Brian Staab, USFS, Vallejo, CA (Staab 2002)

The U.S. Forest Service's (USFS) Best Management Practices (BMP) Evaluation Program in California is focused on hillslope monitoring of BMP implementation and effectiveness. Preliminary results indicate that USFS silvicultural BMPs are generally implemented and effective. Statewide, average implementation and effectiveness rates from 1992-2001 were both approximately 87% (n=2900 random evaluations). Yearly rates of BMP implementation and effectiveness ranged from 83% to 91% and 78% to 92%, respectively. Effectiveness rates were above 85% every year except 1997. Implementation and effectiveness rates, respectively, for specific silvicultural BMPs were as follows: streamside management zones: 82%/79% (n=248); skid trails: 84%/91% (n=276); suspended yarding 97%/90% (n=87); landings: 90%/95% (n=373); timber sale administration (n=62): 95%/98%; special erosion control and revegetation: 84%/96% (n=57); meadow protection: 93%/95% (n=121); road surface, drainage and slope protection: 87%/84% (n=238); stream crossings: 86%/80% (n=259); control of sidecast: 81%/89% (n=185); servicing and refueling: 95%/97% (n=38); in-channel construction practices: 92%/61% (n=115); temporary roads: 91%/88% (n=120); rip rap composition: 91%/82% (n=22); snow removal: 85%/87% (n=163); pioneer road construction: 96%/56% (n=25); management of roads during wet periods: 92%/85% (n=61); prescribed fire: 77%/95% (n=231); vegetation manipulation: 89%/96% (n=93); and revegetation of surface disturbed areas: 84%/76% (n=85).

Oregon Department of Forestry—Best Management Practices Compliance Monitoring Project: Final Report. Joshua Robben and Liz Dent, ODF, Salem, OR (Robben and Dent 2002)

The ODF Forest Practice Monitoring Program implemented the BMP Compliance Monitoring Project to evaluate compliance with BMPs on non-federal forestlands in Oregon. This was a three year statewide project, with the first year (1998) being a pilot study to develop and test protocols. A total of 189 harvest operations were randomly selected, using criteria that favored selection of units with fish-bearing waters. At the selected units, harvesting practices, roads, skid trails, stream crossings, riparian management areas, wetlands, etc. were evaluated for compliance with 150 Forest Practice Rules designed to protect water quality and fish habitat. Monitoring was completed by a former Forest Practices Forester who rated individual BMP applications as compliant or noncompliant. The type and magnitude of resulting riparian and channel impacts were recorded for noncompliant practices.

A total of approximately 13,500 BMP applications were evaluated and the overall compliance rate was 96.3%. Specific practices that were found to have the poorest compliance (less than 96% compliance and five or more noncompliance practices) are: slash piling within waters of the state (89.6%), removal of petroleum-related waste from the unit (82.0%), stream crossing fill stability (84.3%), road surface drainage design (86.5%), road surface drainage maintenance (94.2%), restrictions on felling of trees into small streams (83.1%), skid trails not located within 35 feet of Type F streams (91.5%), skid trails located so that stream water will not flow onto the skid trail (92.5%), removal of temporary crossings (47.8%), protection of other wetlands (69.8%), prior approval requirements (90.4%), and written plan requirements (77.1%).

Approximately 500 noncompliant practices were recorded and 185 of these were administrative requirements not directly affecting water quality. About 65% of the noncompliant practices either had impacted water quality or had the potential to impact riparian and channel conditions in the future. The greatest source areas of sediment delivery were from 36 noncompliant road construction and maintenance practices. To improve BMP compliance, the results of this monitoring work are being presented to landowner groups, operator workshops, and Oregon Department of Forestry conferences. Additionally, the results are being used to clarify guidance language, develop additional implementation tools, and guide future monitoring work.

California Department of Forestry and Fire Protection—Modified Completion Report Monitoring Progress Report. Clay Brandow, CDF, Sacramento, CA (Brandow 2002)

As part of the CDF's Forest Practice Program, the Department's Forest Practice Inspectors collect hillslope monitoring data for areas of the landscape that have been found in previous monitoring work to be either particularly sensitive to disturbance or having significant impacts to water quality. For each THP evaluated, a randomly selected road segment (1000 feet), a randomly selected WLPZ segment (200 feet), and two randomly located watercourse crossings are rated for FPR implementation at the time logging is completed. Effectiveness of erosion control facilities and crossing design/construction are rated a second time for the same road segment and crossings during an Erosion Control Maintenance inspection after one to three overwintering periods. Rating implementation immediately following logging and effectiveness after stressing winter storms follows the guidelines suggested by Lewis and Baldwin (1997) in a statistical review of the Hillslope Monitoring Program. Sample size is a random selection of 12.5% of THPs undergoing Work Completion Report field inspections. As of September 2002, 132 THPs have been sampled, with 101 having a Class I or II WLPZ. Class I WLPZ total canopy has averaged 83% in the Coast District and 68% in the inland (Northern and Southern) districts. Class II total canopy has been similar, with 83% and 69% in the Coast and inland districts, respectively. For the road segments to date, 15% of evaluated stretches have had at least one departure from the FPRs. Most of the departures have related to waterbreak spacing, waterbreak discharge into cover, and waterbreak construction. Additionally, 145 crossings have been sampled, and FPR departure rates have been found to be low (contrary to Hillslope Monitoring Program results). This may be due to: 1) fewer overwintering periods; 2) differences in monitoring forms, rating categories, and reviewer opinions; and 3) requirement for major problems to be fixed prior to plan completion report approval.

US Forest Service—Pacific Southwest Research Station—Caspar Creek Watershed Study. Dr. Robert Ziemer, Chief Research Hydrologist (retired), Redwood Sciences Laboratory, Arcata, CA; Dr. Thomas Lisle, Research Hydrologist, Redwood Sciences Laboratory, Arcata, CA. (Ziemer 1998, Lewis 1998, Cafferata and Spittler 1998, Lewis et al. 2001, Lewis 2002)

Results from the Caspar Creek watershed study located near Fort Bragg, California show that improved forestry practices after 1974 have significantly reduced sediment yields in the past two decades. Selection logging conducted prior to the implementation of the modern Rules in the South Fork of Caspar Creek produced from 2.4 to 3.7 times more suspended sediment compared to that produced by clearcutting in the North Fork under the modern Rules. Suspended sediment monitoring in the North Fork of Caspar Creek following clearcut harvesting of almost half the watershed in three years under the modern Forest Practice Rules showed that annual sediment loads increased 123-269% in the tributaries. At main-stem stations, however, increased loads were detected only in small storms and there was little effect on annual sediment loads. Most of the suspended sediment generated at the North Fork weir resulted from one large landslide that occurred in January 1995.

The overall conclusion from the Caspar Creek watershed study is that logging operations conducted under the modern Forest Practice Rules produce much less sediment than logging in the early 1970's prior to the implementation of these Rules. Unit area sediment loads from four storm events in hydrologic year 2001 show that sediment yields are higher in several South Fork tributary watersheds, without disturbance for almost 30 years, than was found in clearcut tributary basins in the North Fork that were logged approximately 10 years ago. Much of this difference is attributed to poor design, construction, and maintenance of pre-modern Forest Practice Rule roads, landings, and skid trails.

Road rehabilitation work was conducted during the summer of 1998 on three miles of old road constructed along the South Fork in 1967. A total of 33 watercourse crossings were abandoned, removing a total of approximately 28,500 cubic yards of fill material. Surveys of the abandoned crossings have shown that downcutting following large winter storm events, including a 40-year recurrence interval event the first winter following excavation, has resulted in 854 cubic yards of sediment, or three percent of the total amount of sediment removed, being washed downstream. Most of this material came from three crossings. Approximately 500 cubic yards were lost from one abandoned crossing on the mainstem of the South Fork, primarily from upstream residual deposits of sediment above an old splash dam built in the 1860s. The other two problem crossings each lost 50 to 70 cubic yards of sediment due to downcutting at the crossing site. Little additional downcutting has occurred after the first winter following excavation (W. Baxter, CDF—Jackson Demonstration State Forest, Fort Bragg, CA, personal communication).

Study Design

Overview

The Hillslope Monitoring Program began in 1993 with a pilot project designed to develop and test monitoring procedures. Dr. Andrea Tuttle and CDF began the process by modifying previously developed U.S.D.A. Forest Service hillslope monitoring forms developed for the Pacific Southwest Region (USFS 1992). Modifications were made to allow detailed information to be recorded for locations within Timber Harvesting Plans (THPs) that were felt to present the greatest risk to water quality--roads, skid trails, landings, watercourse crossings and watercourse and lake protection zones (Tuttle 1995). The forms developed for the U.S. Forest Service monitoring program did not adequately identify the specific requirements of the Forest Practice Rules. As a result, these initial forms were either substantially modified (i.e., watercourse crossings and landings) or completely re-written (i.e., transect evaluations were developed for roads, skid trails, and watercourse and lake protection zones). Dr. Tuttle and CDF prepared new forms for practices that are unique in the FPRs, and developed methods for measuring and identifying features related to Rule implementation and effectiveness. Harvest units were not included because few of the Rules apply to these areas and previous studies had shown that most of the erosion features were associated with the more disturbed sites (Durgin et al. 1989).

As part of the hillslope component of the Pilot Monitoring Project, Monitoring Study Group members identified all of the separate Forest Practice Rule requirements that could be related to protection of water quality. This resulted in a list of over 1300 separate items, including plan development, the review process, and field application requirements. This list was then pared down to 191 Rule requirements that are implemented during the conduct of a Timber Harvesting Plan and can be evaluated by subsequent field review. Many of the Rule sections with multiple requirements were broken down into their separate components for field evaluations.[1] FPRs related to cumulative watershed effects and the THP review process were not included because they could not be evaluated using an on-the-ground inspection of the THP area. The overall goal of the Hillslope Monitoring Program has been to collect data that can, over time, provide information on: 1) how well the Rules are being implemented in the field, and 2) where, when, and to what degree problems occur—and don't occur—under proper implementation (Tuttle 1995).

The California Division of Mines and Geology (now known as the California Geological Survey) assisted with the hillslope pilot program and provided detailed geomorphic mapping for two of the watersheds used for the pilot work (Spittler 1995). The California Department of Fish and Game completed the pilot project work for the instream monitoring component of the program (Rae 1995). The Pilot Monitoring Program was completed during 1993 and 1994, and final reports were prepared in 1995. Pilot

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[1] The Forest Practice Rules referred to in this report, including all the tables, are based on the Rules in effect in 1994. Changes to the FPRs since that time have affected the letters and numbers assigned to some individual Rules, but the listed Rules remain in effect in the same Rule Section.

Monitoring Program Manager Gaylon Lee of the SWRCB prepared a summary document that included a detailed description of what had been learned about hillslope monitoring and made recommendations for the long-term program (Lee 1997).

Site Selection

Data collection for the BOF/CDF Hillslope Monitoring Program began in 1996 with a stratified random sample of 25 THPs in both Humboldt and Mendocino Counties to collect information from watersheds with coho salmon habitat, due to the proposed federal listing of that species.[2] Contracts were developed with the Resource Conservation Districts (RCDs) in each county, and the RCDs hired Registered Professional Foresters (RPFs) to collect the required field data on THPs that had over-wintered for a period of one to four years. Natural Resources Management Corporation (NRM) was the contractor hired by the Humboldt County RCD, while R.J. Poff and Associates was hired by the Mendocino County RCD. Stratified random sampling was utilized to select the THPs for work completed in 1996. Using erodibility ratings developed as part of a study completed by the California Division of Mines and Geology (now the California Geological Survey) (McKittrick 1994), approximately 50 percent of the THPs evaluated were included in the areas designated as having high overall erosion hazard, 35 percent were included in the moderate category, and 15 percent were included in the low erosion hazard rating.[3]

From 1997 through 2001, field data was collected from a statewide random sample of 50 THPs each year. These THPs were not stratified based on the CGS erodible watershed categories utilized in 1996. While only a fraction of all completed THPs were evaluated, the random sample design ensured that the results were representative of all the THPs harvested during the same period. Beginning in 2001, Nonindustrial Timberland Management Plan (NTMP) Notices of Timber Operations (NTOs) (or NTMP projects) were included as part of the sample because of the growing number of NTMPs statewide, and a lack of information regarding rule implementation and effectiveness on these projects. NTMPs are long-term management plans for small nonindustrial timberland owners. When a portion of the area covered by the NTMP is to be harvested, an NTO is submitted to CDF for review and is valid for one year following approval.

CDF's RBASE Forest Practice Database was queried from 1996 through 1998 in Santa Rosa, Redding, and Fresno to produce a combined list of potential THPs meeting the completion and acceptance dates (approximately 2,500 THPs were in the population).

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[2] Coho salmon were listed by the NMFS as threatened for the Southern Oregon/Northern California Coasts Coho ESU in 1997.

[3] This project rated large (e.g., 50,000 acre) watersheds on their inherent erodibility, excluding land use impacts. Variables input into a GIS model included precipitation, slope, and geology. A low, moderate or high rating was assigned to each factor. Numbers were summed to create an ordinal display of relative susceptibility of watersheds to erosion.

Beginning in 1999, CDF's new Oracle Forest Practice Database system was queried in Sacramento to generate the list of potential THPs and, in 2001, NTMP NTOs, with appropriate completion and acceptance dates.

These queries produced a preliminary, randomized list of THPs and NTMP NTOs to evaluate. Individual THP and NTMP files were then reviewed at CDF's regional offices in Santa Rosa, Redding, and Fresno to determine whether the individual plans met the criteria for when the logging was completed, the length and types of watercourses present, yarding system(s) utilized, plan or project size, and wildland classification described below. THPs eliminated from the preliminary list were replaced with the next THP meeting the above criteria, keeping the original percentages for each CDF Forest Practice District (i.e., Coast, Northern and Southern) established in the random sort.[4] The statewide sample, therefore, is very similar to the distribution of THPs CDF receives at each of its three Forest Practice District offices.

Specifically, THPs and NTMP NTOs were included in the study if they met the following criteria:

1. The THP had been filed and completed under the Forest Practice Rules adopted by the BOF after October 1991 (when the most recent WLPZ rules were implemented prior to adoption of the Threatened and Impaired Watersheds Rule Package in July 2000).

2. The THP was not accepted by CDF after the adoption of the July 2000 Threatened and Impaired Watersheds Rule Package.

3. The plans had been through at least one, but not more than four winters, since logging was completed. To ensure that plans met this requirement, the CDF Work Completion Report for the entire THP must have been signed by a CDF Forest Practice Inspector, and the date used to determine the one to four over-wintering periods was the date supplied by the RPF that indicated when all the logging was completed on the THP. This length of over-wintering provided the opportunity for erosion control measures to be tested by wet-weather prior to the field evaluation of effectiveness.

4. The THP or NTMP NTO was primarily composed of wildlands (e.g., it was not a campground or golf course). Also, the THP or NTMP NTO could not be a road-right-of-way-only plan.

5. The THP or NTMP NTO was not entirely helicopter logged and had significant components of either ground based tractor logging and/or cable yarding systems.

[4] If this were not done, a much higher percentage of THPs would have been selected from the Coast Forest Practice District, since many more of these plans have the required watercourse length.

6. The THP or NTMP NTO had at least 500 continuous feet of a Class I or II watercourse present, or the project boundary was a distance from the Class I or II watercourse that would correspond to what the Forest Practice Rules would prescribe for a WLPZ for that watercourse type and slope.

7. The THP was at least 5 acres in size.

8. The THP was not previously sampled.

Permission for THP access was first requested in a letter written by CDF and then with follow-up telephone calls made by the contractor for those plans where a response was not received. CDF stressed that there was no possibility of legal actions as a consequence of the field inspection, since no citations or violations could be issued by our contractor. Where permission was not granted, the next THP on the list was used. Permission was received from large industrial owners for all but one THP. In contrast, more than 50 percent of the selected THPs on small, nonindustrial timberlands were excluded from the study because of either an inability to locate the landowner, sale of the parcel, or denial of access. This resulted in the study being weighted toward the industrial timberlands.

Starting in 2000, to prevent additional bias in the sample towards large industrial forest landowners, large forest landowner THPs that were rejected due to a lack of access were replaced with other large landowner plans, and small landowner plans were replaced with other small landowner THPs. Large landowners were arbitrarily defined as having combined ownership in California of at least 6,000 acres based on a list of landowners and their ownership size developed by CDF Forest Practice Program staff. This practice was largely successful, but a few large industrial plans were still needed at the last moment when small non-industrial landowners changed their mind about access.

When permission for access was received for 50 THPs and NTMP NTOs, a final list of projects was developed and copies of the THPs and NTMPs were made by the CDF Regional Offices for the contractor. The contractor was supplied with copies of the Pre-Harvest Inspection reports, Amendments, Notices of Violations, and Final Work Completion Reports (including maps). Alternate THPs were supplied for each Forest Practice District in 1999, 2000, and 2001 in addition to the 50 THPs and NTMP NTOs. This was necessary to provide alternate plans for situations where field inspection revealed that the THP would not be acceptable for monitoring (e.g., all the roads had their drainage structures removed for more recent logging activities).

Data Collection

The monitoring work was conducted by independent contractors who acted as third party auditors (Figure 2). CDF developed the bid package, advertised the bid package, accepted bids from qualified contractors, and hired the qualified contractor with the lowest bid for each year from 1997 through 2001. To qualify, bidders must have met the following requirements:

1. The Contractor must have been a Registered Professional Forester (RPF) in the state of California. The Contractor could employ assistants who were not Registered Professional Foresters who worked under the supervision of the RPF and the on-site team conducting each THP or NTMP NTO must have included at least one RPF and one earth scientist (note that one person meeting both requirements could fill this role).

2. The Contractor must have had experience in the development, implementation, and evaluation of THPs on private timberlands within the state of California.

3. The Contractor must have had a working knowledge of the California Forest Practice Rules and experience with tractor and cable logging operations.

4. The Contractor's team must have had experience evaluating hillslope erosion problems, and must have had at least one member who was an earth sciences specialist with soil science or geology expertise and who had experience working with forested environments. To meet this criteria, one of the team members must have been either a **Certified Professional Soil Scientist** (CPSS) (as designated by the American Registry of Certified Professionals in Agronomy, Crops, and Soils) or a **California Registered Geologist** (RG) (as designated by the Board for Registration of Geologists and Geophysicists).[5]

5. The Contractor must have had an extensive background in monitoring, including experience with on-site monitoring to evaluate the impacts of timber operations on water quality.

The contractor for each of these contracts from 1997 to 2001 was R.J. Poff and Associates. Mr. Roger Poff was the U.S.D.A. Forest Service North Sierra Zone Soil Scientist and was stationed on the Tahoe National Forest from 1980 to 1993. He is both a Certified Professional Soil Scientist and a Registered Professional Forester (RPF) in California. Assisting Mr. Poff were Mr. Cliff Kennedy, an RPF in California, and Mr. Joe Hiss, the principles of High Country Forestry.[6]

Field work was conducted during the spring, summer, and fall months. During the site inspections, data was recorded by the contractor on paper field forms supplied by CDF. Detailed information was collected on: 1) randomly located road, skid trail, and watercourse protection zone segments; randomly located landings and watercourse crossings; 2) large erosion events (e.g., mass wasting features) where they were encountered, and 3) non-standard practices and additional mitigation measures when they were utilized at the randomly sampled locations. A set of forms was provided for each of these subject areas, with sub-sections for site information, non-standard practices and additional mitigation measures, rule implementation, and rule

[5] From 1997 to 1999, the bid package specified that the one of the members of the field team must be either a RG, CPSS, or a Certified Professional Erosion and Sediment Control Specialist (CPESC).

[6] Mr. Chris Hipkin, RPF, assisted R.J. Poff and Associates in 1996 in Mendocino County.

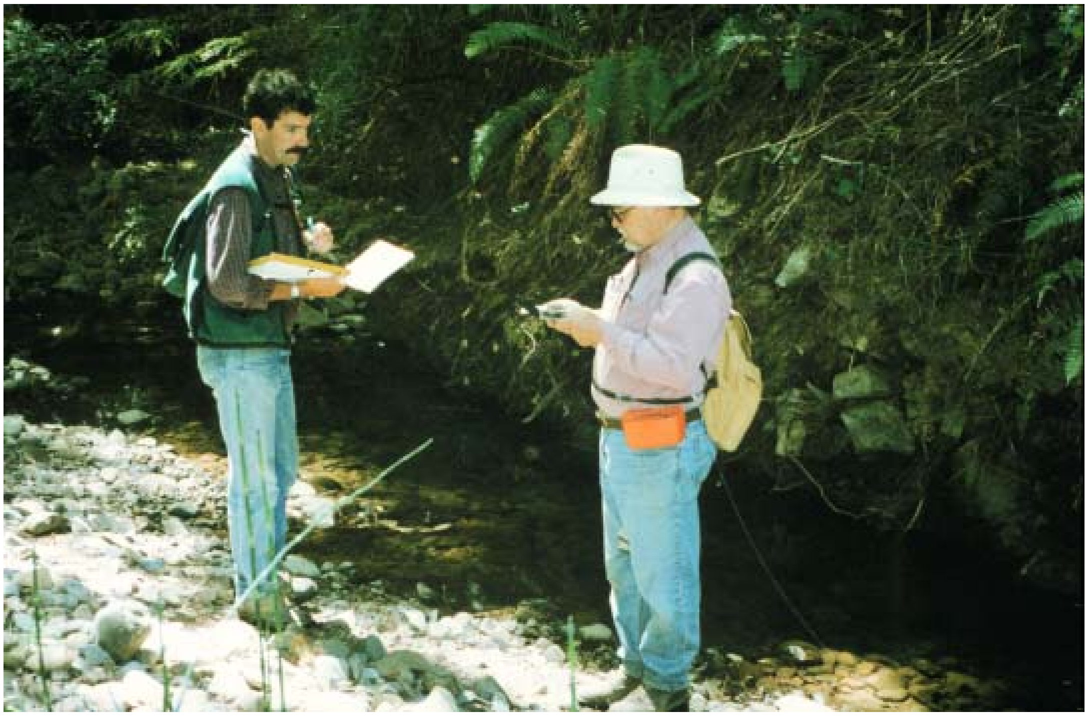

Figure 2. Field data was collected by highly qualified independent contractors who acted as third party auditors. Cliff Kennedy and Roger Poff are shown collecting field data in Mendocino County.

effectiveness. Direct observation of fine sediment delivery to stream channels during storm events was not attempted with this dry season program.

A Hillslope Monitoring Program database was developed in Microsoft Access for Windows (Microsoft Office 97) and runs on a personal computer. It is a relational database, approximately 30 megabytes in size without data. The data collected in 1996 was entered into the database by CDF. From 1997 to 2001, data was entered into the database by CDF's contractor. A preliminary set of queries were developed for the interim report prepared in 1999 (CSBOF 1999). These queries and additional, new queries were utilized for the current report.

Quality Assurance/Quality Control (QA/QC)

Quality assurance consists of actions to ensure quality data collection and analysis, while quality control is associated with actions to maintain data collection and analysis quality consistent with study goals through checks of accuracy and precision. The quality assurance program was composed of three components: 1) minimum qualifications for the contractor (see above), 2) a detailed training program, and 3) protocols provided in a field instruction package. New contractors were trained in the field by CDF Forest Practice personnel who developed the field sampling procedures and a detailed set of instructions on the Hillslope Monitoring Program procedures was provided.

The quality control program was composed of the following components: 1) self-evaluation, 2) CDF review, and 3) independent review. Under self-evaluation, it was stressed that the contractor ensure that the forms were completed satisfactorily and that the features were mapped prior to leaving the field site. CDF field inspections were "front-loaded", meaning that more field inspections were completed early on in the program compared to later years. CDF remeasured selected transects for canopy measurements in made in 1996 and found that the canopy measurements reported by the contractors were approximately seven percent higher than the internal estimate. The CDF average for three transects in Humboldt County and three transects in Mendocino County was 77.4 percent (measured with a spherical densiometer). The contractor's measurement for these transects was 84.8 percent.

For independent review, a random sample of 10 THPs were chosen in 1997 for quality control work. Dr. Stephen Daus and Mr. Michael Parenti were hired by CDF to complete the field work for these THPs a second time to test the repeatability of the process. Three plans were located in the Coast Forest Practice District, three in the Northern District, and four in the Southern District. Eighteen WLPZ transects were evaluated (14 Class II watercourses and four Class I watercourses). The average canopy cover measured with a spherical densiometer by the Daus/Parenti team for the WLPZ transects was 70.7 percent. The corresponding average canopy measurement for the same 10 THPs by the R.J. Poff and Associates team was 64.4 percent. A paired T Test revealed that these means of these two groups are significantly different at alpha <0.05.

Site Characteristics

Of the 300 plans evaluated, 295 were THPs and five were NTMP NTOs. Most of the THPs in the sample were accepted by CDF in the early to mid-1990's and the harvesting was completed by the mid to late 1990's (Figure 3). None of the THPs evaluated were approved under the new July 2000 Threatened and Impaired Watersheds Rule Package.

The THPs and NTMP NTOs sampled from 1996 through 2001 are displayed by Forest Practice District in Table 1. About 60 percent of the plans were from the Coast Forest Practice District. The distribution of large and small landowners is displayed in Table 2, and approximately 60 percent were on timberlands owned by large landowners. Figure 4 shows the general location of the projects which were monitored. Table 3 displays the distribution of THPs and NTMP NTOs by county. Slightly more than half the plans were located in Humboldt and Mendocino Counties. The average size of the THPs classified as being filed by large landowners was 441 acres, while the average size of the THP filed by small landowners was 169 acres. Considering both categories, the overall average size was 341 acres. In total, the 300 projects covered 102,260 acres.

Table 1. Distribution of THPs and NTMP NTOs by Forest Practice District.

Forest Practice District	THPs/NTMP NTOs	Percent
Coast	183	61
Northern	78	26
Southern	39	13

Table 2. Distribution of THPs and NTMP NTOs by landowner category.

Landowner Category	Number of THPs/ NTMP NTOs	Percent of THPs/ NTMP NTOs
Large landowner	189	63
Small landowner	111	37

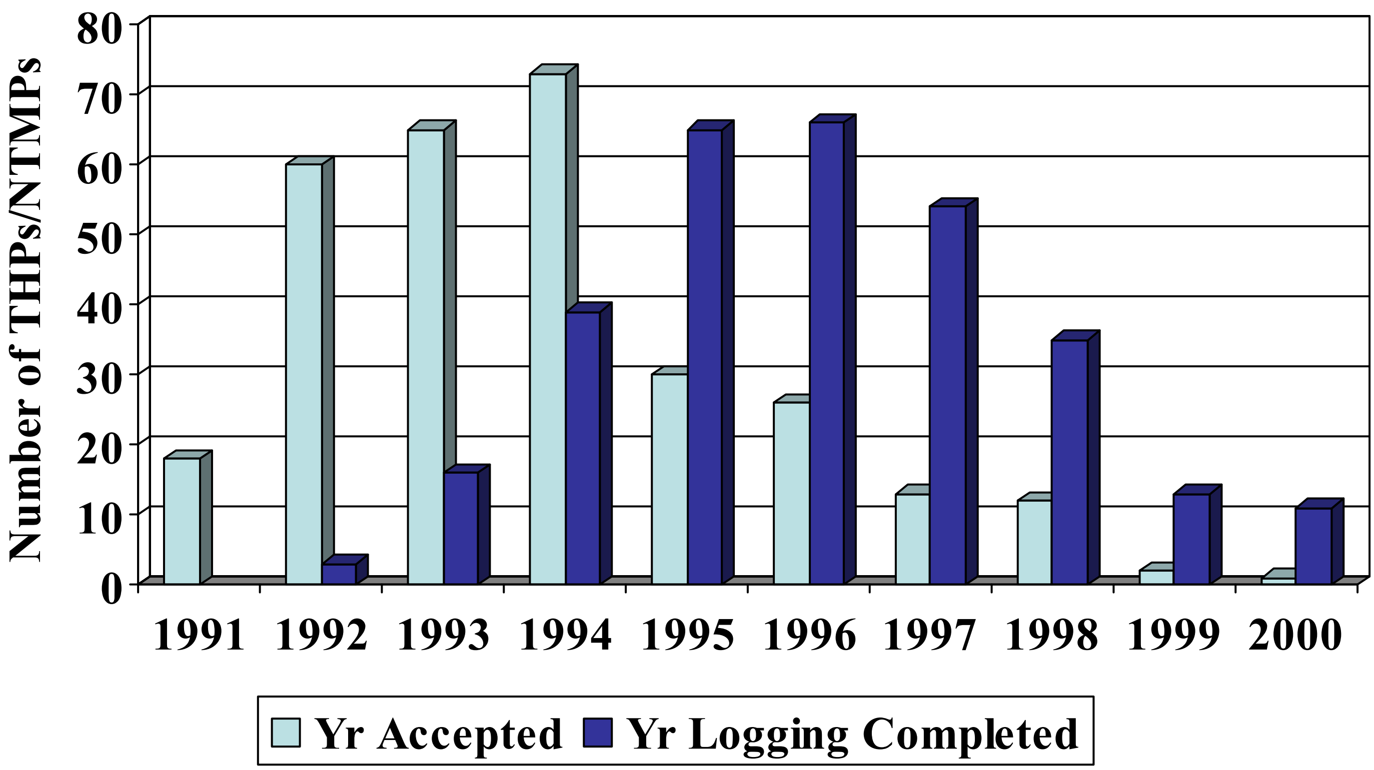

Figure 3. Distribution of when THPs and NTMP NTOs were accepted by CDF and when the logging was completed.

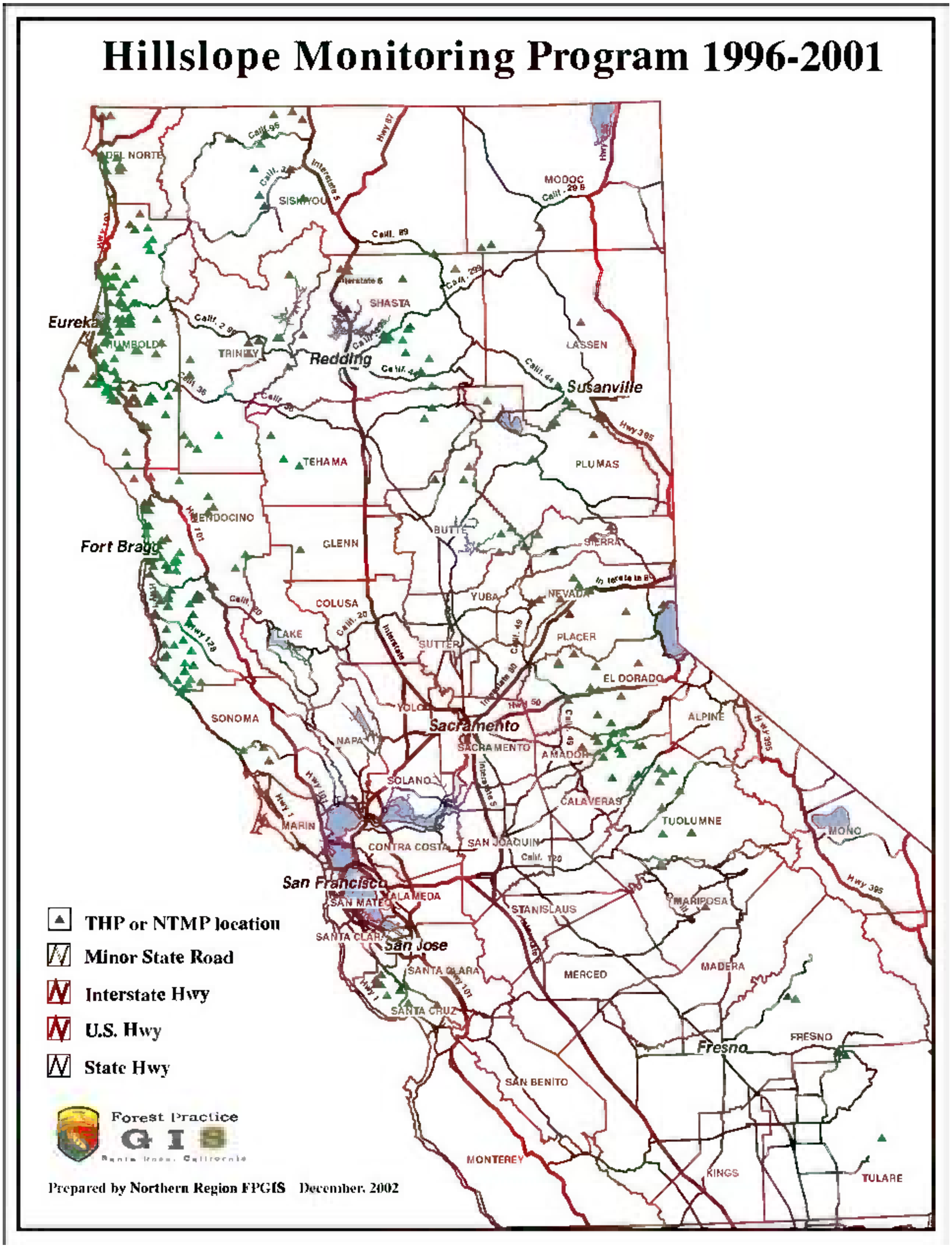

Figure 4. General location of THPs and NTMPs monitored from 1996 through 2001.

Table 3. Distribution of THPs and NTMP NTOs monitored from 1996 through 2001 by county.

County	North Coast THPs: 1996	Statewide THPs: 1997- 2001	Statewide NTMPs: 2001	Total Number of Projects
Coast Forest Practice District				
Del Norte		11		11
Humboldt	25	52	4	81
Mendocino	25	48	1	74
Santa Clara		2		2
Santa Cruz		7		7
Sonoma		4		4
Trinity		4		4
District Total	50	128	5	183
Northern Forest Practice District				
Butte		6		6
Glenn		1		1
Lassen		7		7
Modoc		3		3
Nevada		5		5
Placer		4		4
Plumas		4		4
Shasta		18		18
Sierra		3		3
Siskiyou		12		12
Tehama		5		5
Trinity		9		9
Yuba		1		1
District Total	0	78	0	78
Southern Forest Practice District				
Amador		6		6
Calaveras		8		8
El Dorado		10		10
Fresno		3		3
Mariposa		2		2
Tulare		2		2
Tuolumne		8		8
District Total	0	39	0	39
Totals	**50**	**245**	**5**	**300**

Methods

GENERAL INFORMATION

Five sample features were evaluated within each THP or NTMP NTO: roads, skid trails, landings, watercourse crossings, watercourse protection zones (i.e., WLPZs, ELZs, and EEZs). Two samples of each of these features were evaluated within each selected THP or NTMP NTO if possible. Large erosion events were inventoried where they were encountered on the THP or NTMP project. Additionally, non-standard practices and additional mitigation measures were evaluated when they applied to randomly located sample features.

Conducting the evaluations involved both office and field activity. Office work needed to prepare for the field evaluations included:

- Determining the plan location and access routes.

- Reading the THP or NTMP/NTMP NTO to identify and become familiar with Review Team requirements, alternatives, in-lieu practices, additional mitigations, and addenda in the approved plan.

The following items were completed either in the office or in the field:

- Filling out "Site Information" sheets for each sample site with information that could be obtained from the THP or NTMP NTO document.

- Laying out the road transect grid and WLPZ transect grid for selection of sample transects, as described under “Site Selection” below.

SITE SELECTION

Selection of specific sample areas began with marking approximate 500 foot road segments on all roads on the THP or NTMP NTO map. Each of these segments was assigned a number. A random number table or generator was then used to identify one of the segments. From this point, a coin was flipped to determine direction of travel along the road until a landing was encountered. This randomly selected landing was used for the landing sample. Where more than one road entered or exited the landing, coin flips were used to identify a road transect that began where the selected road left the landing. Coin flips were also used to determine the direction of travel to the first available skid trail transect. Watercourse crossing sites were selected as either the first crossing encountered during the road transect or, if no crossing was encountered, the first crossing along a road selected by a coin flip. Finally, the point on a Class I or Class II watercourse closest to the landing was used as the starting point for the WLPZ transect, and direction of travel along the WLPZ was determined by a coin flip. Either

GPS readings or topographic maps were used to record site locations with UTM coordinates.

FIELD ACTIVITIES COMMON TO ALL SAMPLE AREAS

The first step in the field work was to finish filling out Site Information sheets. This was followed by an effectiveness evaluation of pertinent features that presented an erosion or water-quality problem to permit calculation of the relative proportion of problem to non-problem areas.

Sample area field evaluations were designed to provide a database "sketch" of the sites and transects that were inspected. The resulting detailed information was used to estimate the proportion of Rule or water quality problems in the whole population of similar features. This also allowed evaluation of Forest Practice Rule implementation and effectiveness for protection of water quality and identification of problems requiring revisions or additions to the Forest Practice Rules.

At "problem" sites (such as cut bank failures, gullies, excessive grades, and Rule violations), the problem type, erosion, and sediment delivery codes were recorded and a Rule implementation evaluation was conducted. Any rills, gullies, mass failures, or sloughing features that were encountered as part of the transect and site inspections were followed to determine whether sediment from these erosional features reached a watercourse protection zone or stream channel.[7] The presence of rills, gullies or deposited sediment at the edge of the high flow channel was sufficient to class the sediment as having entered that portion of the stream.

After the field review had been completed, an evaluation of all the Rules was conducted based upon the overall frequency of problem sites and Rule violations found along the transect as a whole. Implementation of the Forest Practice Rules applicable to a given subject area was rated as either exceeding the requirements of the Forest Practice Rules, meeting the requirements, minor departure from requirements, major departure from requirements, not applicable, could not determine (evidence is masked), or could not evaluate (with description of why).

Major departures were assigned when there was a substantial departure from Rule requirements (e.g., no or few waterbars installed for entire transect), or where sediment was delivered to a watercourse. Minor departures were assigned for slight Rule departures (e.g., WLPZ width slightly less than that specified by the Rule).[8]

[7] Rills, gullies, mass failures, and cutbank/sidecast sloughing are defined in the glossary.

[8] Minor and major departures from Forest Practice Rule have similar impact to water quality for watercourse crossings since sediment is assumed to enter the watercourse for both categories.

ROAD AND SKID TRAIL TRANSECT METHODS

Transects

The location of road and skid trail transects on the THP or NTMP NTO were determined using procedures described under Site Selection. Roads or skid trails that were not used as part of the THP or NTMP project being evaluated were not included. The starting point for the transect was the point at which the road or skid trail narrowed to its "normal width" and was outside of the influence of operations on the landing. Where a road forked, the transect followed the road that was of the same general type of construction and level of use. Where a skid trail forked, the branch that continued in the same basic direction (up-hill or down-hill) as the transect to that point was followed. If there were no clear differences, a coin flip was used to determine direction. The direction that was chosen was described in the comments section of the data form to provide a record for follow-up inspections or re-measurement, if required.

At the start of a transect, a measurement string was tied to a secure object, the string box counter was set to zero, and the location of the starting point was described in the comments for future reference. The road or skid trail was walked in the pre-determined transect direction for a distance of 1000 feet or to the end, whichever occurred first.[9]

If the total road distance was less than 800 feet, another transect on a different road segment was started from the landing without resetting the string box counter, and measurements were continued to obtain a total transect length of 1000 feet.

The minimum skid trail transect length was 500 feet. If needed, this distance could be made up of several segments. Skid trails were randomly selected from those entering the landing, where possible. If a skid trail was not available at this location, the nearest trail that brought logs to the measured road segment was used. Skid trail transects were no shorter than the length of trail requiring two waterbars. If the total skid trail distance was less than 300 feet, the transect was continued from the most recently passed trail intersection. Where there was no intersection, the transect was continued from the landing without resetting the string box counter, and the transect was continued in this fashion up to a maximum distance of 1000 feet. If there was less than 500 feet of skid trail, the available trail length was sampled and an explanatory comment was included. If there were no skid trials (i.e., the plan was entirely cable or cable/helicopter yarded), this was noted at the start of one of the skid trail forms.

Data Recording

The general procedure for linear transects was to record the starting and ending distance to each feature as it was encountered. On roads, for example, the beginning and ending point of all features (e.g., inside ditches, cut banks, location of waterbreaks,

[9] Note that main-line logging roads were not sampled if drainage structures had been removed to facilitate log hauling from more recent timber operations. This type of road (i.e., native surfaced primary road with waterbars) was probably under sampled as a result of these more recent operations.

cross drains, etc.) were recorded, regardless of whether or not they presented a water quality problem. Consecutive numbers were assigned to each feature, which, in combination with the THP and transect numbers, became a unique database identifier for that feature. Then codes were entered to indicate the type of feature and any associated drainage problems, erosion source area, erosion causes, and sediment production, plus information about road or trail gradient, sideslope steepness, and dimensions of erosion features. A feature date code was included for all erosion features, features with drainage problems, and other features related to Rule requirements to indicate if the feature was created by the current THP or NTMP project.[10]

LANDING METHODS

Site Identification

The landing to be evaluated was located as previously described under Site Selection. Landing selection was important because it became the basis for locating random sites for the other sample features.

Landing Surface

The entire landing surface was inspected for rills and gullies. Gullies were defined as being six inches or greater in depth and of any length. The total length of all gullies and their average width and depth were recorded on the data forms. Sample points for rills were located along a single transect that bisected the landing into two roughly equal parts perpendicular to the general direction of surface runoff in 1996. The percentage of the landing surface drained by rills was estimated for 1997 through 2001. To be counted, rills had to be a least one inch deep and 10 feet long. Both rills and gullies were inspected to determine whether they continued for more than 20 feet past the toe of the landing fill slope, and gullies were followed to determine if sediment had been delivered to the nearest WLPZ and channel.

Cut Slopes (if present)

The face of the cut slope was inspected for evidence of slope failures, rilling, and gullying. The path of any transported sediment was traced to determine the quantity and whether material was transported to a drainage structure(s) on the landing.

[10] Number codes that were used to indicate erosion and problem feature date were: 1-feature created by current THP; 2-feature predates and was affected by current THP; 3-feature predates and was not affected by current THP; 4-cannot determine feature date; and 5-feature created after THP but was not affected by THP. For example, 1-R indicated that a rill was created by the current THP or NTMP project.

Fill Slopes (if present)

The toe of the fill slope was inspected for evidence of slope failures, rilling, and gullying. Rills or gullies that were not caused by drainage from the landing surface were traced to determine whether they extended to a downslope channel. All slope failures were evaluated to determine the total amount of material moved and whether it reached a watercourse channel.

WATERCOURSE CROSSING METHODS

Site Identification

A watercourse crossing site was established at the first crossing encountered on the road or skid trail transects, which was also noted as a feature on the transect. If no crossing was encountered as part of the transects, the first crossing beyond the end of the road transect was used for this evaluation.

Once the crossing had been identified, the next step was to determine the length of road to be included in the drainage evaluation. This was done by walking in both directions from the crossing and identifying the points where runoff from the road surface, cuts, and fills no longer carried toward the stream crossing. The road length for evaluation also included the cut-off waterbar that should route water away from the crossing.

Fill Slopes

The crossing fill slope was evaluated to determine whether it had vigorous dense cover or if at least 50 percent of its surface was protected by vegetation, mulch, rock, or other stable material. The presence and frequency of rills, gullies, and cracks or other indicators of slope failure were noted, and the size of rills and slope failures was recorded.

Road Surface

The type and condition of road surfacing was assessed and was evaluated for ruts from vehicles and, if ruts were present, whether they impaired road drainage. The presence, frequency and length of rills and gullies on the road surface were also determined along with average gully size and surface drainage conditions. The presence, condition, and effectiveness of cutoff waterbars and inside ditches were evaluated, along with evidence of ponding or other water accumulation on the road.

Culverts

The stream channel at both the culvert inlet and outlet was examined for evidence of scouring. The current degree of plugging at the upstream inlet was assessed along with the diversion potential in case the culvert eventually becomes plugged. Alignment of the culvert, crushing of the inlet and outlet, and degree of corrosion were also evaluated. Pipe length and gradient were determined and evidence of piping around the culvert was identified.

Non-Culvert Crossings (e.g., Rocked Class III crossings)

The crossing was examined to determine the type and condition of armoring and whether downcutting or scouring at the outlet was occurring. Crossing approaches were evaluated to determine if they had been maintained to prevent diversion of stream overflow down the road should the drainage structure become plugged.

Removed or Abandoned Crossings (where applicable)

Removed crossings were examined to determine whether the restored channel configuration was wider than the natural channel and as close as feasible to the natural watercourse grade and orientation. The location of excavated material and any resulting cut bank was assessed to determine if they were sloped back from the channel and stabilized to prevent slumping and minimize erosion. The crossing was also evaluated for the following conditions:

- Permanent, maintenance free drainage.
- Minimizing concentration of runoff, soil erosion and slope instability.
- Stabilization of exposed soil on cuts, fills or sidecast that prevents transport of deleterious quantities of eroded surface soils to a watercourse.
- Grading or shaping of road surfaces to provide dispersal of water flow.
- Pulling or shaping of fills or sidecast to prevent discharge of materials into watercourses due to failures of cuts, fills or sidecast.

WATERCOURSE PROTECTION ZONE (WLPZ, ELZ, EEZ) TRANSECT METHODS

Transects

Two Class I or II WLPZs were sampled on each THP or NTMP project, when available (transects may have been shorter than 1000 feet, but must have been at least 500 feet to be included). These WLPZ segments were located along the nearest, accessible Class I or II watercourse relative to the selected landing sites. When WLPZs were present near only one of the selected landings, both segments were selected from this location. And where there was only one WLPZ on the THP, both segments could have been located along the same watercourse but, where possible, should have represented different conditions (e.g., different stream classes, stream gradients, sideslope gradients, adjacent logging methods, etc.).

For Class I waters, two 1000 foot long transects were sampled parallel to the stream within the WLPZ. One of these was a "mid-zone" transect located between the watercourse bank and the up-slope boundary of the WLPZ. The other was a "streambank" transect located immediately along the stream bank and parallel to the mid-zone transect. For Class II watercourses, only the mid-zone transect was used.

Beginning in 2000, Class III watercourses were included in the Hillslope Monitoring Program. Two Class III watercourses were sampled on each THP or NTMP project, when available. One 300 foot long transect parallel to the watercourse was established for each Class III evaluated. These segments were located along the nearest, accessible Class III watercourse relative to the selected landing sites. The transect was located either: 1) approximately 25 feet from the watercourse where no WLPZ had been established, or 2) where there was a designated protection zone (i.e., WLPZ, ELZ, or EEZ), along the “mid-point” of the designated zone. Class III monitoring protocols were developed in 1999 during a pilot project involving the THPs sampled as part of the 1999 Hillslope Monitoring Program work (Poff and Kennedy 1999).

Data Recording

Within the transects, groundcover and canopy cover were evaluated at regular intervals and at disturbed sites where timber operations had exposed more than 800 continuous square feet of mineral soil. Several other factors were also evaluated wherever they occurred, such as sediment delivery to the channel, streambank disturbance, and channel conditions.

Parameters measured or estimated in the mid-zone transect for Class I and II watercourses included groundcover at every 100 feet, canopy cover at every 200 feet with a spherical densiometer (from 1996 to 1998),[11] WLPZ width at every 200 feet (concurrent with canopy measurement and whenever there was a change in sideslope class), and sediment to the channel wherever it occurred. Measurements in the Class I watercourse streambank transect included canopy cover at 200 foot intervals, disturbance to streambanks wherever it occurred, and other stream related features. In addition, Rule implementation was evaluated continuously along both transects, and any Rule requirements or discrepancies were noted as a feature and were included in the implementation evaluation.

From 1999 to 2001, the canopy sampling method for Class I and II watercourses was changed from use of the spherical densiometer (Figure 5) to use of the sighting tube (Figures 6 and 7). This change was based on findings from a recent study that the sighting tube provides unbiased estimates of true canopy cover, while the densiometer does not (Robards et al. 2000). The procedure for estimating canopy was as follows:

[11] In 1996, the spherical densiometer was used as suggested by Lemmon (1956). The Strickler (1959) modification, which requires counting only 17 grid intersections, was used in 1997 and 1998 to reduce bias.

- Estimate the length of the WLPZ segment to be evaluated to the nearest 100 feet (maximum length was 1000 feet and minimum length was 500 feet). A 200 foot segment was randomly selected from the number of feet in this estimate.

- Canopy was estimated at 44 to 56 systematically located points throughout the 200 foot transect, where the number of points was based on the WLPZ width at the site. Sighting tube lines were run by “zig-zagging” back and forth across the WLPZ (i.e., up and down the hillslope) (see Figure 8).

- A random starting point for the first canopy point was used to reduce sampling bias.

- After leveling the sighting tube in both horizontal and vertical directions, a “hit” or a “miss” was recorded for that point depending on whether the small dot in the center of viewing area appeared to be touching or not touching some form of vegetation.

- The percent canopy for the transect was determined by the total number of “hits” for the transect divided by the total number possible (44 to 56).

The general procedure for recording watercourse protection zone transect data and the use of codes was similar in format to the methods used for roads and skid trails, but with features that were specific to watercourse protection zone conditions and Rule requirements. As with roads, the starting and ending distance to each feature was recorded along with a unique identification number and information about feature type, erosion causes, dimensions of erosion features, and sediment deposition. Additionally, a feature date code was included for all erosion features and other features related to Rule requirements to indicate if the feature was created by the current THP or NTMP project (see footnote number 10).

Groundcover was estimated in an area with a diameter of approximately one foot located directly in front of the observer’s boot toe, where adequate cover was defined as "living plants, stumps, slash, litter, humus, and surface gravel (minimum diameter of 3/4 inch) in amounts sufficient to break the impact of raindrops and serve as a filter media for overland flow.”

Features did not need to intersect the transect line to be included. This was necessary because dense vegetation and other obstructions in watercourse protection zones make following a straight line transect impractical, so the location of the transect line will be biased by access within the zone and some extensive watercourse protection zone features might not intersect the transect. An example of this situation would be a road running parallel to, but not on, the transect.

The Class I and II WLPZ measurements began at one end of the mid-zone transect and included a continuous record of the beginning and end points of features encountered along the transect for a distance perpendicular to the end of the mid-zone transect and proceeded in the opposite direction toward the starting point of the mid-zone transect.

Figure 5. Concave spherical densiometer used for canopy measurements from 1996 to 1998 (the Strickler (1959) modification was utilized in 1997 and 1998 to reduce bias).

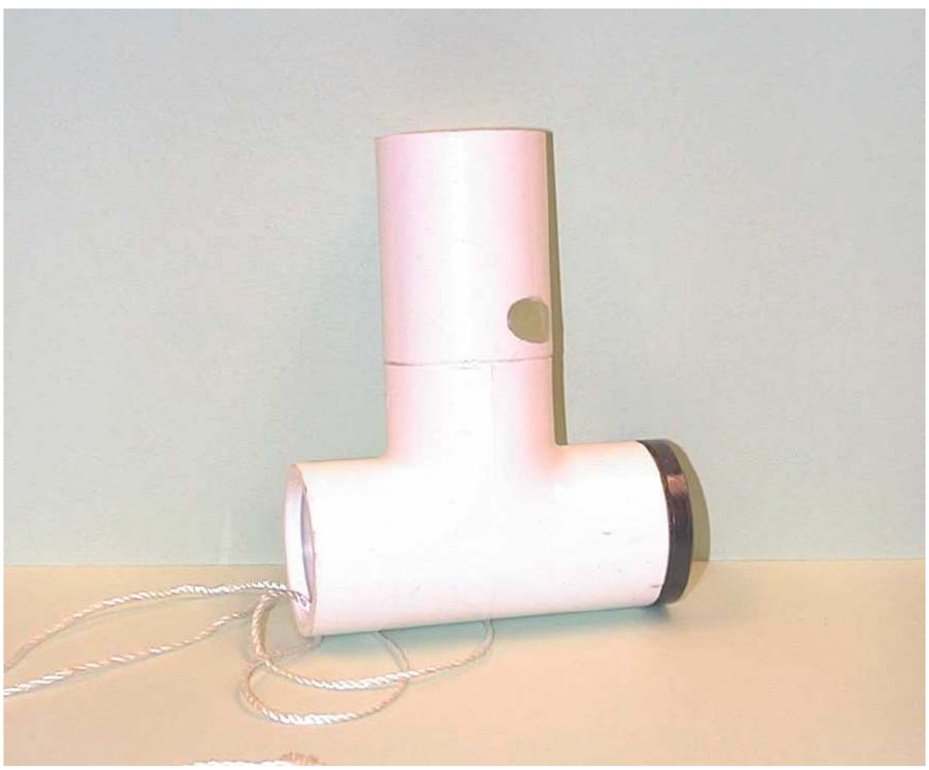

Figure 6. Close-up view of the sighting tube.

Figure 7. The sighting tube in use in the field. This instrument was utilized for obtaining an unbiased estimate of canopy cover from 1999 through 2001.

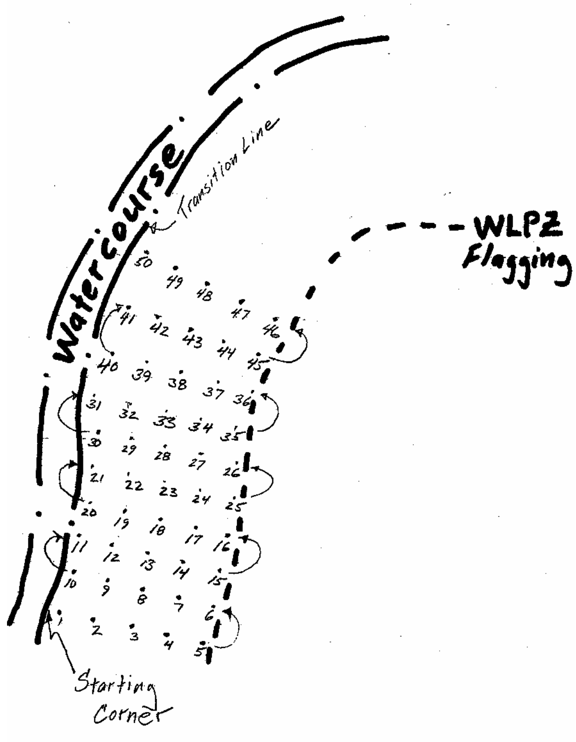

Figure 8. Example of the systematic grid used for a 125-foot WLPZ to determine canopy cover with a sighting tube for a randomly selected 200 foot reach of Class I or II watercourse (total number of sighting tube points varied from 44 to 56 depending on WLPZ width). Diagram drawn by Mr. Clay Brandow, CDF, Sacramento.

For Class III watercourses, ground cover was evaluated every 100 feet, including end points, and at the mid-points of disturbed sites. ELZ, EEZ, or WLPZ widths were determined every 100 feet, including end points. Erosion features were recorded and sediment delivery to channels was documented where it occurred. Canopy was not measured, but where canopy was retained, it was noted with the appropriate code.

LARGE EROSION EVENT EVALUATION METHODS

Erosion events that created voids larger than 100 cubic yards were assessed whenever they were encountered on the THP on NTMP project. For watercourse crossings that had failed, a large erosion event was defined as greater than 10 cubic yards. These sites were identified during the standard site evaluations, while traveling within the THP, or as a result of information provided in the THP or by landowners or managers. Data collected included the location, size, and type of feature; site conditions; and an evaluation of the causal connections between the feature and specific timber operations, along with any applicable Forest Practice Rules. Features were classified as gullies, shallow debris slides, debris torrents, deep seated rotational failures, streambank failures, or catastrophic crossing failures. This process was modified significantly in 1997 based on information provided by the Hillslope Monitoring Program contractors who completed the field work in Mendocino and Humboldt Counties during 1996.

If more than five large erosion events were discovered on a THP or NTMP, only the first five were required to be completely evaluated by the field team. For additional events, only the location, type, and estimate of the cause were briefly noted.

NON-STANDARD PRACTICES AND ADDITIONAL MITIGATION MEASURE METHODS

In addition to completing the site information, implementation, and effectiveness sections of the field forms, the field teams also filled out a form for non-standard practices and additional mitigation measures, for each of the five subject areas.[12] Non-standard practices include in-lieu and alternative practices. These site specific practices and/or additional mitigation measures often did not apply at the randomly selected transects and features, so the totals reported are a relatively small sample that does not include all of the types of practices that were included in the THPs and NTMP projects.

For each of the five evaluation areas (roads, skid trails, landings, watercourse crossings, and watercourse protection zones), four questions were asked:

1. Was an alternative, non-standard, or in-lieu practice approved on the THP or NTMP NTO?

[12] Non-standard practices, alternatives, in-lieu, and exception practices are defined in the Glossary.

2. Were additional mitigation measures beyond the standard Rules included in the approved THP or NTMP NTO?

3. Where present on the sample transect or feature, have the alternative measures been implemented as described in the THP or NTMP NTO?

4. Provide comments on the implementation and effectiveness of the alternative practices.

The field team provided brief qualitative answers to these questions where they were applicable to the randomly located sites being evaluated.

TOTAL SAMPLE SIZE FOR THE PERIOD FROM 1996 TO 2001

If qualifying features had been found for all the THPs and NTMP projects sampled (and all the plans had been tractor yarded), the total sample size would have equaled the "maximum possible" number illustrated in Table 4. The actual sample size, however, is lower (as shown in Table 4) because numerous smaller plans did not have two of each feature to sample and many of the plans were entirely yarded with aerial systems (i.e., cable or cable/helicopter).

Table 4. Potential and actual sample sizes for the Hillslope Monitoring Program from 1996 through 2001.

	Road Segments	**Skid Trail Segments**	**Landings**	**Watercourse Crossings**	**Class I and II WLPZs[13]**	**Class III ELZs, EEZs, WLPZs**
Maximum Possible	600	600	600	600	600	200
Actual Number Sampled	568	480	569	491	501	182

[13] This column includes three Class IV watercourses.

Results

The results of the Hillslope Monitoring Program reported here are organized using the following major categories: roads, skid trails, landings, watercourse crossings, watercourse protection zones, large erosion events, and non-standard practices/additional mitigation measures. The results are generally displayed in a manner similar to that used in the earlier interim Hillslope Monitoring Program Report (CSBOF 1999).

Roads

From 1996 through 2001, 568 randomly located road transects were evaluated, covering a total of approximately 550,200 feet or 104.2 miles. Over 80 percent of the road transects were classified as seasonal roads (Table 5). About 23.4 percent of the road length surveyed had been surfaced with rock. Approximately 81 percent of the road transects monitored were existing roads built prior to the current plan; 19 percent of the transects were classified as new roads.

As part of the road transects, the field team rated the implementation and effectiveness of applicable Forest Practice Rules as they were encountered and as part of an overall evaluation following completion of the transect. In the overall evaluation of road transects, a total of 59 questions were answered in the field based on 46 Forest Practice Rule sections, since some FPRs were broken down into separate components. The majority of the Rules had high percentages (i.e., greater than 90 percent) of cases where implementation ratings either met or exceeded the standard Rule requirements. When considering all the Forest Practice Rules related to roads, the implementation rate where the Rules were met or exceeded was **93.2** percent. For the Forest Practice Rules where the sample size was adequate[14], 23 Rule requirements were found to have combined minor and major departures greater than five percent (Table 6).

Table 5. Percentages of road segment type.

Road Segment Type	Percent
Permanent	10
Seasonal	84
Temporary	4
Combination	2

[14] The results reported here are based on at least **30** observations where the field team assigned an implementation rating of exceeded rule requirement, met requirement, minor departure from requirement, or major departure from requirement. Thirty observations represents five percent or more of the implementation ratings available for each major category (i.e., roads, skid trails, landings, watercourse crossings, and watercourse protection zones).

Table 6. Road related Forest Practice Rule requirements with more than five percent departures based on at least 30 observations from the overall transect evaluation where implementation could be rated (note that some Rule sections are divided into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
923.4(c)	waterbreaks maintained to minimize erosion	458	24.2	22.1	2.2
914.6(f)	where waterbreaks do not work—other erosion controls installed	214	19.2	15.0	4.2
923.1(f)	adequate numbers of drainage structures to minimize erosion	567	18.3	13.6	4.8
923.2(h)	size, number, and location of structures sufficient to carry runoff water	564	17.6	12.2	5.3
914.6(c)	waterbreak spacing according to standards in 914.6(c)	452	17.5	14.8	2.7
914.6(g)	waterbreaks have embankment of at least 6 inches	438	17.4	14.6	2.7
923.1(a)	landings on roads greater than ¼ acre or requiring substantial excavation must be shown on the THP map	243	15.2	3.7	11.5
923.2(h)	size, number, and location of structures sufficient to minimize erosion	565	15.2	11.2	4.1
914.6(g)	waterbreaks cut to depths of at least 6 inches	443	15.1	12.6	2.5
923.2(b)	sidecast minimized for slopes greater than 65% and distances greater than 100 feet	66	13.6	13.6	0.0
923.2(o)	discharge onto erodible fill prevented	510	13.1	9.2	3.9
923.2(d) Coast District	fills constructed with insloping approaches, berms, rock armoring, etc.	192	13.0	8.3	4.7
923.2(m)	sidecast extending greater than 20 feet treated to avoid erosion	202	11.9	4.5	7.4
914.6(f)	waterbreaks built to discharge into cover	464	11.4	9.3	2.2
923.2(d) Northern/ Southern	breaks in grade for drainage are located above and below through-fill, or other measures provided to protect the fill	222	11.3	8.6	2.7
923.6	wet spots rocked or otherwise treated	318	10.4	9.7	0.6
923.2(l)	trash racks, etc. installed where appropriate	173	9.2	6.4	2.9
923.2(p)	waterbars installed according to 914.6	401	8.7	6.5	2.2
923.4(j)	drainage ditches maintained to allow flow of water	306	8.5	8.2	0.3
923.1(d)	slopes greater than 65%, 50% within 100 feet of WLPZ--treat soil	93	7.5	5.4	2.2
923.4(c)	erosion controls maintained during the maintenance period	177	5.6	4.5	1.1
923.1(g) (3)	insloped roads-adequate number of ditch drains installed	237	5.5	4.6	0.8
923.4(e)	roadside berms removed or breached	513	5.5	5.3	0.2

The Rules with the highest percentages of total departures were related to waterbreak maintenance; use of other erosion control measures when waterbreaks are not effective; use of adequate numbers of drainage structures to minimize erosion; sufficient size, number, and location of drainage structures to carry runoff water; and waterbreak spacing. All the Rules evaluated had major departure percentages of less than five percent except for three: 1) if the landing on road was greater than ¼ acre or had substantial excavation, it must be shown on THP map; 2) sidecast extending greater than 20 feet must be treated to avoid erosion, and 3) the size, number, and location of drainage structures must be sufficient to carry runoff water.

A total of 1,132 erosion features were noted on the road transects. These features included rilling, gullying, mass failures, cutbank/sidecast sloughing, and other erosion types. Gullies were defined as erosion channels deeper than six inches, while rills were defined as small surface erosion channels that: 1) were greater than two inches deep at the upslope end when found singly or greater than one inch deep where there were two or more, and 2) were longer than 20 feet if located on a road surface or of any length when located on a cut bank, fill slope, cross drain ditch, or cross drain outlet. Mass failures were defined as downslope movement of soil and subsurface material that occurs when its internal strength is exceeded by the combination of gravitational and other forces. Mass erosion processes include slow moving, deep-seated earthflows and rotational failures and rapid, shallow failures on hillslopes (debris slides) and in downstream channels (debris torrents). Sloughing was defined as shallow, surficial sliding associated with either the cutbank or fill material along a forest road or skid trail, with smaller dimensions than would be associated with mass failures.

The distribution of erosion features is displayed in Table 7. Total erosion volumes from cutbank/sidecast sloughing, mass failure, and gullying is estimated to be roughly 3,600; 76,200; and 2,500 cubic yards, respectively.[15] This equates to approximately 790 cubic yards per mile.[16] Of the mass failures, one feature (450 feet x 270 feet x 15 feet) accounted for 88.6 percent of the total mass failure volume.[17] Without including this large feature, the average erosion volume is reduced to 142 cubic yards per mile. These estimates are based on the volumes of voids remaining at the hillslope locations, not the amount of sediment delivered to watercourse channels. Table 7 also shows the

[15] Note that rilling volumes were not determined. Erosion from rilling is generally a much smaller component of total hillslope erosion when compared to that from mass wasting and gullying. For example, Rice et al. (1979) found that rilling accounted for only three percent of the total hillslope erosion following tractor logging in the South Fork Caspar Creek watershed. Rice and Datzman (1981) reported rill erosion to be eight percent of the total erosion measured in northwestern California.

[16] Measuring only erosion voids of 13 cubic yards or more, Rice and Lewis (1991) reported that the average road erosion rate measured in the Critical Sites Erosion Study was 524 cubic yards/mile for their North Coast analysis unit (rain-dominated portions of the North Coast with redwood and Douglas-fir).

[17] This mass wasting feature was classified as a deep seated rotational failure on 70 percent slopes and located in the Northern Forest Practice District. Management related factors included waterbar discharge onto erodible material and subsurface water concentration.

number of erosion features recorded in the first three year period (1996 through 1998) and the second three year period (1999 through 2001). For all types of erosion features, the numbers are lower for the 1999 through 2001 period. Possible reasons for this difference are presented in the Discussion and Conclusions section of this report.

Table 8 shows the percentage of road transects with one or more erosion features of a given erosion type. Almost half the road transects had at least one rill, roughly a quarter of the transects had one or more gullies, and about four percent had at least one mass failure.

When an erosion problem feature or other type of problem (such as inadequate waterbar construction, tension cracks in the road surface, etc.) was discovered, implementation of the applicable Forest Practice Rule(s) was also rated for that problem point. A total of 40 Rule requirements were rated for implementation at problem sites along the road transects. Of these, 21 Rules were associated with approximately 95 percent of the problem points (Table 9). The most commonly cited Rules were: 1) sufficient size, number, and location of drainage structures to carry runoff water, 2) adequate numbers of drainage structures to minimize erosion, and 3) sufficient size, number, location of drainage structures to minimize erosion. As was reported in the interim Hillslope Monitoring Program report (CSBOF 1999), the vast majority of problem

Table 7. Road transect erosion features related to the current THP or NTMP project.

Erosion Feature	Number of Features 1996-1998	Number of Features 1999-2001	Total Number of Features 1996-2001
Cutbank/sidecast Sloughing	80	48	128
Mass Failure	18	12	30
Gullying	148	120	268
Rilling	478	225	703
Other Erosion Features	3	0	3
Totals	727	405	1,132

Table 8. Percent of road transects with one or more erosion features associated with the current plan for selected types of erosion features.

Erosion Feature	Percent of Transects with One or More Features
Sloughing	12.2
Mass Failures	3.9
Gullying	25.5
Rilling	48.9

points recorded along the road transects were judged to be due to either minor or major departures from specific Rule requirements. When considering all the implementation ratings assigned at problem points, only about two percent were associated with situations where the Rule requirements were judged to have been met or exceeded and 98 percent were associated with departures from Rule requirements.

Table 9. Problem point implementation ratings that account for approximately 95 percent of all the Forest Practice Rule requirements rated along road transects.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
923.2(h)	size, number, and location of structures sufficient to carry runoff water	452	0.2	80.8	19.0
923.1(f)	adequate numbers of drainage structures to minimize erosion	438	2.7	78.8	18.5
923.2(h)	size, number, and location of structures sufficient to minimize erosion	401	4.7	78.3	17.0
914.6(f)	waterbreaks built to discharge into cover	236	0.0	87.3	12.7
914.6(c)	waterbreak spacing according to standards in 914.6(c)	234	5.1	78.6	16.2
923.2(o)	discharge onto erodible fill prevented	217	0.0	85.7	14.3
914.6(g)	waterbreaks have embankment of at least 6 inches	186	0.0	86.6	13.4
923.4(c)	waterbreaks maintained to minimize erosion	186	0.0	75.3	24.7
914.6(g)	waterbreaks cut to depths of at least 6 inches	166	0.0	84.3	15.7
923.2(p)	waterbars installed according to 914.6	89	6.7	74.2	19.1
914.6(f)	where waterbreaks do not work--other erosion controls installed	67	0.0	73.1	26.9
923.4(l)	soil stabilization on cuts, fills, sidecast	59	1.7	83.1	15.3
923.4(m)	inlet/outlet structures/additional structures have been maintained	38	0.0	84.2	15.8
923.2(m)	sidecast extending greater than 20 feet treated to avoid erosion	31	0.0	22.6	77.4
923.4(j)	drainage ditches maintained to allow flow of water	28	10.7	85.7	3.6
914.6(f)	waterbreaks built to provide unrestricted discharge	26	0.0	80.8	19.2
923(d)	road located to avoid unstable areas	24	0.0	87.5	12.5
923.4(c)	erosion controls maintained during maintenance period	20	0.0	70.0	30.0
914.6(f)	waterbreaks built to spread water to minimize erosion	19	0.0	68.4	31.6
923.2(g)	excess material stabilized so as to avoid impact	19	0.0	36.8	63.2
923.2(k)	road constructed without overhanging banks	19	0.0	100.0	0.0

The results displayed in Table 9 may be biased by the design of the program. Lewis and Baldwin (1997) suggested in their statistical review of this project that implementation should be rated immediately following the completion of logging and prior to stressing storm events to provide an unbiased assessment of whether a practice was implemented correctly. That is, it is likely that some percentage of the problem points might not have been classed as Rule departures if they had been evaluated at the end of timber operations. CDF's Modified Completion Report monitoring will provide information on implementation following harvesting that may help us address this concern. The logistics and funding of the current version of the Hillslope Monitoring Program did not allow for two site visits by the contractor.

The data collected along road transects allows us to determine the proportion of problem features versus non-problem features, particularly for road drainage structures. The counts of existing road drainage structures with and without problem points is displayed in Table 10. For the total population of waterbreaks evaluated, approximately seven percent did not conform to Rule requirements or had an associated erosion feature. Rolling dips and culverted cross drains had deficiencies about five percent of the time. Note that multiple types of Rule requirement violations are possible at each drainage structure with a problem. Therefore the number of drainage structures with problems will be less than the counts for major and minor Rule departures. Additionally, the number of structures with problems is lower than the counts for Rule departures since Rule implementation was rated whenever there was an erosion feature present, regardless of whether or not it was associated with a specific drainage structure.

Table 10. Counts of drainage structures evaluated along road transects with and without problem points.

Drainage Structure Type	Total Number	Number with No Problems	Number with Problems	Percent with Problems
Waterbreaks	1,879	1,756	123	6.5
Rolling Dips	605	578	27	4.5
Leadoff Ditch	315	309	6	1.9
Culvert Cross Drain	306	291	15	4.9
Other Drainage Structure	39	38	1	2.6
Totals	3,144	2,972	172	5.5

The source, cause, and depositional area associated with the recorded erosion features were also documented during the evaluations of the road transects. The different erosion types and their dominant source areas are displayed in Table 11. Cutbank and sidecast sloughing features were primarily associated with road cut slopes, with a smaller component coming from fill slopes. Mass failures were mostly associated with fill slopes below roads. Gullying had many source areas, but was most commonly

Table 11. Number of source location codes and the number delivering sediment to the high or low flow channel for the recorded erosion features associated with the current THP or NTMP NTO on road transects.

Source Area	Sloughing		Mass Failure		Gullying		Rilling	
	#[1]	# with delivery[2]	#[1]	# with delivery[2]	#[1]	# with delivery[2]	#[1]	# with delivery[2]
Cut Slope	68	1	6	0	4	1	5	2
Fill Slope	17	5	15	9	54	18	30	5
Hillslope Above Road	4	0	6	2	7	3	10	1
Hillslope Below Road	1	0	0	0	0	0	0	0
Road Surface	1	0	2	1	45	18	542	66
Waterbar Ditch	0	0	0	0	7	1	5	3
Waterbar Outlet	1	0	0	0	96	12	61	6
Inside Ditch	0	0	0	0	20	4	15	3
Rolling Dip Ditch	0	0	0	0	3	3	5	1
Rolling Dip Outlet	0	0	0	0	26	4	7	0
Other Erosion Source	0	0	0	0	5	2	6	0
Totals	**92**	**6**	**29**	**12**	**267**	**66**	**686**	**87**

[1]Totals in Table 11 differ from Table 7 because of missing source code data.
[2]Corrected for missing data.

associated with waterbar outlets, fill slopes, and the road surface. Rilling, in contrast, was almost always associated with the road surface.

The causes of the recorded erosion features are shown in Table 12. Dominant causes for cutbank and sidecast sloughing included the cutslope being too tall, unstable terrain, the cutslope being too steep, steep side slopes, and unstable fill. The most commonly cited causes of mass failures along the road transects were unstable terrain, unstable fill, and steep side slopes. Approximately 85 percent of the gullies recorded were judged to be caused by drainage feature problems. Similarly, about 70 percent of the rills documented were coded as being associated with drainage feature problems. When rills occurred with road drainage structures (i.e., waterbreaks, rolling dips, lead off ditches) located somewhere along the length of the rill, the rill ended at the drainage structure 57 percent of the time. Highly erodible surface material and steep road gradient were also frequently cited causes of rilling.

Because drainage feature problems are the major cause associated with gullying and rilling on the road transects (Table 12), additional detail for this category is shown in Table 13. For gullying, cover (drainage structure did not discharge into vegetation, duff, slash, rocks, etc.) and spacing of drainage features (too far apart) were the most frequently cited problems. Inappropriate spacing of drainage structures was cited approximately 60 percent of the time for drainage feature problems associated with rilling. Also commonly recorded were inappropriate location to capture surface runoff and inadequate cover. Mass failures were usually not associated with drainage feature problems. When they were, inadequate cover and cross drain culvert shotgun outlets without adequate armoring at the point of discharge were the most frequent codes cited.

Similarly, cutbank or sidecast sloughing was usually not associated with a drainage feature problem. When it was, traffic impact on drainage structure function was the most frequently recorded problem.

Table 12. Number of recorded erosion cause codes related to development of identified erosion features associated with the current THP or NTMP NTO on road transects (note that multiple cause codes can be assigned to a single erosion feature).

Erosion Cause	Sloughing		Mass Failure		Gullying		Rilling	
	Number	%	Number	%	Number	%	Number	%
Fill Slope too Long	1	1	0	0	0	0	1	0
Cut Slope too Steep	20	17	3	6	2	1	1	0
Cut Slope too Tall	35	29	5	9	0	0	2	0
Drainage Feature Problem	3	3	4	8	239	85	538	72
Highly Erosive Surface Material	8	7	3	6	16	6	99	13
Steep Side Slopes	13	11	9	17	1	0	15	2
Unstable Fill	13	11	12	23	5	2	1	0
Unstable Terrain	22	18	13	24	1	0	1	0
Rutting	0	0	0	0	3	1	27	4
Steep Road Gradient	0	0	0	0	5	2	52	7
Other Erosion Cause	4	3	4	7	8	3	13	2
Totals	119	100	53	100	280	100	750	100

Table 13. Number of drainage feature problems associated with erosion features on road transects (note that multiple drainage feature problem codes can be assigned to a single erosion feature).

Drainage Feature Problem	Sloughing		Mass Failure		Gullying		Rilling	
	Number	%	Number	%	Number	%	Number	%
Blocked Ditch	2	9	0	0	4	1	6	1
Cover	4	17	2	29	142	34	86	10
Flow	3	13	0	0	9	2	7	1
Shotgun Outlet without Armoring	1	4	2	29	2	0.5	2	0
Location Inappropriate	2	9	0	0	81	20	110	13
Spacing	2	9	0	0	129	31	480	57
Divert	0	0	0	0	12	3	42	5
Runoff Escaped	0	0	0	0	5	1	7	1
Maintenance	0	0	1	14	11	3	47	6
Plugged Inlet	0	0	1	14	2	0.5	0	0
Rolling Dip Break	0	0	0	0	3	1	4	0.5
Height	0	0	0	0	0	0	3	0.5
Traffic	5	22	1	14	3	1	34	4
Other	4	17	0	0	10	2	7	1
Totals	23	100	7	100	413	100	835	100

Whether sediment actually reached a watercourse from the erosion features found along the road transects is of critical concern to the protection of beneficial uses of water. Figure 9 shows the percentage of identified erosion features that delivered sediment to channels. Since winter documentation of fine sediment delivery to streams was not possible with this program, the percentages of sediment delivery to the high or low flow channel displayed in Figure 9 are likely to underestimate total sediment delivery. The field team attempted to document the closest approach of sediment from a given erosion feature to the watercourse it was directed toward, using field evidence remaining in the dry spring, summer, and fall months. This evidence included: 1) fine and coarse sediment deposition on the forest floor, and 2) rill or gully discharge directly into the high or low flow channel.

The sediment delivery percentages to the high flow channel are similar to those reported in the interim Hillslope Monitoring Program report, after the evaluation of 150 THPs (CSBOF 1999). In that report, it was stated that the percentage of sloughing, mass failures, gullying, and rilling features delivering sediment to the channel was 6 percent, 47 percent, 18 percent, and 13 percent, respectively. Following the evaluation of 300 projects, the percentages of sediment delivery to the high or low flow channel for sloughing, mass failures, gullying, and rilling features are 6.2 percent, 39.3 percent, 24.5 percent, and 12.6 percent, respectively (Figure 9). No sediment was transported to the channel for 93.8 percent of the sloughing features, 60.7 percent of the mass wasting features, 75.5 percent of the gullies, and 87.4 percent of the rills. Of the rills that delivered sediment to watercourses, 70.2 percent delivered to Class III watercourses. For gullies that delivered sediment, 49.2 percent input sediment to Class III watercourses. Sediment delivery data was not reported for 4.8 percent of the rilling features, 1.1 percent of the gullies, 6.7 percent of the mass failures, and 23.4 percent of the sloughing events.

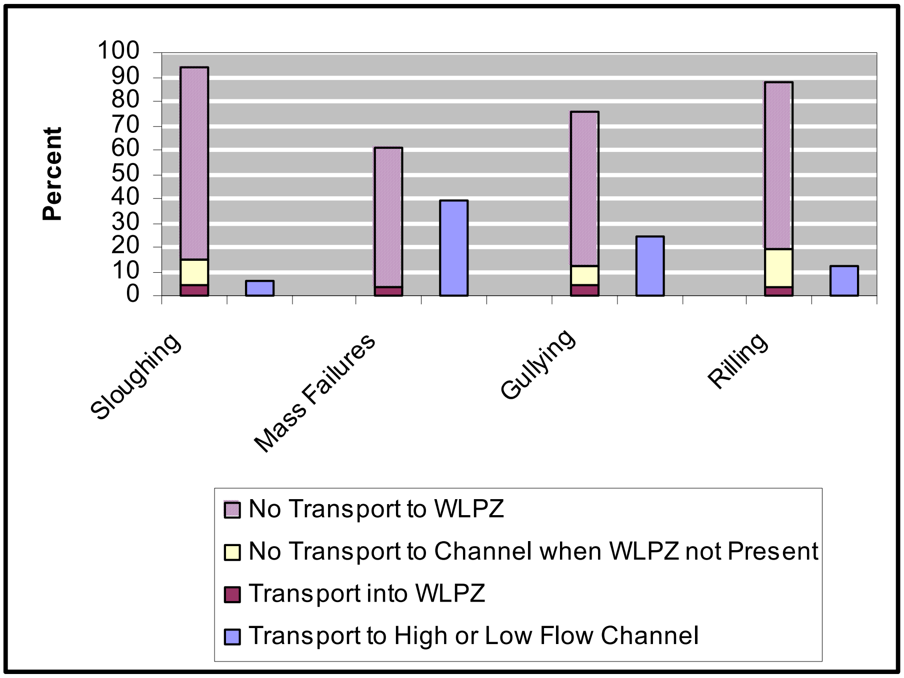

Figure 9. Percent of erosion features with dry season evidence of delivered sediment to the high or low flow channel of a watercourse from road transect erosion features related to the current THP or NTMP NTO.

Skid Trails

From 1996 through 2001, 480 randomly located skid trail transects were evaluated, covering a total of approximately 352,000 feet or 66.7 miles. The time of logging operations for approximately 90 percent of the skid trail transects was judged to be the dry season, with eight percent classified as winter operations, and two percent as either a combination of the wet and dry seasons or unknown. The silvicultural systems associated with the sampled skid trail transects were: 33% selection, 14% alternate prescription, 13% clearcut, 10% shelterwood, 9% commercial thinning, 5% transition, 4% seed tree, 2% sanitation salvage, and 2% rehabilitation, with 8% having combinations of silvicultural systems.[18] Data was not recorded on whether the skid trails were existing prior to the operation of the plan or created as part of the current project. The overall sample size (480 skid trails) is considerably lower than that for road transects because some of the THPs were entirely cable yarded. Field procedures and forms for skid trails are similar to those used for roads, so the results are presented in a similar manner.

As part of the skid trail transects, the field team rated the implementation and effectiveness of applicable Forest Practice Rules as they were encountered, and as part of an overall evaluation following completion of the 500 to 1,000 foot transects. A total of 26 questions were developed to answer in the field based on 22 Forest Practice Rule sections, since some Rules were broken down into separate components. In the overall evaluation of skid trail transects, the Rules were met or exceeded **95.1** percent of the time. For Forest Practice Rules where the sample size was adequate (i.e., 30 observations), seven Rule requirements were found to have combined minor and major departures greater than five percent (Table 14). The highest percentage of total departures from Forest Practice Rule requirements were for Rules requiring the installation of other erosion control structures where waterbreaks cannot disperse runoff, waterbreak spacing, and waterbreak maintenance. All the Forest Practice Rules evaluated had major departure percentages of less than five percent except for one: waterbreak spacing equals the standards specified in 14 CCR 914.6 (934.6, 954.6).

A total of 203 erosion features were found on the skid trail segments. The number of these features for each erosion type and observation period is shown in Table 15. Rilling accounted for more than 70 percent of the number of features. The total erosion volumes from cutbank/sidecast sloughing, mass failures, and gullying is estimated to be roughly 5, 1100, and 400 cubic yards, respectively. As was the case for the road transects, these volume estimates are based on the dimensions of voids remaining on the hillslopes, not the amount of sediment delivered to watercourse channels. Also similar to what was reported for the road transects, the number of erosion features for all types of erosion were lower in the period 1999 through 2001 than from 1996 to 1998. Possible reasons for this difference are given in the Discussion and Conclusions section of this report.

[18] Some skid trails were obliterated during site preparation activities.

The percentage of skid trail transects that had one or more erosion features of a given erosion type is shown in Table 16. Approximately 20 percent of the transects had at least one rill recorded, about seven percent had one or more gullies, and one percent had at least one mass failure.

Table 14. Skid trail related Forest Practice Rule requirements with more than 5 percent total departures based on at least 30 observations from the overall transect evaluation where implementation could be rated (note that some of the Rule sections are separated into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
914.6(f)	where waterbreaks cannot disperse runoff, other erosion controls installed as needed	158	20.3	17.7	2.5
914.6(c)	waterbreak spacing equals standards	467	19.3	13.7	5.6
923.4(c)	waterbreaks maintained to divert runoff water	444	10.6	9.9	0.7
914.6(g)	waterbreaks have embankment of 6 inches	445	7.4	6.1	1.3
914.6(e)	waterbreaks installed for natural channels	219	6.4	3.7	2.7
914.6(g)	waterbreaks cut to minimum depth of 6 inches	445	5.8	4.7	1.1
914.6(c)	waterbreaks installed at 100 foot intervals on cable roads	213	5.6	4.2	1.4

Table 15. Skid trail transect erosion features related to the current THP or NTMP project.

Erosion Feature	Number of Features 1996-1998	Number of Features 1999-2001	Total Number of Features 1996-2001
Cutbank/sidecast Sloughing	3	1	4
Mass Failure	6	1	7
Gullying	35	12	47
Rilling	104	41	145
Totals	148	55	203

Table 16. Percent of skid trail transects with one or more erosion features associated with the current plan for selected types of erosion features.

Erosion Feature	Percent of Transects with One or More Features
Sloughing	0.8
Mass Failures	1.0
Gullying	6.7
Rilling	19.2

As with the road transects, when an erosion feature or other problem was found along the skid trail transects, implementation of the applicable Forest Practice Rule(s) was rated for that problem point. A total of 12 Rule requirements were rated for implementation at skid trail problem sites. Of these, nine Rules were associated with over 95 percent of the problem points (Table 17). All but one of these problem points were related to either minor or major departures from specific Forest Practice Rule requirements. Therefore, only about 0.2 percent of problem points were associated with situations where the Rule requirements were judged to have been met or exceeded, and 99.8 percent were associated with minor or major departures from Rule requirements.

Table 17. Problem point implementation ratings that account for over 95 percent of all the Forest Practice Rule requirements rated along skid trail transects.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
914.6(c)	waterbreak spacing equal standards	106	0.0	87.7	12.3
914.6(g)	waterbreaks have embankment of 6 inches	72	0.0	95.8	4.2
923.4(c)	waterbreaks maintained to divert water	62	0.0	100.0	0.0
914.6(f)	if waterbreaks do not work, other structures stall be installed	48	0.0	91.7	8.3
914.6(g)	waterbreaks cut to minimum depth of 6 inches	48	0.0	100.0	0.0
914.6(f)	waterbreaks allow discharge into cover	42	0.0	100.0	0.0
914.6(f)	waterbreaks--unrestricted discharge	42	0.0	100.0	0.0
914.6(f)	waterbreaks spread water to minimize erosion	25	0.0	92.0	8.0
914.6(g)	waterbars placed diagonally	24	4.2	95.8	0.0

The proportion of skid trail drainage features with and without problems is shown in Table 18. Nearly all these drainage structures were waterbreaks, and approximately four percent of them did not conform to Rule requirements or had an associated erosion feature. The number of waterbreaks with specific associated problems is much lower than the total counts of Rules rated for implementation at problem points (Table 17) because: 1) multiple Rule deficiencies are possible at each drainage structure with a problem, and 2) Rule implementation was rated at each erosion feature on a skid trail transect, whether or not it was associated with a specific drainage structure.

Table 18. Counts of drainage structures evaluated along skid trail transects with and without problem points.

Drainage Structure Type	Total Number	Number with No Problems	Number with Problems	Percent with Problems
Waterbreaks	2,940	2,830	110	3.7
Rolling Dips	51	50	1	2.0
Other Drainage Structure	1	1	0	0
Totals	2,992	2,881	111	3.7

As with the road transects, the source, cause, and depositional site associated with a recorded erosion feature was documented during the evaluation of skid trail transects. Cutbank and sidecast sloughing originated entirely from cut slopes, while mass failures were mostly associated with cut and fill slopes (Table 19). Over 90 percent of rilling features and two-thirds of gullying events were associated with the skid trail surface. About 24 percent of the skid trail gullies were related to waterbreak ditches or outlets.

Table 19. Number of source location codes and the number delivering sediment to the high or low flow channel for the recorded erosion features associated with the current THP or NTMP NTO on skid trail transects.

Source Area	Sloughing		Mass Failure		Gullying		Rilling	
	#	# with delivery	#	# with delivery	#	# with delivery	#	# with delivery
Cut Slope	4	0	2	0	0	0	0	0
Fill Slope	0	0	2	0	0	0	0	0
Hillslope Above Road	0	0	0	0	2	0	1	0
Skid Trail Surface	0	0	1	0	31	5	123	5
Waterbar Ditch	0	0	0	0	4	0	3	0
Waterbar Outlet	0	0	1	0	7	1	4	0
Inside Ditch	0	0	0	0	1	1	1	0
Rolling Dip Ditch	0	0	0	0	1	0	0	0
Rolling Dip Outlet	0	0	0	0	0	0	1	0
Totals	4	**0**	6	**0**	46	**7**	133	**5**

Erosion cause codes associated with the skid trail transects are displayed in Table 20. Mass failures on skid trails were mostly related to unstable terrain and unstable fill. Drainage feature problems contributed to gullying approximately 65 percent of the time, with highly erodible surface material and steep trail gradient each being cited about 10 percent of the time. Drainage feature problems were related to rilling features about 70 percent of the time, with highly erodible surface material and steep trail gradient contributing to the cause of about 15 percent and eight percent of the rills, respectively.

A summary of drainage feature problems found on skid trails is shown in Table 21. Cutbank/sidecast sloughing and mass failures were not found to be related to drainage feature problems. Approximately half of the drainage feature problems related to skid trail gullying were attributed to inadequate spacing of drainage structures, with another 20 percent related to inappropriate locations of the drainage structures to capture surface runoff. Similarly, almost 60 percent of the drainage feature problems related to rilling were attributed to inadequate spacing, with 17 percent related to inappropriate locations of the drainage structures and 12 percent associated with the inability of the drainage structure to divert runoff fully off the trail surface.

Table 20. Number of recorded erosion cause codes related to development of identified erosion features associated with the current THP or NTMP NTO on skid trail transects (note that multiple cause codes can be assigned to a single erosion feature).

Erosion Cause	**Sloughing**		**Mass Failure**		**Gullying**		**Rilling**	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
Cut Slope too Steep	1	20	0	0	0	0	0	
Cut Slope too Tall	1	20	0	0	0	0	0	
Drainage Feature Problem	0	0	0	0	35	65	101	70
Highly Erosive Surface Material	2	40	1	8	5	9	22	15
Steep Side Slopes	1	20	2	15	2	4	2	1
Unstable Fill	0	0	3	23	3	5	1	1
Unstable Terrain	0	0	6	46	0	0	0	0
Rutting	0	0	0	0	0	0	1	1
Steep Skid Trail Gradient	0	0	0	0	5	9	12	8
Organic Matter in Fill	0	0	0	0	1	2	0	0
Other Erosion Cause	0	0	1	8	3	6	6	4
Totals	5	100	13	100	54	100	145	100

Table 21. Number of drainage feature problems associated with erosion features on skid trail transects (note that multiple drainage feature problem codes can be assigned to a single erosion feature).

Drainage Feature Problem	**Sloughing**		**Mass Failure**		**Gullying**		**Rilling**	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
Angle	0	0	0	0	0	0	2	1
Cover	0	0	0	0	7	12	5	3
Flow	0	0	0	0	2	4	0	0
Location Inappropriate	0	0	0	0	11	19	28	17
Spacing	0	0	0	0	26	46	92	56
Divert	0	0	0	0	5	9	19	12
Runoff Escaped	0	0	0	0	0	0	1	1
Maintenance	0	0	0	0	3	5	7	4
Height	0	0	0	0	0	0	1	1
Traffic	0	0	0	0	2	3	5	3
Other	0	0	0	0	1	2	4	2
Totals	0	0	0	0	57	100	164	100

The percentage of inventoried skid trail erosion features related to current operations that had dry season evidence of sediment reaching the high or low flow channel of a watercourse is shown in Figure 10. The percentages of sediment delivering features for sloughing, mass failures, gullying, and rilling features are 0, 0, 13.0, and 3.8 percent, respectively. Sediment delivery data was not reported for 8.3 percent of the rilling features, 2.1 percent of the gullies, 14.3 percent of the mass failures, and 0 percent of the sloughing events. No sediment was transported to the channel from any of the sloughing features or mass failures, 87 percent of the gullies, and 96.2 percent of the rills. For gullies that delivered sediment, 83.3 percent delivered sediment to Class III watercourses. All of the sediment delivered to channels from skid trail rills went to Class III watercourses. The proportions of erosion features delivering sediment from skid trails are considerably lower than that reported from similar types of erosion features found on the road transects (Figure 9).

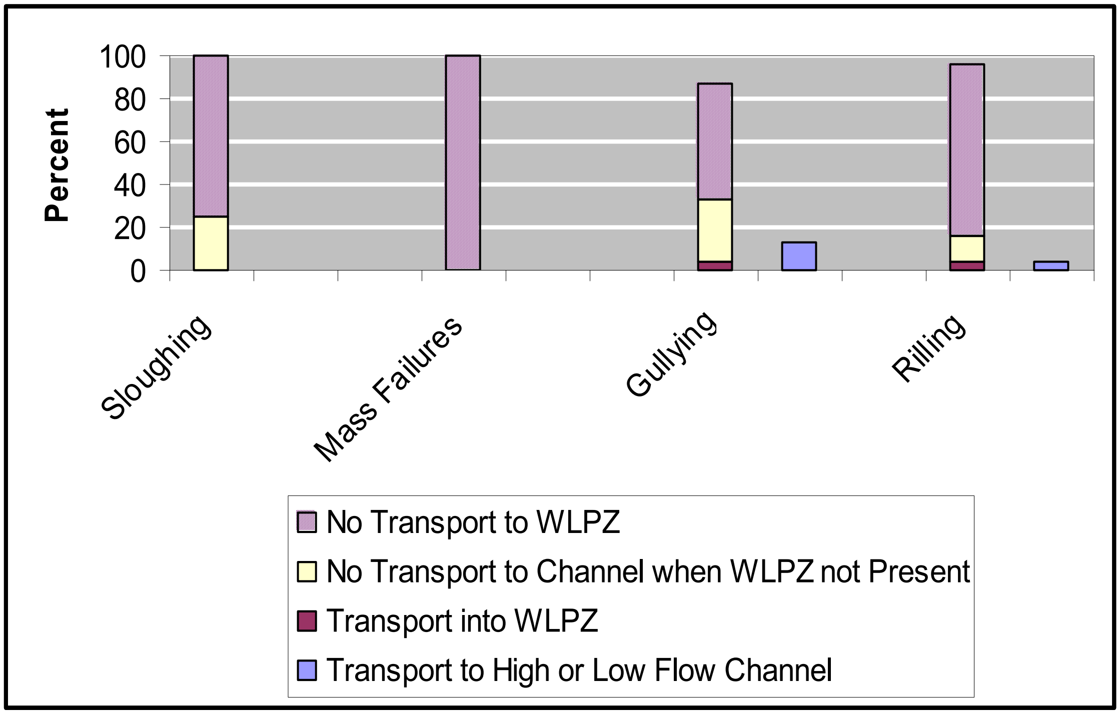

Figure 10. Percent of erosion features with dry season evidence of delivered sediment to the high or low flow channel of a watercourse from skid trail transect erosion features related to the current THP or NTMP NTO.

Landings

A total of 569 landings were evaluated from 1996 through 2001. Landing location and construction characteristics evaluated by the field team included: slope position, distance to the nearest watercourse, sideslope steepness, construction date, size, and fill dimensions. Landings were constructed on a ridge top, a "nose of a ridge", or above a break in slope about 85 percent of the time (Figure 11). Approximately 52 percent of the landings were more than 300 feet from the nearest watercourse receiving drainage off the landing, 31 percent were 100 to 300 feet away, 10 percent were from 50 to 100 feet, and seven percent were less than 50 feet from the nearest watercourse. Two percent of the landings were constructed on slopes greater than 65 percent, seven percent of the landings were on slopes from 46 to 65 percent, 35 percent of the landings were on slopes from 31 to 45 percent, and 56 percent of the landings were on slopes from 0 to 30 percent. Approximately 69 percent of the landings monitored were existing landings built prior to the current plan; 31 percent of the landings were classified as new features. About 88 percent of the landings were less than or equal to ¼ acre in size (Figure 12). Approximately 69 percent of the landings had a maximum fill thickness of 0 to five feet, 24 percent had a maximum thickness of six to 10 feet, and seven percent had a maximum thickness of greater than 10 feet.

Implementation and effectiveness of applicable Forest Practice Rules were rated both at problem points and for the whole landing for 23 separate requirements based on 20 FPR sections. Overall implementation related to landings was rated following complete inspection of the landing and its cut slope and fill slope areas. In the overall evaluation, the Rules were met or exceeded **93.5** percent of the time. For Rule requirements with at least 30 observations, four were found to have more than five percent major and minor departures (Table 22). The Rule with the highest percentage of major departures and total departures was 14 CCR 923.1(a) [943.1(a), 963.1(a)], which requires an RPF to map landings greater than ¼ acre in size or those requiring substantial excavation. A major departure from the Rule requiring treatment of fill material when it has access to a watercourse was assigned to four percent of the landings, and ten percent were judged to have either a minor or major departure from the Rule requiring adequate numbers of drainage features.

As with the road and skid trail transect evaluations, the field team rated the implementation and effectiveness of landing related Rules at specific problem points (Table 23). A total of 106 problem points were recorded under the general categories of landing surface, landing surface drainage, landing cut slopes, and landing fill slopes. About 89 percent of the landings had no problem points assigned. On the remaining 11 percent, approximately one-third of the problem points were related to rills or gullies that were formed from concentrated runoff below the outlet of a drainage structure on the surface of the landing. Problem points are fairly evenly distributed among the remaining 10 sources displayed in Table 23, but the sum of fill slope erosion problems is nearly as large the number of problems related to concentrated runoff from surface drainage structures.

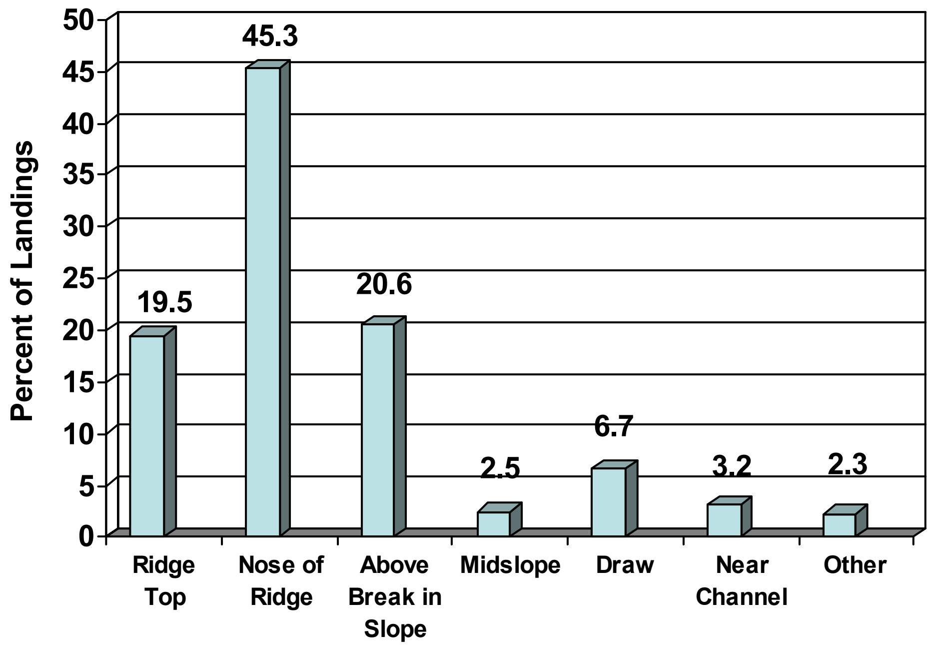

Figure 11. Distribution of landing geomorphic locations.

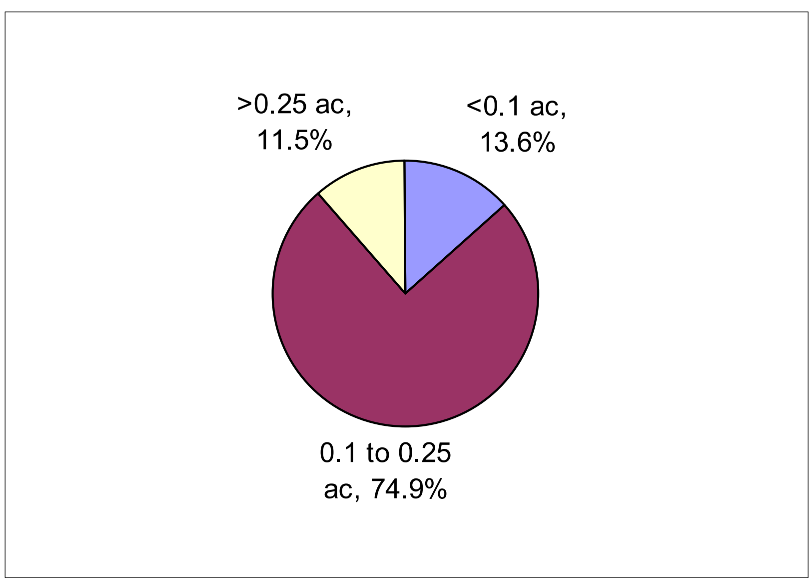

Figure 12. Landing size.

Table 22. Landing related Forest Practice Rule requirements with more than five percent total departures based on at least 30 observations from the overall evaluation where implementation could be rated (note that some of the Rule sections are separated into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
923.1(a)	landings greater than 1/4 acre or requiring substantial excavation--shown on THP map	220	17.3	6.4	10.9
923.5(f)(4)	fill extending 20 feet with access to watercourse--treated	93	11.8	7.5	4.3
923.1(f)	adequate numbers of drainage structures	549	10.0	8.0	2.0
923.6	wet spots rocked or treated	154	5.8	5.8	0.0

At each problem point, the Forest Practice Rule(s) associated with that problem was rated for implementation (Table 24). Only 14 CCR 923.1(f) [943.1(f), 963.1(f)], which requires adequate numbers of drainage structures on landings to minimize erosion on landing surfaces, sidecast, and fills, was cited frequently. All of the problem points found on landings were judged to be caused by either minor or major departures from specific Forest Practice Rule requirements.

An overall effectiveness rating for each of the potential problem types listed in Table 23 was also completed for each landing. The complete summary of the landing effectiveness questions is displayed in Table A-1 in the Appendix. About 2.5 percent of the landings monitored had significant gullying on the landing surface. Of the landings with fill slopes (approximately two/thirds of the landings evaluated), about eight percent had gullies on the fill slopes and roughly three percent had slope failures that transported more than one cubic yard of material. For the landings with cut slopes (approximately 52 percent of the landings evaluated), roughly two percent had gullies on the cut slopes and about seven percent had slope failures with more than one cubic yard of material transported.

The landing evaluation also included a determination of the final location of sediment deposition originating from landing surfaces and fill slopes (Figure 13). Erosion features from two percent of the fill slopes produced sediment that entered channels, and another four percent of the time it reached the WLPZ. Similarly, erosion features from two percent of the drainage structures on the landing surfaces produced sediment that entered watercourses, and another six percent of the time it reached the WLPZ.[19]

Table 23. Distribution of problem points recorded at landings. Note that one landing can have multiple problem points.

Landing Area	Problem Type	Problem Count
Landing Surface	Rilling	8
	Gullying	9
Landing Surface Drainage	Erosion resulting from the drainage runoff structure or ditch	34
	Sediment movement from drainage structure	9
Landing Cut Slopes	Rilling	6
	Gullying	4
	Slope failures	5
Landing Fill Slopes	Rilling	8
	Gullying	8
	Slope failures	10
	Sediment movement to nearest channel	5
Total		106

Table 24. Problem point implementation ratings that account for 95 percent of all the Forest Practice Rule requirements rated at landings.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
923.1(f)	adequate numbers of drainage structures	63	0	76.2	23.8
923.5(f)(3)	landing sloped/ditched to prevent erosion	11	0	81.8	18.2
923.5(f)(2,4)	fill extending 20 feet with access to a watercourse--treated	9	0	33.3	66.7
923(g)	minimize cut/fill on unstable areas	6	0	0.0	100.0
923.1(d)	slopes greater than 65% or 50% within 100 feet-treated	6	0	50.0	50.0
923.5(f)(1)	slopes greater than 65% or 50% within 100 feet-treat edge	4	0	25.0	75.0
923.8	abandonment-minimize concentration of runoff	3	0	100.0	0.0

[19] Note that these ratings were only applied to landings where the appropriate features were present. For example, if no fill slopes were present, landing fill slope effectiveness questions were not answered. In total, 377 landings had fill slopes and 294 had cut slopes out of the 569 landings evaluated.

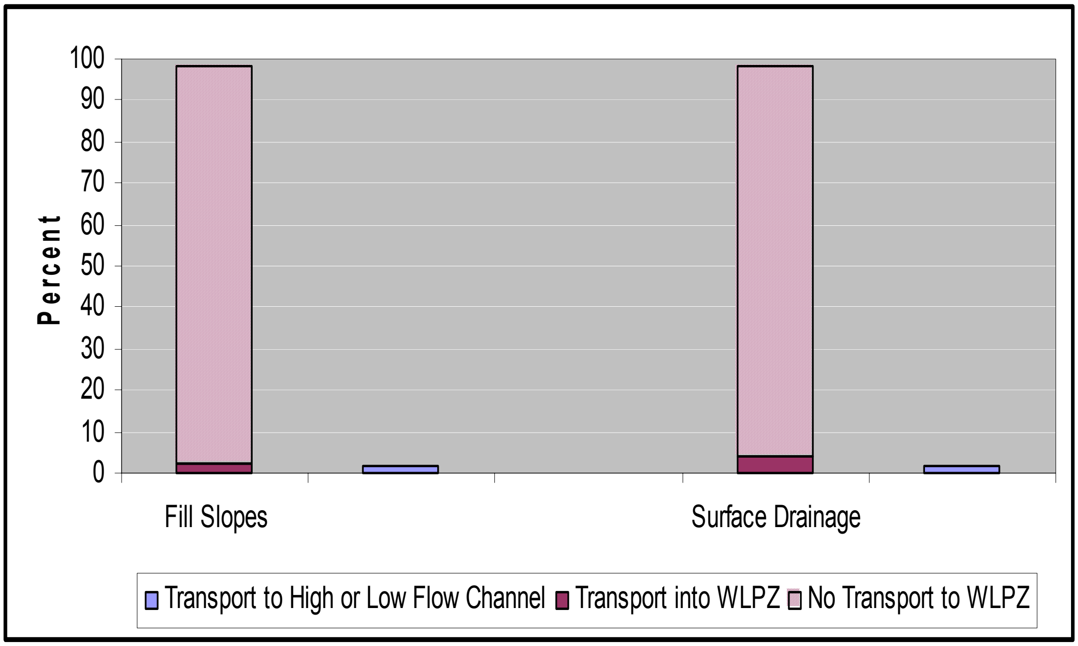

Figure 13. Percent of landing features related to the current THP or NTMP project that had dry season evidence of sediment delivered to either the WLPZ or the high/low flow channel of a watercourse.

Watercourse Crossings

A total of 491 watercourse crossings were evaluated from 1996 through 2001. Approximately 68 percent of these crossings had existing culverts (Figure 14), 12 percent were abandoned or removed road crossings, nine percent were fords, six percent were skid trail crossings, and two percent had bridges (Figure 15). The distribution of culvert sizes is displayed in Figure 16. The majority of pipe sizes are relatively small, reflecting the sampling criteria that favored choosing crossings located along road transects, which were often located above the break in slope near ridgelines. Approximately 64 percent of the crossings were existing road-related structures built prior to the beginning of the current plan; 18 percent were new road features; 12 percent were abandoned or removed crossings for roads; and six percent were removed, existing ford, or new skid trail crossings. Seventy-three percent of the crossings were associated with seasonal roads, 16 percent with permanent roads, four percent with temporary roads, six percent with skid trails, and less than one percent with abandoned roads. Forty-seven percent of the crossings were located in Class III watercourses, 46 percent in Class II drainages, six percent in Class I's, and less than one percent in Class IV watercourses.

Figure 14. Typical watercourse crossing sampled in the Hillslope Monitoring Program. This culvert was a crossing included in the sample for the 2002 field season.

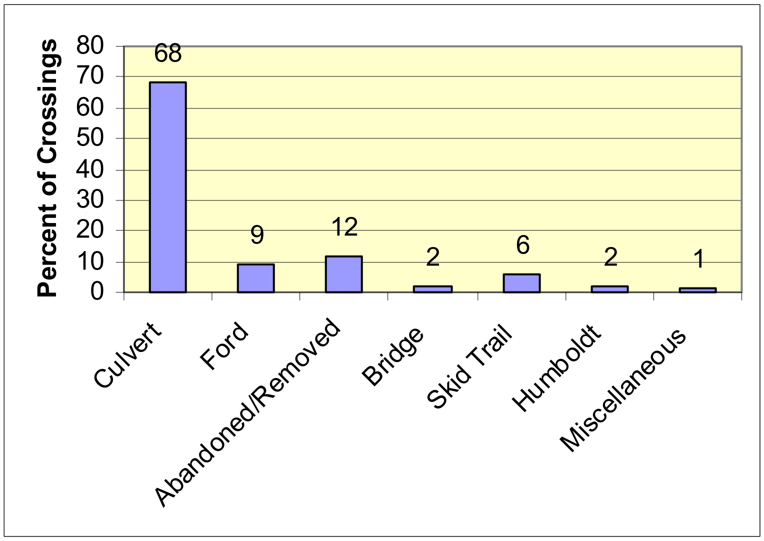

Figure 15. Distribution of watercourse crossing types evaluated from 1996 through 2001. The total number of crossings was 491.

Implementation and effectiveness of applicable Forest Practice Rules were rated both at problem points and for the whole crossing for 27 separate requirements from 24 Rule sections. Overall implementation of Rules related to watercourse crossings was rated following the complete inspection of the crossing, including the fill slope areas and the road segments draining to the crossing. In the overall evaluation, the Rules were met or exceeded **86.3** percent of the time. For Rule requirements with at least 30 observations, 21 were found to have more than five percent major and minor departures (Table 25). The Rules with the highest percentages of total departures were 14 CCR **923(o)** [943(o), 963(o)], **923.2(h)** [943.2(h), 963.2(h)], and **923.2(d)** [943.2(d), 963.2(d)], which prohibit discharge onto fill without appropriate energy dissipators; require appropriate size, numbers, and locations of structures to minimize erosion; and require fills across channels to be built to minimize erosion, respectively. Nine Rules had major departure percentages of more than five percent, which is substantially more than were found for the other hillslope areas (roads, skid trails, landings, and watercourse protection zones). Additional requirements with high levels of departures included Rules dealing with crossing diversion potential and proper crossing abandonment.

The field team rated the implementation and effectiveness of FPRs at problem points for specific components of watercourse crossings when they were encountered during the field inspection (Table 26). A total of 482 problem points were recorded under the general categories of crossing fill slopes, road surface drainage to the crossing, culverts, non-culverted crossings, removed or abandoned crossings, and road approaches at abandoned crossings. Problem points were identified on 45 percent of the crossings, indicating that deficient crossings often had more than one problem point. The most frequent problems were: culvert plugging, diversion potential, fill slope gullies, scour at the outlet of the culvert, ineffective road surface cutoff waterbreaks, and fill slope mass failures.

To determine if the high overall rate of crossing problems is coming from older crossings or continuing under current Rules, the database was queried to separate results from existing crossings, newly installed crossings, abandoned/removed road crossings, and skid trail crossings (Table 26). This revealed that the 88 new crossings had 68 total problem points, the 313 existing crossings (including culverts, fords, Humboldt crossings, and bridges) had 366 problem points, the 61 abandoned/removed road crossings had 43 problem points, and the 29 skid trail crossings had five problem points, which gives average values of 0.77, 1.17, 0.70, and 0.17 problem points per crossing for new, existing, abandoned/removed, and skid trail crossings, respectively.

A two-sample T test was used to test the difference between the means of the number of problem points for existing and new **culverted** crossings (the results are displayed in Table 27). This analysis revealed that the average of 0.77 problem points for new culvert crossings is significantly different (<0.01) than the average of 1.22 problem points at existing culverted crossings. However, problem points related to diversion potential, fill slope gullies, culvert plugging, and cut-off waterbreaks on roads draining to the crossing were still relatively common at new culvert crossings.

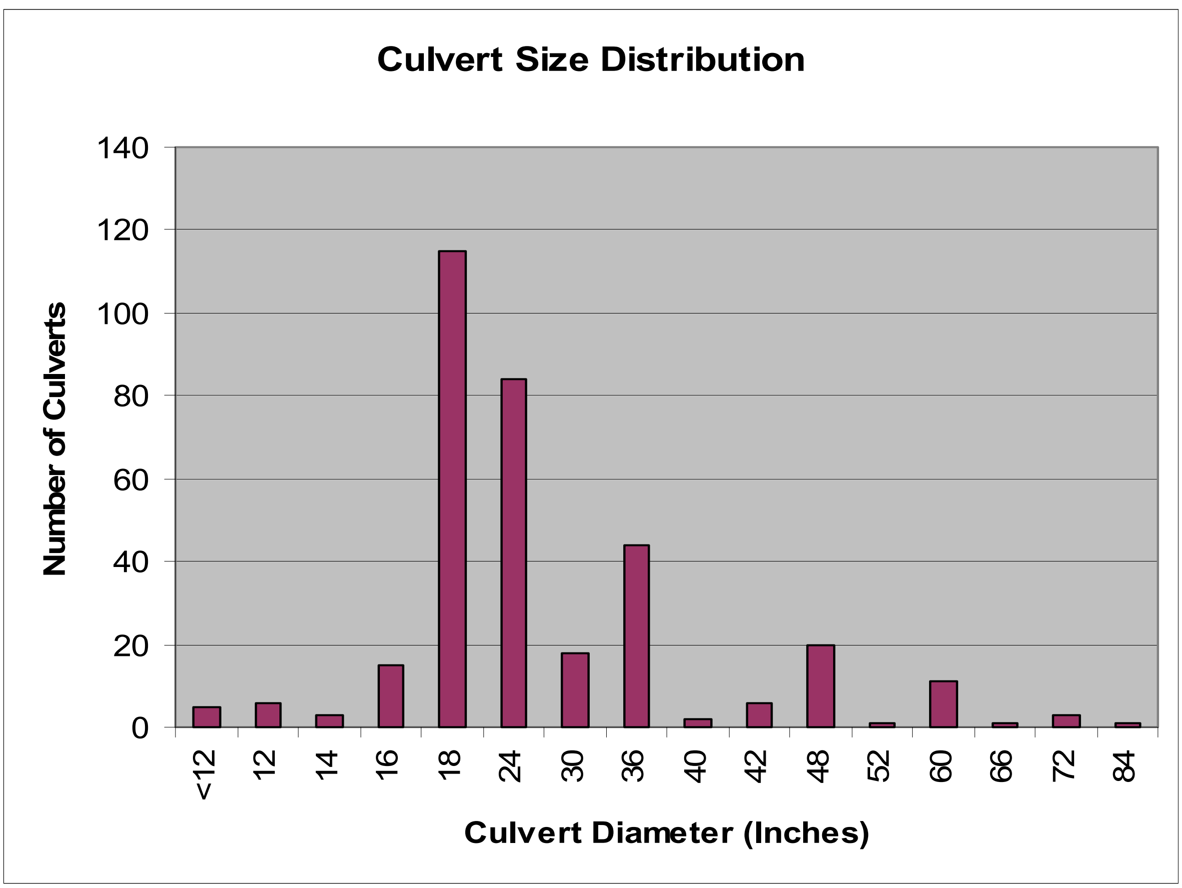

Figure 16. Culvert size distribution for watercourse crossings with pipes.

Table 25. Watercourse crossing related Forest Practice Rule requirements with more than five percent total departures based on at least 30 observations from the overall evaluation where implementation could be rated (note that some of the Rule sections are separated into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
923.2(o)	no discharge on fill unless energy dissipators present	388	23.7	11.1	12.6
923.2(h)	size, number, and location of structures minimizes erosion	394	20.6	9.4	11.2
923.2(d) Coast	fills across channels built to minimize erosion	295	19.0	9.2	9.8
923.4(n)	crossing/approaches maintained to avoid diversion	403	16.6	12.7	4.0
923.4(1)	trash racks installed where there is abundant LWD	89	15.7	13.5	2.2
923.8	abandonment—minimize concentration of runoff	65	15.4	10.8	4.6
923.(c)	waterbreaks maintained to divert into cover	339	15.3	12.1	3.2
923.3(e)	crossing/fills built to prevent diversion	398	14.6	9.0	5.5
923.4(d)	crossing open to unrestricted passage of water	480	14.2	10.2	4.0
923.4(d)	trash racks installed where needed at inlets	78	14.1	10.3	3.8
923.8(d)	abandonment--pulling/shaping of fills	61	13.1	3.3	9.8
923.8(c)	abandonment--grading of road for dispersal	63	11.1	6.3	4.8
923.3(d)(2)	removed--cut bank sloped back to stop slumping	63	11.1	4.8	6.3
923.8(b)	abandonment--stabilization of exposed cuts/fills	63	11.1	6.3	4.8
923.3(d)(1)	removed--fills excavated to reform channel	64	10.9	7.8	3.1
923.2(h)	size, number, location of structures sufficient to carry runoff	394	10.7	3.6	7.1
923.8(e)	abandonment--fills excavated to reform channel	59	10.2	5.1	5.1
923.4	trash racks in place as specified in the THP	80	10.0	10.0	0.0
923.8(e)	abandonment--cutbanks sloped back	59	6.8	0.0	6.8
923.4(f)	50-year flood flow requirement	372	5.4	3.8	1.6
923.2(e)	throughfills built in one-foot lifts	39	5.1	2.6	2.6

Table 26. Distribution of problem points recorded for existing, new, abandoned, and skid trail watercourse crossings. Note that one crossing can have multiple problem points.

Crossing Feature	Problem Type	Existing Crossings (n = 313)	New Crossings (n = 88)	Road Abandoned/ Removed (n = 61)	Skid Trail Removed/ Ford (n = 29)	Totals
Fill Slopes	Vegetative cover	11	4	1	0	16
	Rilling	24	4	0	0	28
	Gullies	35	10	1	1	47
	Cracks	5	2	0	0	7
	Slope failure	28	4	2	0	34
Road Surface Draining to Crossing	Rutting	10	1	2	0	13
	Rilling	6	2	2	1	11
	Gullies	5	1	3	0	9
	Surfacing of approaches	5	2	2	1	10
	Cut-off waterbar	29	6	2	1	38
	Inside ditch condition	11	0	0	0	11
	Ponding	7	4	0	0	11
Culverts	Scour at inlet	5	0	NA	NA	5
	Scour at outlet	35	3	NA	NA	38
	Diversion potential	38	10	NA	NA	48
	Plugging	45	9	NA	NA	54
	Alignment	2	1	NA	NA	3
	Degree of corrosion	3	0	NA	NA	3
	Crushed inlet/outlet	8	0	NA	NA	8
	Pipe length	1	0	NA	NA	1
	Gradient	26	2	NA	NA	28
	Piping	10	1	NA	NA	11

Crossing Feature	Problem Type	Existing Crossings (n = 313)	New Crossings (n = 88)	Road Abandoned/ Removed (n = 61)	Skid Trail Removed/ Ford (n = 29)	Totals
Non-Culvert Crossings	Armoring	9	1	1	0	11
	Scour at outlet	5	1	1	0	7
	Diversion	3	0	0	1	4
Removed or Abandoned	Bank stabilization	NA	NA	5	0	5
	Rilling of banks	NA	NA	1	0	1
	Gullies	NA	NA	5	0	5
	Slope failure	NA	NA	2	0	2
	Channel configuration	NA	NA	5	0	5
	Excavated material and cutbank	NA	NA	3	0	3
	Grading and shaping	NA	NA	3	0	3
Road Approaches at Abandoned Crossings	Grading and shaping of road surface	NA	NA	2	0	2
Totals		**366**	**68**	**43**	**5**	**482**

Table 27. Distribution of watercourse crossing types and average numbers of problem points assigned for each crossing type.

Crossing Type	Number of Crossings	Number of Problem Points	Average Number of Problem Points/ Crossing
Existing Culvert	251	306	1.22*
New Culvert	83	64	0.77*
Existing Ford	40	39	0.98
New Ford	4	4	1.00
Abandoned/Removed (road)	61	43	0.70
Abandoned/Removed (skid trail)	19	1	0.05
Existing Skid Trail (ford)	8	4	0.50
New Skid Trail (ford)	2	0	0
Existing Humboldt	7	17	2.43
New Humboldt	1	0	0
Existing Bridge	11	0	0
Existing Rolling Dip	2	1	0.5
Other	2	3	1.50
Totals	**491**	**482**	**0.98**

* A two-sample T test comparing the number of problem points at existing versus new culverted crossings revealed that the means of these groups are significantly different at alpha < 0.01.

As with the other hillslope monitoring area categories, when a problem point was discovered, the field team rated the implementation and effectiveness of applicable Forest Practice Rule(s) associated with that problem (Table 28). Problems at crossings were associated with poor implementation of 24 Rule requirements, with 15 being cited as responsible for 95 percent of the problem points. All of the problem points were caused by either minor or major departures from specific Rule requirements. Overall, approximately 51 percent of the implementation ratings at the crossing problem points were recorded as minor Rule departures, while 49 percent were rated as major departures.

An overall effectiveness rating for each of the potential problem types listed in Table 26 was also completed for each crossing. A complete summary of watercourse crossing effectiveness questions is displayed in Table A-2 in the Appendix. Significant scour at the outlet of culvert crossings was found 33 percent of the time, with some degree of plugging occurring 24 percent of the time. Some level of diversion potential was noted for about 27 percent of the culverted crossings. Approximately 11 percent of the fill slopes at crossings had some amount of slope failure present. The road surface drainage cutoff structure above the crossing allowed all or some of the water running down the road to reach the crossing at about 23 percent of the sample sites. For abandoned or removed crossings, approximately 82 percent had channels established close to natural grade and orientation, with about 18 percent having minor or major differences.

Sediment delivery to watercourses is assumed to be 100 percent at crossings since these structures are built directly in and adjacent to the channels. Therefore, the evaluation of sediment delivery from the various types of problems associated with crossings was not conducted.

Table 28. Problem point implementation ratings that account for 95 percent of all the Forest Practice Rule requirements rated at watercourse crossings.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
923.2(h)	size, number, and location of structures minimizes erosion	126	0	43.7	56.3
923.2(o)	no discharge on fill unless energy dissipators installed	118	0	39.8	60.2
923.4(n)	crossing/approaches maintained to avoid diversion	71	0	77.5	22.5
923.2(h)	size, number, and location of structures sufficient to carry runoff	68	0	44.1	55.9
923.2(d) Coast	fills across channels built to minimize erosion	67	0	29.9	70.1
923.3(e)	crossing/fills built to prevent diversion	58	0	51.7	48.3
923.4(d)	crossing open to unrestricted passage of water	55	0	69.1	30.9
923.4(c)	waterbreaks maintained to divert into cover	43	0	74.4	25.6
923.8	abandonment—minimizes concentration of runoff	16	0	56.3	43.8
923.2(h)	size, number, and location of structures-maintains natural drainage pattern	15	0	73.3	26.7
923.8(d)	abandonment--pulling/shaping of fills appropriate	11	0	27.3	72.7
923.3(d)(2)	removed crossings--cut bank sloped back to prevent slumping and to minimize erosion	10	0	40.0	60.0
923.8(c)	abandonment--grading of road for dispersal	9	0	55.6	44.4
923.8(b)	abandonment--stabilization of exposed cuts/fills	9	0	55.6	44.4
923.3(d)(1)	removed crossings--fills excavated to reform channel	7	0	71.4	28.6

Watercourse Protection Zones (WLPZs, ELZs, EEZs)

From 1996 through 2001, 683 randomly located watercourse and lake protection zone (WLPZ) transects, equipment limitation zone (ELZ) transects, and equipment exclusion zone (EEZ) transects were evaluated, covering a total of approximately 510,800 feet or 96.8 miles for all three categories. The distribution of transects for each watercourse class is displayed in Figure 17. Approximately 17 percent of the WLPZs were associated with Class I watercourses (21.5 miles), 56 percent with Class IIs (64.4 miles), 27 percent with Class IIIs (10.4 miles), and less than one percent with Class IV waters (0.5 miles). Class III watercourses were not sampled as part of the Hillslope Monitoring Program from 1996 through 1999, but were included in 2000 and 2001.[20] For about 36 percent of the watercourse protection zone transects, the slope distance from the channel bank to the nearest road was greater than 150 feet; 18 percent had a distance of 100 to 150 feet; 25 percent had a distance of 50 to 100 feet, and 21 percent had a distance of less than 50 feet. The type of yarding upslope from the transect was classified as tractor 69 percent of the time, cable 22 percent, cable/tractor 6 percent, helicopter 2 percent, and tractor/helicopter less than 1 percent. Roads were located in 75 WLPZs, one equipment limitation zone (ELZ), and one equipment exclusion zone (EEZ).[21]

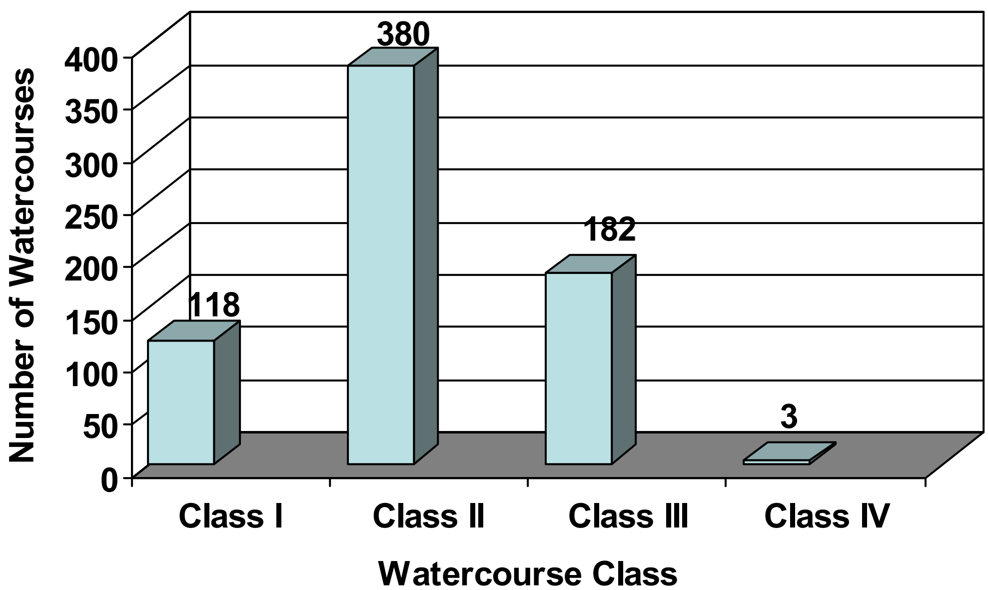

Figure 17. Distribution of watercourse classes evaluated from 1996 to 2001.

[20] Twelve Class III watercourses with WLPZs were evaluated in 1999 and 2 Class III watercourses with WLPZs were evaluated in 1997.

[21] WLPZs are not required for Class III watercourses. ELZs have been required for Class IIIs since January 1, 1998 (see 14 CCR 916.4(c)(1)). EEZs are often specified for these types of watercourses as well. ELZs allow heavy equipment in the zone only where explained in the THP and approved by the Director; EEZs are zones where heavy equipment is totally excluded.

As part of the WLPZ , ELZ, and EEZ transects, the field team rated the implementation and effectiveness of applicable Forest Practice Rules as they were encountered and as part of a subsequent overall evaluation following completion of the transect. A total of 56 questions were developed from 34 Rule sections and answered in the overall evaluation. When considering all the Forest Practice Rules related to watercourse protection zones, the implementation rate where the Rules were met or exceeded was **98.4** percent. The five Rule requirements with at least 30 observations and five percent or more major and minor departures are shown in Table 29. Three of these Rules relate to the requirement for the RPF to evaluate riparian areas for sensitive conditions, including the use of existing roads within the standard WLPZ and unstable and erodible watercourse banks. These factors are to be identified in the THP and considered when proposing WLPZ widths and protection measures. The other two Rules in Table 29 require that WLPZ widths must be at least equal to that specified in Table 1 (14 CCR 916.5 [936.5, 956.5]) in the Forest Practice Rules.

Very few erosion features associated with the current plan were found on the watercourse protection zone transects (Table 30). A total of 37 erosion features were recorded, with mass failures accounting for almost 50 percent. Most of the mass failures documented in the watercourse protection zones, however, were judged to either predate the current THP (127 features), were created after the THP but were not affected by the THP (17 features), or it was impossible to determine the feature date (17 features). The frequency of the erosion features associated with the current plan per mile of watercourse protection zone transect monitored is displayed in Table 31. Total erosion volumes for mass failures, sloughing, and gullying were approximately 2,900, 50, and 100 cubic yards, respectively. As was the case for the road and skid trail transects, these volume estimates are based on the dimensions of the voids remaining

Table 29. Watercourse protection zone (WLPZ, ELZ, and EEZ) related Forest Practice Rule requirements with more than five percent total departures based on at least 30 observations for the overall transect evaluation where implementation could be rated (note that some of the Rule sections are separated into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
916.2(a)(4)	sensitive conditions--existing roads in WLPZ—appropriate mitigation measure(s) applied	133	9.0	4.5	4.5
916.4(a)	sensitive conditions--existing roads in WLPZ—identified in the THP	132	7.6	3.8	3.8
916.4(a)	sensitive conditions--erodible banks—identified in the THP	316	6.0	5.4	0.6
916.4(b)(3)	width of WLPZ conforms to Table 1 in the FPRs	593	5.6	4.7	0.8
916.4(b)	WLPZ widths as wide as specified in Table 1 in the FPRs	597	5.5	4.5	1.0

Table 30. Watercourse protection zone (WLPZ, ELZ, EEZ) transect erosion features associated with the current THP or NTMP NTO.

Erosion Feature	Number of Features 1996-1998	Number of Features 1999-2001	Total Number of Features 1996-2001
Cutbank/sidecast Sloughing	1	3	4
Mass Failure	13	5	18
Gullying	4	2	6
Rilling	5	4	9
Totals	23	14	37

on the hillslopes, not the amount of sediment delivered to watercourse channels. Also, similarly to what was reported for the road and skid transects, the number of erosion features for the various types of erosion were generally lower in the period 1999 through 2001 than from 1996 to 1998 (Table 30). Possible reasons for this difference are provided in the Discussion and Conclusions section of this report.

The percentage of watercourse protection zone transects that had one or more erosion features associated with the current plan of a given erosion type is shown in Table 32. Approximately 1.3 percent of the transects had at least one rill recorded, about 0.7 percent had one or more gullies, 2.0 percent had at least one mass failure, and 0.6 percent had sloughing present. These percentages are much lower than were found on roads and skid trails (see Tables 8 and 16).

When an erosion feature or other problem was found along the watercourse protection zone transects, implementation of the applicable Forest Practice Rule(s) was also rated for that problem point. A total of 27 Rule requirements were rated for implementation at watercourse protection zone problem sites. Of these, 20 Rules were associated with over 95 percent of the problem points (Table 33). When considering all the ratings

Table 31. Frequency of various types of erosion features associated with the current plan for the watercourse protection zone transects monitored.

Erosion Type	Class I (# features/mile)	Class II (# features/mile)	Class III (# features/mile)
Cutbank/Sidecast Sloughing	0	0.05	0.1
Mass Failure	0.4	0.2	0.2
Gullying	0.1	0.05	0.1
Rilling	0.1	0.1	0.1
Totals	0.6	0.4	0.5

Table 32. Percent of watercourse protection zone transects (all watercourse classes combined) with one or more erosion features associated with the current plan for selected types of erosion features.

Erosion Feature	Percent of Transects with One or More Features
Sloughing	0.6
Mass Failures	2.0
Gullying	0.7
Rilling	1.3

assigned at problem points encountered, about seven percent were associated with situations where the Rule requirements were found to have been met or exceeded and roughly 93 percent of the problem points were associated with minor or major departures from Rule requirements. The most commonly cited Rules rated for implementation at problem points were: 1) an inappropriate WLPZ width, 2) trees were not felled away from the watercourse channel, and 3) heavy equipment was not excluded from the watercourse protection zone and the approved THP did not permit this activity.

Canopy cover was measured with the spherical densiometer from 1996 through 1998 (Figure 18) and the sighting tube from 1999 through 2001. Mean total canopy cover measurements are displayed in Table 34. In all cases, average post-harvest values were above 70 percent. Average canopy values were also determined for each of the three CDF Forest Practice Districts for the sighting tube data (Figure 19). Mean values were highest in the Coast Forest Practice District (approximately 80 percent for both Class I and IIs) and lower in the interior districts. Lower values inland are probably related to warmer, drier conditions and the presence of slower growing tree species. In all cases, mean total canopy levels exceeded the Forest Practice Rule requirements in place for Class II watercourses. This is likely true for Class I watercourses as well, but overstory and understory canopy were not differentiated in this project as described by the Rules.[22]

Surface (or ground) cover was evaluated at 100 foot intervals along the watercourse protection zone transects for Class I, II, and III watercourses (Table 35). In all cases, surface cover exceeded the post-harvest Rule standard of 75 percent. Surface cover was generally similar for the three different Forest Practice Districts. Southern District Class I surface cover was slightly lower than that found in the other two districts. In the Coast Forest Practice District, high precipitation and summer fog near the ocean promote an environment that is quickly covered with surface vegetation. In the drier

[22] Since pre-harvest canopy measurements were not made at the THP and NTMP project sites, it is not possible to state what the change in canopy was due to timber harvesting activities associated with the current plan.

inland districts, bare soil is common in some locations even prior to logging. For all three districts, Class II and III surface cover means were higher than that for Class I watercourses.

Table 33. Problem point implementation ratings that account for over 95 percent of all the Forest Practice Rule requirements rated along watercourse protection zone segments.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
916.4(b)(3)	width of WLPZ conforms to Table 1	43	0	62.8	37.2
916.4(b)	WLPZ widths as wide as specified in Table 1	42	0	59.5	40.5
916.3(e)	trees in WLPZ felled away from channel	25	4	60.0	36.0
916.4(d)	heavy equipment excluded from the zone unless explained and approved	13	0	46.2	53.8
916.5(e)"I"	Class II--50% of total canopy left in WLPZ	11	0	45.5	54.5
916.3(c)	roads, landings outside of WLPZs	10	0	30.0	70.0
916.5(b)	beneficial uses consistent with WLPZ classes	9	0	33.3	66.7
916.2(a)(4)	sensitive conditions--unstable banks--mitigation measure(s) applied	8	0	100.0	0.0
916.4(b)	THP provides for upslope stability	8	25	62.5	12.5
916.5(a)(3)	side slope classes used to determine WLPZ width and protective measures	7	0	71.4	28.6
916.4(b)	THP provides for protection of water temperature	7	28.6	42.9	28.6
916.2(a)(4)	sensitive conditions--existing roads in WLPZ-- mitigation measure(s) applied	6	0	16.7	83.3
916.3(g)	Class I/II--2 living conifers per acre 16 in. or greater DBH, 50 ft tall retained within 50 feet of the watercourse	6	16.7	66.7	16.7
916.4(a)	sensitive conditions--existing roads in WLPZ identified in the THP	6	0	33.3	66.7
916.4(b)	THP provides for channel stabilization	6	33.3	33.3	33.3
916.4(b)	THP provides for filtration of organic material	4	50	50.0	0.0
916.5(e)"G"	Class I--50% overstory and 50% understory retained	3	0	100.0	0.0
916.4(a)	sensitive conditions--erodible banks identified in the THP	3	0	100.0	0.0
916.4(b)(4)	WLPZ width segregated by slope class	3	0	100.0	0.0
916.4(c)(3)	Class III--soil removed or stabilized	3	0	66.7	33.3

Table 34. Mean WLPZ total canopy cover measurements.

Year/Location	Class I Canopy Cover (%)	Class II Canopy Cover (%)
1996—North Coast Spherical Densiometer	79	77
1997 to 1998—Statewide Spherical Densiometer	74	75
1999 to 2001—Statewide Sighting Tube	73	75

Figure 18. Measuring canopy cover with the spherical densiometer in western Mendocino County in 1996.

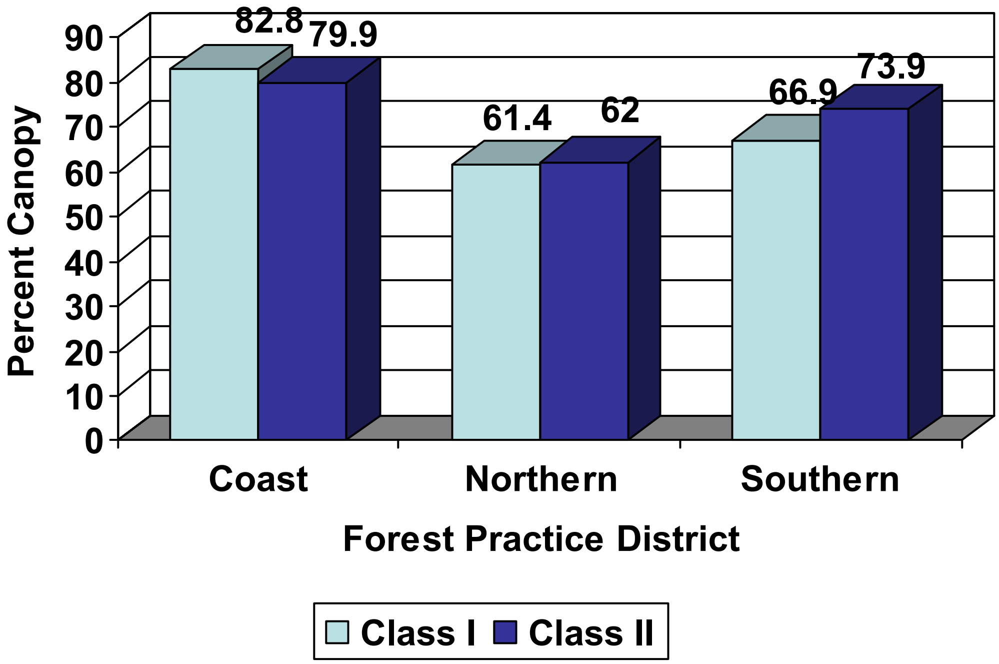

Figure 19. Total canopy cover percentages for Class I and II watercourses from 1999 through 2001 by Forest Practice District (data measured with a sighting tube).

Table 35. Mean surface cover values for the three CDF Forest Practice Districts.

CDF Forest Practice District	Class I Surface Cover (%)	Class II Surface Cover (%)	Class III Surface Cover (%)
Coast	82.5	97.1	98.3
Northern	81.9	95.3	93.0
Southern	76.2	95.4	97.6

Mean watercourse protection zone widths were estimated or measured as part of the transect effectiveness evaluation process. Mean widths for Forest Practice Rule side slope categories are shown in Table 36. It was often difficult for the field team to determine the upper extent of the WLPZ—particularly where selective silvicultural systems were used above the WLPZ. Flagging used to denote the WLPZ was often gone or difficult to locate following several overwintering periods, resulting in the estimation of WLPZ widths in some cases. It is also unknown exactly how many of the WLPZs sampled utilized the allowable reduction granted for cable yarding systems (50 foot reduction for Class I and 25 foot reduction for Class II watercoures). Thirty percent of the WLPZ transects had cable or helicopter yarding upslope of the transect (this includes areas that were listed as both cable and tractor). As reported above (Table 29), WLPZ width problems were only cited on about six percent of the transects, and major departures for the overall evaluation were only recorded for one percent of the transects.

The percentage of inventoried watercourse protection zone erosion features related to current operations that had dry season evidence of sediment reaching the high or low flow channel of a watercourse is shown in Figure 20. The percentages of sediment delivering features for sloughing, mass failures, gullying, and rilling features are 66.7, 64.3, 83.3, and 88.9 percent, respectively. No sediment was transported to the channel for 33.3 percent of the sloughing features, 35.7 percent of the mass failures, 16.7 percent of the gullies, and 11.1 percent of the rills. Of the rills that delivered sediment to watercourses, 12.5 percent delivered to Class III watercourses. For gullies that delivered sediment, 20 percent input sediment to Class III watercourses. Sediment delivery data was not reported for 0 percent of the rilling features, 0 percent of the gullies, 22.2 percent of the mass failures, and 25 percent of the sloughing events. The proportions of erosion features delivering sediment in watercourse protection zones are considerably higher than that reported from similar types of erosion features found on the road and skid trail transects (Figures 9 and 10), due to the close proximity of these features to the channel.

Table 36. Mean WLPZ width estimates.

Watercourse Class	**Side Slope Gradient Category (%)**	**Mean WLPZ Width (feet)**	**Standard Forest Practice Rule Width (feet)**
I	<30	79	75
	30 to 50	96	100
	≥50	119	150[23]
II	<30	53	50
	30 to 50	72	75
	≥50	90	100[12]

[23] 50 foot and 25 foot reductions in WLPZ width are allowed with cable yarding for Class I and II watercourses, respectively (see Table 1, 14 CCR 916.5 [936.5, 956.5]).

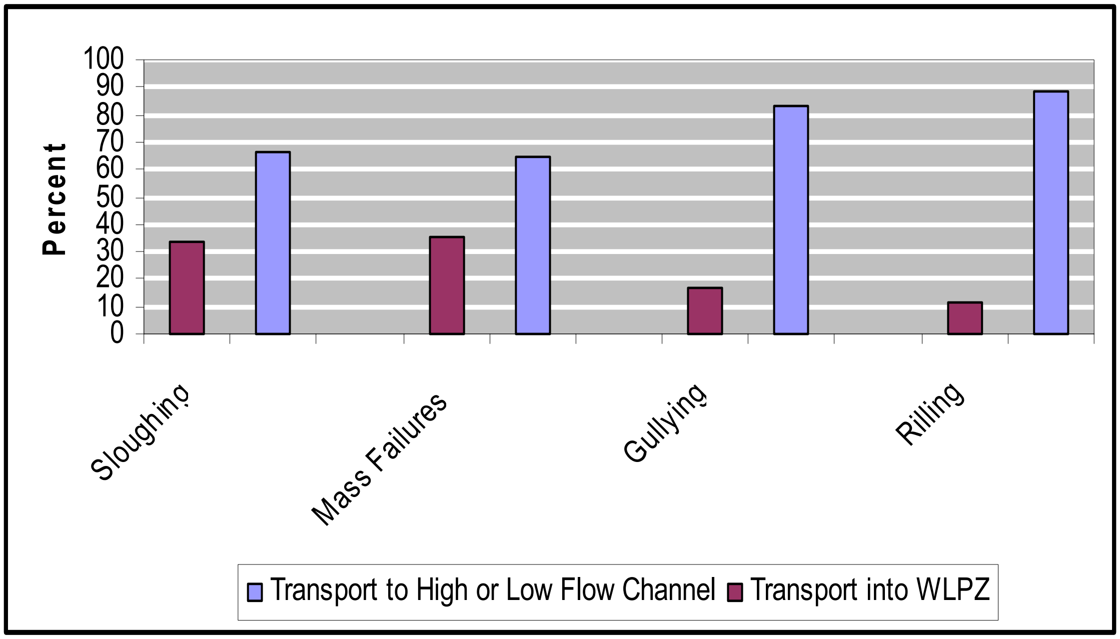

Figure 20. Percent of erosion features with dry season evidence of delivered sediment to the high or low flow channel of a watercourse from watercourse protection zone transect features associated with the current THP or NTMP project.

Large Erosion Events

While the sampling approach for roads, skid trails, landings, watercourse crossings, and watercourse protection zones utilized a very detailed evaluation for a small portion of a THP or NTMP Project, the inventory of large erosion events and associated site and management factors covered a significant portion of the THP or NTMP Project area as a whole. This more extensive approach was used in an attempt to determine the impacts of large erosion events, which may be responsible for a majority of hillslope erosion while occurring on a very limited portion of the landscape that a randomized sample approach is likely to miss. This is particularly important where mass wasting is the dominant erosional process (Rice and Lewis 1991, Lewis and Rice 1989, Lee 1997).

Erosion sites with: 1) 100 cubic yards or more on hillslopes, and 2) 10 cubic yards or more at failed watercourse crossings, were documented wherever they were found. Large erosion events were identified primarily when traveling within the THP, either by foot or in a vehicle, as part of the evaluations for randomly located road segments, skid trail segments, landings, crossings, and watercourse protection zones. Additional large erosion events were identified from THP maps. Recorded information included the size and type of erosional feature, site conditions, and specific timber operations. Where specific Forest Practice Rules could be connected to a feature, they were recorded as well. These types of evaluations were completed only for the statewide hillslope monitoring work (1997 through 2001).[24]

In-unit mass wasting was not included in this inventory because surveys of logging unit(s) were not required in the other components of the Hillslope Monitoring Program. Therefore, the impacts of the Forest Practice Rules on in-unit mass wasting, other than those large erosion events primarily triggered by the roads, skid trails, watercourse crossings, and landings evaluated within the plan, were largely undetermined (Stillwater Sciences 2002).[25]

A total of 50 large erosion events were located on the 250 THPs and NTMP projects included in this portion of the Hillslope Monitoring Program. These events were found on 37 THPs, or 15 percent, with nine plans having multiple features. Of the 50 total

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[24] The 1996 large erosion event monitoring in Humboldt and Mendocino Counties was considered a pilot project to further refine how the data would be collected. The initial procedure used in 1996 is described in Tuttle (1995). The process was modified significantly based on information provided by the Hillslope Monitoring Program contractors who completed the field work in Mendocino and Humboldt Counties during 1996.

[25] Additional information on this subject can be found for Humboldt County watersheds in PWA (1998a, 1998b) and Marshall (2002), Mendocino County in Cafferata and Spittler (1998), and Northern California in general as part of the Critical Sites Erosion Study (Durgin et al. 1989, Lewis and Rice 1989, Rice and Lewis 1991). Also, the California Geological Survey has preliminary data on frequency of mass wasting events in clearcut units and adjacent uncut units in Jackson Demonstration State Forest, located near Fort Bragg, California (contact Mr. Thomas Spittler, CGS, Santa Rosa, CA). Information on mass wasting related to forestry operations in Oregon is available in Robison et al. (1999).

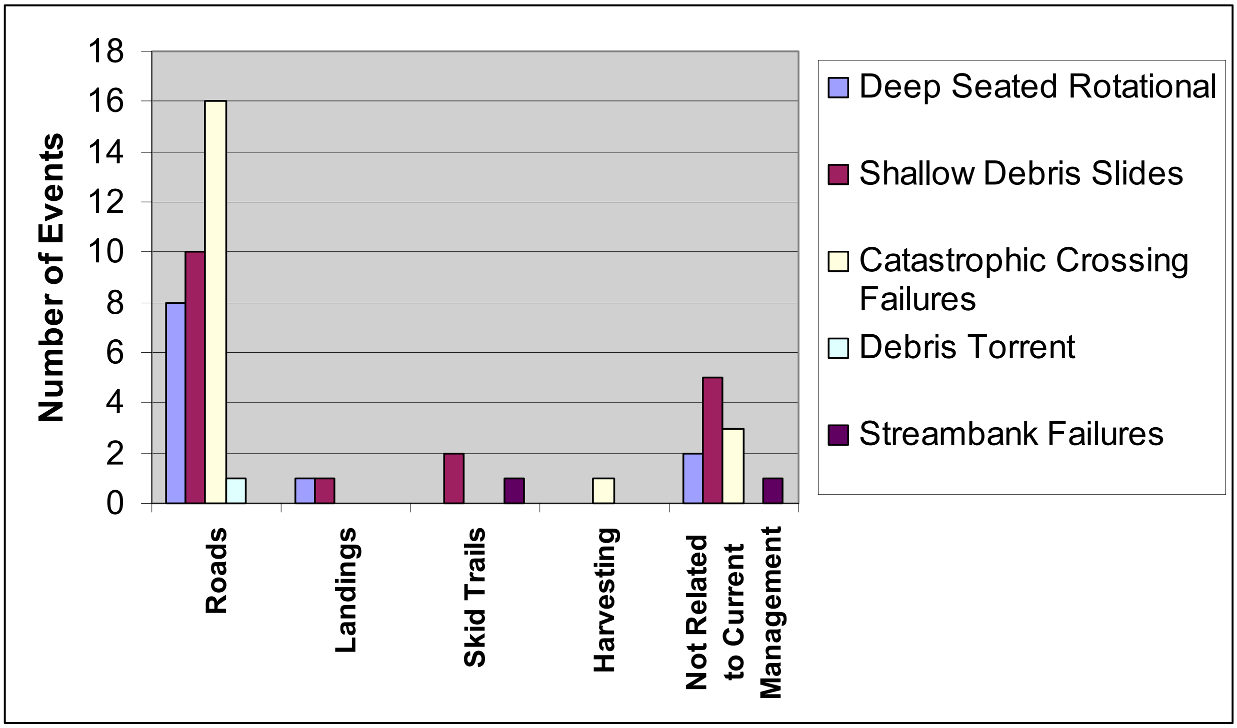

Figure 21. Primary causes of large erosion events and type of feature (note that multiple causes were assigned in some instances).

features, 39 were classified as being related to current timber management activities (Figure 21).

As shown in Table 37, nearly all of the shallow debris slide features were found in the Coast Forest Practice District, as were the majority of the deep seated rotational features. Since there were 4.7 and 2.3 times more THPs and NTMP projects in the Coast Forest Practice District when compared to the Southern and Northern Districts (Table 1), respectively, the actual frequency of catastrophic crossing failures is much higher in the inland districts. This can be partly explained by the very large rain-on-snow event which occurred in January 1997, which was at least a 100-year recurrence interval runoff event in many parts of the Sierra Nevada Mountains. Streambank failures related to the current plan and debris torrents were recorded infrequently. As with the numbers of erosion features recorded on road, skid trail, and watercourse protection zone transects, the numbers of large erosion events were considerably lower in period from 1999 through 2001 (15 features) than during the 1997-1998 period (35 features) (Figure 22).

Average volumes for the various types of erosion features related to current management activities in all three Forest Practice Districts were as follows: deep seated rotational failures—19,800 cubic yards, shallow debris slide features—3,500 cubic yards, catastrophic crossing failure features—65 cubic yards, streambank failures—600 cubic yards, and debris torrent features—550 cubic yards.

Table 37. Frequency distribution of large erosion events that were encountered on THPs and NTMP projects evaluated from 1997 through 2001.

Type of Feature	Coast	Northern	Southern	Total
Deep seated rotational	7	3	1	11
Shallow debris slide	14	3	0	17
Debris torrent	1	0	0	1
Streambank Failure	1	0	1	2
Catastrophic crossing failure	6	6	7	19
Totals	29	12	9	50

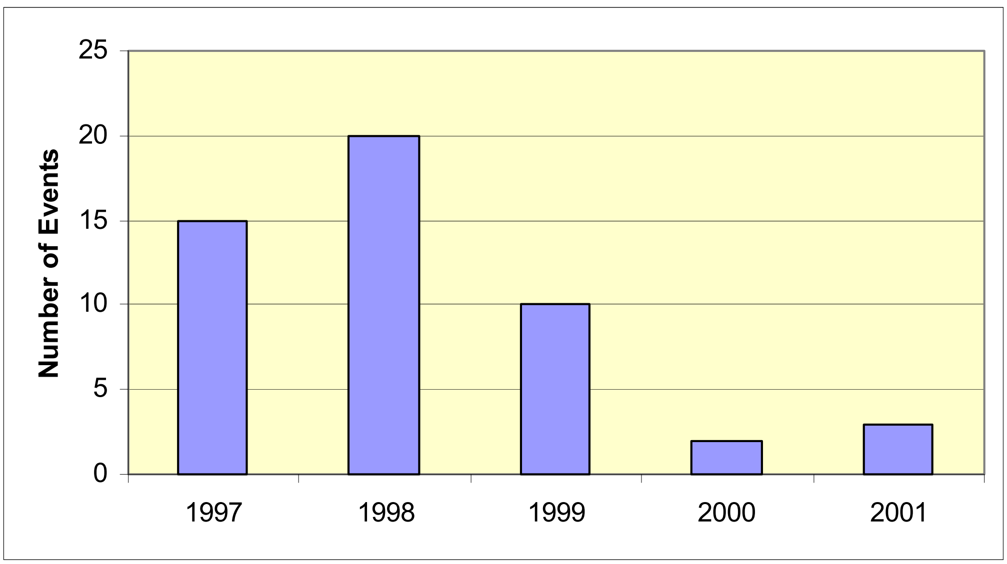

Figure 22. Year data was recorded on the large erosion events inventoried.

Most of the inventoried large erosion events related to management activities in the current plan were associated with roads (35), with smaller numbers of events associated with skid trails (3), landings (2), and harvesting (1). Cause codes and associated features are displayed in Figure 21, while specific cause codes are shown in Table 38 (multiple cause codes were assigned in some instances, so the total is greater than the 39 events). The most frequent causes of management related large erosion events were: cutbanks with slope support removed; subsurface water concentration;

culverts with plugged inlets; fill slopes with overloaded, deep sidecast; and culverts which were judged to be too small.

Table 38. Management related causes of inventoried large erosion events (note that multiple causes were often assigned to a single event).

Type of Feature	Cause of Feature	Count
Roads	Waterbars-discharge onto erodible material	3
	Waterbars-improperly constructed or located	3
	Fill slopes-too steep	3
	Fill slopes-overloaded, deep sidecast	6
	Fill slopes-poorly compacted	4
	Fill slopes-excessive organic material	1
	Culverts too small	5
	Culverts-discharge onto erodible material	2
	Culverts-inlet plugged	8
	Culverts-broken and leaking into the roadbed	1
	Inside ditch-ditch blocked and/or diverted	1
	Inside ditch-other drainage onto road not handled	4
	Cutbanks- too steep	3
	Cutbanks-slope support removed	11
	Subsurface flow alteration	1
	Cross drains-too small	1
	Cross drains-discharge onto erodible material	1
	Cross drains-improperly constructed or located	3
	Subsurface water concentrations-discharge onto erodible material	9
Skid Trails	Waterbars-not properly draining area	2
	Cutbanks-too steep	1
	Cutbanks-slope support removed	2
	Surface water concentration-rilling and gullying	1
	Surface water concentration-discharge on erodible material	2
Landings	Cutbanks-too steep	1
	Cutbanks-slope support removed	1
	Fill slopes-excessive organic material	1
	Waterbars-discharge onto erodible material	1
	Subsurface flow alteration	1
Harvesting	Alteration of natural drainage during yarding	1

Non-Standard Practices and Additional Mitigation Measures

Additional mitigation measures beyond the standard Rule requirements are often added to THPs. These mitigations may be the basis for acceptance and approval of proposed in-lieu or alternative practices and, ultimately, the THP. This summary should be considered an initial, first-phase review of non-standard practices (including in-lieu and alternative practices) and additional mitigation measures, from which future work can be built upon. Further evaluation of the implementation and effectiveness of these types of practices is needed.

A more complete evaluation approach was not developed during the Pilot Monitoring Program (1993-1995) due to the difficulty in addressing the variability of prescriptions developed for site specific problems (Lee 1997), but is needed for future monitoring work. The Hillslope Monitoring Program Interim Report (CSBOF 1999) did not address this topic, so this is the first time that these data have been summarized. It is important to note that site-specific practices and/or additional mitigation measures often did not apply at the randomly selected transects and features, so the totals reported below are a small sample that does not include all of the types of practices that were included in the THPs and NTMP projects. Additionally, the features were not examined to the same degree of rigor as on the randomly located transects evaluated for standard Rule compliance and at large erosion sites, and the narrative evaluations were based on requirements specified in the THP provided to the contractors, some of which may have been modified through amendments that were not reviewed.[26]

A brief summary of the qualitative responses provided for non-standard practice and additional mitigation measure implementation and effectiveness follows for each feature type.

Roads

Of the 568 road transects evaluated in the field, a total of 45 transects had entries in the Hillslope Monitoring Program database for the implementation and effectiveness of non-standard practices or additional mitigation measures. The most commonly approved non-standard practice was the use of roads in WLPZs,[27] followed by roads on steep slopes (greater than 65 percent). Frequently prescribed additional mitigation measures were: 1) seeding and mulching or rocking road surfaces and 2) decreasing the distance between waterbreaks (to high or extreme erosion hazard rating standards). As shown in Table 39, about 15 percent of these sites had existing or potential problems, of which four percent was associated with lack of implementation and nine percent with

[26] The field team was not always supplied with a complete set of the reviewing agencies' Pre-Harvest Inspection reports and Amendments to the THP.

[27] Currently, construction or reconstruction of a road within a WLPZ is an in-lieu practice (14 CCR 916.3(c) [936.3(c), 956.3(c)], except at new crossings approved as part of the Fish and Game Code process. Use of existing roads in WLPZs is addressed in 14 CCR 916.4(a) [936.4(a), 956.4(a)], but is not considered an in-lieu practice.

acceptable implementation. Overall, the specified practices were not fully implemented at about 13 percent of the applicable sites, and approximately 70 percent were judged to be properly implemented and effective. For approximately three percent of the applicable sites, full implementation of the specified measures was lacking but effectiveness was judged to be acceptable.

Skid Trails

Non-standard practices or additional mitigation measures were evaluated at thirty-seven of the 480 skid trail transects completed for this project. The most common practices included: 1) more frequent waterbreak spacing than required by the standard Rules, 2) tractor operations on slopes steeper than permitted by the standard FPRs, and 3) use of existing skid trails in watercourse protection zones. As shown in Table 40, only four of these practices (9 percent) were described as having existing or potential problems, of which three were associated with poor implementation and one with acceptable implementation. The specified practices were not fully implemented on approximately 25 percent of the applicable sites and were judged to be properly implemented and effective about 60 percent of the time.

Landings

A total of 28 landings had entries for non-standard practices or additional mitigation measures, out of a possible 569 features. Nearly all of these were alternatives with approval for use of WLPZ landings, usually in conjunction with additional mitigation measures that generally specified the use of seeding and mulching or rocking. As shown in Table 41, about seven percent of the sites where these practices and measures were applied had existing or potential problems, all of which were associated with acceptable implementation. About four percent of the practices were not fully implemented and almost 90 percent were properly implemented and effective.

Watercourse Crossings

Of the 491 watercourse crossings evaluated, non-standard practices or additional mitigation measures were evaluated at 18 sites as part of the hillslope monitoring process. Common mitigation measures applied at these sites included: mulching and seeding fill slopes or abandoned crossings, and use of rock for inlet or road approaches. As shown in Table 42, three of the practices at these 18 crossings (about 11 percent) had existing or potential problems, of which all were associated with acceptable implementation. Approximately 15 percent of the practices were not fully implemented. Fifty-six percent of the practices evaluated were judged to be properly implemented and effective.

Watercourse Protection Zones (WLPZs, ELZs, and EEZs)

Of the 683 watercourse protection zones transects evaluated in the field, 56 transects had entries in the Hillslope Monitoring Program database for the implementation and effectiveness of non-standard practices or additional mitigation measures. Commonly specified practices and mitigation measures were: 1) use of existing roads within WLPZs, 2) use of existing skid trails in the WLPZ , 3) no-cut WLPZs, 4) additional canopy retention requirements in the WLPZ over the standard Rule, and 5) wider WLPZs than required by the standard Rule. When evaluating the frequent practice of using existing WLPZ roads, the field team often stated that there was no *apparent* sediment delivery to the watercourse channel. It is important to recognize that these inspections were completed in the dry summer and fall months, when observation of possible fine sediment transport during winter storm events was not possible.

Table 43 displays the implementation and effectiveness ratings for the non-standard practices and additional mitigation measures for watercourse protection zones. About eight percent of these practices and measures were applied had existing or potential problems, of which one percent was associated with poor implementation and seven percent with acceptable implementation. Approximately five percent of the practices were not fully implemented. Seventy-four percent of the practices were properly implemented and effective (see the comments about fine sediment transport above).

Table 39. Summary of recorded non-standard practices and additional mitigation measures for roads.

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Use of WLPZ road	20	17	2		1				
No harvesting between road and stream	1	1							
Extreme EHR waterbar spacing	2	1					1		
High EHR waterbar spacing with 12 inch waterbars	1	1							
High erosion hazard rating for waterbar spacing	4			1				1	2
Use of reduced waterbar spacing	2	1	1						
Place hay bale at WLPZ waterbar outlets	1	1							
Seed and mulch road surface	4	4							
Straw mulch on road	3	3							
Road rocking	6	6							
Rock crossing approaches	1		1						
Rock Class III crossings	1	1							
Road on >65% slopes	3	3							
Roads on >65% slope and road segment >15% grade	1	1							
Full bench road construction	2	2							
Full bench road construction on unstable slopes<65%	1							1	
Outslope roads	2			1			1		
Endhauling	1	1							
Place fill in safe location	2			1					1
Push excess material to slopes <40%	1	1							
No sidecast	2	2							
No deposition from clearing cutbanks and/or brow log	1								1
Remove overhanging banks	1			1					
Reconstruct roads in wet areas	1	1							
Road moved and new crossing installed	1	1							
Class III off of road/improve drainage through landing	1	1							
Road abandonment	1								1
Remove culvert	1					1			
Winter hauling limited to firm road surface	1		1						
No winter hauling when sediment can reach stream	2		2						
Dip out crossing and mulch	1	1							
Use of excavator	1	1							
Whole tree yarding from road	1			1					
Block road	2	1						1	
Totals	76	52	7	5	1	1	2	3	5
Percent	100	68.4	9.2	6.6	1.3	1.3	2.6	4	6.6

"I/E" = Implemented and Effective/No Problem Observed
"I/P" = Implemented and Problem or Potential Problem Exists
"I/UE" = Implemented and Unknown Effectiveness
"UI/E" = Unknown Implementation and Effective/No Problem Observed
"UI/P" = Unknown Implementation and Problem or Potential Problem Exists
"NI/E" = Not Implemented and Effective/No Problem Observed
"NI/P" = Not Implemented and Problem or Potential Problem Exists
"NI/U" = Not Implemented and Unknown Effectiveness

Table 40. Summary of recorded non-standard practices and additional mitigation measures for skid trails.

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Use of WLPZ skid trail	4	2	1	1					
Use of WLPZ road for heavy equipment	1	1							
More frequent waterbar spacing than standard rule	2	1						1	
Waterbreak spacing at extreme EHR	7	4					1		2
Waterbreak spacing at high EHR	9	4					2	2	1
High EHR waterbar spacing with 12 inch waterbars	2			2					
Seed and mulch removed skid trail crossing	2	1		1					
Mulch approaches ot removed skid trail crossing	1	1							
Seed and mulch skid trails in WLPZ	2	1					1		
Seed and mulch skid trails on slopes >40%	1						1		
Seed and slash skid trails	1	1							
Slash and mulch skid trails	1	1							
Chip and slash skid trails	1	1							
Use of existing skid trails on slopes >65%	4	4							
Use of tractors in cable area	1	1							
Use of existing skid trails without watercourse crossings	2	2							
Skid trail crossing of Class II watercourse	1			1					
Tractor yarding during dry conditiong in winter period	1	1							
Tractor crossing of Class IV watercourse	1			1					
Totals	44	26	1	6	0	0	5	3	3
Percent	100	59.1	2.3	13.6	0	0	11.4	6.8	6.8

"I/E" = Implemented and Effective/No Problem Observed
"I/P" = Implemented and Problem or Potential Problem Exists
"I/UE" = Implemented and Unknown Effectiveness
"UI/E" = Unknown Implementation and Effective/No Problem Observed
"UI/P" = Unknown Implementation and Problem or Potential Problem Exists
"NI/E" = Not Implemented and Effective/No Problem Observed
"NI/P" = Not Implemented and Problem or Potential Problem Exists
"NI/U" = Not Implemented and Unknown Effectiveness

Table 41. Summary of recorded non-standard practices and additional mitigation measures for landings.

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Use of WLPZ landing	17	15	2						
Use of ELZ landing	1	1							
Rock landing surface	4	4							
Seed and mulch landing surface	4	4							
Slash and mulch landing surface	2	2							
Inslope landing, mulch, install brow log	1	1							
Drain to avoid discharge on fillslope	1								1
Install ditch for drainage	1						1		
Outslope landing	2	2							
Seed and mulch, install brow log, hay bale	1	1							
Seed landing	2	2							
Mulch landing	3	3							
Install brow log on landing surface	2	1	1						
Landing >1/4 ac for helicopter yarding	1	1							
Helicopter landing in WLPZ	1	1							
Relocate landing away from Class III watercourse 50 feet	1	1							
Rechannel watercourse	1	1							
Totals	45	40	3	0	0	0	1	0	1
Percent	100	88.9	6.7	0	0	0	2.2	0	2.2

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"NI/U" = Not Implemented and Unknown Effectiveness

Table 42. Summary of recorded non-standard practices and additional mitigation measures for watercourse crossings.

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Rock road at crossing	4	2		1					1
Install 3/4 inch rock	1		1						
Rock Class III watercourse crossing	1	1							
Rock armor inlet of crossing	2	2							
Seed and mulch fill slopes at watercourse crossing	1		1						
Seed and mulch banks of removed crossing	1						1		
Straw mulch removed watercourse crossing	1	1							
Mulch 20 feet on either side of the crossing	1	1							
Seed and mulch road surface approaches to crossing	1	1							
Straw mulch new or reconstructed crossing	1			1					
Hydromulch fill slopes	2			2					
Use of existing watercourse crossing	2	2							
Install trash rack	1						1		
Install standpipe	2	2							
Remove 36 inch pipe, rock armor for slope stabilization	1	1							
Use of gravel ford crossing	1			1					
Install concrete sacks to stabilize downstream fill slope	1	1							
Install brow logs, berm logs	1						1		
Rechannel Class III watercourse along road	1	1							
Block road	1		1						
Totals	27	15	3	5	0	0	3	0	1
Percent	100	55.6	11.1	18.5	0	0	11.1	0	3.7

"I/E" = Implemented and Effective/No Problem Observed
"I/P" = Implemented and Problem or Potential Problem Exists
"I/UE" = Implemented and Unknown Effectiveness
"UI/E" = Unknown Implementation and Effective/No Problem Observed
"UI/P" = Unknown Implementation and Problem or Potential Problem Exists
"NI/E" = Not Implemented and Effective/No Problem Observed
"NI/P" = Not Implemented and Problem or Potential Problem Exists
"NI/U" = Not Implemented and Unknown Effectiveness

Table 43. Summary of recorded non-standard practices and additional mitigation measures for watercourse protection zones (WLPZs, ELZs, and EEZs). [see the previous tables for the definitions of the abbreviations used below]

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Use of existing WLPZ road for hauling	19	18		1					
Use of existing road and landing in WLPZ	1			1					
Reconstruction of road in WLPZ	1	1							
Use of existing WLPZ road for skidding logs	1	1							
Use of existing WLPZ skid trail	2	2							
Extreme EHR waterbreak spacing	1	1							
Seed and mulch existing WLPZ road	2	1							1
Slash pack skid trails	1	1							
Seed and mulch removed skid trail crossing	1	1							
Rocked road in WLPZ	3	3							
Rocked cross drains on WLPZ road	1	1							
No sidecast in WLPZ from existing road	1	1							
No harvesting in WLPZ	5	3		1					1
No harvesting in WLPZ except at cable corridors	1			1					
Equipment exclusion zone (EEZ) established	1	1							
EEZ 10 feet for Class III watercourse	1	1							
No equipment in WLPZ between road and stream	1	1							
No harvesting in WLPZ between road and stream	1	1							
Reduction in WLPZ width from 150 ft to 115 ft	1	1							
WLPZ width increased to 200 ft	2	2							
WLPZ width increased to 150 ft	1			1					
WLPZ width increased to 100 ft	1	1							
WLPZ width 150 ft; no variable zone based on slope	1							1	
Class II WLPZ 75 ft regardless of slope	1	1							
WLPZ width wider than standard Rule requirement	3	2		1					
WLPZ width--maximum distance possible in Rules	1	1							
75% retention of overstory vegetation	1	1							
70% overstory and 50% understory retention	1			1					
70% overstory retention	4		3	1					
70% total canopy retention	3	1	2						
50% canopy retention in ELZ for Class III watercourse	2			2					
Retain 5 largest trees in WLPZ	1	1							
Retain 5 trees/acre >32 inches DBH	1	1							
Very limited harvesting in WLPZ	2	2							
Removal of debris jams in channel	2	2							
Remove slash from WLPZ	1								1
Allow tree falling to occur across watercourse	2	1		1					
Exception to Rule requiring 2 conifers >16 in w/in 50 ft	1	1							
Totals	76	56	5	11	0	0	0	1	3
Percent	100	73.7	6.6	14.5	0	0	0	1.3	3.9

Discussion and Conclusions

Project Limitations

The Hillslope Monitoring Program has primarily reviewed Timber Harvesting Plans, with a very limited evaluation of Nonindustrial Timber Management Plans. Exemptions, Emergency Notices, and Conversions have not been monitored. The THP "Review Process" and the degree to which this process contributes to water quality problems has not been considered (Lee 1997). Also, since winter documentation of fine sediment delivery to streams was not possible with this program, the percentages of sediment delivery to watercourse channels from erosion features found on roads, landings, and skid trails are likely to underestimate total sediment delivery. Analysis completed on the data set to date has primarily been composed of frequency counts and has been limited by time and access to database analysts. Additional data analysis will be conducted in the future.

Key points regarding what has been learned are summarized and discussed below.

<u>Implementation rates of the Forest Practice Rules related to water quality are high, and individual practices required by the Forest Practice Rules are effective in preventing hillslope erosion features when properly implemented</u>.

Table 44 shows that overall ratings of the FPRs for each monitoring subject area are high—over 90% for all but watercourse crossings. This result is similar to what has been reported for other western states. For example average implementation rates for BMPs have been reported as 96 percent, 94 percent, and 92 percent in Oregon, Montana, and Idaho, respectively (Ice et al. 2002). In California, implementation of applicable Rules at problem points was nearly always (98% overall) found to be less than that required by the FPRs (Table 45). Therefore, problem points were almost always caused by non-compliance with the FPRs. These results are consistent with findings reported in earlier studies conducted in California (Dodge et al. 1976, CSWRCB 1987). The above conclusion refers to "individual practices," since the THP Review and inspection process was not evaluated as part of the Hillslope Monitoring Program.

Table 44. Summary of acceptable (i.e., meets or exceeds requirements) Forest Practice Rule implementation ratings for transects (roads, skid trails, watercourse protection zones) and features (landings and watercourse crossings) as a whole.

Hillslope Monitoring Program Sample Area	% Acceptable Implementation
Road Transects	**93.2**
Skid Trail Transects	**95.1**
Landings	**93.5**
Watercourse Crossings	**86.3**
Watercourse Protection Zones (WLPZ, ELZ, EEZ)	**98.4**
Total	**94.5**

Table 45. Summary of Forest Practice Rule implementation ratings at problem points for individual Hillslope Monitoring Program evaluation areas.

Hillslope Monitoring Program Sample Area	Percent Acceptable Implementation	Percent Major or Minor Departure from Requirements
Road Transects	**2**	**98**
Skid Trail Transects	**0**	**100**
Landings	**0**	**100**
Watercourse Crossings	**0**	**100**
Watercourse Protection Zones	**7**	**93**
Total	**2**	**98**

Watercourse crossing problems remain frequent, with nearly half the crossings evaluated having at least one problem point.

Large numbers of problem points were found at crossings. Reasons for this include:

- crossings are sometimes built incorrectly,
- many types of crossings have a relatively short expected life,
- culverts are sized with planned failure if a discharge event exceeds a selected recurrence interval (often 50 or 100 years),
- culverted crossings are often not built to properly accommodate large wood and sediment,
- maintenance of crossings—particularly culverts—is often difficult due to remote locations, lack of staff, and road passage problems in winter months,
- abandonment principles are subjective, difficult to apply in the field, and require considerable experience for proper implementation,
- upgrading old crossings can be very expensive, and
- shared use agreements on roads with crossings can complicate the responsibility and timing of improvement work.

The most frequent types of crossing problems encountered during the hillslope monitoring work were culvert plugging, diversion potential, fill slope gullies, scour at the outlet of the culvert, ineffective road surface cutoff waterbreaks, and fill slope mass failures. These problems are primarily related to the design, construction, and maintenance of crossings. Replacing and upgrading numerous crossings along a road segment can be a large, difficult, and expensive task for a landowner. Inventorying for the worst crossings with the most potential for adverse impacts to water quality and developing a plan to complete the work may be a realistic solution (see Flanagan et al. 1998). Gucinski et al. (2001) list several techniques for decreasing the negative hydrologic effects of roads, several of which relate to crossings.

Proper crossing abandonment requires considerable expertise and experience. Guidelines for accomplishing this work are provided in Weaver and Hagans (1994). Long-term sediment savings can be provided by removing crossings that will eventually fail (Madej 2001), but a small short-term flush of sediment is likely to occur during the first winter following heavy equipment work. Weaver (2001) estimated that this will often be on the order of 5 to 10 cubic yards per crossing.[28] Monitoring of crossing removal work in the Caspar Creek watershed found that an average of approximately 10 cubic yards was eroded from abandoned crossings during the first winter (excluding the one crossing in the South Fork that was retaining old splash dam deposits—see the Summary of Related Studies section earlier in this report for additional details).

Roads with drainage structure problems are the main cause of sediment delivery to stream channels.

About half the road transects evaluated by the Hillslope Monitoring Program field crews had one or more rills, approximately 25 percent had at least one gully, and four percent had a mass failure associated with the current plan. Forest Practice Rules related to these features were nearly always found to be out of compliance, usually due to drainage feature problems. Specifically, these problems were most often related to having: 1) inadequate size, number, and location of drainage structures to carry runoff water and minimize erosion, and 2) inadequate waterbreak spacing and waterbreak discharge into cover. About six percent of all evaluated drainage structures had problem points assigned to them. Gullies delivered sediment to channels about 24.5 percent of the time and rills about 12.6 percent of the time.

The monitoring results reported here are consistent with those described by MacDonald and Coe (2001—see the Related Studies section of this report). For their sites in the Central Sierra Nevada Mountains, they found that 16 percent of the segments and 20 percent of the road length had gullies or sediment plumes that were within 10 meters (32.8 feet) of a stream channel. In this study, contributing surface area multiplied by slope (A*S) was the best predictor of road surface erosion, and decreasing A*S by improving and maintaining road drainage was recommended to reduce erosion on native surfaced roads. In other words, proper spacing of rolling dips, waterbreaks, and where necessary, culvert cross drains, is a key component to reducing road surface erosion. Numerous publications have described techniques to reduce road surface erosion (see for example Burroughs and King 1989).

Hillslope monitoring results in Oregon are also consistent with data collected in California. Robben and Dent (2002) report that non-compliance with road related BMPs, especially drainage and maintenance requirements, was the largest source of sediment delivery to stream channels in their BMP compliance monitoring project. They also state that because the surveys were performed in the dry season, they likely underestimated the number of sediment delivery sources and total eroded volume. Skaugset and Allen (1998) stated that relief of road drainage at stream crossings was the most common source of sediment delivery in western Oregon. This study found that 25 percent of the surveyed road length delivered sediment directly to a stream channel. Additionally, Luce and Black (1999) found that sediment production was related to road surfaces, unvegetated ditches, and cutslope lengths draining to stream channels.

[28] This estimate was made based on field work conducted in Humboldt County.

Watercourse protection zones provide for adequate retention of post-harvest canopy and surface cover, and for prevention of harvesting related erosion.

Class I watercourses made up approximately 17 percent of the evaluated watercourses, 56 percent were Class IIs, and 27 percent were Class IIIs. Statewide, mean post-harvest total canopy cover exceeded 70 percent, regardless of instrument used for measurement. Mean total canopy exceeded Forest Practice Rule requirements in all three Forest Practice Districts, and was approximately 80 percent in the Coast Forest Practice District for both Class I and II watercourses. Surface cover exceeded 75 percent for all watercourse types in all three Forest Practice Districts. Required WLPZ widths generally met Rule requirements, with major departures from Rule requirements recorded only about one percent of the time. Additionally, the frequency of erosion events related to current timber operations in watercourse protection zones was very low for Class I, II, and III watercourses.

These results are consistent with the Modified Completion Report Monitoring program data collected by CDF Forest Practice Inspectors discussed earlier in the Related Studies section (Brandow 2002). Canopy measurements were remarkably similar for Class I and II watercourses in all three Forest Practice Districts. Similarly, erosion features related to the current operations in Class I and II WLPZs have been very rare.

With the federal listing of coho salmon as a threatened species in 1997 for the Southern Oregon/Northern California Coasts Coho ESU, it has been a common practice in the Coast Forest Practice District to either have 70 percent post-harvest canopy in Class I watercourses (CDF 1997) or prescribe no-harvest zones.[29] Greatly reduced harvesting within WLPZs has also been a common practice for interior area THPs in recent years. However, total canopy cover in the interior area is lower than on the Coast, which is probably due to past harvesting, slower conifer growth rates, and drier growing conditions for understory vegetation.

The monitoring work described in this report does not allow conclusions to be made regarding instream channel conditions for fish habitat (CSBOF 1999), and evaluating the biological significance of the Rules was not part of this program. For example, no relationship between post-harvest canopy levels and acceptable water temperatures for coldwater fish species can be determined from the data collected in this study. This type of monitoring has been and is currently being conducted in numerous locations throughout the state (see for example Lewis et al. 2000 and James 2001). Instream sediment production from timber operations conducted under the modern Forest Practice Rules, and impacts to macroinvertebrate communities and anadromous fish are available from the Caspar Creek watershed study (see Lewis et al. 2001, Rice et al. 2002, Bottorff and Knight 1996, Nakamoto 1998, and the summary provided in the

[29] The July 2000 Threatened and Impaired Watersheds Rule Package approved by the BOF requires at least 85 percent overstory canopy post-harvest for the first 75 feet for planning watersheds with listed or candidate anadromous salmonid species, but THPs accepted by CDF after July 1, 2000 (when the Rule package went into effect) have not been included in the plans evaluated by the Hillslope Monitoring Program to date.

Related Studies section of this report). Additionally, research is underway by Drs. Mary Ann Madej (USGS) and Peggy Wilzbach (HSU) on the relative importance of size-specific, inorganic vs. organic components of the suspended load of streams and the influence of these components on stream health, as reflected in the efficiency of growth of juvenile salmonids and their invertebrate food base. This work is being conducted in the Caspar Creek and Redwood Creek watersheds of California. Data on large wood loading and recruitment in second-growth redwood/Douglas-fir watersheds found in the Coast Forest Practice District is available in Benda et al. (2002).

<u>Landings and skid trails are not producing substantial impacts to water quality</u>.

Erosion problems on landing surfaces, cut slopes, and fill slopes were relatively rare. Only about 11 percent of the landings evaluated were assigned problem points and the largest category of these occurrences was related to rills or gullies that formed from concentrated runoff below the outlet of a landing surface drainage structure. Dry season evidence of sediment delivery from landing surface drainage and fill slope erosion features to watercourse channels was recorded only seven and six times, respectively, from 569 landings.

Rill and gully erosion features on skid trails were found to deliver sediment to watercourse channels 3.8 percent and 13 percent of the time, respectively. Nearly all of these erosion problems were related to improper implementation of FPRs specifying installation of drainage structures. Low rates of sediment delivery from skid trails with properly installed and functioning drainage structures are not surprising, since earlier work in California has shown that skid trails used under the current Forest Practice Rules have not had a large impact on water quality. For example, Euphrat (1992) studied sediment transport related to timber harvesting in the Mokelumne River watershed in the central Sierra Nevada Mountains. The data he collected on numerous skid trails revealed that sediment was not transported to watercourses, and the data implied that relatively little material flowed off other well drained skid trail segments. Additionally, data collected by MacDonald and Coe (2001) in the central Sierra Nevada Mountains has shown that most harvest units (primarily tractor logged with skid trails) and landings produced relatively little sediment. Recently, Benda (2002) reported no erosion off well drained skid trails at the Southern Exposure research site in the Antelope Creek watershed in Tehama County.

<u>The frequency of erosion events has decreased substantially in the last three years of the program.</u>

The numbers of rills, gullies, mass failures and cutbank/sidecast sloughing features found on road, skid trail, and watercourse protection zone transects and the number of large erosion events decreased for the period from 1999 through 2001 when compared to 1996 through 1998. The primary reason for this decrease is probably reduced storm size, intensity, and frequency after the winter of 1997/1998. The January 1997 storm produced a 100-year discharge event in many Sierra Nevada Mountain watersheds, and was also a very significant event in the Coast Forest Practice District. For example, in southern Humboldt County in the Bull Creek basin, the January 1997 event is the flood of record, surpassing even the legendary December 1964 flood. The following winter of 1997/1998 (water year 1998) was a strong El Niño winter, with large, nearly continuous storm events. This hydrologic year produced the winter of record for total precipitation in the Caspar Creek watershed and produced numerous legacy road related landslide features in the South Fork basin (Cafferata and Spittler 1998). Maximum annual instantaneous peak discharge values for three free flowing stream systems located throughout Northern and Central California are displayed in Figure 23 and show much higher values in water years 1995, 1996, and 1997, when compared to those that occurred in 1998 through 2001. Therefore, it is possible to conclude that the Hillslope Monitoring Program study period has included large stressing storm events that have tested the Forest Practice Rules related to water quality—particularly in the first three years of the project.

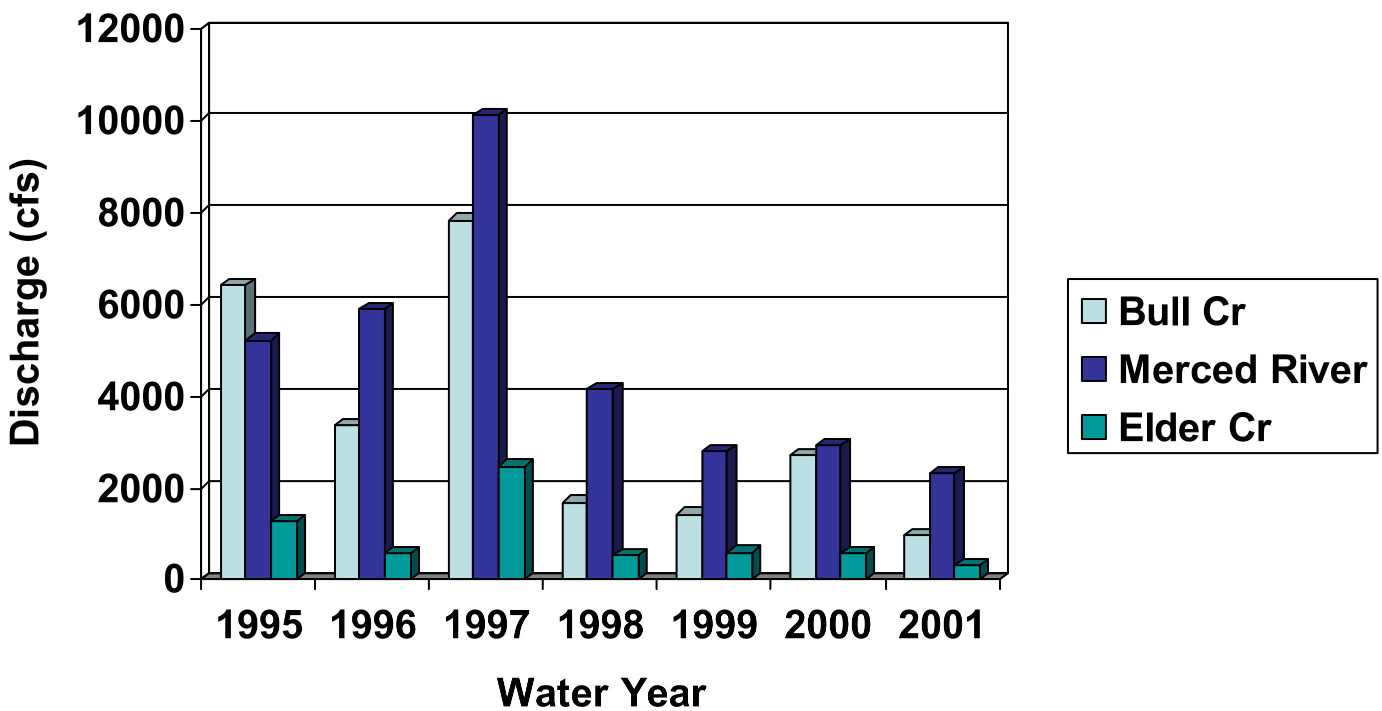

Figure 23. Stream gauging station maximum annual instantaneous peak discharge data for three free flowing river systems. The Merced River at Happy Isles is located in Yosemite National Park in the central Sierra Nevada Mountains, Bull Creek is located in southern Humboldt County, and Elder Creek is located in western Mendocino County.

The connection between storm size and intensity and the frequency of erosion features is supported by the results that Coe and MacDonald (2002), who noted large interannual variability in sediment production rates over three years of monitoring at their central Sierra Nevada sites, and attributed these differences to the magnitude and type of the precipitation.   For example, sediment production for the 1999-2000 winter was 3 to 11 times higher than the sediment production rates for the 2000-2001 winter.

Additional reasons for reduced erosion feature frequency for the second three year period include increased familiarity with field methods and a change in the THP selection process. The lead contractor for the project, Mr. Roger Poff, has stated that rilling on road and skid trail transects may have been overestimated during the first two years (1996 and 1997) of the project, primarily because of the complexity of the data recording process and the learning curve required to successfully complete adequate data collection. Rills were not usually measured to determine if they met the stated criteria for this type of feature and were probably tallied too frequently (R.J. Poff, personal communication). Also, there were more small non-industrial landowner THPs and NTMP projects, with generally smaller plan size for the period from 2000 to 2001, which probably reduced the opportunity for finding the various types of erosion features.

The Hillslope Monitoring Program results to date are similar to data collected on CDF violations for THPs related to water quality.

Water quality violations of the Rules are identified and corrected, where possible, as part of the normal CDF Forest Practice Inspection process. Information from CDF's Forest Practice Program Database shows that 975 violations were issued on the 4,749 THPs open from 1998 through 2000.[30] These violations can be separated into three basic groups: harvesting practices and erosion control (347), watercourse and lake protection (308), and logging roads and landings (320). The FPRs with the highest number of violations generally involved waterbreak requirements, timber operations in the winter period, proper removal of temporary crossings, roads and landings located outside of WLPZs, removal of debris from very small watercourses, WLPZ trees felled away from the watercourse, removal of accidental depositions in watercourses, crossings open to unrestricted passage of water, size/number/location of drainage structures adequate to minimize erosion, and crossing removal adequate to prevent erosion. This type of information complements the data from the Hillslope Monitoring Program and CDF's Modified Completion Report monitoring work. Together, these three independent data sources allow cross-checking and corroboration of the results of each type of monitoring (Ice et al. 2002).

[30] This data analysis was completed by Mr. Clay Brandow, CDF, Sacramento.

Several reasons exist for why THPs with approved Work Completion Reports can have relatively high percentages of total departures from Forest Practice Rule requirements.

The deviations from the FPRs reported in the 1999 Interim Report (CSBOF 1999) for THPs with approved Work Completion Reports has prompted criticism of the adequacy of the CDF's inspection and enforcement program (see for example, Stillwater Sciences 2002). Reasons for these post-inspection Rule problems include:

- CDF Forest Practice Inspectors focus on the whole THP to identify threats to water quality and often will not find minor departures. Most of the Rule departures associated with problem points in the six years of hillslope monitoring have been minor departures with little or no direct impact to water quality. Of all the total number of departures for the problem point sites, 76.5 percent have been minor and 23.5 percent major departures. The category with the highest percentage of major departures is watercourse crossings, with approximately 49 percent major departures at identified problem points.

- CDF inspectors must balance the time necessary to enforce the repairing of a single or small problem against forgone inspections on other plans where there may be significant numbers of problems or a significant consequence from a problem.

- Some FPRs are qualitative in nature, and a minor deviation identified in the Hillslope Monitoring Program when an erosion feature is found would not necessarily trigger a rule violation by CDF during an inspection before the erosion occurred. A common example of this type of Rule is 14 CCR 923.2(h) [943.2(h), 963.2(h)], which requires drainage structures of sufficient size, number and location to minimize erosion.

- In the Hillslope Monitoring Program, major departures are assigned for sediment delivery with or without a significant departure from Rule requirements.

Several steps have been taken to improve implementation of the FPRs related to water quality since 1999. These include implementation of the Modified Completion Report monitoring process by CDF Forest Practice Inspectors in 2000 (see discussion on this program in the Related Studies section of this report), BOF passage of a rule requiring RPF supervision of active logging operations in 2000,[31] and information dissemination/ training related to monitoring results provided to CDF Foresters and RPFs in California.

[31] This Rule was passed by the BOF in 2000 and went into effect on January 1, 2001. See 14 CCR 1035.1, Registered Professional Forester Responsibility.

<u>Preliminary results on the use of non-standard practices and additional mitigation measures indicate the need for more thorough inspection and a more focused study design to adequately examine the implementation and effectiveness of these practices.</u>

The determination of whether proposed non-standard practices (i.e., alternatives, in-lieus, exceptions, etc., collectively referred to as non-standard practices) and additional mitigation measures are appropriate for a given site is a major component of the Timber Harvesting Plan Review Process, so there is clearly a need for monitoring the adequacy of these practices. However, the focus of the Hillslope Monitoring Program has been on evaluating the adequacy of standard Forest Practice Rules, so results from the limited data collected on non-standard practices should be considered as preliminary.

The data collected to date show that existing or potential problems were found on approximately 15 percent of road transects, 7 percent of landings, 11 percent of crossings, 9 percent of skid trail transects, and 8 percent of watercourse protection zone transects where non-standard practices and additional mitigation measures were prescribed. Improper implementation of these practices was 13 percent on roads, 25 percent on skid trails, 4 percent on landings, 15 percent at crossings, and 5 percent for watercourse protection zones. These results are consistent with the findings for the standard Forest Practice Rules for watercourse protection zone transects, with both standard and non-standard Rules having high overall implementation ratings and few problems. Additionally, these preliminary results suggest that better implementation of non-standard practices could be achieved with more thorough inspection by RPFs and CDF Forest Practice Inspectors.

<u>The California Forest Practice Rule requirements with the lowest overall implementation related to water quality have been identified and education efforts related to these Rules are required</u>.

To focus on areas where improvement in Rule design or implementation would provide the greatest benefits to water quality, Table 46 summarizes the 20 Forest Practice Rule requirements with four percent or more major departures (the table shows 24 Rule requirements, but one Rule was cited for both roads and landings[32], and three Rules were cited for both roads and crossings). The need for improved implementation of these Rule requirements, in particular, should be made known to RPFs, LTOs, and CDF Forest Practice Inspectors. Seven rule requirements relate to roads, one to skid trails, two to landings, 13 to watercourse crossings, and one to watercourse protection zones.

[32] Note that 14 CCR 923.1(a) is a THP mapping requirement and does not directly cause an adverse impact water quality.

Table 46. Forest Practice Rule requirements with at least four percent major departures based on at least 30 observations where implementation could be rated (note this table was developed from Tables 6, 14, 22, 25, and 29).

Location	Rule No.	Description of Rule	Major Departure %
Roads	914.6(f)	where waterbreaks do not work--other erosion controls installed	4.2
Roads	923.1(f)	adequate numbers of drainage structures to minimize erosion	4.8
Roads	923.2(h)	size, number, and location of structures sufficient to carry runoff water	5.3
Roads	923.1(a)	landing on road greater than ¼ acre or requiring substantial excavation--shown on THP map	11.5
Roads	923.2(h)	size, number, and location of structures sufficient to minimize erosion	4.1
Roads	923.2(d) Coast	fills constructed with insloping approaches, berms, rock armoring, etc., to minimize erosion	4.7
Roads	923.2(m)	sidecast extending greater than 20 feet with access to a watercourse protected by a WLPZ treated to reduce erosion	7.4
Skid Trails	914.6(c)	waterbreak spacing equals standards	5.6
Landings	923.1(a)	landings greater than ¼ acre or requiring substantial excavation--shown on THP map	10.9
Landings	923.5(f)(4)	sidecast or fill extending greater than 20 feet with access to watercourse—treated to reduce erosion	4.3
Crossings	923.2(o)	no discharge on fill unless suitable energy dissipators are used	12.6
Crossings	923.2(h)	size, number, and location of structures minimizes erosion	11.2
Crossings	923.2(d) Coast	fills across channels built with insloping approaches, berms, rock armoring, etc., to minimize erosion	9.8
Crossings	923.4(n)	crossing/approaches maintained to avoid diversion	4.0
Crossings	923.8	abandonment—minimize concentration of runoff	4.6
Crossings	923.3(e)	crossing/fills built to prevent diversion	5.5
Crossings	923.4(d)	crossing open to unrestricted passage of water	4.0
Crossings	923.8(d)	abandonment--pulling/shaping of fills	9.8
Crossings	923.8(c)	abandonment--grading of road for dispersal of water flow	4.8
Crossings	923.3(d)(2)	removed--cut bank sloped back to prevent slumping and to minimize soil erosion	6.3
Crossings	923.8(b)	abandonment--stabilization of exposed cuts/fills	4.8
Crossings	923.2(h)	size, number, location of structures sufficient to carry runoff	7.1
Crossings	923.8(e)	abandonment--fills excavated to reform channel	5.1
WLPZs	916.2(a)(4)	sensitive conditions--existing roads in WLPZ—appropriate mitigation measure(s) applied	4.5

Recommendations

Based on the results compiled from six years of Hillslope Monitoring Program data, we recommend the following items:

TRAINING

1. Develop robust training programs based on monitoring results for LTOs, RPFs, CDF Forest Practice Inspectors, and members of other reviewing agencies. Training program agendas will be tailored to the needs of the various targeted audiences.

2. Require more thorough and consistent inspection of watercourse crossings by CDF Forest Practice Inspectors and other reviewing agencies based on the above training programs.

3. Inform CDF Forest Practice Inspectors on monitoring results at the annual CDF Forest Practice enforcement training course in Fort Bragg. Note that while the course is offered annually, each Inspector attends the class every four years. Additionally, inform CDF Forest Practice Inspectors of monitoring results and needed improvements at annual forester meetings.

4. Develop a Licensed Timber Operator (LTO) implementation guidance document for installation of watercourse crossings and road drainage structures. This effort should be coordinated with the other reviewing agencies, particularly the California Department of Fish and Game. The goal is to produce a relatively simple document that quickly and simply illustrates the most important principles for successful crossing and drainage structure design and installation. For example, some of the concepts to include for crossings would be proper: gradient, alignment, diversion potential, pipe length, armoring, etc.

5. Raise awareness of key hillslope monitoring findings to forest landowners, the public, Licensed Timber Operators, RPFs, and other interested parties. This is to be accomplished through updates provided to the BOF's Licensing News, the CLFA Update, CDF Mass Mailings to RPFs, and other regularly produced newsletters.

6. Work with the California Licensed Foresters Association (CLFA), Associated California Loggers (ACL), Forest Landowners of California (FLOC), the California Forestry Association (CFA), and other forestry related trade associations to develop workshops that address key issues identified through hillslope monitoring. For example, a CLFA workshop on watercourse crossings is scheduled for March, 2003.

ROAD MANAGEMENT PLAN

7. Upgrade those watercourse crossings with problems, including old, existing structures, with a voluntary, cooperative Road Management Plan, including an agreed to schedule to complete upgrading work.

MODIFICATIONS FOR THE HILLSLOPE MONITORING PROGRAM

8. Revise the Hillslope Monitoring Program to adequately examine: 1) additional mitigation measures applied to THPs, and 2) non-standard practices applied to THPs (including in-lieu and alternative practices).

9. Revise the Hillslope Monitoring Program to: 1) address the changes in the Forest Practice Rules since the BOF passed the Threatened and Impaired Watersheds Rule Package in July 2000, and 2) reduce emphasis on semi-qualitative assessments by conducting more rigorous and scientifically defensible tests of individual practice effectiveness (e.g., pre and post-harvest, overstory/understory, conifer/hardwood canopy data; detailed information on watercourse crossings built as part of the current plan under the Threatened and Impaired Watersheds Rule Package, allowing for passage of wood and sediment as well as 100-year flood flows; and detailed information on newly constructed road drainage structures, including contributing surface area, slope, surfacing, grading, erosion problems, sediment delivery, etc.).

WORK NEEDED TO COMPLEMENT THE HILLSLOPE MONITORING PROGRAM

10. Continue to support the implementation and funding of instream monitoring projects that have a peer-reviewed study design, including pre-project data collection, to answer questions about Forest Practice Rule effectiveness and compliance with Regional Water Quality Control Board Basin Plan standards.

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Glossary

Abandonment – Leaving a logging road reasonably impassable to standard production four wheel-drive highway vehicles, and leaving a logging road and landings, in a condition which provides for long-term functioning of erosion controls with little or no continuing maintenance (14 CCR 895.1).

Alternative practice – Prescriptions for the protection of watercourses and lakes that may be developed by the RPF or proposed by the Director of CDF on a site-specific basis provided that several conditions are complied with and the alternative prescriptions will achieve compliance with the standards set forth in 14 CCR 916.3 (936.3, 956.3) and 916.4(b) [(936.4(b), 956.4(b)]. 14 CCR 916.6 (936.6, 956.6). More general alternative practices are permitted under 14 CCR 897(e).

Beneficial uses of water – As described in the Porter-Cologne Water Quality Control Act, beneficial uses of water include, but are not limited to: domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish and wildlife, and other aquatic resources or preserves. In Water Quality Control Plans, the beneficial uses designated for a given body of water typically include: domestic, municipal, agricultural, and industrial supply; industrial process; water contact recreation and non-water contact recreation; hydropower generation; navigation; groundwater recharge; fish spawning, rearing, and migration; aquatic habitat for warm-water species; aquatic habitat for coldwater species; and aquatic habitat for rare, threatened, and/or endangered species (Lee 1997).

Best management practice (BMP) - A practice or set of practices that is the most effective means of preventing or reducing the generation of nonpoint source pollution from a particular type of land use (e.g., silviculture) that is feasible, given environmental, economic, institutional, and technical constraints. Application of BMPs is intended to achieve compliance with applicable water quality requirements (Lee 1997).

Canopy - the foliage, branches, and trunks of vegetation that blocks a view of the sky along a vertical projection. In the Hillslope Monitoring Program, this was estimated from 1996 through1998 with a spherical densiometer and from 1999 through 2001 with a sighting tube. The Forest Practice Rules define canopy as “the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody species” (14 CCR 895.1).

Cutbank/sidecast sloughing – Shallow, surficial sliding associated with either the cutbank or fill material along a forest road or skid trail, with smaller dimensions than would be associated with mass failures.

Feature - Any constructed component of a landing, road, skid trail, or watercourse crossing (e.g., cut bank, fill slope, inside ditch, cross drain, water break).

Exception – A non-standard practice for limitations on tractor operations (14 CCR 914.2(f)(3), 934.2(f)(3), 954.2(f)(3)).

Gully - Erosion channels deeper than 6 inches (no limitation on length or width). Gully dimensions were estimated.

In-lieu practice – These practices apply to Rule sections for watercourse protection where provision is made for site specific practices to be proposed by the RPF, approved by the Director and included in the THP in lieu of a stated Rule. The RPF must reference the standard Rule, explain and describe each proposed practice, how it differs from the standard practice, indicate the specific locations where it will be applied, and explain and justify how the protection provided by the proposed practice is at least equal to the protection provided by the standard Rule (14 CCR 916.1, 936.1, 956.1).

Large erosion event - These events were defined for the Hillslope Monitoring Program as 100 cubic yards for a mass failure void left on a hillslope, or at least 10 cubic yards for catastrophic crossing failures.

Mass failure – Downslope movement of soil and subsurface material that occurs when its internal strength is exceeded by the combination of gravitational and other forces. Mass erosion processes include slow moving, deep-seated earthflows and rotational failures, as well as rapid, shallow movements on hillslopes (debris slides) and in downstream channels (debris torrents).

Minor/major departure – Major departures were assigned to problem points when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements (e.g., no or few waterbreaks installed for an entire transect). Minor departures were assigned for slight Rule departures where there was no evidence that sediment was delivered to watercourses (e.g., WLPZ width slightly less than that specified by the Rule).

Non-standard practice - A practice other than a standard practice, but allowable by the Rules as an alternative practice, in-lieu practice, waiver, exclusion, or exemption (Lee 1997).

Parameter - The variable being studied by sampling, observation, or measurement (Lee 1997).

Permanent road – A road which is planed and constructed to be part of a permanent all-season transportation facility. These roads have a surface which is suitable for the hauling of forest products throughout the entire winter period and have drainage structures, if any, at watercourse crossings which will accommodate the fifty-year flow. Normally they are maintained during the winter period (14 CCR 895.1). After July 1, 2000, watercourse crossings associated with permanent roads have been required to accommodate the estimated 100-year flood flow, including debris and sediment loads.

Problem point - In the Hillslope Monitoring Program the occurrence of: 1) erosion features (rills, gullies, mass failures, or cutbank/sidecast sloughing) found at sample sites or along transects, 2) canopy reduction, streambank erosion, or ground cover reduction in a watercourse protection zone, or 3) Forest Practice Rule violations (e.g., waterbreak improperly constructed) (Lee 1997).

Process - The procedures through which the Rules/BMPs are administered and implemented, including: (a) THP preparation, information content, review and approval by RPFs, Review Team agencies, and CDF decision-makers, and (b) the timber operations completion, oversight, and inspection by LTOs, RPFs, and CDF inspectors (Lee 1997).

Quality assurance - The steps taken to ensure that a product (i.e., monitoring data) meets specified objectives or standards. This can include: specification of the objectives for the program and for data (i.e., precision, accuracy, completeness, representativeness, comparability, and repeatability), minimum personnel qualifications (i.e., education, training, experience), training programs, reference materials (i.e., protocols, instructions, guidelines, forms) for use in the field, laboratory, office, and data management system (Lee 1997).

Quality control - The steps taken to ensure that products which do not meet specified objectives or standards (i.e., data errors and omissions, analytical errors) are detected and either eliminated or corrected (Lee 1997).

Repeatability - The degree of agreement between measurements or values of a monitoring parameter made under the same conditions by different observers (Lee 1997).

Rill - Small surface erosion channels that (1) are greater than 2 inches deep at the upslope end when found singly or greater than 1 inch deep where there are two or more, and (2) are longer than 20 feet if on a road surface or of any length when located on a cut bank, fill slope, cross drain ditch, or cross drain outlet. Dimensions were not recorded.

Rules - Those Rules that are related to protection of the quality and beneficial uses of water and have been certified by the SWRCB as BMPs for protecting the quality and beneficial uses of water to a degree that achieves compliance with applicable water quality requirements (Lee 1997). Forest Practice Rules are included in Title 14 of the California Code of Regulations (14 CCR).

Seasonal road – A road which is planned and constructed as part of a permanent transportation facility where: 1) commercial hauling may be discontinued during the winter period, or 2) the landowner desires continuation of access for fire control, forest management activities, Christmas tree growing, or for occasional or incidental use for harvesting of minor forest products, or similar activities. These roads have a surface adequate for hauling of forest products in the non-winter period; and have drainage structures, if any, at watercourse crossings which will accommodate the fifty-year flood flow. Some maintenance usually is required (14 CCR 895.1). After July 1, 2000, all permanent watercourse crossings have been required to accommodate the estimated 100-year flood flow, including debris and sediment loads.

Standard practice - A practice prescribed or proscribed by the Rules (Lee 1997).

Surface cover – The cover of litter, downed woody material (including slash, living vegetation in contact with the ground, and loose rocks (excluding rock outcrops) that resist erosion by raindrop impact and surface flow (14 CCR 895.1).

Temporary road – A road that is to be used only during the timber operation. These roads have a surface adequate for seasonal logging use and have drainage structures, if any, adequate to carry the anticipated flow of water during the period of use (14 CCR 895.1).

Waterbreak – A ditch, dike, or dip, or a combination thereof, constructed diagonally across logging roads, tractor roads and firebreaks so that water flow is effectively diverted. Waterbreaks are synonymous with waterbars (14 CCR 895.1).

Appendix

Table A-1. Landings--effectiveness ratings.

Evaluation Category	Number of Observations	Description
Surface Rilling and Gullying		
a. Rilling on Landing Surface	430	None
	79	Less than 1 rill/100 ft (0-20%)
	16	Some rilling (less than 1 rill/20 ft of transect)
	0	Greater than 1 rill/20 ft (greater than 20%)
	2	Greater than 20% of landing drained by rills
	41	0-20% of landing drained by rills
b. Gullies on Landing Surface	461	None
	90	Less than 1 gully per 100 ft transect
	3	Some gullying (less than 1 gully per 20 ft of transect)
	0	Gullying that exceeds 1 gully per 20 ft of transect
	11	Gullying present with recorded dimensions
Surface Drainage		
a. Drainage Runoff Structure	270	No evidence of erosion from concentrated flow where drainage leaves landing surface or drainage outlet
	54	Rills or gullies present but do not extend greater than 20 ft below edge of landing or drainage outlet
	24	Presence of rills or gullies which extend greater than 20 ft below edge of landing or drainage outlet
b. Sediment Movement	325	No evidence of transport to WLPZ
	14	Sediment deposition in WLPZ but not to channel
	7	Evidence of sediment transport to, or deposition in channel
Landing Cut Slopes		
a. Rilling	274	No evidence of rills
	15	Rills present but do not extend to drainage structure or ditch
	5	Rills present and extend to drainage structure or ditch
b. Gullies	289	No evidence of gullies
	1	Gullies present but do not extend to drainage structure or ditch
	4	Gullies present and extend to drainage structure or ditch

Evaluation Category	Number of Observations	Description
Landing Cut Slopes		
c. Slope Failures	272	Less than 1 cubic yard of material moved
	18	More than 1 cubic yard moved but it is not transported to drainage structure or ditch
	3	More than 1 cubic yard moved, some material transported to drainage structure or ditch
Landing Fill Slopes		
a. Rilling	332	No evidence of rills
	42	Rills present but do not extend to drainage channels below toe of fill
	2	Rills present and extend to drainage channels below toe of fill
b. Gullies	345	No evidence of gullies
	26	Gullies present, but do not extend to drainage channels below toe of fill
	5	Gullies present and extend greater than a slope length below toe of fill
c. Slope Failures	355	No material moved
	12	Less than 1 cubic yard moved
	8	More than 1 cubic yard moved but does not enter channel
	2	More than 1 cubic yard moved, some material enters channel
d. Sediment Movement	363	No evidence of transport to WLPZ
	8	Sediment deposition in WLPZ but not carried to channel
	6	Evidence of sediment transport to, or deposition in channel

Table A-2. Crossings--effectiveness ratings.

Evaluation Category	Number of Observations	Description
Fill Slopes at Crossings		
a. Vegetative Cover	285	Vigorous dense cover or fillslope of stable material
	101	Less than full cover, but greater than 50% if fillslope has effective cover or is of stable material
	24	Less than 50% of fillslope has effective cover or is of stable material
b. Rilling	332	Rills may be evident, but are infrequent, stable and no evidence of sediment delivery to channel
	46	Few rills present (less than 1 rill per lineal 5 ft) and not enlarging, with little apparent deposition in channel
	32	Numerous rills present (greater than 1 rill per lineal 5 ft), apparently enlarging or with substantial evidence of delivery to channel
c. Gullies	344	None
	14	Gullies present, not enlarging, little apparent deposition in channel
	12	Gullies present and enlarging or threatening integrity of fill
	40	Gully with dimensions provided
d. Cracks	378	None evident
	22	Cracks present, but appear to be stabilized
	7	Cracks present and widening, threatening integrity of fill
e. Slope Failure	302	None
	64	Less than 1 cubic yard (lowest category available in 1996, “none” was not available)
	18	0 to 1 cubic yard of material
	27	Greater than 1 cubic yard of material
Road Surface Draining to Crossings		
a. Rutting	403	No ruts present
	61	Some ruts present, but design drainage not impaired
	13	Rutting impairs road drainage
b. Rilling	433	Little or no evidence of rills
	32	Rills occupy less than 10% of road surface area, or do not leave road surface
	11	Rills occupy greater than 10% of surface and continue off road surface onto crossing or fill
c. Gullies (>6 in deep)	383	None
	8	Gully with dimensions provided

Evaluation Category	Number of Observations	Description
d. Surfacing of Crossing Approach	359	No loss of road surface
	31	Less than 30% of road surface area degraded by surface erosion
	5	Greater than 30% of road surface area degraded by surface erosion
e) Cut-off Waterbar Condition	248	Functional
	49	Allows some water to reach crossing location
	25	Allows all water running down the road to reach crossing location
f) Inside Ditch Condition	107	Open
	19	Some sediment/debris accumulation
	6	Blocked with sediment/debris
g. Ponding	400	No evidence of ponded water
	61	Ponding present, but does not appear to threaten integrity of fill
	12	Ponding present and is causing fill subsidence or otherwise threatening integrity of fill
h. Road Surface Drainage	53	Stable drainage with little or no sediment delivery to stream
(only used in 1996)	22	Slight sediment delivery but configuration is stable or stabilizing
	8	Continuing sediment delivery to stream and configuration is unstable/degrading
Culverts		
a. Scour at Inlet	316	No evidence of scour
	15	Scour evident but extends less than 2 channel widths above inlet and no undercutting of crossing fill
	5	Scour evident that extends more than 2 channel widths above inlet or scour is undercutting crossing fill
b. Scour at Outlet	226	No evidence of scour
	74	Scour evident, but extends less than 2 channel widths below outlet, and no undercutting of crossing fill
	36	Scour evident that extends more than 2 channel widths below outlet, or scour undercuts crossing fill
c. Diversion Potential	243	Crossing configured to minimize fill loss (road doesn't slope downward from crossing in at least one direction)
	62	Crossing has road that slopes downward in at least one direction with drainage structure
	30	If culvert fails, flow will be diverted out of channel and down roadway
d. Plugging	257	No evidence of sediment or debris
	50	Sediment and/or debris is accumulating, less than 30% of inlet or outlet is blocked
	29	Sediment and/or debris is blocking greater than 30% of inlet or outlet

Evaluation Category	Number of Observations	Description
e. Alignment	270	Appropriate
	2	Low angle channel approach
	3	High angle channel approach or discharge is not in channel
f. Degree of Corrosion	222	None to slight (metal discolored but not missing)
	18	Moderate--some corroded metal missing but pipe still competent
	2	Severe--pipe can be punctured with screwdriver or similar tool
g. Crushed Inlet/Outlet	251	None
	23	Pipe deformed but less than 30% of inlet/outlet blocked
	1	Pipe deformed and greater than 30% of inlet/outlet blocked
h. Pipe Length	323	Appropriate
	10	Length causing only minor amount of gullying or fill slope erosion
	2	Length directly related to large gullies or fillslope erosion around pipe
i. Gradient	230	Appropriate--at base of fill and at grade of original streambed
	26	Pipe inlet set slightly too low or slightly too high in fill
	21	Pipe inlet set too high or too low, causing debris accumulation, or water to under cut the culvert
j. Piping	263	No evidence of flow beneath or around culvert
	14	Flow passes beneath or around culvert, or piping erosion evident
Non-Culvert Crossing		
a. Armoring	60	Appropriate
	12	Minor downcutting evident at crossing due to inadequate armoring
	8	Major downcutting evident at crossing due to inadequate armoring
b. Scour at Outlet	59	No evidence of scour
	19	Scour evident, but extends less than 2 channel widths below outlet, and no undercutting of crossing fill
	6	Scour evident that extends more than 2 channel widths below outlet, or scours undercuts crossing fill
c. Diversion	77	Crossing configured to minimize fill loss (road does not slope downward from crossing in at least one direction)
	3	Crossing has road that slopes downward in at least one direction but is unlikely to divert flow down road
	3	Overflow will be diverted down road

Evaluation Category	Number of Observations	Description
Removed or Abandoned		
a. Bank Stabilization	60	Vigorous dense vegetation cover or other stabilization material
	21	Less than full cover, but greater than 50% of channel bank has effective cover or has stable material
	4	Less than 50% of channel bank has effective cover or is composed of stable material
b. Rilling of Banks	79	Rills may be evident but infrequent, stable, with no sediment delivery to channel
	5	Few rills present (less than 1 per lineal 5 ft) and rills not enlarging
	1	Numerous rills present (greater than 1 rill per lineal 5 ft) or apparently enlarging
c. Gullies	80	None evident
	5	Gully with dimensions provided
d. Slope Failures	82	Less than 1 cubic yard of material
	2	Greater than 1 cubic yard of material moved but does not enter stream
	1	Greater than 1 cubic yard of material moved, material enters stream
e. Channel Configuration	69	Wider than natural channel and close to natural watercourse grade and orientation
	12	Minor differences from natural channel in width, grade, or orientation
	3	Narrower than natural channel width, or significant differences from natural channel grade or orientation
f. Excavated Material	77	Sloped to prevent slumping and minimize erosion
	4	Slumps or surface erosion present, but less than 1 cubic yard of material enters channel
	1	Slumps or surface erosion present, greater than 1 cubic yard of material enters channel
g. Grading and Shaping	72	No evidence of erosion or sediment discharge to channel due to failures of cuts, fills or sidecast
	10	Less than 1 cubic yard of material transported to channel due to failures of fills or sidecast
	2	Greater than 1 cubic yard material transported to channel due to failures of fills or sidecast
Road Approaches at Abandoned Crossings		
a. Grading and Shaping	60	No evidence of concentrated water flow to channel from road surface (in excess of designed drainage or erosion of drainage facility)
	9	Less than 1 cubic yard of material transported to channel from eroded surface soil on road approaches
	2	Greater than 1 cubic yard of material transported to channel from eroded surface soil on road approaches

INTERIM REPORT TO THE CALIFORNIA STATE BOARD OF FORESTRY AND FIRE PROTECTION

HILLSLOPE MONITORING PROGRAM:

MONITORING RESULTS FROM 1996 THROUGH 1998

PREPARED BY THE MONITORING STUDY GROUP OF THE CALIFORNIA STATE BOARD OF FORESTRY AND FIRE PROTECTION

JUNE 1999
SACRAMENTO, CALIFORNIA

EXECUTIVE SUMMARY

The Monitoring Study Group was created by the California State Board of Forestry and Fire Protection to determine how effective the Forest Practice Rules are in protecting water quality. The California Department of Forestry and Fire Protection (CDF) implemented hillslope monitoring in 1996 on 50 randomly selected Timber Harvesting Plans (THPs) in Humboldt and Mendocino Counties to provide information on forest practices within the range of coho salmon. The program expanded in 1997 and 1998, with 50 randomly selected THPs evaluated each year throughout the state. Field work on all 150 THPs was conducted by private contractors who were Registered Professional Foresters with significant amounts of experience developing THPs and using the Forest Practice Rules. An earth scientist was required to be part of the contractor's field team for the state-wide work.

THPs selected for hillslope monitoring had to: 1) have been accepted for filing under the revised Forest Practice Rules after October 1991, 2) have been through at least one but not more than four winters since logging was completed, 3) have been logged with crawler tractors and/or cable yarding systems, and 4) contain at least 500 continuous feet of a Class I or II watercourse. A randomly selected pool of THPs was generated and permission for access was requested. Access was granted by large industrial landowners for all but one THP, but roughly one-third of the small-nonindustrial landowners failed to grant access. About 65% of the sampled THPs were on large industrial timberlands, and 35% had non-industrial timberland owners or other types of ownership (state, small companies, etc.). The Coast Forest Practice District contained 66% of the THPs, while the Northern and Southern Districts had 22 and 12%, respectively. Only THPs were evaluated (no Emergencies, Exemptions, or Non-industrial Timber Management Plans were included).

Evaluation of individual THPs occurred at five sample areas that past studies indicated were the greatest risk to water quality—roads, skid trails, landings, watercourse crossings, and watercourse and lake protection zones (WLPZs). Comprehensive forms were developed for recording site information, implementation data, and effectiveness data for each of these five sample areas. In total, 190 Forest Practice Rule requirements that could be determined by field review were evaluated. The data in this report are only for the standard Rules (not alternatives or in-lieu practices). Class III protection, impacts from winter operations, and restorable uses of water (three areas referred to in CDF's 1995 survey report on watercourse protection as having concern for proper implementation and effectiveness) have not been addressed by this project except where intersected by erosion features that also involve one of the previously described sample areas.

All five sample areas were evaluated twice within each THP if possible. Roads, skid trails and WLPZs were sampled using transects that were 1000 feet in length when available (in all cases they were at least 500 feet long). Landings and watercourse crossings were evaluated as individual features without transects. All sample areas were randomly located within the THP. Large erosion events were inventoried when they were encountered on a THP. Implementation of the Forest Practice Rules applicable to a given sample site was rated as either exceeding the Rule requirements, meeting the requirements, minor departure from requirements, or major departure from requirements (with other categories for not applicable, etc.). Major departures were assigned when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements. In contrast, minor departures were assigned for slight Rule departures when there was no evidence that sediment was delivered to watercourses.

Results to date have been developed from frequency counts. As this program continues, additional analyses may be performed to determine if there are significant differences between Rule applications and site or operator factors. It is also important to note that the results apply only to implementation and effectiveness on hillslope locations—and are not directly linked to current instream conditions.

Roads and their associated crossings were found to have the greatest potential for sediment delivery to watercourses. Twenty-two road Rule requirements had either minor or major departures for implementation more often than 5% of the time (based on a sample of at least 30 observations where implementation could be rated). Similarly, 14 Rule requirements for crossings had minor or major departures that exceeded the 5% level. Most of the road Rule implementation departures fell within the minor departure category, while a larger proportion of the crossing Rule implementation ratings were for major departures. Results to date indicate that greater attention should be focused on improvement of crossing design, construction, and maintenance due to the high levels of departures from Rule requirements and the close proximity of crossings to channels. For roads, better implementation of Rules related to drainage structure design, construction, and maintenance is needed. Mass failures associated with current timber operations were mostly related to roads and produced the highest sediment delivery to watercourse channels when compared to other erosion processes. The majority of the road related mass failures were associated with fill slope problems—indicating that proper road construction techniques are critical for protecting water quality.

Watercourse and lake protection zones generally met Forest Practice Rule requirements for width, canopy, and ground cover. Very few erosion features associated with current THPs were recorded within WLPZs. Six rule requirements for WLPZs had either minor or major departures for implementation more often than 5% of the time, but the vast majority of the departures were in the minor category.

Landings had few erosion features associated with current operations and generally did not deliver significant amounts of sediment to watercourses. Four landing Rule requirements had either minor or major departures for implementation more often than 5% of the time, and most ratings were within the minor category. Impacts from skid trails were also relatively minor compared to those produced by roads and crossings. Frequency of erosion problem points on skid trails was much lower than that documented on road transects. Only three skid trail Rule requirements had either minor or major departures for implementation that exceeded 5% of the observations. The majority of the departures fell within the minor category.

Several general observations regarding the Hillslope Monitoring Program and the preliminary results that have been produced were made by the Monitoring Study Group. These observations include the need to: (1) develop training programs for Registered Professional Foresters, Licensed Timber Operators, and equipment operators about the Forest Practice Rules that were found to have the poorest implementation, (2) continue monitoring in order to test infrequently encountered Forest Practice Rules and infrequent natural events, (3) continue monitoring to provide a sufficient sample size to evaluate non-standard (i.e., in-lieu and alternative) practices, (4) evaluate current quality assurance/quality control (QA/QC) information and determine what additional work needs to be completed, and (5) complete a more in-depth analysis of the existing hillslope monitoring data set.

In summary, the Forest Practice Rules and individual THP requirements (i.e., site-specific mitigation measures developed through recommendations of interagency Review Teams) were generally found to be sufficient to prevent hillslope erosion features. The Hillslope Monitoring Program results, however, do not allow us to draw conclusions about whether the existing Rules are providing properly functioning habitat for aquatic species because evaluating the biological significance of the current Rules was not part of this project. For all five sample areas, erosion problem points were almost always associated with improperly implemented Forest Practice Rules. In other words, nearly all of the erosion problems resulted from non-compliance. These conclusions are similar to those reached in the “208 Team” report (SWRCB 1987), where it was reported that the standard practices in the Rules generally appeared to provide adequate water quality protection when they were properly implemented, and poor Rule implementation was the most common cause of observed water quality impacts.

ACKNOWLEDGEMENTS

The Monitoring Study Group would like to acknowledge and thank several individuals and companies for their assistance with the Hillslope Monitoring Program. Roger Poff of R.J. Poff and Associates and Cliff Kennedy and Joe Hiss of High Country Forestry displayed great personal interest in the program, worked hard to make the program succeed, helped improve the monitoring protocols, and entered data in the database. All three have provided assistance in developing database queries and have reviewed drafts of this report. Dr. Don Warner, Calif. State Univ., Sacramento, developed the Hillslope Monitoring database and the queries run on the data sets. Don has displayed a high degree of technical competence, as well as patience in dealing with a very large and complex database. In 1996, Gary Rynearson, Jim Hawkins and Lou Tirado of Natural Resources Management Corporation collected the field data in Humboldt County. Chris Hipkin assisted R.J. Poff and Associates with the 1996 field data collection in Mendocino County. Tom Schott and Curtis Ihle representing the Mendocino and Humboldt County Resource Conservation Districts respectively, played significant roles in making the 1996 monitoring projects in their counties successful.

Simpson Timber Company, Georgia-Pacific Corporation, Pacific Lumber Company, Sierra Pacific Industries, Stimson Timber Company, Mendocino Redwood Company, Louisiana Pacific Corporation, William M. Beaty and Associates, Eel River Sawmills, Fruit Growers Supply Company, Soper-Wheeler Company, Gualala Redwoods Company, Wetsel-Oviatt Lumber Company, Barnum Timber Company, and Roseburg Resources Company provided access onto their timberlands, as well as assistance in locating Timber Harvesting Plans. We also thank all the small non-industrial timberland owners who granted access to their parcels.

Chuck Abshear, Norm Cook and Janice Stine queried CDF RBASE databases for a pool of Timber Harvesting Plans from 1996 through 1998 in Santa Rosa, Fresno, and Redding, respectively. Scott Gregory, Student Assistant, entered the 1996 data in the database and completed numerous tasks to make the program run smoothly. Mavis Hotchkiss developed the CDF contracts that allowed the monitoring work to proceed. CDF Forest Practice Program staff members Pete Cafferata and John Munn were responsible for compiling and summarizing information and were the primary authors of the report.

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INTRODUCTION

Difficult questions are increasingly being asked by agency scientists, legislators, and the public about the impacts of current forestry operations on critical downstream beneficial uses of water. Unfortunately, in many cases there has been insufficient scientifically valid data available to answer the types of questions that have been asked. The listing and potential listing of numerous fish and wildlife species under the federal Endangered Species Act (ESA) and the listing of numerous watersheds as impaired waterbodies under Section 303(d) of the Clean Water Act have heightened the need for valid data on impacts to these resources from current timber operations. As a result, monitoring the impacts of forestry practices on water quality and anadromous fish habitat has received a greater degree of emphasis in the 1990's (MacDonald et al. 1991, MacDonald and Smart 1993, Wissmar 1993, Dissmeyer 1994).

In California, the State Board of Forestry and Fire Protection (BOF) and the California Department of Forestry and Fire Protection (CDF) have jointly worked throughout the 1990's to develop and implement a long-term monitoring program which could provide information to decision makers and the public regarding the effectiveness of the current Forest Practice Rules in protecting water quality. The BOF formed the Monitoring Study Group (MSG) in 1989 to develop this long-term program. The long-term monitoring program includes both instream and hillslope components.

The Hillslope Monitoring Program has received the most emphasis to date. Specific objectives of this program include: (1) determining if the Forest Practice Rules (FPRs) affecting water quality are properly implemented—implementation monitoring, and (2) determining if the FPRs affecting water quality are effective in meeting their intent when properly implemented—effectiveness monitoring. These two types of monitoring are necessary for differentiating between water quality problems created by non-compliance with a FPR, versus problems with the forest practice. The goal is to provide information on where, when, and in what situations problems occur under proper implementation (Tuttle 1995).

This report summarizes the results that have been obtained from data collected on 150 Timber Harvesting Plans (THPs) that were evaluated from 1996 through 1998 as part of the Hillslope Monitoring Program. **These are to be considered interim results, as this program is an on-going project that will continue to collect field data. Additionally, only frequency count data is presented--without statistical tests.** As more data are collected and sample sizes become larger, detailed statistical analysis will be performed on the hillslope monitoring data sets.

Other projects have been undertaken in California that provide information regarding impacts from timber operations conducted under the modern (i.e., after 1974) Forest Practice Rules. Readers of this report are encouraged to review results from research projects such as the Caspar Creek watershed studies (Ziemer 1998, Lewis et al. 1998), and the Critical Sites Erosion Study (Durgin et al. 1989, Lewis and Rice 1989, Rice and Lewis 1990).

BACKGROUND INFORMATION

Monitoring forestry practices in California has historically related to protection of water quality. Much less emphasis has been placed on monitoring impacts of logging on terrestrial wildlife species by CDF and the BOF, since the California Department of Fish and Game has had the lead for that type of monitoring. The relationship between monitoring and water quality grew out of CDF and the BOF's desire to have the Forest Practice Rules and Review Process certified as Best Management Practices by the U.S. Environmental Protection Agency (EPA), beginning as early as 1977.

After the passage in 1983 of the modern watercourse protection rules specifying protection based on the beneficial uses of water present, the Forest Practice Rules and Review Process were conditionally certified as meeting Best Management Practices standards for Section 208 of the Clean Water Act by the State Water Resources Control Board (SWRCB). The Water Board required that a monitoring and assessment program be implemented for this certification. Due to lack of sufficient funding for a comprehensive four-year program, a one-year qualitative assessment of forest practices was undertaken in 1986 by a team of four resource professionals (Johnson 1993). The "208 Report" (SWRCB 1987) resulted from this review of 100 Timber Harvesting Plans completed over the entire state. The team found that the Rules generally were effective when properly implemented on terrain that was not overly sensitive. They recommended several changes to the Forest Practice Rules based on their observations.

In 1988, CDF, the Board of Forestry (BOF), and the SWRCB entered into a Management Agency Agreement (MAA) that required the BOF to improve forest practice regulations for better protection of water quality, largely based on the "208 Report". At this point, the SWRCB approved certification. EPA, however, withheld certification until the conditions of the MAA were satisfied, one of which was to develop a long-term monitoring program to determine the effectiveness of the Forest Practice Rules and Review Process in protecting water quality. The BOF formed an interagency task force, later known as the Monitoring Study Group, to develop the long-term monitoring program.

The MSG, working with the consulting firm William Kier Associates, held public outreach meetings throughout the state in 1990 to capture what the public felt was important in a monitoring program. The two biggest concerns expressed by members of the public were the protection of cold water fish habitat and domestic water supplies. They also stated that the monitoring program being developed should be able to detect changes in these beneficial uses resulting from timber operations (CDF 1991). The MSG used the information collected by Kier to write a detailed report for the BOF (BOF 1993). This document stressed the need for both implementation and effectiveness monitoring, as well as the value of a pilot project to develop appropriate techniques for both instream and hillslope monitoring. The Pilot Monitoring Program was completed during 1993 and 1994, and reports documenting the work were written in 1995. The Department of Fish and Game conducted the instream pilot work and documented training and quality control needs for several instream monitoring parameters, as well as the range in variability encountered (Rae 1995).

For the hillslope component of the pilot program, Dr. Andrea Tuttle and CDF modified previously developed U.S. Forest Service hillslope monitoring forms (USFS 1992) to allow detailed information to be recorded for locations within Timber Harvesting Plans (THPs) that were felt to present the greatest risk to water quality--roads, skid trails, landings, crossings and watercourse and lake protection zones (Tuttle 1995). The forms developed for the U.S. Forest Service monitoring program did not adequately identify the specific requirements of the Forest Practice Rules. As a result, these initial forms were either substantially modified (i.e., watercourse crossings and landings) or completely re-written (i.e., transect evaluations were developed for roads, logging operations, and watercourse and lake protection zones). Harvest units were not included because few of the Rules apply to these areas and previous studies had shown that most of the erosion features were associated with the more disturbed sites (Durgin et al. 1989).

The Monitoring Study Group members identified all of the separate Forest Practice Rule requirements that could be related to protection of water quality. This resulted in a list of over 1300 separate items, including plan development, the review process, and field application requirements. This was then pared down to 190 Rule requirements that are implemented during the conduct of a Timber Harvesting Plan and can be evaluated by subsequent field review. Cumulative watershed effects Rules and Rules related to the THP Review process were not included because they could not be evaluated using an on-the-ground inspection of the THP area. Many of the Rules were broken down into separate components to specify the multiple requirements for field evaluations.

The Division of Mines and Geology assisted with the hillslope pilot program and provided detailed geomorphic mapping for two of the watersheds used for the pilot work (Spittler 1995). Pilot Monitoring Program Manager Gaylon Lee of the SWRCB wrote a summary document and recommendations for the long-term program (Lee 1997).

Due to the fact that hillslope monitoring can provide a more immediate, cost effective and direct feedback loop to resource managers on impacts from current timber operations when compared to instream monitoring (particularly channel monitoring which involves coarse sediment parameters) (Reid and Furniss 1999), CDF and BOF chose to place more emphasis on hillslope monitoring for the Long-Term Monitoring Program. A pilot cooperative instream monitoring project is currently in progress in the Garcia River watershed, located in southern Mendocino County (Euphrat et al. 1998).

THP SAMPLE SELECTION

The CDF/BOF long-term monitoring program was officially launched in 1996, with the collection of hillslope monitoring data on 25 randomly selected THPs in both Humboldt and Mendocino Counties. The initial phase of the hillslope monitoring program was conducted on the North Coast with the goal of collecting information from watersheds with coho salmon habitat due to the recent listing of that species. Contracts were developed with the Resource Conservation Districts in each county, who in turn hired Registered Professional Foresters (RPFs) to collect the detailed field data on THPs that had over-wintered for a period of 1 to 4 years. Natural Resources Management Corporation was the contractor hired by the Humboldt County RCD, while R.J. Poff and Associates was hired by the Mendocino County RCD (Figure 1). Stratified random sampling was utilized to select the THPs for the work completed in 1996. Based on erodibility ratings developed for a study completed by CDMG (McKittrick 1994), approximately 50% of the THPs were included in the areas designated as high overall erosion hazard, 35% were included in the moderate category, and 15% were included in the low erosion hazard rating.[1]

The second phase of the hillslope monitoring program—the statewide sample of THPs—was begun in 1997. CDF directly hired a contractor to collect field data on 50 randomly selected plans statewide in both 1997 and 1998. The contractor for these contracts was R.J. Poff and Associates. An RPF and an earth scientist (professional soil scientist, registered geologist or certified erosion and sediment control specialist) were required to participate in the field work. THPs were randomly selected from a state-wide pool and no longer stratified based on the CDMG erodible watershed categories utilized in 1996.

THPs were included in the random selection for 1996 through 1998 if they met the following criteria:

1. The THP had been filed and completed under the Forest Practice Rules adapted by the BOF after October 1991 (when the most recent WLPZ rules were implemented).

2. The plans selected had been through at least one but not more than four winters since logging was completed. The CDF Completion Report for the entire THP must have been signed by a CDF Forest Practice Inspector, and the date used to determine the 1-4 over-wintering periods was the date

[1] This project rated large (e.g., 50,000 ac) watersheds on their inherent erodibility, excluding land use impacts. Variables input into a GIS model included precipitation, slope, and geology. A low, moderate or high rating was assigned to each factor. Numbers were summed to create an ordinal display of relative susceptibility of watersheds to erosion.

supplied by the RPF that indicated when all the logging was completed on the THP.

3. The THP primarily involved wildlands (e.g., it is not a campground or golf course). Also, the THP was not a road-right-of-way-only plan.

4. The THP had significant components of either ground based logging and/or cable yarding systems and was not entirely helicopter logged.

5. The THP had at least 500 continuous feet of a Class I or II watercourse present.

6. The THP was at least 5 acres in size.

7. The THP was not previously sampled.

CDF's RBASE Forest Practice Database was queried from 1996 through 1998 in Santa Rosa, Redding, and Fresno to produce a combined list of potential THPs meeting the completion and acceptance dates (approximately 2,500 THPs were in the population). A randomized list was produced to provide a preliminary set of THPs to evaluate. Individual THP files were reviewed at each of the three locations to determine when the logging was completed, watercourses present, yarding system(s), size, and wildland classification. THPs eliminated from the preliminary list were replaced with the next acceptable THP meeting the above criteria, keeping the original percentages for each CDF Forest Practice District (i.e., Coast, Northern and Southern) established in the original random sort.[2] Statewide sampling, therefore, is very similar to the distribution of THPs CDF receives at each of its three Forest Practice District offices.

Permission for THP access was requested by letter with follow-up telephone calls for those where a response was not received. Where permission was not granted, the next THP on the list was used. Permission for large industrial owners was received for all but one THP. In contrast, approximately 30% of the selected THPs on small, nonindustrial timberlands were excluded from the study because of either an inability to locate the landowner, sale of the parcel, or denial of access. This resulted in the study being weighted toward the industrial timberlands (Table 1).

[2] If this were not done, a much higher percentage of THPs would have been selected from the Coast Forest Practice District, since many more of these plans have the required watercourse length.

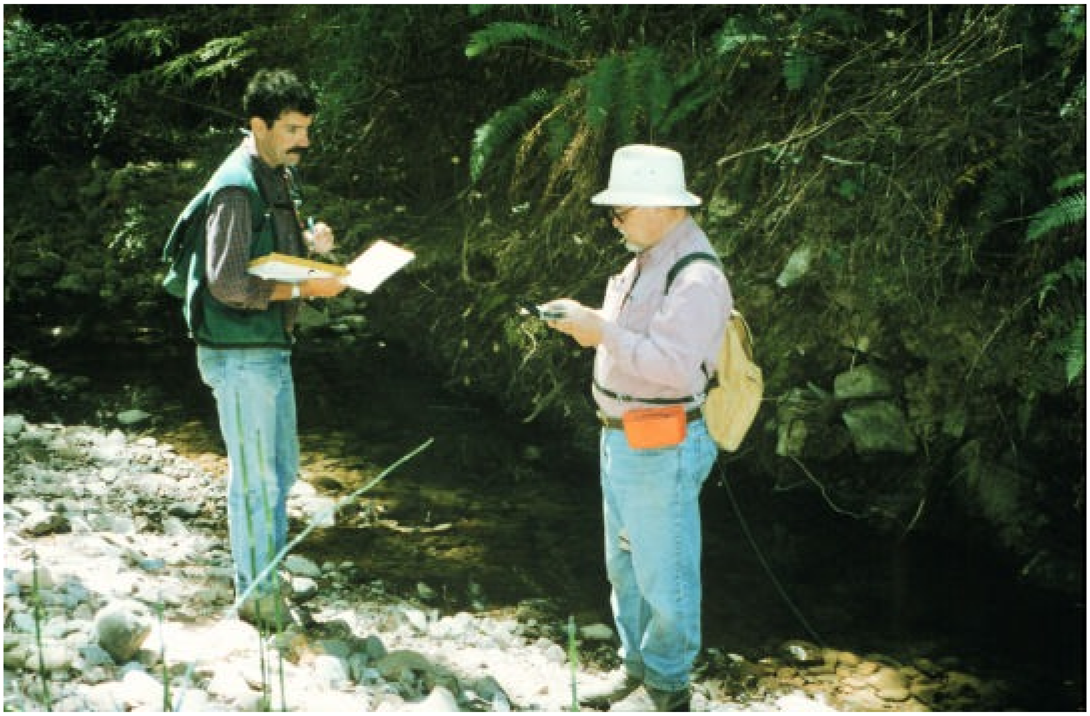

Figure 1. Cliff Kennedy and Roger Poff collecting field data in Mendocino County in 1996.

The THPs sampled from 1996 through 1998 are displayed by Forest Practice District in Table 2 (due to the exclusive sampling in the Coast Forest Practice District in 1996, the sample is disproportionately high for that District). Table 3 displays the distribution of THPs by county.

Table 1. Distribution of THPs by landowner category.

Landowner Category	THPs Selected	THPs Reviewed	Percent Selected	Percent Reviewed
Large industrial timberland owners	76	98	51	65
Small nonindustrial owners/others[3]	74	52	49	35

[3] Other types of landowners include small companies, State Forests, city properties, and water company properties.

Table 2. Distribution of THPs by Forest Practice District.

Forest Practice District	THPs	Percent
Coast	99	66
Northern	33	22
Southern	18	12

Table 3. Distribution of THPs evaluated from 1996 through 1998 by county.

County	North Coast 1996	Statewide 1997-1998	Total Number of THPs
Coast Forest Practice District			
Del Norte		6	6
Humboldt	25	17	42
Mendocino	25	21	46
Trinity		1	1
Sonoma		1	1
Santa Cruz		2	2
Santa Clara		1	1
Northern Forest Practice District			
Shasta		8	8
Butte		4	4
Lassen		2	2
Placer		2	2
Nevada		2	2
Modoc		2	2
Siskiyou		6	6
Trinity		4	4
Glen		1	1
Sierra		1	1
Yuba		1	1
Southern Forest Practice District			
Tuolumne		5	5
Amador		6	6
Calaveras		2	2
El Dorado		3	3
Fresno		2	2
Totals	**50**	**100**	**150**

METHODS

GENERAL INFORMAITON

There are five sample areas to be evaluated within each THP: landings, roads, logging operations (skid trails), watercourse and lake protection zones (WLPZs), and watercourse crossings. All five sample areas are evaluated twice within each selected THP if possible. Additionally, large erosion events are inventoried where they are encountered on the THP.

Conducting the evaluations involves both office and field activity. Office work needed to prepare for the field evaluations includes:

- Reading the THP to identify and become familiar with Review Team requirements, alternatives, in-lieu practices, mitigations, and addenda in the approved plan.

- Filling out "Site Information" sheets for each sample site. These are the top sheets in each packet. Much of this information can be obtained from the THP.

- Lay out road segment grid as described under “Site Selection” below.

SITE SELECTION

Selection of specific sample areas begins with marking approximate 500 foot road segments on all roads on the THP map. Each of these segments is assigned a number. Then a random number table or generator is used to identify one of the segments. From this point, a coin is flipped to determine a direction of travel until a landing is encountered. This randomly selected landing is used for the landing sample. Where more than one road enters or exits the landing, coin flips are used to identify a road transect that begins where the selected road leaves the landing. Coin flips are also used to determine the direction of travel to the first available skid trail transect. Watercourse crossing sites are selected as either the first crossing encountered during the road transect or, if no crossing is encountered, the first crossing along a road selected by coin flip. Finally, the closest approach of a Class I or Class II watercourse is used as the starting point for the WLPZ transect, and direction of travel along the WLPZ is determined by a coin flip. Either GPS readings or topographic maps may be used to record site locations with UTM coordinates.

FIELD ACTIVITIES COMMON TO ALL SAMPLE AREAS

A first step in the field work is to finish filling out Site Information sheets. This is followed by an effectiveness evaluation of pertinent features that present an erosion or water-quality problem, and that permit calculation of the relative proportion of problem to non-problem areas.

Sample area field evaluations are designed to provide a database "sketch" of the sites and transects that are inspected. The resulting detailed information about features is used estimate the proportion of rule or water quality problems in the whole population of similar features. This also allows evaluation of Forest Practice Rule implementation and effectiveness for protection of water quality and identification of problems requiring revisions or additions to the Rules.

At "problem" sites (such as cut bank failures, gullies, excessive grades, and rule violations), the problem type, erosion and sediment delivery site are recorded and a rule implementation evaluation is conducted. Any rills, gullies, or mass failures that are encountered as part of the transect and site inspections are followed to determine whether sediment from these erosional features reached a WLPZ or stream channel. The presence of rills, gullies or deposited sediment at the edge of the high flow or low flow channel is sufficient to class the sediment as having entered that portion of the stream.

After the field review has been completed, an evaluation of all the Rules is conducted based upon the overall frequency of problem sites and rule violations along the transect as a whole. Implementation of the Forest Practice Rules applicable to a given subject area is rated as either exceeding the requirements of the Forest Practice Rules or THP requirements, meeting the requirements, minor departure from requirements, major departure from requirements, not applicable, cannot determine (evidence is masked), or cannot evaluate (supply reason).

Major departures were assigned when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements (e.g., no or few waterbars installed for entire transect). Minor departures were assigned for slight Rule departures where there was no evidence that sediment was delivered to watercourses (e.g., WLPZ width slightly less than that specified by the Rule).[4]

[4] Minor and major departures from Rule/THP requirements have similar impact to water quality for watercourse crossings since sediment is assumed to enter the watercourse for both categories.

ROAD AND SKID TRAIL TRANSECT METHODS

Transects

The transect starting point is located using procedures described under Site Selection. Roads or skid trails that were not used as part of the THP being evaluated are not included. The starting point for the road or skid trail transect is the point at which it narrows to its "normal width" and is outside of the influence of operations on the landing. Where a road forks, the transect follows the road that is of the same general type of construction and level of use. Where a skid trail forks, the branch that continues in the same basic direction (up-hill or down-hill) as the transect to that point is followed. If there are no clear differences, a coin flip is used to determine direction. The direction that was chosen is described in the comments section to provide a record for follow-up inspections or re-measurement.

At the start of a transect, a measurement string is tied to a secure object, the string box counter is set to zero, and the location of the starting point is described in the comments for future reference. The road or trail is walked in the pre-determined transect direction for a distance of 1000 feet or to the end, whichever occurs first.[5]

If the total road distance is less than 800 feet, another transect on a different road segment is started from the landing without resetting the string box counter, and measurements are continued to get a total transect length of 1000 feet.

The minimum skid trail transect length is 500 feet. If needed, this distance can be made up of several segments. Skid trails are randomly selected from those entering the landing if possible. If a skid trail is not available at this location, the nearest trail that brought logs to the measured road segment is used. Skid trail transects are no shorter than the length of trail requiring two waterbars. If the total skid trail distance is less than 300 feet, the transect is continued from the most recently passed trail intersection. Where there has been no intersection, the transect is continued from the landing without resetting the string box counter, and the transect is continued in this fashion up to a maximum of 1000 feet. If there is less than 500 feet of skid trail, the available trail length is sampled and an explanatory comment is included. If there are no skid trials, this is noted at the start of one of the logging operations forms.

[5] Note that main-line logging roads were not sampled if drainage structures had been removed to facilitate log hauling from more recent timber operations. This type of road (i.e., native surfaced primary road with waterbars) was under sampled due to this problem.

Data Recording

The general procedure for linear transects is to record the starting and ending distance to each feature as it is encountered. On roads, for example, the beginning and ending point of all features (e.g., inside ditches, cut banks, location of waterbreaks, cross drains, etc.) are recorded, regardless of whether or not they present a water quality problem. Consecutive numbers are assigned to each feature, which, in combination with the THP and transect numbers, becomes a unique database identifier for that feature. Then codes are entered to indicate the type of feature and any associated drainage problems, erosion causes, and sediment production, plus information about road or trail gradient, sideslope steepness, and dimensions of erosion features.

LANDING METHODS

Site Identification

The landing to be evaluated is located as previously described under Site Selection. Landing selection is important because it becomes the basis for locating random sites for the other sample areas.

Landing Surface

The entire landing surface is inspected for rills and gullies. Gullies are defined as being 6" or greater in depth and of any length. The total length of all gullies and their average width and depth is recorded on the data forms. Sample points for rills were located along a single transect that bisects the landing into two roughly equal parts perpendicular to the general direction of surface runoff in 1996. The percentage of the landing surface drained by rills was estimated for 1997-1998. To be counted, rills had to be a least one inch deep and 10 feet long. Both rills and gullies are inspected to determine whether they continue for more than 20 ft. past the toe of the landing fill slope, and gullies are followed to determine if sediment has been delivered to the nearest WLPZ and channel.

Cut Slopes (if present)

The face of the cut slope is inspected for evidence of slope failures, rilling and gullying. The path of any transported sediment is traced to determine the quantity and whether material is transported to drainage structure(s) on the landing.

Fill Slopes (if present)

The toe of the fill slope is inspected for evidence of slope failures, rilling and gullying. Rills or gullies that are not caused by drainage from the landing surface are traced to determine whether they extend to a downslope channel. All slope failures are evaluated to determine the total amount of material moved and whether the material moved reaches a stream channel.

WATERCOURSE CROSSING METHODS

Site Identification

A watercourse crossing site is established at the first crossing encountered in the road or skid trail transects, and is noted as a feature on the transect. If no crossing is encountered as part of the transects, the first crossing beyond the end of the road transect is used for this evaluation.

Once the crossing has been identified, the next step is to determine the length of road to be included. This is done by walking in both directions from the crossing and identifying the points where runoff from the road surface, cuts, and fills no longer carries toward the stream crossing. The road length for evaluation also includes the cut-off waterbar that should route water away from the crossing.

Fill Slopes

The crossing fill slope is evaluated to determine whether it has vigorous dense cover or if at least 50% of its surface is protected by vegetation, mulch, rock, or other stable material. The presence and frequency of rills, gullies and cracks or other indicators of slope failure are noted, and the size of rills and slope failures is recorded.

Road Surface

The type and condition of road surfacing is assessed and is evaluated for ruts from vehicles and, if ruts are present, whether they impair road drainage. The presence, frequency and length of rills and gullies on the road surface are also determined along with average gully size and surface drainage conditions. The presence, condition, and effectiveness of cutoff waterbars and inside ditches is evaluated along with evidence of ponding or other water accumulation on the road.

Culverts

The stream channel at both the culvert inlet and outlet is examined for evidence of scouring. The potential for plugging at the upstream inlet is assessed along with the diversion potential in case the culvert does become plugged. Alignment of the culvert, crushing of the inlet and outlet, and degree of corrosion are also evaluated. Pipe length and gradient are determined and evidence of piping around the culvert is identified.

Non-Culvert Crossings (e.g., Rocked Class III crossings)

The crossing is examined to determine the type and condition of armoring and whether downcutting or scouring at the outlet is occurring. Crossing approaches are evaluated to determine if they have been maintained to prevent diversion of stream overflow down the road should the drainage structure become plugged.

Removed or Abandoned Crossings (where applicable)

Removed crossings are examined to determine whether the restored channel configuration is wider than the natural channel and as close as feasible to the natural watercourse grade and orientation. The location of excavated material and any resulting cut bank are assessed to determine if they are sloped back from the channel and stabilized to prevent slumping and minimize erosion. The crossing is also evaluated for the following conditions:

- Permanent, maintenance free drainage.
- Minimizing concentration of runoff, soil erosion and slope instability.
- Stabilization of exposed soil on cuts, fills or sidecast that prevents transport of deleterious quantities of eroded surface soils to a watercourse.
- Grading or shaping of road surfaces to provide dispersal of water flow.
- Pulling or shaping of fills or sidecast to prevent discharge of materials into watercourses due to failures of cuts, fills or sidecast.

WLPZ TRANSECT METHODS

Transects

Two WLPZs are sampled on each THP, when available (transects may be shorter than 1000 feet, but must be at least 500 feet to be included). These WLPZ segments are located along the nearest, accessible Class I or II watercourse relative to the selected landing sites. When WLPZs are present near only one of the selected landings, both segments are selected from this location. And where there is only one WLPZ on the THP, both segments may be located along the same watercourse but, where possible, should represent different conditions (e.g., different stream classes, stream gradients, sideslope gradients, adjacent logging methods, etc.).

For Class I waters, two 1000 foot long transects are sampled parallel to the stream within the WLPZ. One of these is a "mid-zone" transect located between the watercourse bank and the up-slope boundary of the WLPZ. The other is a "streambank" transect located immediately along the stream bank and parallel to the mid-zone transect. For Class II watercourses, only the mid-zone transect is used.

Data Recording

Within the transects, groundcover and canopy cover are evaluated at regular intervals and at disturbed sites where timber operations have exposed more than 800 continuous square feet of mineral soil. Several other factors are also evaluated wherever they occur, such as sediment delivery to the channel, streambank disturbance, and channel conditions.

Parameters estimated in the mid-zone transect include groundcover at every 100 feet, canopy cover at every 200 feet, WLPZ width at every 200 feet (concurrent with canopy measurement) and whenever there is a change in sideslope class, and sediment to the channel wherever it occurs. Measurements in the Class I watercourse streambank transect include canopy cover at 200 foot intervals, disturbance to streambanks wherever it occurs, and other stream related features. In addition, rule implementation is evaluated continuously along both transects, and any rule requirements or discrepancies are noted as a feature and are included in the implementation evaluation.

The general procedure for recording WLPZ transect data and the use of codes is similar in format to the methods used for roads and skid trails, but with features that are specific to WLPZ conditions and rule requirements. As with roads, the starting and ending distance to each feature is recorded along with a unique identification number and information about feature type, erosion causes, dimensions of erosion features, and sediment deposition.

Groundcover is estimated in an area with a diameter of approximately one foot located directly in front of the observer's boot toe, where adequate cover is defined as "living plants, stumps, slash, litter, humus, and surface gravel (minimum diameter of 3/4 inch) in amounts sufficient to break the impact of raindrops and serve as a filter media for overland flow." To date, canopy cover has been measured using a spherical densiometer (Figure 2). However, future measurements will be made using sighting tube transects with randomly located starting points to reduce the potential for bias resulting from overstory conditions in areas adjoining the measurement site (Robards et al. 1999) (Figure 3).

Features do not need to intersect the transect line to be included. This is necessary because dense vegetation and other obstructions in WLPZs make a straight line transect impractical to accomplish, so the location of the transect line will be biased by access within the WLPZ, and some extensive WLPZ features may not intersect the transect, as would be the case with a road running parallel to, but not on, the transect. In cases of steep terrain and limited visibility, identifying features at a distance from the transect line is benefited by the assistance of a second person who is not limited by the string box and can move about within the WLPZ.

The WLPZ measurements begin at one end of the mid-zone transect and include a continuous record of the beginning and end points of features encountered along the transect for a distance of 1000 feet. The streamside transect begins at a point perpendicular to the end of the mid-zone transect and proceeds in the opposite direction toward the starting point of the mid-zone transect.

LARGE EROSION EVENT EVALUATION METHODS

Erosion events with voids larger than 100 cubic yards are assessed whenever they are encountered on the THP. For watercourse crossings that have failed, a large erosion event is defined as greater than 10 cubic yards. These sites may be identified during the standard site evaluations, while traveling within the THP, or as a result of information provided by landowners or managers. Information collected includes the location, size, and type of feature, and an evaluation of the causal connections between the feature and specific timber operations, along with any applicable Forest Practice Rules.

If more than five large erosion events are discovered on a THP, only the first five are required to be completely evaluated by the field team. For additional events, only the location, type, and estimate of the cause are briefly noted.

DATABASE DEVELOPMENT

The Hillslope Monitoring Database was developed in Microsoft Access for Windows (Microsoft Office 97) and runs on a personal computer. It is a relational database, approximately 30 megabytes in size, and flexible enough to accommodate monitoring form changes. A preliminary set of queries has been developed that is the basis for the results presented in this report. Future queries and sorts will provide more information on Forest Practice Rule implementation and effectiveness. As an example, queries are planned to provide information about how geologic type affects the frequency of erosion events on road transects.

Figure 2. Concave spherical densiometer with the Strickler (1959) modification.

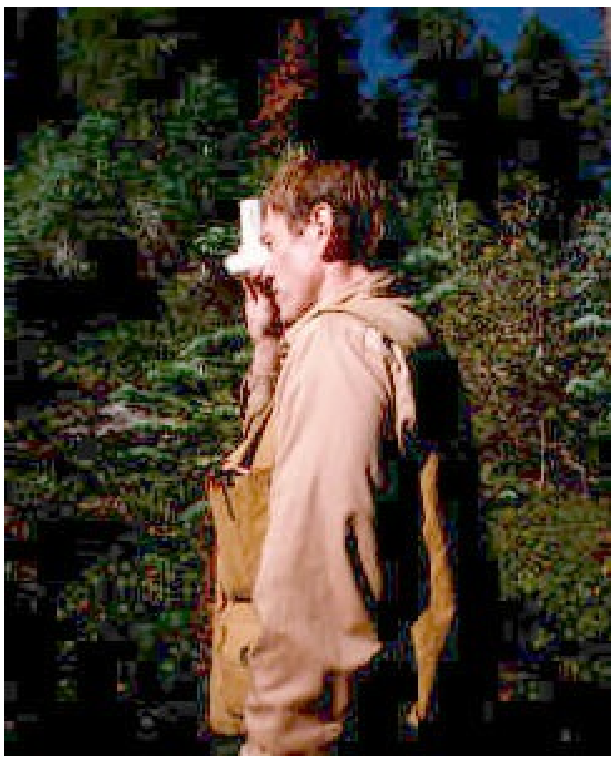

Figure 3. Sighting tube use for unbiased estimate of canopy cover.

RESULTS

The results of the hillslope monitoring conducted to date are summarized by major category: roads, logging operations, landings, watercourse crossings, watercourse and lake protection zones, and large erosion events. The data that are presented are frequency counts; detailed statistical tests have not been run to date. Statistical tests that involve categorical data, such as the implementation data, will require large sample sizes which generally are not available at this time (Lewis and Baldwin 1997). Future reports on the Hillslope Monitoring data will include the results of statistical tests when sample sizes are appropriate.

ROADS

From 1996 through 1998, 292 randomly located road transects were evaluated, for a total of 279,150 feet (52.87 mi.). Approximately 81% of the road transects were classified as seasonal, 12% as permanent, 5% as temporary, and 2% as a combination of road types. About 29% of the road length reviewed had been surfaced with rock.

Upon completing the evaluation of the randomly located 1000 foot road transect, the field team rated the overall implementation of specific Forest Practice Rules that relate to roads and water quality (Table A-1). A total of 59 questions were answered in the field based on 46 Forest Practice Rules, since some Rules were broken down into separate components. Most of the Forest Practice Rules evaluated on road transects had high percentages (i.e., greater than 90%) of cases where implementation ratings either met or exceeded the standard Rule. For Forest Practice Rules where the sample size was adequate [6], 22 Rule requirements were found to have combined minor and major departures greater than 5% (Table 4). However, the majority of the implementation ratings that triggered Rules to be displayed in Table 4 were for minor departures from Rule requirements.

The Rules with the highest numbers of departures were related to waterbreak spacing, maintenance, and construction standards; adequate number, size,

[6] For all categories (i.e., roads, skid trails, landings, watercourse crossings, and WLPZs), there had to have been at least **30** observations where field team assigned an implementation rating of exceeded rule requirement, met requirement, minor departure from requirement, or major departure from requirement. Thirty observations represents 10% or more of the implementation ratings in all cases.

Table 4. Road related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that some Rules are broken into component requirements, table is ordered by total departures).[7]

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
914.6(c)	Waterbreak spacing according to standards	20.1	2.7
923.1(f)	Adequate numbers of drainage facilities provided to minimize erosion	16.7	3.1
923.4(c)	Waterbreaks maintained to minimize erosion	16.7	2.7
923.2(h)	Drainage structures of sufficient size, number and location to carry runoff water	13.9	3.2
923.2(h)	Drainage structures of sufficient size, number and location to minimize erosion	14.4	2.5
923.2(b)	Sidecast minimized for slopes>65% for distances >100 feet	16.7	0
914.6(g)	Waterbreaks have an embankment of at least 6 inches	12.1	1.4
923.2(o)	Discharge onto erodible fill prevented	10.4	1.9
914.6(f)	Waterbreaks installed to discharge into cover	12.3	0
923.1(a)	If landing on road >1/4 ac or required substantial excavation-shown on map	7.3	4.8
914.6(g)	Waterbreaks constructed with a depth of at least 6 inches cut into firm roadbed	11.0	0.9
923.2(p)	Waterbreaks installed according to standards in 914.6	9.4	1.0
923.1(d)	For slopes >65% or 50% within 100 ft of WLPZ, soil treated to minimize erosion	8.2	2.0
914.6 (f)	Where waterbreaks don't work--other erosion controls	7.0	0.9
923.4 (j)	Drainage ditches maintained to allow flow of water	7.3	0
923.2 (d) C	Fills constructed with insloping approaches, etc.	6.1	1.2
923.2 (d) N	Breaks in grade above/below throughfill	7.0	0
923.6	Wet spots rocked or otherwise treated	6.7	0
923.1 (a)	Road shown on THP map correctly	5.6	0.3
923.4 (c)	Erosion controls maintained during maintenance period	5.9	0
923.2(l)	Trash racks, etc. installed where appropriate	5.6	0
923.2 (m)	Sidecast extending >20 ft treated to avoid erosion	2.6	2.6

[7]Major departures were assigned when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements (e.g., no or few waterbars installed for entire transect). Minor departures were assigned for slight Rule departures where there was no evidence that sediment was delivered to watercourses (e.g., WLPZ width slightly less than that specified by the Rule).

and the location of drainage structures to minimize erosion; prevention of discharge onto erodible fill; and sidecast limitations on steep slopes. Erosion problem points (i.e., rills, gullies, cutbank or sidecast sloughing, mass failures) were described on the road transects where they were encountered. A total of 727 erosion problem points associated with the sampled THPs were noted. While some road transects had no erosion problem points, the overall average equated to one problem point for every 380 feet of road. The distribution of erosion features associated with current Timber Harvesting Plans are summarized in Table 5. Total erosion volumes from cutbank/sidecast sloughing, mass failures, and gullying were approximately 1990, 3010, and 1050 yds^3, respectively.[8] These estimates are the volumes of voids remaining at hillslope locations, not the amount of sediment delivered to watercourse channels. When a problem point was discovered, implementation of the appropriate Forest Practice Rule(s) was also rated. A total of 41 Rule requirements were rated for implementation at erosion problem points along road transects. Of these, 13 were responsible for approximately 90% of the problem points associated with roads (Table 6).

Table 5. Erosion features found on road transects created by the current THP.

Erosion Feature	Number of Features
Cutbank/sidecast sloughing	80
Mass Failure	18
Gullying	148
Rilling	478
Other Erosion Features	3

From Table 6, it is clear that the vast majority of the problem points noted along the road transects were judged to be due to either minor or major departures from specific Forest Practice Rule requirements. When considering all the implementation ratings assigned at erosion problem points encountered, only 3.1% were associated with situations where the Forest Practice Rule requirements were judged to have been met or exceeded and 96.9% were associated with minor or major departures from the Rule requirements. In other

[8] Note that rilling volumes were not determined. Erosion from rilling is generally a much smaller component when compared to that from mass wasting and gullying. For example, Rice et al. (1979) found that rilling accounted for only 3% of total hillslope erosion following tractor logging in the South Fork Caspar Creek watershed. Other volumes listed are to be considered preliminary data. Only when lengths, depths, and widths were all greater than 1 foot were volumes calculated to make these estimates. Additionally, all the width, depth and length data were rounded to the nearest integer. Efforts are now underway to revise these calculations and use the one-tenth foot values available for width and depth estimates.

Table 6. Forest Practice Rules that account for approximately 90% of all the Rule requirements rated for implementation at erosion problem points along road transects.

Forest Practice Rule	# of Times FPR Cited	Description of Rules Rated for Implementation where Problems Occurred	Exceeds/ Met Rule (%)	Minor (%)	Major (%)
923.1(f)	254	Adequate number of drainage facilities to minimize erosion	4.7	83.9	11.4
923.2(h)	240	Drainage structures of sufficient size, number and location to minimize erosion	7.9	78.3	13.8
923.2(h)	226	Drainage structures of sufficient size, number and location to carry runoff water	0.4	86.7	12.8
914.6(c)	195	Waterbreak spacing according to standards	6.2	80.0	13.8
923.4(c)	134	Waterbreaks maintained to minimize erosion	0	69.4	30.6
914.6(f)	125	Waterbreaks discharge into cover	0	98.4	1.6
923.2(o)	119	Discharge onto erodible fill prevented	0	95.8	4.2
914.6(g)	71	Waterbreaks have embankment of at least 6 inches	0	77.5	22.5
914.6(g)	61	Waterbreaks cut to depth of 6 inches	0	73.8	26.2
923.2(p)	51	Waterbreaks installed according to 914.6	11.8	66.7	21.6
914.6(f)	28	Where waterbreaks are not effective, other erosion controls installed as needed	0	89.3	10.7
923.4(i)	25	Soil stabilization treatments installed on cuts, fills, or sidecast to minimize surface erosion	4.0	88.0	8.0
923.4(j)	19	Drainage ditches maintained to allow free flow of water	15.8	84.2	0

words, nearly all of the problems resulted from non-compliance. For a small percentage of the problem points, even though properly implemented, the Rule(s) still resulted in erosion problems.[9]

Table 7 displays the counts of road drainage structures inventoried with and without problem points. From the total population of waterbreaks evaluated, approximately 10% did not conform to the requirements of the Rules. Rolling dips and culverted cross drains had deficiencies 7% and 5% of the time, respectively. Note that multiple types of Rule requirement violations are possible at each drainage structure with a problem. Therefore the sum of drainage structures with problems will be less than the counts for major and minor Rule departures.

[9] Lewis and Baldwin (1997) suggested in their statistical review of this project that implementation would have to be rated immediately following the completion of logging and prior to stressing storm events to remove observer bias. That is, it is likely that some percentage of the problem points might not have been classed as Rule departures if they had been evaluated at the end of timber operations. The percentage of departures for which this is true is unknown. CDF's Modified Completion Report will provide information on implementation following harvesting that may help us address this problem.

Table 7. Counts of drainage structures evaluated along road transects with and without problems.

Drainage Structure Type	Total Number	Count–No Problem	Count—Problem	% with Problems
Waterbreaks	1,055	957	98	9.3
Rolling Dips	271	251	20	7.4
Leadoff Ditch	138	136	2	1.5
Culvert cross drain	137	130	7	5.1
Other drainage structure	38	37	1	2.6

Information recorded during the road transect evaluations allows us to determine the source, cause, and depositional area associated with the erosion features. Table 8 displays the different types of erosion and percentages of features associated with varying types of source areas. Cutbank and sidecast sloughing came predominantly from road cutbanks, with a lesser component from fill slopes. Mass failures were associated mostly with fill slopes, with much smaller components from cutslopes and hillslopes above the road. Gullying was more equally distributed through all the source codes, but the major sources were waterbar outlets, fill slopes, and road surfaces, respectively. Rilling, in contrast, was nearly always associated with the road surface.

Erosion cause codes are displayed in Table 9.[10] Most of the observed cutbank and sidecast sloughing was associated with cut slopes that were judged to be either too steep or too tall. Other frequently cited codes for contributing causes

Table 8. Number (and percentage) of the source location of the recorded erosion features for road transects (note that multiple source codes can be assigned to single erosion features).

Source	Sloughing	Mass Failure	Gullying	Rilling
Cut Slope	38 (70.4)	2 (11.8)	4 (2.7)	5 (1.1)
Fill Slope	9 (16.7)	12 (70.6)	30 (20.0)	15 (3.2)
Road Surface	1 (1.9)	1 (5.9)	24 (16.0)	388 (83.6)
Hillslope Above Road	4 (7.4)	2 (11.8)	6 (4.0)	7 (1.5)
Hillslope Below Road	1 (1.9)	0	0	0
Inside Ditch	0	0	14 (9.3)	6 (1.3)
Rolling Dip Outlet	0	0	10 (6.7)	1 (0.2)
Waterbar Outlet	1 (1.9)	0	54 (36.0)	35 (7.5)
Waterbar Ditch	0	0	4 (2.7)	3 (0.6)
Rolling Dip Ditch	0	0	2 (1.3)	1 (0.2)
Other	0	0	2 (1.3)	2 (0.6)
Total	54 (100)	17 (100)	150 (100)	464 (100)

[10] Note that more than one cause code could be recorded for an erosion event.

were steep side slopes, unstable fill, and highly erodible surface material. Unstable slopes, steep side slopes, and unstable terrain were the most commonly cited cause codes associated with mass failures. More than three-quarters of the observed gullying was coded as being associated with drainage feature problems. Approximately 10% of the time, highly erodible surface material was also listed as a cause of the observed gully. Finally, over 60% of the rilling was associated with drainage feature problems, with highly erodible surface material and steep road gradient being less frequently cited cause codes.

Because drainage feature problems were the most commonly cited cause for gullying and rilling, additional detail for this category is displayed in Table 10. For gullying, spacing of drainage structures (judged to be too wide) was the most frequently cited problem, closely followed by cover (drainage structure did not discharge into vegetation, duff, slash, rocks, etc.). Inappropriate location of the drainage structure was the third most frequently cited drainage problem. The results for rilling are similar to those for gullying. Spacing of drainage structures was cited over 70% of the time when rilling was encountered, with cover being recorded about 8% of the time. Drainage feature problems were often not cited as being associated with mass failures. When they were, shotgun outlets without armoring, plugged culvert inlets, cover, and maintenance were the most frequently cited problems. Similarly, sloughing was usually not associated with drainage feature problems, as illustrated by the fact that the most commonly cited drainage feature problem was the "other" category.

Table 9. Number (and percentage) of recorded erosion cause codes that contributed substantially to development of recorded erosion features on road transects (note that multiple cause codes can be assigned to a single erosion feature).

Cause	Sloughing	Mass Failure	Gullying	Rilling
Drainage feature problem	2 (2.6)	4 (10.8)	124 (76.5)	322 (61.1)
Highly erosive surface	8 (10.5)	3 (8.1)	16 (9.9)	95 (18.0)
Other	4 (5.3)	4 (10.8)	8 (4.9)	12 (2.3)
Steep road gradient	0	0	5 (3.1)	51 (9.7)
Unstable fill	9 (11.8)	10 (27.0)	4 (2.5)	0
Rutting	0	0	3 (1.9)	27 (5.1)
Steep side slopes	11 (14.5)	8 (21.6)	1 (0.6)	15 (2.8)
Unstable terrain	7 (9.2)	6 (16.2)	1 (0.6)	1 (0.2)
Cut slope too long	1 (1.3)	0	0	1 (0.2)
Cut slope too steep	16 (21.1)	1 (2.7)	0	1 (0.2)
Cut slope too tall	18 (23.7)	1 (2.7)	0	2 (0.4)
Total	76 (100)	37 (100)	162 (100)	527 (100)

The location of sediment deposition resulting from these various types of erosion features is of critical concern when addressing protection of beneficial uses of water. Figure 3 displays the sediment deposition categories for the various types of erosion features previously described above. Only 6% of the sloughing features were found to have transported sediment to the channel; another 3% had material transported into the WLPZ. For gullying, about 18% of features had sediment transported into the channel, with another 3% deposited in the WLPZ. Mass wasting resulted in sediment transported into the channel 47% of the time, and material entering the WLPZ an additional 3% of the time. Finally, rilling features had sediment deposited in channels 13% of the time, with an additional 3% deposited in the WLPZ.

Table 10. Number (and percentage) of drainage feature problems associated with erosion features on road transects (note that multiple drainage feature codes can be assigned to a single erosion feature).

Drainage Feature Problem	Sloughing	Mass Failure	Gullying	Rilling
Spacing	1 (10)	0	73 (36.0)	342 (70.5)
Cover	2 (20)	1 (20)	67 (33.0)	39 (8.0)
Location Inappropriate	0	0	26 (12.8)	16 (3.3)
Divert	0	0	10 (4.9)	32 (6.6)
Maintenance	0	1 (20)	7 (3.4)	33 (6.8)
Flow	0	0	7 (3.4)	7 (1.4)
Other	4 (40)	0	5 (2.5)	5 (1.0)
Rolling dip break	0	0	3 (1.5)	4 (0.8)
Shotgun outlet w/out armoring	1 (10)	2 (40)	2 (1.0)	0
Runoff escaped	0	0	2 (1.0)	2 (0.4)
Blocked ditch	2 (20)	0	1 (0.5)	2 (0.4)
Plugged inlet	0	1 (20)	0	0
Height	0	0	0	3 (0.6)
Total	10 (100)	5 (100)	203 (100)	485 (100)

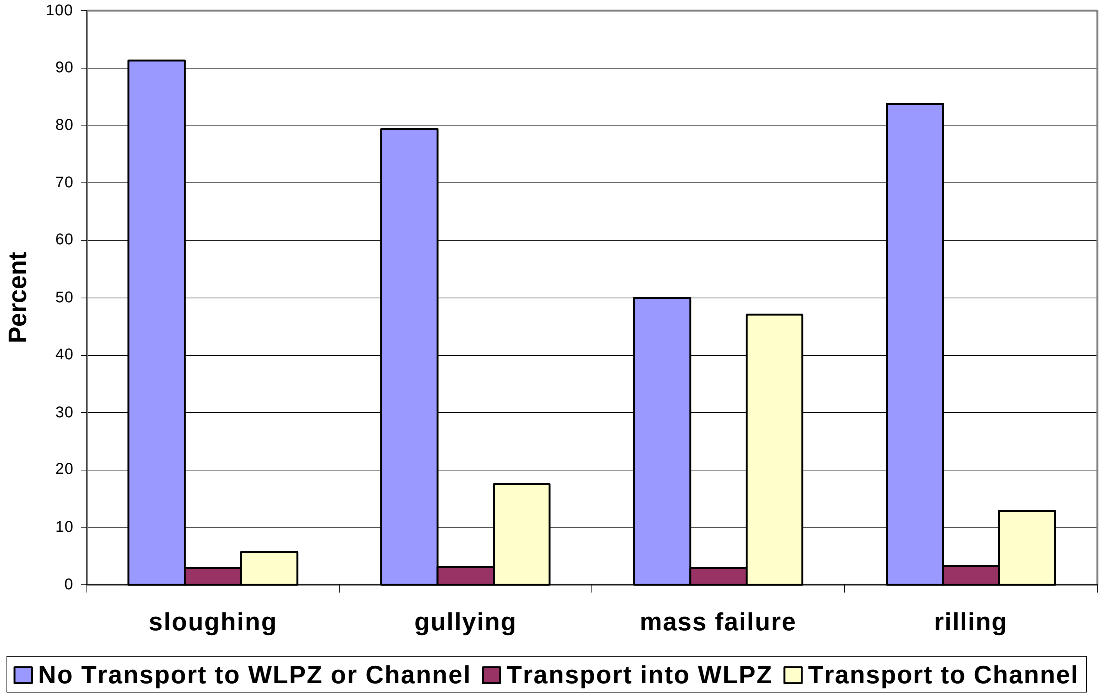

Figure 4. Sediment deposition sites for erosion features produced from current THPs and associated with road transects (percent of the number of occurrences for each feature type).

Logging Operations (Skid Trail Transects)

The logging operations component of the hillslope monitoring program sampled 246 randomly located skid trail transects, for a total of 173,976 feet (32.95 mi.). For THPs that had been yarded exclusively with cable systems, this portion of the field work was omitted. Field procedures and forms are similar for both roads and logging operations—except that implementation ratings are assigned for Forest Practice Rules relating to ground skidding operations and the site information recorded is somewhat different. Therefore, results will be presented in a similar manner.

Overall implementation ratings of the Forest Practice Rules relating to logging operations on skid trail transects are displayed in Table A-2. A total of 26 questions were developed from 22 Forest Practice Rules. Table 11 shows that for Rule requirements with at least 30 observations, three Rules were found to have more than 5% major and minor departures. The highest percentage of departures from Forest Practice Rule requirements were for Rules specifying the installation of other erosion control structures where waterbreaks cannot disperse runoff, waterbreak spacing, and waterbreak maintenance.

Table 11. Skid trail related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that table is ordered by total departures).

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
914.6 (f)	Where waterbreaks cannot disperse runoff, other erosion controls installed as needed	19.7	3.9
914.6(c)	Waterbreak spacing equals standards	11.0	4.7
923.4 (c)	Waterbreak maintained to divert runoff water	7.1	0.4

Problem points were described along skid roads where they were observed by the field team. A total of 148 erosion problem points were recorded that could be attributed to the current THP, equating to an average of one problem point for every 1,175 feet of skid trail evaluated. Eight Forest Practice Rule requirements were associated with significant numbers of erosion problem points (Table 12). All of the problem points encountered along skid trails were judged to be due to either minor or major departures from specific Forest Practice Rule requirements. The total count of waterbreaks along skid trail transects was 1,614. Sixty-four of these waterbreaks were inventoried as problem points that did not conform to the requirements of the Rules. This equates to approximately 4% of all waterbreaks.

Erosion features associated with current Timber Harvesting Plans are summarized in Table 13. Gullying, rilling, and mass failures were recorded in roughly the same percentages as were recorded for the road transects--but much less frequently. Total erosion volumes for gullying, mass failure, and cutbank/sideslope sloughing were approximately 200, 1070, and 5 yds^3, respectively.[8] These estimates are the volumes of voids remaining at hillslope locations, not the amount of sediment delivered to watercourse channels.

Table 12. Forest Practice Rules that account for approximately 90% of all the Rules rated for implementation at problem points along skid trail transects.

Forest Practice Rule	# of Times FPR Cited	Description of Rules Rated for Implementation where Problems Occurred	Exceeds/ Met Rule (%)	Minor (%)	Major (%)
914.6(c)	68	Waterbreak spacing equal standards	0	85.3	14.7
914.6(f)	37	Waterbreaks discharge into cover	0	100	0
914.6(f)	29	If waterbreaks inappropriate—other structures installed to minimize erosion	0	89.7	10.3
923.4(c)	28	Waterbreaks maintained to divert runoff	0	100	0
914.6(f)	28	Waterbreaks built for unrestricted discharge at lower end	0	100	0
914.6(g)	23	Waterbreaks installed diagonally	0	100	0
914.6(g)	23	Waterbreaks have embankments 6 in high	0	87.0	13.0
914.6(f)	20	Waterbreaks installed to spread runoff water to minimize erosion	0	90.0	10.0

As with the road evaluations, information recorded along the skid trail transects included the source, cause, and deposition associated with these erosion features. Cutbank and sidecast sloughing originated entirely from cut slopes, while 95% of skid trail rilling was associated with the skid trail surface. Mass failures were mostly from cut and fill slopes. Greater than 70% of the gully erosion was associated with the skid trail surface, of which 20% was related to waterbar outlets.

Table 13. Erosion features created by the current THP found on skid trails.

Erosion Feature	Number of Features
Gullying	35
Mass Failure	6
Cutbank/Sidecast Sloughing	3
Rilling	104

Erosion cause codes are displayed in Table 14. Approximately 60% of the rilling was associated with drainage feature problems, with highly erosive surface material (21%) and steep trail gradients (10%) also being cited frequently. Similarly, 60% of the gullying was caused by drainage feature problems, with steep trail gradient (12%) and highly erosive surface material (12%) also cited. About 40% of the mass failures on skid trails were judged to be caused by unstable terrain, with unstable fill and steep side slopes also mentioned.

The most frequently cited drainage feature problems for rilling were spacing of waterbreaks (68%), incomplete diversion of water by waterbreaks (12%), and inappropriate location (11%). For gullying, spacing was recorded 58% of the time, with inappropriate location (16%) and lack of discharge into cover (11%) cited frequently as well.

Table 14. Number (and percentage) of erosion cause codes that contributed substantially to development of recorded erosion features on skid trail transects (note that multiple cause codes can be assigned to a single erosion feature).

Cause	Sloughing	Gullying	Mass Failure	Rilling
Drainage feature problem	0	25 (59.5)	0	64 (60.4)
Highly erosive surface material	1 (33.3)	5 (11.9)	1 (8.3)	22 (20.8)
Steep trail gradient	0	5 (11.9)	0	11 (10.4)
Steep side slopes	1 (33.3)	2 (4.8)	2 (16.7)	2 (1.9)
Other	0	2 (4.8)	1 (8.3)	5 (4.7)
Unstable fill	0	2 (4.8)	3 (25)	1 (0.9)
Organic matter in fill	0	1 (2.4)	0	0
Cut slope too steep	1 (33.3)	0	0	0
Unstable terrain	0	0	5 (41.7)	0
Rutting	0	0	0	1 (0.9)
Total	3 (100)	42 (100)	12 (100)	106 (100)

Figure 4 shows the frequency of sediment deposition sites for rilling and gullying. Sloughing and mass failures are not included because of the small number of occurrences. Approximately 4% of the rills deposited sediment into watercourses; another 4% deposited material into the WLPZ.[11] For gullying, 26% deposited material into channels, with another 5% depositing material into the WLPZ.

[11] Euphrat (1992) documented little transport of sediment to watercourse channels from skid trails in the Mokelumne River watershed.

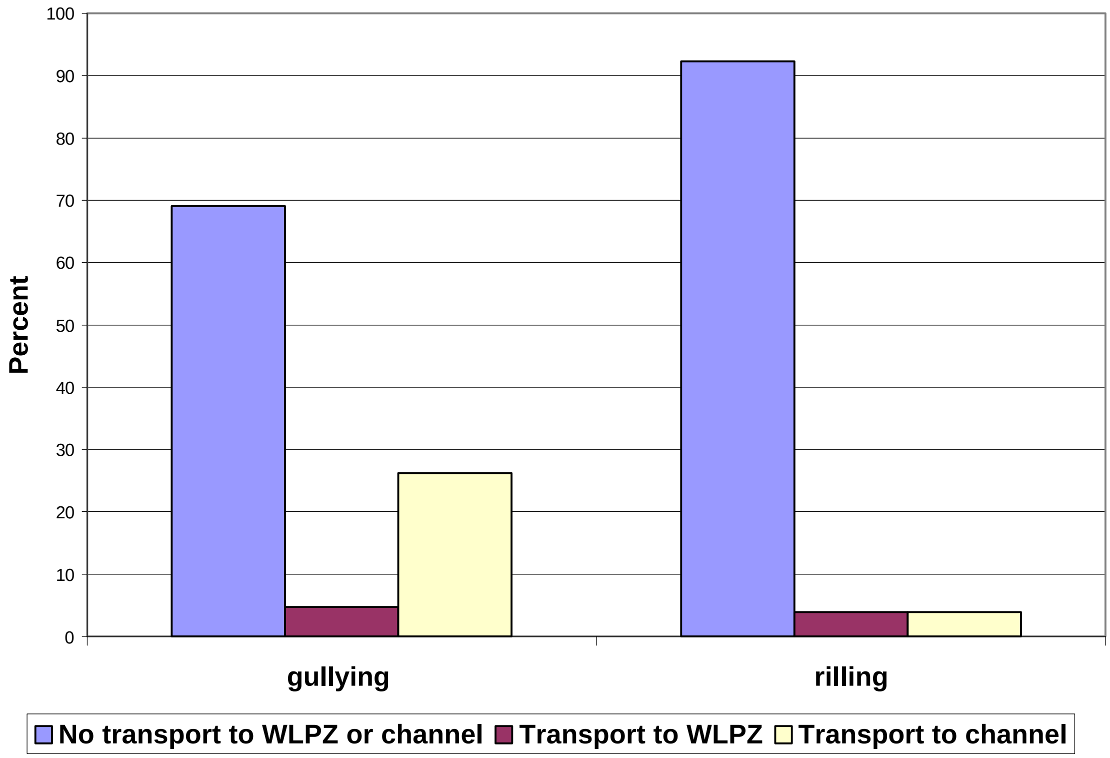

Figure 5. Sediment deposition sites for rilling and gullying produced from current THPs and associated with skid trail transects.

Landings

A total of 291 landings were evaluated as part of the Hillslope Monitoring Program from 1996 through 1998. Approximately 53% of the landings were more than 300 feet from the nearest watercourse receiving drainage off the landing, and 85% were more than 100 feet away. About 87% were constructed on slopes less than 45%, and 48% were built on slopes less than 30%. The landings evaluated were constructed on the “nose of a ridge”, above a break in slope, or on a ridge top 84% of the time.

Overall implementation ratings of the Forest Practice Rules relating to landings are displayed in Table A-3. A total of 23 questions were developed from 20 Forest Practice Rules. Table 15 shows that for Rule requirements with at least 30 observations, four were found to have more than 5% major and minor departures. The Rule with the highest percentage of total departure was 923.1(a), which requires the RPF to map landings greater than one-quarter acre in size, or those requiring substantial excavation. About 10% of the landings were judged to have either minor or major departure from the Forest Practice Rule requiring adequate numbers of drainage facilities. Rules requiring treatment of fill material when it has access to a watercourse and rocking of wet areas had smaller percentages of departures from stated requirements.

Table 15. Landing related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that table is ordered by total departures).

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
923.1(a)	Landings>1/4ac or substantial excavation--shown on THP map	11.0	5.9
923.1(f)	Adequate #s of drainage structures	9.0	1.5
923.5(f)(2,4)	Fill extending 20ft with access to watercourse—treated	8.5	0
923.6	Wet spots rocked or treated	6.5	0

Problem points were described for specific components of landings where they were observed by the field team. A total of 36 problem points were recorded, equating to an average of approximately one problem point for every eight landings evaluated. While seven Forest Practice Rules were cited as being poorly implemented causing these problem points, only 923.1(f) which requires adequate drainage structures, was cited frequently (Table 16). All of the problem points encountered at landings were judged to be due to either minor or major departures from specific Forest Practice Rule requirements.

Table 16. Forest Practice Rules that account for approximately 90% of all the Rule requirements rated for implementation at problem points for landings).

Forest Practice Rule	# of Times FPR Cited	Description of Rules Rated for Implementation where Problems Occurred	Exceeds/ Met Rule (%)	Minor (%)	Major (%)
923.1(f)	24	Adequate #s of drainage structures	0	79.2	20.8
923.5(f)(3)	6	Sloped/ditched to prevent erosion	0	83.3	16.7
923.8	3	Abandonment-minimize concentration of runoff	0	100	0
923.5(f)(2)	2	Ditches associated with the landing clear of obstructions	0	100	0

The problem points associated with the landings evaluated are displayed in Table 17. The majority of the problems were associated with either fill slopes or surface drainage features. Presence of significant erosion features (rills or gullies) below the edge of the landing surface associated with drainage structure outlets were the most frequently cited type of problem encountered. Significant amounts of sediment transport were cited as problem points on only four occasions.

Table 17. Distribution of problem points noted at landings.

Type of Problem	Cut Slopes	Fill Slopes	Surface	Below Edge of Landing
Mass Failures	1	3		
Gullies		6		
Rilling	1	3	4	
Rilling/Gullying				14
Sediment Transport		1	3	

The complete summary of the landing effectiveness questions is displayed in Table A-4. Rills or gullies resulting from concentrated flow at drainage structure outlets were present about 28% of the time, and erosion features extending beyond 20 feet below the edge of the landing were found slightly more than 5% of the time.

The location of sediment deposition originating from landing surfaces and fill slopes was also evaluated (Figure 5). For fill slopes, 2% of the time material entered channels, with another 3% reaching the WLPZ. Similarly for surface drainage, 1.5% reached channels, with another 5% reaching the WLPZ.

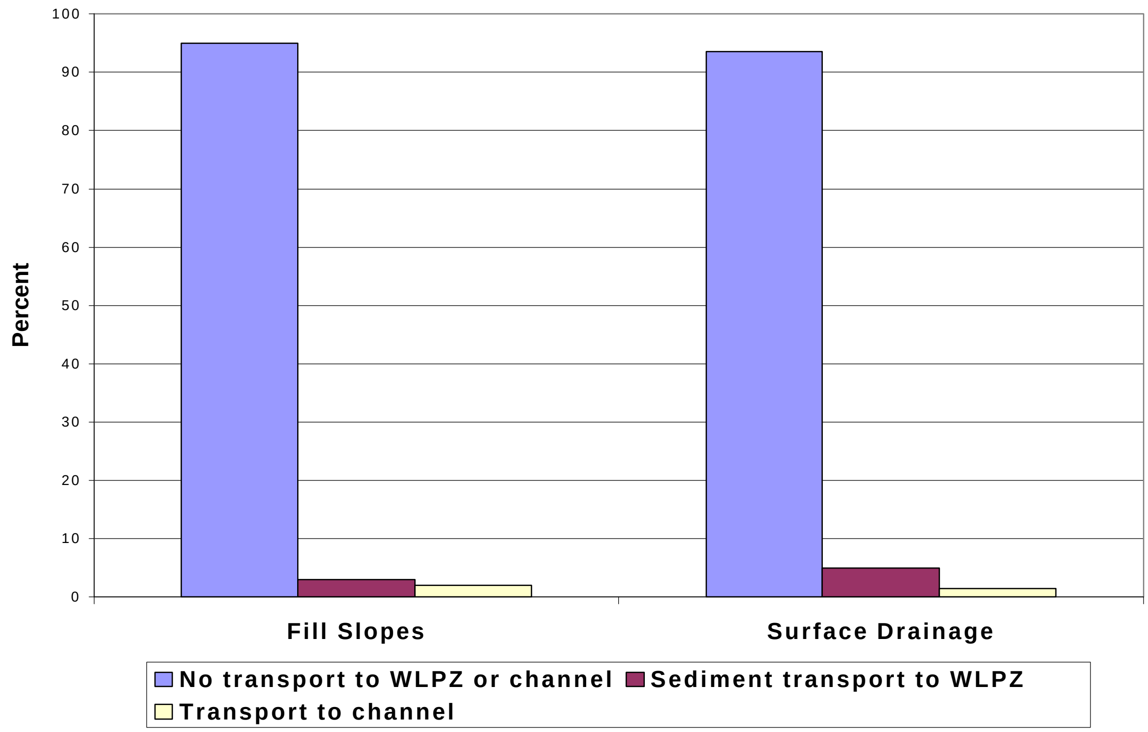

Figure 6. Sediment deposition sites associated with landing fill slopes and surface drainage.

Watercourse Crossings

A total of 263 watercourse crossings were evaluated from 1996 through 1998. Approximately 73% were crossings with culverts, while 16.5% were fords, 2.5% were structural crossings, and 8% were other types of crossings. Seventy percent of the crossings were associated with seasonal roads, 19% with permanent roads, 5% with temporary roads, and 6% with skid trails. Eighty-five percent of the crossings were existing when evaluated, 8% were abandoned, and 7% were removed for the winter period. Fifty percent of the crossings were in Class III watercourses, 45% in Class II drainages, 4% in Class I's, and less than 1% in Class IV watercourses.

Overall implementation ratings of the Forest Practice Rules relating to crossings are displayed in Table A-5. A total of 27 questions were rated for implementation and were developed from 24 Forest Practice Rules. Table 18 shows that for Rule requirements with at least 30 observations, 14 were found to have more than 5% major and minor departures. The Rule with the highest percentage of total departure is 923.2(o), which prevents discharge onto erodible fill material unless energy dissipators are used. Numerous rules requiring proper channel configuration following crossing removal or abandonment also had high departures from stated requirements. The Rules requiring crossings to avoid diversion potential, fills built to minimize erosion, crossings open to unrestricted passage of water, and trash racks in place where appropriate also were cited as having substantial departure percentages.

Problem points were described for specific components of crossings where encountered. A total of 254 problem points were recorded, equating to nearly one problem point for every crossing evaluated. Thirty-seven percent of the watercourse crossings had problem points assigned, indicating that deficient crossings generally had more than one problem point. Poor implementation of 22 Forest Practice Rules were cited as being responsible for these problem points, with 14 Rule requirements being cited the majority of the time (Table 19). All of the problem points were judged to be due to either minor or major departures from requirements of specific Forest Practice Rules. Approximately 64% of the Rule implementation ratings for watercourse crossing problem points were judged to be minor departures, while 36% were rated as major departures from Rule requirements.[12]

[12] Minor and major departures from Rule requirements for crossings relate to the severity of the problem discovered and less on sediment delivery (since sediment delivery at crossings is assumed to be 100%). For example, a culvert with 10% blockage would equate to a minor departure for 923.4(d), while a culvert with 50% blockage would be rated as a major departure.

Table 18. Watercourse crossing related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that some Rules are broken into component requirements, table is ordered by total departures).

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
923.2(o)	No discharge on fill unless energy dissipators are used	13.5	7.1
923.3(d)(1)	Removed-fills excavated to reform channel	16.1	3.2
923.8	Abandonment—minimized concentration of runoff water	12.9	6.5
923.2(d)	Fills across channels built to minimize erosion	10.8	6.7
923.4(1)	Trash racks installed where lots of LWD	12.8	5.1
923.8(d)	Abandonment—pulling/shaping of fills	6.7	10.0
923.4(n)	Crossing/approaches maintained to avoid diversion	14.1	2.4
923.3(d)(2)	Removed-cut bank sloped back to prevent slumping	9.7	6.5
923.3(e)	Crossings/fills built to prevent diversion	10.7	3.4
923.4(c)	Waterbreaks maintained to divert into cover	12.9	0.8
923.4(d)	Crossing open to unrestricted flow of water	9.7	3.4
923.4(d)	Trash racks installed where needed at inlets	6.7	6.7
923.2(h)	Drainage structures of sufficient size, #, and location to carry runoff water	6.5	5.8
923.4	Trash racks in place as specified in THP	6.1	0

The problem points associated with crossings are displayed in Table 20. Fill slope gullies, culvert plugging, and diversion accounted for 15, 14, and 11% of the problem points, respectively. Fill slope failures (7%), fill slope rilling (7%), and fill slope vegetative cover (6%) accounted for smaller percentages of problem points.

The complete summary of the crossing effectiveness questions is displayed in Table A-6. Significant scour at the outlet of crossings was found 35% of the time, with some degree of plugging occurring 22% of the time. Diversion potential was noted for about 17% of the culverted crossings. Almost 40% of the fill slopes at crossings had some amount of slope failure present. Road surface drainage towards the crossing had either slight or significant sediment delivery 36% of the time. For abandoned or removed crossings, approximately 80% had channels established close to natural grade and orientation, with about 20% having minor or major differences. Sediment delivery to watercourses can generally be assumed to be 100% at crossings since these structures are built directly in channels.

Table 19. Forest Practice Rules that account for approximately 90% of all the Rule requirements rated for implementation at problem points for watercourse crossings.

Forest Practice Rule	# of Times FPR Cited	Description of Rules Rated for Implementation where Problems Occurred	Exceeds/ Met Rule (%)	% Minor Departure	% Major Departure
923.2(o)	36	No discharge on fill without energy dissipators	0	58.3	41.7
923.4(n)	32	Crossing/approaches maintained to avoid diversion potential	0	84.4	15.6
923.2(h)	31	Structures of sufficient size, #, locations to minimize erosion	0	51.6	48.4
923.3(e)	27	Crossing/fill built to prevent diversion	0	66.7	33.3
923.4(d)	27	Crossing open to unrestricted passage of water	0	66.7	33.3
923.2(d)	24	Fills across channels built to minimize erosion	0	50.0	50.0
923.4(c)	12	Waterbreaks maintained to divert water into cover	0	91.7	8.3
923.2(h)	10	Size, #, location of structures sufficient to carry runoff water	0	30	70
923.8	7	Abandonment-minimizes concentration of runoff, erosion	0	57.1	42.9
923.8(b)	7	Abandonment-adequate stabilization of exposed soil on cuts, fills, sidecast	0	57.1	42.9
923.4(1)	6	Trash rack installed where LWD	0	83.3	16.7
923.8(d)	6	Abandonment-pulling/shaping fills	0	50	50
923.3(d)(2)	6	Removed-excavated material sloped back and stabilized to prevent erosion	0	66.7	33.3
923.2(h)	6	Size, #, location of structures sufficient to maintain drainage pattern	0	83.3	16.7

Table 20. Distribution of problem points noted at watercourse crossings.

Drainage Type	Problem Type	Count
Culvert	Plugging	36
	Diversion	29
	Scour at outlet	13
	Gradient	12
	Scour at inlet	4
	Piping	3
	Crushed	2
	Corrosion	1
Fill Slopes	Gullies	38
	Slope failures	18
	Rilling	17
	Vegetative cover	16
	Cracks	4
Road Surface Draining to Crossings	Rutting	7
	Inside Ditch	5
	Rilling	5
	Ponding	4
	Gullies	2
Non-Culvert Crossing	Armoring	7
	Scour at outlet	3
Removed/Abandoned Crossing	Road Approach-grading	10
	Grading/Shaping	7
	Channel bank gullies	4
	Configuration	5
	Channel bank slope failure	1
	Bank stabilization	1

Watercourse and Lake Protection Zones (WLPZs)

The Hillslope Monitoring Program sampled 274 watercourse and lake protection zone (WLPZ) transects, with a total of 244,940 feet (46.39 mi) of transects evaluated.[13] Approximately 76% of the transects were along Class II watercourses, 23% next to Class I watercourses, and 1% beside Class III watercourses with WLPZs. For about 43% of the transects, the slope distance from the channel bank to the nearest road was greater than 150 feet; 17% had a distance of 50-100 feet, 15% had a distance of 100-150 feet, 14% had a distance of 0-20 feet, and 11% had a distance of 20-50 feet.

Following the completion of WLPZ transect(s), the field team rated the overall implementation of specific Forest Practice Rules related to WLPZs (Table A-7). A total of 55 questions were developed from 34 Forest Practice Rules. Table 21 shows that for Rule requirements with at least 30 observations, six were found to have more than 5% major and minor departures. Three of these Rules deal with the requirement for the RPF to evaluate riparian areas for sensitive conditions—including unstable and erodible watercourse banks and use of existing roads within the standard WLPZ. These factors are to be identified in the THP and considered when proposing WLPZ widths and protection measures. Two Rules cited require that WLPZ widths be at least equal to that specified in Table 1 in the Forest Practice Rules. The remaining Rule requires accidental depositions of soil to be removed from watercourses.

Very few erosion features caused by current Timber Harvesting Plans were noted when completing the WLPZ transects (Table 22). Most of the erosion features noted were judged to either predate the current THP, were created after the THP but were not affected by the THP, or it was impossible to determine the feature date. Only one of the mass failures was associated with problems with Rule implementation. The remaining features were natural streambank or inner gorge failures not related to logging operations. Total erosion volumes for mass failures and gullying were 2,050 and 65 yd^3, respectively.

[13] Class III watercourses were not evaluated from 1996 through 1998, but a pilot project for evaluating protection of Class III watercourses is expected to be implemented during the summer of 1999.

Table 21. WLPZ related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that some Rules are broken into component requirements, table is ordered by total departures).

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
916.4(a)	Sensitive conditions—erodible banks—identified in THP	9.0	1.8
916.2(a)(4)	Sensitive conditions—existing roads in WLPZ—appropriate mitigation measure applied	7.0	2.8
916.4(a)	Sensitive conditions—existing roads in WLPZ—identified in THP	5.7	2.9
916.4(b)(3)	Width of WLPZ conforms to Table 1 in FPRs	6.4	0.8
916.4(b)	WLPZ widths as wide as specified in Table 1	5.6	0.8
916.3(b)	Accidental depositions of soil removed from watercourses	5.9	0

Table 22. Erosion features associated with the current THP and recorded during WLPZ transect evaluations.

Erosion Feature	Count
Cutbank or sidecast sloughing	1
Mass Failure	13
Gullying	4
Rilling	5

Mean WLPZ widths and side slope gradients were estimated for the transects evaluated. Mean widths for side slope categories are displayed in Table 23. It was often difficult for the field team to determine the upper extent of the WLPZ—particularly where selective silvicultural systems were used above the WLPZ. Flagging used to denote the WLPZ commonly is very difficult to locate following several overwintering periods. Therefore, the WLPZ widths must be regarded as rough estimates. It is also unknown at this time how many of these WLPZs utilized the allowable reduction granted for using cable yarding systems above the WLPZ (50 ft reduction for Class I and 25 ft reduction for Class II watercoures). Thirty percent of the WLPZ transects had only cable or helicopter yarding upslope of the transect.

Ground cover was evaluated at 100 foot intervals along the WLPZ transects. Mean ground cover was estimated to be 87 percent. It should be noted that ground cover varied greatly for different Forest Practice Districts. In the Coast District, higher moisture levels create more leaf fall and forb cover—resulting in very high ground cover, while in the drier inland districts, bare soil is common in WLPZs even without logging disturbances. Canopy cover was estimated with the spherical densiometer (1996 without modification, 1997-98 with the Strickler (1959) modification to reduce bias). Mean canopy was found to be above 70% in all cases (Table 24).[14] Canopy estimates are for total canopy in all cases (not overstory or understory, as is specified for Class I watercourses).

Table 23. Mean WLPZ width estimates.

Watercourse Class	Side Slope Gradient Category (%)	Mean WLPZ Width (ft)	Standard Forest Practice Rule (ft)
I	<30	80	75
	30-50	100	100
	>=50	115	100-150[15]
II	<30	55	50
	30-50	75	75
	>=50	90	75-100

Table 24. Mean WLPZ canopy estimates.

Watercourse Class	Year/Location	Canopy (%)
I	1996 (North Coast)	79
I	1997-1998 (statewide)	74
II	1996 (North Coast)	77
II	1997-1998 (statewide)	75

[14] Robards et al. (1999) have reported that the spherical densiometer produces a biased estimate of canopy and recommend the use of the sighting tube to reduce bias. In a field test conducted on Jackson Demonstration State Forest, the range of densiometer estimates was reported to be from 20% low to 10% high compared to actual canopy closure. In 1999, the Hillslope Monitoring Program will use the sighting tube for estimating canopy cover.

[15] 50 foot and 25 foot reductions in WLPZ width are allowed with cable yarding for Class I and II watercourses, respectively.

Large Erosion Events

Large erosion events were identified when traveling within the THP; as part of the evaluations for randomly located road segments, skid trail segments, landings, crossings, and WLPZs; or from information provided by landowners. The type, size, location, and cause of the large erosion event were described. This work was completed only for the statewide survey completed in 1997-1998 (not for the 1996 work in Mendocino and Humboldt Counties). For the 100 THPs included for this evaluation, a total of 35 large events were documented. Of these, 27 were related to current timber management activities (Table 25). Nearly all the shallow debris slides described were found in the Coast Forest Practice District, as were half of the deep seated rotational failures. Six of the ten catastrophic crossing failures were from the Southern Forest Practice District, largely due to the very large rain-on-snow event which occurred in January 1997 (100-yr+ in many Sierran watersheds). Large erosion events were located on 24 of the 100 THPs, with seven THPs having multiple large erosion events.

Mean erosion volumes for the various types of features related to current management activities are as follows: deep seated rotational (3,600 yd^3), shallow debris slide (3,700 yd^3), catastrophic crossing failure (200 yd^3), and streambank failure (600 yd^3). Most of the large erosion events were related to roads (24), with smaller numbers associated with landings (2) and skid trails (3). Eight of the features were judged to be unrelated to current management activities.[16] General cause code and associated feature type are displayed in Figure 6. Specific causes associated with the large erosion events are displayed in Table 26. The most frequent causes associated with large erosion events were: cutbanks with slope support removed; culverts with the inlet plugged; fill slopes with overloaded, deep sidecast; fill slopes with poorly compacted material; and surface water concentration.

[16] Note that multiple causes were assigned in some instances, so the total is greater than the total number of large erosion events.

Table 25. Frequency distribution of large erosion events related to current management activities that were encountered on THPs evaluated from 1997-1998.

Type	Coast	Northern	Southern	Total
Deep seated rotational	3	2	1	6
Shallow debris slide	9	1	0	10
Catastrophic crossing failure	1	3	6	10
Streambank failure	0	0	1	1
Total	**13**	**6**	**8**	**27**

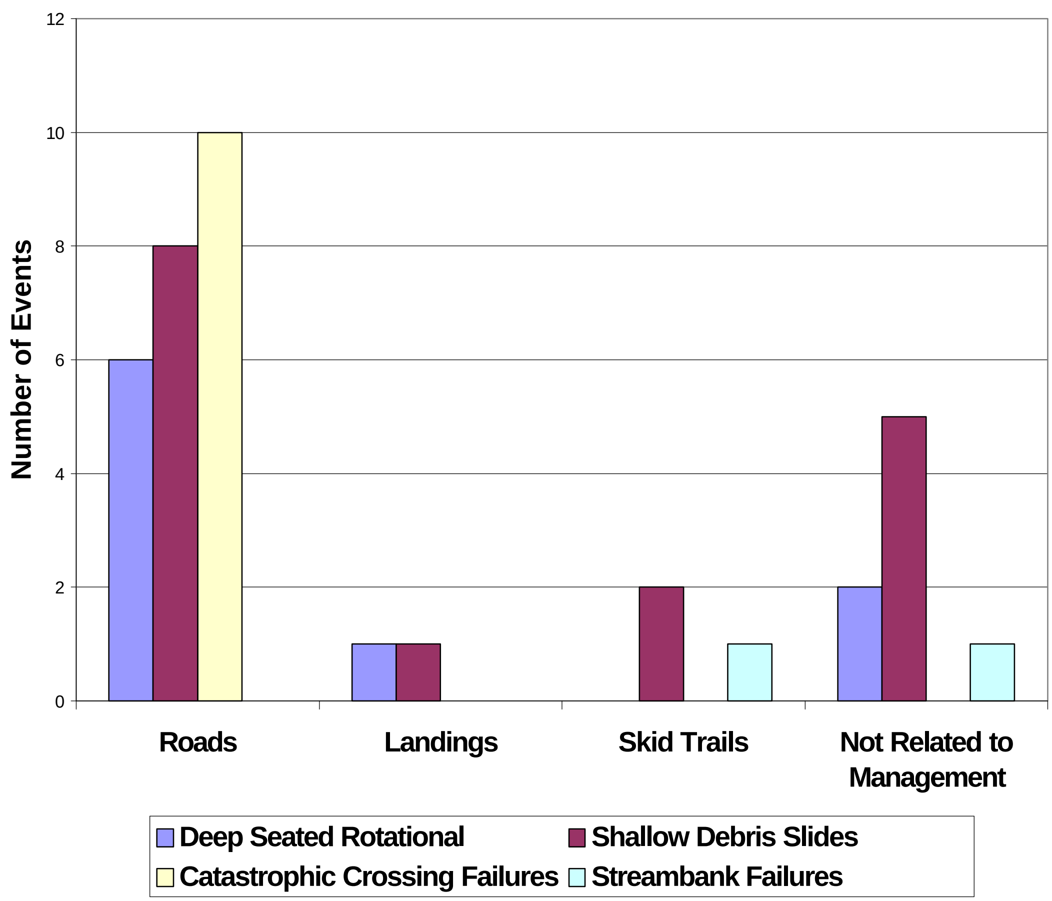

Figure 7. Causes of large erosion events and type of feature.

Table 26. Specific management related causes associated with large erosion events.

Type	Cause of Feature	Count
Roads		
	Waterbars-discharge onto erodible material	1
	Waterbars-improperly constructed or located	2
	Fill slopes-too steep	2
	Fill slopes-overloaded, deep sidecast	4
	Fill slopes-poorly compacted	4
	Fill slopes-excessive organic material	1
	Surface water concentration	4
	Culverts too small	2
	Culverts-discharge onto erodible material	1
	Culverts-inlet plugged	4
	Inside ditch-ditch blocked and/or diverted	1
	Inside ditch-other drainage onto road no handled	2
	Cutbanks- too steep	1
	Cutbanks-slope support removed	7
	Subsurface flow alteration	1
Skid Trails		
	Waterbars-not properly draining area	1
	Cutbanks-too steep	1
	Cutbanks-slope support removed	2
	Surface water concentration-rilling and gullying	1
	Surface water concentration-discharge on erodible material	1
Landings		
	Cutbanks-too steep	1
	Cutbanks-slope support removed	1
	Fill slopes-excessive organic material	1

DISCUSSION AND CONCLUSIONS

The data that has been collected to date as part of the Hillslope Monitoring Program point toward several preliminary conclusions. This is an on-going program, and additional information and more detailed queries will be available for future reports. Therefore, it is still too early to arrive at final conclusions. Further, this work has evaluated the implementation and effectiveness of selected **standard** Forest Practice Rules that can be evaluated in the field (not alternative or in-lieu practices). It also did not evaluate the THP "review process" or the degree to which this process contributes to observed water quality problems (Lee 1997). Finally, it is important to note that only THPs have been evaluated, not Exemptions, Emergency Notices, Conversions, or Non-industrial Timber Management Plans (NTMPs).

The following preliminary conclusions are based on data collected to date for the implementation and effectiveness of standard Forest Practice Rules related to water quality that could be evaluated in the field at selected sites (i.e., roads, landings, skid trails, crossings and WLPZs) on 150 THPs:

1. **Erosion problem points noted for roads, skid trails, landings, crossings, and WLPZs were almost always associated with improperly implemented Forest Practice Rules.**

The data collected to date suggests that the vast majority of erosion problem points were caused by minor or major departures from specific Forest Practice Rule requirements. Nearly all the problem points were judged to result from non-compliance. For example on the road transects, only about three percent of the implementation ratings assigned at erosion features were for situations where the Rule requirements were judged to have been met or exceeded.

The Forest Practice Rules and individual THP requirements (i.e., site-specific mitigation measures developed through recommendations of interagency Review Teams) were generally found to be sufficient to prevent hillslope erosion features when properly implemented on the ground by Licensed Timber Operators (LTOs).[17] To improve implementation, new training programs for LTOs and their employees should be encouraged, and these programs should include a field component.

[17] Rice and Datzman (1981) previously reported that operator performance may equal site characteristics as a source of variation in logging related erosion.

2. **Roads and their associated crossings were found to have the greatest potential for delivery of sediment to watercourses. Implementation of Forest Practice Rules that specify drainage structure design, construction and maintenance need improvement.**

More than 80% of the road transects evaluated from 1996 through 1998 were seasonal roads, and less than 30% of the sampled road mileage was surfaced with rock. Overall, 36 Rule requirements for roads and crossings were found to have more than 5% minor and major departures, considerably more than that found for landings, skid trails and WLPZs. The Forest Practice Rules with the highest departures from stated road requirements were related to waterbreak spacing, maintenance, and construction standards; adequate number, size, and location of drainage structures; prevention of discharge onto erodible fill; and sidecast limitations on steep slopes. Erosion problem points were noted, on average, approximately every 400 feet. Rilling was common, but had low sediment delivery to channels; mass failures were noted much less frequently but had high sediment delivery. Rilling and gullying were primarily caused by drainage feature problems, while mass failures were most commonly associated with unstable fill material.

In most types of terranes, earlier studies have reported that roads produce 75-95% of the erosion related to timber operations (Rice 1989). Based on the data collected to date as part of this program, these estimates still seem reasonable in the late 1990's.[18] The data suggests that there is considerable room for improvement in road design and construction—particularly regarding fill slopes, cutslopes, and crossings (see No. 4 below). As documented by Lewis and Rice (1989) as part of the Critical Sites Erosion Study, site factors overwhelm management impacts in most terranes. Therefore, *where* roads are built will remain critical for reducing the likelihood of producing significant sediment input to channels.

3. **Mass failures related to current timber operations are most closely associated with roads and produce the highest sediment delivery to watercourse channels when compared to other erosional processes.**

Data from 100 THPs shows that about one-quarter of the plans had large erosion features. More than 80% of the large erosion events that were documented as part of the statewide survey were associated with roads and crossings. Estimates from the randomly located road transects revealed that about 50% of the mass failures delivered material to stream channels—much higher than the

[18] Exceptions include landscapes that are highly unstable and have significant components of erosion resulting from inner gorge landsliding, such as have been found in portions of southern Humboldt County (PWA 1998).

average sediment delivery associated with sloughing, rilling, and gullying. The majority of the mass failures were associated with fill slopes, with cutbank and culvert problems also commonly noted. The data from both the large erosion event record and the randomly located road transects suggests that RPFs must locate and design, and LTOs must construct, drain, and maintain roads in a manner that will reduce the frequency of mass failure events.

4. Numerous problems were noted at watercourse crossings. Implementation of Forest Practice Rules that specify design, construction, and maintenance of crossings require considerable improvement.

Conclusions about watercourse crossings are based on a sample with 95% of the crossings in Class II or III watercourses. Very few Class I crossings were reviewed, because the random selection of crossings was tied to road transects and roads that were commonly located high on hillslopes. Only 15% of the crossings evaluated had been removed or abandoned, so the sample sizes for these types of crossings is still relatively small. The data collected to date shows that problem points at watercourse crossings are a major source of sediment delivered to watercourses. Because crossings are adjacent to and within channels, eroded material has direct access to the watercourses. Approximately 40% of the crossings had one or more problems, while more than 60% had none, indicating that they were functioning properly. Common problems included fill slope gullies, plugging, scour at the outlet, and high diversion potential. Although not readily derived from the database, the field crew members observed that where a well designed and constructed crossing was encountered in a THP being reviewed, the other crossings in the plan were usually also well constructed. These data indicate that more attention is needed with the design, construction, and review of crossings. Recent research has provided RPFs and Licensed Timber Operators new information on how to build better crossings (Flanagan et al. 1998).

5. Watercourse and lake protection zones (WLPZs) have been found to generally meet Forest Practice Rule requirements for width, canopy, and ground cover. Additionally, very few erosion features associated with current THPs were recorded in WLPZs.

Approximately three-quarters of the WLPZs evaluated to date have been on Class II watercourses, which are much more common than the generally larger Class I waters. The data collected in WLPZs indicates that minimum canopy requirements following harvesting on Class I and II watercourses are being exceeded, since an average of greater than 70% canopy cover following harvesting has been measured using the spherical densiometer. Similarly, mean ground cover requirements in WLPZs following logging was estimated to exceed 85%. Required WLPZ widths generally met Rule requirements, with major departures from Rule requirements noted only about 1% of the time. Erosion events originating from current THPs and encountered on mid-zone or streambank WLPZ transects were found to be rare. The implementation data suggests that RPFs should do a better job of taking existing roads and erodible, unstable stream banks into account when designing WLPZs and specifying protection measures.

6. Landings did not have substantial numbers of erosion events associated with current operations and erosion events on landings generally did not transport sediment to watercourses.

More than half of the randomly selected landings were greater than 300 feet from the nearest watercourse (I, II, III, or IV), almost 90% were built on slopes less than 45%, and more than 80% were built on a ridge or above the break in slope. These factors indicate why landings generally did not create significant water quality problems and why very few erosion events transported sediment from landings, with the exception of landings located very near watercourses (generally old landings built for previous entries). Drainage structures associated with landings were cited as needing improvement about 10% of the time, but most of the Rule requirement implementation ratings were for minor departures, indicating that direct adverse impacts to water quality were infrequent.

7. Skid trail segments had a lower frequency of erosion features related to current operations when compared to road segments. Overall, skid trails are having much less impact to water quality than roads.

The frequency of erosion problems noted on skid trail transects was fairly low when compared to problems documented on roads. For example, problem points assigned to waterbreaks that did not conform to the Rule requirements on skid trails occurred at about half the rate as on road transects (i.e., 4% vs. 9%). The overall average was one erosion problem point assigned for every 1,175 feet of skid trail evaluated, verses one problem every 380 feet for roads. Rills were noted fairly frequently on skid trails but had very low delivery to watercourse channels. Gullies were noted with about one-third the frequency of rills, but had a higher percentage of sediment delivery to watercourse channels. Spacing of waterbreaks was the most commonly cited drainage feature problem associated with skid trail rilling and gullying.

8. **Recent timber operations cannot be linked to current instream channel conditions based on results from the Hillslope Monitoring Program.**

This program has evaluated Forest Practice Rule effectiveness on hillslopes—not in the stream channels. This type of monitoring can provide a rapid feedback loop to managers for improving hillslope practices. It does not, however, address current instream channel conditions which are often the result of land use impacts that took place decades ago. Instream measurements can be difficult to relate to individual forest practices (Murphy 1995). In addition, results presented in this interim report do not allow us to draw conclusions about whether the existing Rules are providing properly functioning habitat for aquatic species because evaluating the biological significance of the current Rules is not part of this project. For example, hillslope monitoring in WLPZs does not allow us to draw conclusions regarding whether canopy levels resulted in acceptable water temperatures for anadromous fish, or whether the observed timber operations retained an adequate number of mature trees for large woody debris recruitment that is needed to create complex habitats for anadromous fish species. Also, the adequacy of the Rules in addressing cumulative watershed effects are not covered by this program.[19]

GENERAL OBSERVATIONS

The findings of this interim report mirror those of the “208 Team” (SWRCB 1987), where it was reported that: (1) the standard Rules generally appeared to provide adequate water quality protection when they were properly implemented, and (2) poor Rule implementation was the most common cause of observed water quality impacts. More than 95% of the Forest Practice Rules associated with erosion problem points encountered from 1996 through 1998 were rated as having either minor or major departures from Rule requirements. This indicates that the Rules are generally effective in preventing erosion events when properly implemented. In a nation-wide survey on monitoring, Brown and Binkley (1994) reported that forest practices can protect water quality if prescriptions are carefully developed and implemented.

The Forest Practice Rules listed in Table 27 have been identified as having the highest percentages of total departures from Rule requirements and should be made known to RPFs, LTOs and their employees, and to CDF Forest Practice Inspectors. They need to be made aware of which Rules are not being

[19] The adequacy of the Forest Practice Rules addressing cumulative watershed effects is currently being reviewed by several scientific and agency task forces, with final reports expected during the summer of 1999.

implemented well in the field, and these groups should be targeted for intense training efforts.

Much remains to be learned about Forest Practice Rule implementation and effectiveness. Many of the Forest Practice Rules have not been adequately tested to date because the situations in which they apply are very limited. The continued long-term collection of hillslope data will enable the performance of these Rules to be adequately reviewed. Similarly, many situations have yet to be fully studied as part of the Hillslope Monitoring Program. For example, protection of Class III watercourses has yet to be addressed. Class III protection was noted as one of three areas of Rule requirements where concerns were expressed over both implementation and effectiveness by resource professionals in a survey of watercourse and lake protection zone protection measures (CDF 1995).[20] Similarly, impacts to hillslopes that have been cable yarded have not been included in the program (other than documenting large erosion events where encountered). The evaluation of non-standard practices (in-lieu and alternative practices) will also require considerably more work before conclusions can be made whether these practices provide the same level of protection as the standard Rules.[21]

The Hillslope Monitoring Program can be improved in several areas. Only a small amount of quality assurance/quality (QA/QC) control work has been completed to date to test the repeatability of the data reported.[22] CDF conducted very limited QA/QC work for canopy measurements in 1996 and found that the canopy measurements reported by the contractors was approximately 7% higher than that estimated internally. Transects established on 10 THPs from the 1997 THPs have been remeasured but that data has yet to be compared to the original data. Recent CDF staff additions will allow improved QA/QC work in the future. In addition, CDF has yet to implement a program to resample a certain percentage of THPs to monitor impacts from strong stressing storms. This work would be particularly important on those THPs which had not been tested by large storm events during the overwintering periods prior to the first THP

[20] The other two areas were winter operations and restorable uses of water.

[21] The SWRCB (1987) report stated that the use of non-standard practices frequently resulted in less protection than would have been provided by standard practices.

[22] Even though little work has been completed to test repeatability, the data presented in this report was collected with a high degree of consistency, since R.J. Poff and Associates evaluated 125 out of 150 THPs.

evaluation.[23] There are plans to begin this type of expanded hillslope monitoring program in the near future.

Table 27. Forest Practice Rule requirements with at least 10% total departures based on at least 30 observations where implementation could be rated (note this table was developed from Tables 4, 11, 15, 18, and 21).

Location	Rule No.	Description
Roads/ skid trails	914.6(c)	Waterbreak spacing equals standards
Roads/ landings	923.1(f)	Adequate numbers of drainage facilities
Roads	923.2(b)	Sidecast minimized for slopes > 65% for distances > 100 ft
Roads	923.1(d)	For slopes >65% or 50% within 100 ft of WLPZ, soil treated to minimize erosion
Roads/ crossings	923.2(h)	Drainage structures of sufficient size, number and location to minimize erosion, carry runoff water
Roads/ crossings	923.2(o)	No discharge onto erodible fill unless energy dissipators are used
Roads	914.6(g)	Waterbreaks have an embankment of at least 6 inches
Roads/ crossings	923.4(c)	Waterbreaks maintained to divert into cover
Roads	923.2(h)	Drainage structures of sufficient size, number and location to minimize erosion
Roads	914.6(f)	Waterbreaks installed to discharge into cover
Roads/ landings	923.1(a)	If landing on road >1/4 ac or required substantial excavation, --shown on THP map
Roads	914.6(g)	Waterbreaks constructed with a depth of at least 6 inches cut into firm roadbed
Roads	923.2(p)	Waterbreaks installed according to standards in 914.6
Skid trails	914.6(f)	Where waterbreaks cannot disperse runoff, other erosion controls installed as needed
WLPZ	916.4(a)	Sensitive conditions—erodible banks identified in THP
Crossings	923.3(d)(1)	Removed fills excavated to reform channel
Crossings	923.8	Abandonment—minimizes concentration of runoff water
Crossings	923.2(d)	Fills across channels built to minimize erosion
Crossings	923.4(1)	Trash racks installed where abundant LWD
Crossings	923.8(d)	Abandonment-pulling/shaping of fills
Crossings	923.4(n)	Crossings/approaches maintained to avoid diversion
Crossings	923.3(d)(2)	Removed crossings-cut bank sloped back to prevent slumping
Crossings	923.4(d)	Crossing open to unrestricted passage of water
Crossings	923.4(d)	Trash racks installed where needed at inlets
Crossings	923.3(e)	Crossings/fills built to prevent diversion

[23] Lewis and Baldwin (1997) suggest that stressing storm events need to be defined and effectiveness should only be evaluated after stressing events have occurred. Some measure of the magnitude of the stressing events should be included in the analysis.

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GLOSSARY

Abandonment – Leaving a logging road reasonably impassable to standard production four wheel-drive highway vehicles, and leaving a logging road and landings, in a condition which provides for long-term functioning of erosion controls with little or no continuing maintenance (CFPR 895.1).

Beneficial uses of water - According to the Porter-Cologne Water Quality Control Act, the beneficial uses of water include, but are not limited to: domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish and wildlife, and other aquatic resources or preserves. In Water Quality Control Plans, the beneficial uses designated for a given body of water typically include the following: domestic, municipal, agricultural, and industrial supply; industrial process; water contact recreation and non-water contact recreation; hydropower generation; navigation; groundwater recharge; fish spawning, rearing, and migration; aquatic habitat for warm-water species; aquatic habitat for coldwater species; and aquatic habitat for rare, threatened, and/or endangered species (Lee 1997).

Best management practice (BMP) - A practice or set of practices that is the most effective means of preventing or reducing the generation of nonpoint source pollution from a particular type of land use (e.g., silviculture) that is feasible, given environmental, economic, institutional, and technical constraints. Application of BMPs is intended to achieve compliance with applicable water quality requirements (Lee 1997).

Canopy - the foliage, branches, and trunks of vegetation that blocks a view of the sky along a vertical projection, and estimated from 1996 through1998 for this project with a spherical densiometer. The Forest Practice Rules define canopy as the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody species (CFPR 895.1).

Cutbank/sidecast sloughing - Shallow surficial sliding associated with either the cutbank of fill material of a forest road, with smaller dimensions than would be associated with mass failures.

Feature - Any constructed feature along a landing, road, skid trail, or watercourse crossing (e.g., cut bank, fill slope, inside ditch, cross drain, water bar).

Gully - Erosion channels deeper than 6 inches (no limitation on length or width). Gully dimensions were estimated.

Large erosion event - For hillslope mass failures, these events are 100 cubic yards for a void left on a hillslope; for catastrophic crossing failures, these events are defined as at least 10 cubic yards.

Mass failure – Downslope movement of debris that occurs when the internal strength of a soil is exceeded by gravitational and other stresses. Mass erosion processes include slow moving, deep-seated earthflows and rotational failures, as well as rapid, shallow movements on hillslopes (debris slides) and downstream channels (debris torrents).

Minor/major departure – Major departures were assigned when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements (e.g., no or few waterbars installed for entire transect). Minor departures were assigned for slight Rule departures where there was no evidence that sediment was delivered to watercourses (e.g., WLPZ width slightly less than that specified by the Rule).

Non-standard practice - A practice other than a standard practice, but allowable by the Rules as an alternative practice, in-lieu practice, waiver, exclusion, or exemption (Lee 1997).

Parameter - The variable being studied by sampling, observation, or measurement (Lee 1997).

Permanent road – A road which is planed and constructed to be part of a permanent all-season transportation facility. These roads have a surface which is suitable for the hauling of forest products throughout the entire winter period and have drainage structures, if any at watercourse crossings which will accommodate the fifty-year flow. Normally they are maintained during the winter period (CFPR 895.1).

Problem point - In Hillslope Monitoring Program, the occurrence of: (a) rilling, gullying, mass failures, or cutbank/sidecast sloughing found along landings, roads, skid trails, watercourse crossings, or WLPZs and (b) canopy reduction, streambank erosion, or ground cover reduction in a WLPZ. Problem points also include Forest Practice Rule violations (e.g., waterbreak improperly constructed) (Lee 1997).

Process - The process by which the Rules/BMPs are administered and implemented, including: (a) the process elements for THP preparation, information content, review and approval by RPFs, Review Team agencies, and CDF decision-makers, and (b) the process elements for timber operation conduct, inspection, and completion by LTOs and CDF inspectors (Lee 1997).

Quality assurance - The steps taken to ensure that a product (i.e., monitoring data) meets specified objectives or standards. This can include: specification of the objectives for the program and for data (i.e., precision, accuracy, completeness, representativeness, comparability, and repeatability), minimum personnel qualifications (i.e., education, training, experience), training programs, reference materials (i.e., protocols, instructions, guidelines, forms) for use in the field, laboratory, office, and data management system (Lee 1997).

Quality control - The steps taken to ensure that products which do not meet specified objectives or standards (i.e., data errors and omissions, analytical errors) are detected and either eliminated or corrected (Lee 1997).

Repeatability - The degree of agreement between measurements or values of a monitoring parameter made under the same conditions by different observers (Lee 1997).

Rill - Small surface erosion channels that (1) are greater than 2 inches deep at the upslope end when found singly or greater than 1 inch deep where there are two or more, and (2) are longer than 20 feet if on a road surface or of any length when located on a cut bank, fill slope, cross drain ditch, or cross drain outlet. Dimensions were not recorded.

Rules - Those Rules that are related to protection of the quality and beneficial uses of water and have been certified by the SWRCB as BMPs for protecting the quality and beneficial uses of water to a degree that achieves compliance with applicable water quality requirements (Lee 1997).

Seasonal road – A road which is planned and constructed as part of a permanent transportation facility where: 1) commercial hauling may be discontinued during the winter period, or 2) the landowner desires continuation of access for fire control, forest management activities, Christmas tree growing, or for occasional or incidental use for harvesting of minor forest products, or similar activities. These roads have a surface adequate for hauling of forest products in the non-winter period; and have drainage structures, if any, at watercourse crossings which will accommodate the fifty-year flood flow. Some maintenance usually is required (CFPR 895.1).

Standard practice - A practice prescribed or proscribed by the Rules (Lee 1997).

Surface cover – The cover of litter, downed woody material (including slash, living vegetation in contact with the ground, and loose rocks (excluding rock outcrops) that resist erosion by raindrop impact and surface flow (CFPR 895.1).

Temporary road – A road that is to be used only during the timber operation. These roads have a surface adequate for seasonal logging use and have drainage structures, if any, adequate to carry the anticipated flow of water during the period of use (CFPR 895.1).

Waterbreak – A ditch, dike, or dip, or a combination thereof, constructed diagonally across logging roads, tractor roads and firebreaks so that water flow is effectively diverted therefrom. Waterbreaks are synonymous with waterbars (CFPR 895.1).

Appendix[24]

[24] For Tables A-1, A-2, A-3, A-5, and A-7, the columns are defined as follows: (1) Forest Practice Rule number, (2) brief description of Forest Practice Rule, (3) total number of times the Rule was rated for implementation following evaluation of the entire transect/feature, (4) total number of times implementation rating was either exceeded Rule requirements, met Rule requirements, minor departure from Rule requirements, or major departure from Rule requirements, (5) number of implementation ratings for both exceeded Rule requirements and met Rule requirements divided by column no. 4 and multiplied by 100, (6) number of implementation ratings for minor departure of Rule requirements divided by column no. 4 and multiplied by 100, and (7) number of implementation ratings for major departure of Rule requirements divided by column no. 4 and multiplied by 100.

Table A-1. Roads—implementation ratings for transects as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
923(d)	Road located to avoid bottoms of steep canyons	287	255	98.8	1.2	0
923(d)	Road located to avoid marshes/wet areas	289	209	98.1	1.9	0
923(d)	Road located to avoid unstable areas	289	180	96.1	3.9	0
923(d)	Road located to avoid watercourses	288	268	98.5	1.1	0.4
923.4(i)	Soil stabilization on cuts, fills, sidecast	287	185	95.7	3.8	0.5
923.6	Wet spots rocked or otherwise treated	288	134	93.3	6.7	0.0
923.1(a)	if landing on road >1/4ac, shown on THP map	288	124	87.9	7.3	4.8
1038(b)(5)	Permitted activities-new road construction/reconstr.	288	2	100.0	0.0	0.0
923.4(j)	Drainage ditches maintained to allow flow of water	288	192	92.7	7.3	0.0
914.6(f)	Waterbreaks built to discharge into cover	289	228	87.7	12.3	0.0
914.6(f)	Waterbreaks built to spread water to min. erosion	288	226	97.8	2.2	0.0
914.6(g)	Waterbreaks constructed diagonally	288	220	98.2	1.8	0.0
914.6(g)	Waterbreaks cut to depths of at least 6 inches	288	218	88.1	11.0	0.9
914.6(g)	Waterbreaks have embankment of at least 6 inches	287	215	86.5	12.1	1.4
923(c)	Road planned to fit topography, minimize disturbance	288	287	98.6	1.4	0.0
923(e)	Road located to minimize number of crossings	288	283	99.3	0.7	0.0
923(f)	Road located on benches/flatter slopes, stable soils	288	286	96.2	3.8	0.0
923(g)	Excavation or placement of fills on unstable soils	288	195	97.9	2.1	0.0
923.1(a)	Road shown on THP map correctly	288	286	94.1	5.6	0.3
923.1(a)	if road reconstructed--failures shown on THP map	289	81	96.3	3.7	0.0
923.1(e)	if new, grade> 15% or 20% less than 500 ft	288	77	100.0	0.0	0.0
923.1(f)	Adequate #s of drainage structures to min. erosion	292	288	80.2	16.7	3.1
923.1(g)	Road width appropriated for yarding system used	288	282	99.6	0.4	0.0
923.2(d)C	Fills constructed with insloping approaches, etc	288	82	92.7	6.1	1.2
923.2(d)N	Breaks in grade above/below throughfill	288	100	93.0	7.0	0.0
923.2(g)	Excess material stabilized so as avoid impact	288	263	98.5	0.8	0.8
923.2(h)	Size, #, location of structures okay to carry runoff water	288	281	82.9	13.9	3.2

923.2(h)	Size, #, location of structures sufficient to min. erosion	290	285	83.2	14.4	2.5
923.2(l)	Trees with >25% roots exposed by construction cut	288	269	98.9	0.7	0.4
923.2(m)	Sidecast extending>20 ft treated to avoid erosion	288	76	94.7	2.6	2.6
923.2(o)	Discharge onto erodible fill prevented	289	259	87.6	10.4	1.9
923.2(v)	Construction in WLPZ limited to crossings	288	106	100.0	0.0	0.0
923.4(c)	Waterbreaks maintained to minimize erosion	291	221	80.5	16.7	2.7
923.4(c)	Erosion controls maintained during maintenance period	288	102	94.1	5.9	0.0
923.4(f)	drainage structures removed if not sized for 50-yr flow	288	111	98.2	1.8	0.0
923.4(m)	inlet/outlet structures/add. Structures been maintained	289	202	95.5	4.5	0.0
923.8(a)	abandoned roads-blockage of road completed	288	4	50.0	50.0	0.0
923.8(b)	abandoned roads-stabilization of exposed soil	288	4	100.0	0.0	0.0
923.8(d)	abandoned roads-pulling or shaping of fills/sidecast	288	3	66.7	33.3	0.0
923.8(e)	removed crossing-fills excavated to form appropriate channel	288	4	75.0	25.0	0.0
923.8(e)	removed crossing-excavated material sloped back	288	4	100.0	0.0	0.0
923.8(e)	if removal of crossing not feasible, diversion pot. Handled	287	2	100.0	0.0	0.0
1038(b)(2)	permitted activities-new tractor roads on slopes>40%	288	1	100.0	0.0	0.0
914.6(c)	waterbreak spacing according to standards in 914.6(c)	288	224	77.2	20.1	2.7
914.6(f)	waterbreaks built to provide unrestricted discharge	288	226	98.7	0.9	0.4
914.6(f)	where waterbreaks don't work--other erosion controls	287	115	92.2	7.0	0.9
923.1(d)	slopes >65%, 50% within 100 ft of WLPZ-treat soil	288	49	89.8	8.2	2.0
923.1(g)(3)	insloped roads-adequate number of ditch drains	288	141	95.7	4.3	0.0
923.2(b)	sidecast minimized for slopes >65% distance >100 ft	289	30	83.3	16.7	0.0
923.2(h)	size, #, location of structures-natural drainage pattern	289	272	98.5	1.5	0.0
923.2(I)	trash racks, etc installed where appropriate	289	71	94.4	5.6	0.0
923.2(k)	road without overhanging banks	288	270	99.3	0.7	0.0
923.2(u)	slash placed to avoid discharge to Class I/II	288	223	100.0	0.0	0.0
923.4(e)	roadside berms removed or breached	288	248	98.0	2.0	0.0
923.4(g)	temporary roads blocked before winter period	288	17	64.7	29.4	5.9
923.8(c)	abandonment-shaping to allow dispersal of water	288	4	100.0	0.0	0.0

923.8	abandonment-allows permanent drainage	288	4	75.0	25.0	0.0
923.8	abandonment-minimizes concentration of runoff	287	4	50.0	50.0	0.0
923.2(p)	waterbars installed according to 914.6	287	191	89.5	9.4	1.0

Table A-2. Skid Trails--implementation ratings for transects as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
1038(b)(9)	permitted acts--cutting in WLPZ	240	2	100.0	0.0	0.0
1038(b)(4)	permitted acts--ops on slides, etc.	240	2	100.0	0.0	0.0
1038(b)(6)	permitted acts--ops in WLPZs	240	2	50.0	0.0	50.0
1038, 1038.1	permitted acts--ops comply with FPRs	240	2	100.0	0.0	0.0
914.1(a)	trees felled away from watercourses	243	188	99.5	0.5	0.0
914.2(f)(1)	tractor ops avoided slopes >65%	240	133	100.0	0.0	0.0
914.2(f)(2)	ops avoided slopes>50% above I/II	240	97	99.0	1.0	0.0
914.2(f)(3)	ops avoided slopes>50% high, extreme	241	55	100.0	0.0	0.0
914.3 Coast	ops avoided cable yarding areas	240	34	97.1	2.9	0.0
914.6(f)	waterbreaks allow discharge into cover	240	229	97.8	1.7	0.4
914.6(f)	waterbreaks spread water to min erosion	240	229	96.9	2.2	0.9
914.6(f)	if waterbreaks don't work, other structures	240	76	76.3	19.7	3.9
914.6(g)	waterbars placed diagonally	240	229	98.3	1.3	0.4
1038(b)(1)	permitted acts--ops on slopes>50%	240	3	100.0	0.0	0.0
1038(b)(2)	permitted acts--new trails >40%	239	3	100.0	0.0	0.0
914.2(c)	tractor roads minimized-#, width	240	237	96.2	3.4	0.4
914.2(d)	tractor ops avoided unstable soils	240	160	99.4	0.6	0.0
914.2(e)	slash/debris placed to avoid class I or II	240	215	99.5	0.5	0.0
914.6(c)	waterbreak spacing = standards	241	236	84.3	11.0	4.7
914.6(c)	waterbreaks--100 ft intervals cable roads	241	127	95.3	2.4	2.4
914.6(e)	waterbreaks for natural channels	239	108	95.4	1.9	2.8
914.6(f)	waterbreaks -unrestricted discharge	240	229	97.8	1.7	0.4
914.6(g)	waterbreaks cut to minimum depth 6 in.	240	228	97.8	2.2	0.0
914.6(g)	waterbreaks have embankment of 6 in	239	227	96.9	2.6	0.4
914.7(c)(3)	appropriate ops for winter period	240	3	100.0	0.0	0.0
923.4(c)	waterbreaks maintained to divert water	240	225	92.4	7.1	0.4

Table A-3. Landings--implementation ratings for landings as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
923(g)	Minimize cut/fill on unstable areas	290	206	98.1	1.5	0.5
923.1(a)	>1/4ac, substantial excavation-shown on THP map	291	118	83.1	11.0	5.9
923.1(d)	Slopes>65% or 50% within 100ft-treat	288	14	92.9	7.1	0.0
923.1(f)	Adequate #s of drainage structures	288	267	89.5	9.0	1.5
923.5(a)	New--slopes>65%, sidecast minimized	288	4	75.0	25.0	0.0
923.5(f)(2,4)	Fill extending 20ft with access--treated	289	47	91.5	8.5	0.0
923.5(f)(5)	Fill removed—channel reformed correctly	288	3	100.0	0.0	0.0
923.6	Wet spots been rocked/treated	288	46	93.5	6.5	0.0
923.8(a)	Abandonment--blocked to vehicles	287	5	100.0	0.0	0.0
923.8(b)	Abandonment--stabilization of cuts/fills	287	5	100.0	0.0	0.0
923.8(e)	Abandonment--proper channel formed	287	2	100.0	0.0	0.0
923.8(e)	Abandonment--cut banks sloped back	287	2	100.0	0.0	0.0
923.8(e)	Where fill removal infeasible-overflow channel	287	1	100.0	0.0	0.0
923.8	Abandonment-min. concentration of runoff	288	5	60.0	40.0	0.0
923.5(d)	Min. size consistent with yarding system	289	288	95.5	4.5	0.0
923.5(f)(1)	Slopes>65% or 50% within 100ft-treat edge	288	13	92.3	7.7	0.0
923.5(f)(2)	Ditches clear of obstructions	287	172	95.3	4.7	0.0
923.5(f)(3)	Sloped/ditched to prevent erosion	288	271	95.6	4.1	0.4
923.5(f)(5)	Sidecast/fill across watercourse pulled	288	2	100.0	0.0	0.0
923.5(f)(5)	Fill removed—cut banks sloped back	288	3	66.7	33.3	0.0
923.8(c)	Abandonment--grading for water dispersal	287	5	60.0	40.0	0.0
923.8(d)	Abandonment--fill pulled to prevent discharge	287	4	75.0	25.0	0.0
923.8	Abandonment--maintenance free drainage	288	5	100.0	0.0	0.0

Table A-4. Landings--effectiveness ratings.

Surface Rilling and Gullying	Effectiveness Category Percent	Effectiveness Category
a. Rilling on Landing Surface	56.1	None
	43.2	<1 rill/100 ft (0-20%)
	0.7	>1 rill/20 ft (>20%)
b. Gullies on Landing Surface	66.2	None
	32.7	< 1 gully per 100 ft transect
	1.1	Some gullying (< 1 gully per 20 ft of transect)
	0	Gullying that exceeds 1 gully per 20 ft of transect
Surface Drainage		
a. Drainage Runoff Structure	72.1	No evidence of erosion from concentrated flow where drainage leaves landing surface
	22.5	Rills or gullies present but do not extend >20 ft below edge of landing
	5.4	Presence of rills or gullies which extend >20 ft below edge of landing
b. Sediment Movement	93.6	No evidence of transport to WLPZ
	4.9	Sediment transport in WLPZ but not to channel
	1.5	Evidence of sediment transport or deposition in channel
Landing Cut Slopes		
a. Rilling	90.7	No evidence of rills
	6.6	Rills present but do not extend to drainage structure or ditch
	2.7	Rills present and extend to drainage structure of ditch

b. Gullies	97.3	No evidence of gullies
	0.5	Gullies present but do not extend to drainage structure or ditch
	2.2	Gullies present and extend to drainage structure or ditch
c. Failures	92.2	Less than 1 cubic yard of material moved
	6.1	More than 1 cubic yard moved but it is not transported to drainage structure or ditch
	1.7	More than 1 cubic yard moved, some material transported to drainage structure or ditch
Landing Fill Slopes		
a. Rilling	86.2	No evidence of rills
	13.4	Rills present but do not extend to drainage channels below toe of fill
	0.4	Rills present and extend to drainage channel below toe of fill
b. Gullies	88.5	No evidence of gullies
	10.6	Gullies present, but do not extend to drainage channels below toe of fill
	0.9	Gullies present and extend greater than a slope length below toe of fill
c. Slope Failures	94	No material moved
	4.6	Less than 1 cubic yard moved
	0.9	More than 1 cubic yard moved but does not enter channel
	0.5	More than 1 cubic yard moved, some material enters channel
d. Sediment Movement	94.9	No evidence of transport
	3.2	Sediment deposition in WLPZ but not carried to channel
	1.9	Evidence of sediment transport to or deposition in channel

Table A-5. Crossings--implementation ratings for crossings as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
923.4(d)	trash racks installed where needed at inlets	249	30	86.7	6.7	6.7
914.8(d)	tractor crossing--cut bank sloped back from channel	249	14	100.0	0.0	0.0
923.3(c)	restricted passage of fish allowed	249	10	60.0	30.0	10.0
923.4(1)	trash racks installed where lots of LWD	249	39	82.1	12.8	5.1
923.4(f)	50-year flood flow requirement	255	187	95.2	3.7	1.1
923.8(c)	abandonment--grading of road for dispersal	249	29	93.1	3.4	3.4
923.8(d)	abandonment--pulling/shaping of fills	249	30	83.3	6.7	10.0
923.8(e)	abandonment--fills excavated to reform channel	249	28	92.9	3.6	3.6
923.8	abandonment—minimize concentration of runoff	249	31	80.6	12.9	6.5
914.8(d)	tractor crossing--fills removed to reform channel	250	14	92.9	7.1	0.0
923.2(d)	fills across channels built to minimize erosion	164	120	82.5	10.8	6.7
923.2(e)	throughfills built in one-foot lifts	165	12	83.3	8.3	8.3
923.2(h)	size, #, location of structures okay to carry runoff	164	155	95.5	1.3	3.2
923.2(h)	size, #, location of structures minimizes erosion	164	155	87.7	6.5	5.8
923.2(h)	size,#,location of structures-nat.drainage pattern	164	155	96.8	2.6	0.6
923.2(o)	no discharge on fill unless energy dissipators	165	155	79.4	13.5	7.1
923.3(d)(1)	removed--are fills excavated to reform channel	249	31	80.6	16.1	3.2
923.3(d)(2)	removed--cut bank sloped back to stop slumping	249	31	83.9	9.7	6.5
923.3(e)	crossing/fills built to prevent diversion	249	206	85.9	10.7	3.4
923.4(c)	waterbreaks maintained to divert into cover	163	132	86.4	12.9	0.8
923.4(d)	crossing open to unrestricted passage of water	249	238	87.0	9.7	3.4
923.4(n)	crossing/approaches maintained to avoid diversion	249	205	83.4	14.1	2.4
923.4	trash racks in place as specified in THP	250	33	93.9	6.1	0.0
923.8(b)	abandonment--stabilization of exposed cuts/fills	249	29	82.8	10.3	6.9
923.8(e)	abandonment--cutbanks sloped back	249	28	92.9	0.0	7.1
923.8(e)	removal not feasible--diversion potential handled	247	9	88.9	0.0	11.1
923.8	abandonment--maintenance free drainage	249	31	96.8	0.0	3.2

Table A-6. Crossings--effectiveness ratings.

<u>Fill Slopes at Crossings</u>	**Effectiveness Category Percent**	**Effectiveness Category**
a. Vegetative Cover	68.1	Vigorous dense cover or fill slope of stable material
	23.6	Less than full cover, but >50% if fill slope has effective cover
	8.3	<50% of fill slope has effective cover
b. Rilling	78.6	Rills may be evident, infrequent, stable and no evidence of sediment delivery
	13.5	Few rills present (<1 rill per lineal 5 ft) not enlarging with little apparent deposition
	7.9	Numerous rills present (>1 rill per lineal 5 ft) enlarging or with evidence of delivery to channel
c. Gullies	86.9	None
	7.1	Gullies present, not enlarging, little apparent deposition in channel
	6	Gullies present and enlarging or threatening integrity of fill
d. Cracks	89.2	None evident
	8	Cracks present, but appear to be stabilized
	2.8	Cracks present and widening, threatening integrity of fill
e. Slope Failure	61.4	None
	32.1	Less than 1 cubic yard of material
	2.8	>1 cubic yard of material
	3.7	>1 cubic yard moved and material enters stream
<u>Road Surface Draining to Crossings</u>		
a. Rutting	83.3	No ruts present
	14.3	Some ruts present but design drainage not impaired
	2.4	Rutting impairs road drainage
b. Rilling	89.4	Little or no evidence of rilling
	8.6	Rills occupy <10% of road surface area, or do not leave road surface
	2	Rills occupy >10% of surface and continue off road surface onto crossing or fill
c. Ponding	82.6	No evidence of ponded water
	14.1	Ponding present, but does not appear to threaten integrity of fill
	3.3	Ponding present and is causing fill subsidence or otherwise threatening integrity of fill
d. Road Surface Drainage	63.9	Stable drainage with little or no sediment delivery to stream
	26.5	Slight sediment delivery but configuration is stable or stabilizing
	9.6	Continuing sediment delivery to stream and configuration is unstable/degrading

Culverts		
a. Scour at Inlet	92	No evidence of scour
	5.7	Scour evident but extends less than 2 channel widths above inlet and no undercutting of crossing fill
	2.3	Scour evident that extends more than 2 channel widths above inlet or scour is undercutting crossing fill
b. Scour at Outlet	63.8	No evidence of scour
	23	Scour evident, but extends less than 2 channel widths below outlet, and no undercutting of crossing fill
	13.2	Scour evident that extends more than 2 channel widths below outlet or scour undercuts crossing fill
c. Diversion Potential	83.5	Crossing configured to minimize fill loss (road does not slope downward from crossing in at least one direction)
	11	Crossing has road that slopes downward in at least one direction with drainage structure
	5.5	If culvert fails, flow will be diverted out of channel and down roadway
d. Plugging	78.2	No evidence of sediment, debris
	12.6	Sediment and/or debris is accumulating <30% of inlet or outlet is blocked
	9.2	Sediment and/or debris is blocking >30% of inlet or outlet
e. Piping	97.7	No evidence of flow beneath or around culvert
	2.3	Flow passes beneath or around culvert, or piping erosion evident
Non-Culvert Crossing		
a. Diversion	100	Crossing is configured to minimize fill loss
	0	Overflow will be diverted down roadway
Removed or Abandoned		
a. Bank Stabilization	61	Vigorous dense vegetation cover or other stabilization material
	34.1	Less than full cover, but >50% of channel bank has effective cover or has stable material
	4.9	<50% of channel bank has effective cover or is composed of stable material
b. Rilling of Banks	87.8	Rills may be evident but infrequent, stable, with no sediment delivery to channel
	12.2	Few rills present (<1 per lineal 5 ft) and rills not enlarging
	0	Numerous rills present (>1 rill per lineal 5 ft) or apparently enlarging
c. Gullies	100	None evident
	0	Gullies present but not enlarging
	0	Gullies present and enlarging or threatening integrity of fill
d. Slope Failures	97.6	Less than 1 cubic yard of material
	2.4	>1 cubic yard of material moved, material enters stream
	0	>=1 cubic yard of material moved but does not enter stream

e. Channel Configuration	80.5	Wider than natural channel and close to natural watercourse grade and orientation
	14.6	Minor differences from natural channel in width, grade, or orientation
	4.9	Narrower than natural channel width, or significant differences from natural channel grade or orientation
f. Excavated Material	92.5	Sloped to prevent slumping and minimize erosion
	7.5	Slumps or surface erosion present, but <1 cubic yard of material enters channel
	0	Slumps or surface erosion present, >1 cubic yard of material enters channel
g. Grading and Shaping	80	No evidence of erosion or sediment discharge to channel due to failures of cuts, fills or sidecast
	20	<1 cubic yard of material transported to channel due to failures of fills or sidecast
	0	>1 cubic yard material transported to channel due to failures of fills or sidecast
Road Approaches at Abandoned Crossings		
a. Grading and Shaping	76.5	No evidence of concentrated water flow to channel from road surface
	20.6	<1 cubic yard of material transported to channel from eroded surface soil on road approaches
	2.9	>1 cubic yard of material transported to channel from eroded surface soil on road approaches

Table A-7. WLPZs--implementation ratings for WLPZs as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
916.4(b)	THP provided for filtration of organic material	263	258	100.0	0.0	0.0
916.2(a)(4)	Sensitive conditions--overflow channels	264	84	100.0	0.0	0.0
916.4(b)	THP provided for flow changes by LWD	263	252	100.0	0.0	0.0
916.2(a)(4)	Sensitive conditions--flood prone areas	264	77	100.0	0.0	0.0
916.3(c)	Roads, landings outside of WLPZs	264	224	98.2	1.3	0.4
916.3(e)	Trees in WLPZ felled away from channel	264	238	97.5	2.5	0.0
916.4(a)	Sensitive conditions--erodible banks	264	111	89.2	9.0	1.8
916.4(a)	Sensitive conditions--changeable channels	264	89	98.9	1.1	0.0
916.4(b)(4)	WLPZ width segregated by slope class	264	235	97.4	2.6	0.0
916.4(b)(5)	No reduction in width with unrocked roads in WLPZ	264	3	100.0	0.0	0.0
916.4(b)(6)	75% surface cover retained in WLPZ	264	252	100.0	0.0	0.0
916.4(b)	THP provided for protection for water temp.	262	258	99.2	0.8	0.0
916.4(b)	THP provided for channel stabilization	264	251	98.8	1.2	0.0
916.4(d)	Heavy equip excluded unless explained	264	246	97.2	2.4	0.4
916.4(b)	THP provided for upslope stability	264	258	97.7	2.3	0.0
916.5(a)(3)	Side slope classes used to determine WLPZ	263	254	97.2	2.4	0.4
916.5(e)"D"	Class I-base mark applied below cut line	265	56	100.0	0.0	0.0
916.5(e)"F"	Class IV-when required in THP-trees marked	264	1	100.0	0.0	0.0
916.5(e)"F"	Class III-when required in THP-trees marked	264	3	100.0	0.0	0.0
916.5(e)"H"	Class III-50% of understory vegetation left in WLPZ	264	3	100.0	0.0	0.0
916.5(e)"I"	Class II-50% of total canopy left in WLPZ	264	203	96.6	2.5	1.0
916.5(e)"I"	Class IV-50% of total canopy left in WLPZ	264	3	100.0	0.0	0.0
916.7(b)	Where 800 sq ft exposed--replanting?	263	1	100.0	0.0	0.0
916.7, 916.7(b)	Where 800 sq ft exposed--grass seeding	264	8	100.0	0.0	0.0
916.7	Where 800 sq ft exposed--rip rap	264	1	100.0	0.0	0.0
916.2(a)(4)	Sensitive conditions-debris jam potential	263	98	98.0	2.0	0.0

916.2(a)(4)	Sensitive conditions--unstable banks	264	107	98.1	0.9	0.9
916.2(a)(4)	Sensitive conditions--existing roads in WLPZ	264	71	90.1	7.0	2.8
916.3(d)	Vegetation by wet areas retained/protected	264	113	100.0	0.0	0.0
916.3(d)	Soil within meadows/wet areas protected	264	98	100.0	0.0	0.0
916.3(g)	Class I/II-2 living conifers 16 in DBH, 50 ft tall	264	255	99.2	0.8	0.0
916.3.b	Accidental depositions of soil removed	264	34	94.1	5.9	0.0
916.4(a)	Sensitive conditions--existing roads in WLPZ	267	70	91.4	5.7	2.9
916.4(a)	Sensitive conditions--debris jam potential	264	96	95.8	4.2	0.0
916.4(a)	Sensitive conditions--overflow channels	264	83	100.0	0.0	0.0
916.4(a)	Sensitive conditions-flood prone areas	264	74	100.0	0.0	0.0
916.4(b)(3)	Width of WLPZ conform to Table 1 in FPRs	264	251	92.8	6.4	0.8
916.4(b)(5)	For I/IIs, where WLPZ reduced--still 50 ft wide	264	22	95.5	4.5	0.0
916.4(b)(5)	No WLPZ reduction when unrocked road	264	3	100.0	0.0	0.0
916.4(b)	WLPZ widths as wide as specified in Table 1	264	251	93.6	5.6	0.8
916.4(c)(2)	Class III/IV--measures in Table 1 applied	264	5	100.0	0.0	0.0
916.4(c)(3)	Class III-soil removed or stabilized	264	1	100.0	0.0	0.0
916.4(c)(3)	Temporary crossings removed	264	30	96.7	0.0	3.3
916.4(d)(1)	Class I-location of equipment flagged in WLPZ	264	8	100.0	0.0	0.0
916.5(a)(1)	Location of watercourse used to set WLPZ	271	269	98.5	1.5	0.0
916.5(a)(2)	Restorable beneficial uses used to set WLPZ	265	262	99.6	0.4	0.0
916.5(e)"E"	Class II-base mark below cut line of trees	264	181	98.3	1.1	0.6
916.5(e)"G"	Class I-50% overstory and 50% understory	264	59	100.0	0.0	0.0
916.7(b)	Stabilization 800 sq ft-improve sediment filter	264	10	100.0	0.0	0.0
916.7(b)	Stabilization 800 sq ft-minimize erosion	264	10	100.0	0.0	0.0
916.7(b)	Stabilization 800 sq ft-stabilize banks	264	10	100.0	0.0	0.0
916.7, 916.7(b)	Where 800 sq ft exposed-mulching	264	9	100.0	0.0	0.0
916.7	Stabilization 800 sq ft-prevent soil movement	264	8	100.0	0.0	0.0
916.2(a)(4)	Sensitive conditions--changeable channels	264	87	98.9	1.1	0.0
916.5(b)	Beneficial uses consistent w/WLPZ classes	263	260	98.8	1.2	0.0

7/15/02

Soquel Demonstration State Forest
Instream Temperature Monitoring 2001
East Branch of Soquel Creek, Fern Gulch Creek and Amaya Creek

METHODS

Hobo and Stow-Away temperature data loggers (Hobos) were installed at various locations in Soquel Demonstration State Forest (SDSF) in order to continuously monitor stream water and air temperatures throughout the dry season. Hobos recorded temperatures from June 12, 2001 to October 19, 2001.

Locations and Installation

Monitoring locations were chosen based on the following criteria:

- Locations that would demonstrate stream temperature variations of Soquel Creek as it flows through the forest, as well as the temperature of Amaya Creek and Fern Gulch Creek;
- Locations of fish refugia (deeper, shaded areas with cover).

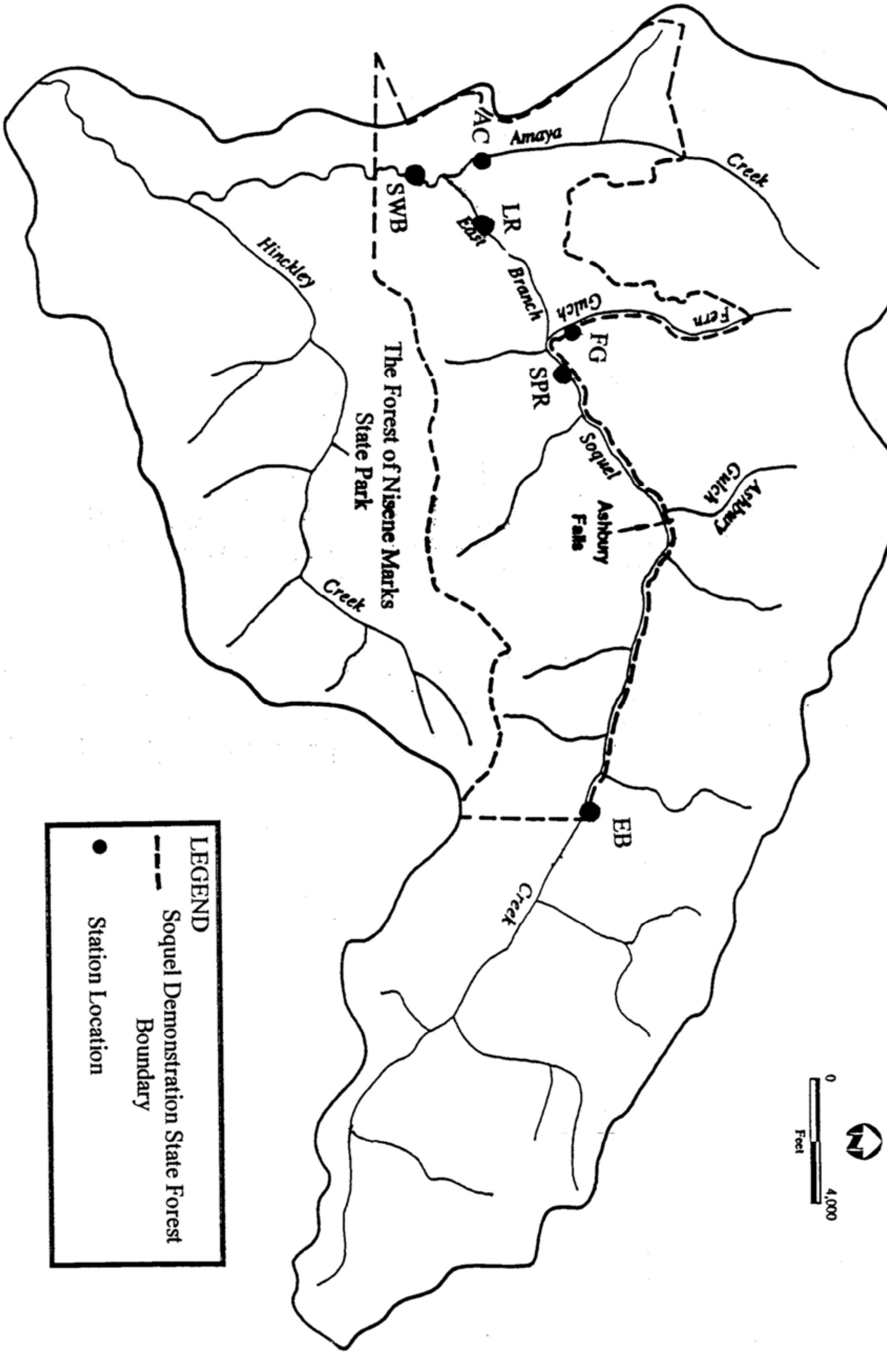
The last criterion was especially important because high water temperatures contribute to lower salmonid survival rates, and fish retreat to these locations to escape warm water temperatures.

Each Hobo was sealed in a clear plastic canister full of clean dry gravel and (except where otherwise indicated) tightly attached to a rock with baling wire, placed in the stream, and covered with cobbles. This method of attachment was used to keep the Hobos submerged throughout the dry season and to hide them to avoid tampering. Included in the canisters were the name of the site and an SDSF business card with "if found please call" written on it. The Hobos were placed in the canisters so that the red light (which indicates it is recording) could be seen from the outside. Red polka dotted flagging was hung at each site to facilitate relocation.

Hobo locations were the same approximate sites as previous years (see map). New Hobos were placed in Fern Gulch Creek and near Long Ridge Crossing in Soquel Creek this year. Hobo locations were as follows:

> East Boundary - on the east branch of Soquel Creek near the boundary between SDSF and Redwood Empire lands. A green sign on Hihn's Mill Road indicates the property boundary. From there, the pink flagging can be followed downhill to the creek. Downstream from the boundary is a slide descending from Highland Way, a car body and a large debris jam (about 75 feet long and 12 feet high). The data logger was placed at the upper end of the debris jam in a small pool (about one foot deep) formed by large woody debris.

Hobo Temperature Data Logger Stations Map



Spanish Ranch - on the east branch of Soquel Creek at Spanish Ranch Crossing. Approximately 50 feet upstream from the bottom of the electro-fishing station, under the roots of a clump of redwood trees on the left bank (looking downstream). This site has almost 100% shade canopy.

Spanish Ranch Air - in redwood clump (mentioned above) approximately 10 feet above the creek level.

Long Ridge Crossing - approximately 200 feet downstream from Long Ridge Crossing where a redwood log has fallen across Soquel Creek creating a small bridge that is used as a trail crossing. Approximately 10 feet downstream from the fallen log on the left side of the creek the Hobo temp was tucked under some downed woody debris, which was marked with red polka dotted flagging.

Southwest Boundary - east branch of Soquel Creek 900 feet below the bridge crossing. Placed in a small pool under the third alder root wad, about 30 feet downstream from where the rock face ends on the left bank. This site is mostly riffle habitat with very little water deeper than six inches.

Fern Gulch Creek - approximately 300 feet upstream from the confluence of Soquel Creek and Fern Gulch Creek. The Hobo temp was placed in a small pool (created by a log across the creek) on the right side beneath the undercut bank. To reach the confluence, head towards Soquel Creek from Hihn's Mill Road approximately 200 feet west of Sawpit Trail.

Amaya Creek - approximately 100 feet upstream from the confluence with the east branch of Soquel Creek. Two large redwood slabs form a shallow pool; one slab forms a spillway, and the other forms the overhanging left bank. The Hobo was placed under the latter log.

Interval

All Hobos were "launched" to record for six months, which BoxCar Pro 4.0 automatically sets for a two-hour or half-hour interval depending on the make of the Hobo temp. Long Ridge Crossing, East Boundary, and Fern Gulch Creek were automatically set on half-hour interval readings.

Data Analysis

All data was downloaded in BoxCar Pro 4.0 and exported to Excel for graphing and analysis. Temperature measurements taken during transport to and from monitoring sites were eliminated. A rolling seven-day average was calculated and graphed over the raw temperature readings. This number was calculated for each data point as the average temperature for the previous 3.5 days and following 3.5 days. With twelve temperature measurements taken in a 24-hour period (or 48 if the Hobo temp was taking half-hour readings), the resulting number is an average of 84 (or 336) data points. The seven-day rolling average historically has more closely corresponded with fish success than straight temperature readings, because it reflects the duration of high temperatures. All temperature data displayed in the following tables is from absolute data, not from the 7-day rolling average.

RESULTS

Results are shown on graphs in the appendix. These graphs were taken from the data tables, which are too large to be printed but can be viewed on a computer screen. All Hobo data are on the SDSF computer hard drive - C:\FILE CABNET\Hobo Reports\Hobo Temps 2001\2001 Hobo Excel Data.

Data for the Southwest boundary were not recorded and are depicted in each table by N/A. The Southwest boundary Hobo temp was launched with a new battery, but must have experienced an internal malfunction during the four months. In previous years the Hobo temps have not always recorded data for the full 4-6 months. When reviewing data from prior years, N/A indicates that the Hobo temp did not record the data properly or no data were collected for the site. In the beginning of October, the Spanish Ranch Air Hobo temp was found on the forest floor instead of its original position (attached 10 feet high in a redwood tree). This may have had an effect on the results of the Spanish Ranch Air temperature readings.

DISCUSSION

The highest temperatures were recorded from late June to the beginning of August. High temperatures (ºF) for each site are shown below in Table 1 for 2000 and 2001.

Table 1. High Temperatures (°F), Date, and Time by Site for 2000 and 2001

Site	High Temp. 2000	Date(s)	Time	High Temp. 2001	Date(s)	Time
East Boundary	N/A	N/A	N/A	64.91	7/03,7/04	15:59
Spanish Ranch	66.9	7/31,8/5	17:28	70.82	7/03	17:04
Long Ridge Crossing	N/A	N/A	N/A	70.39	6/19, 6/21,6/29,	16:00
Southwest Boundary	N/A	N/A	N/A	N/A	N/A	N/A
Fern Gulch Creek	N/A	N/A	N/A	61.48	7/03, 7/04	13:00
Amaya Creek	62.36	6/21,6/26,6/27, 7/23,7/31,8/4, 8/5,812	17:31	68.73	7/03	15.05
Spanish Ranch Air	81.59	7/23	15:29	85.52	7/02	13:00

Maximum water and air temperatures were higher in 2001 than 2000. In both 2000 and 2001, temperatures were higher in Soquel Creek at the sites lower in the watershed. Temperature fluctuations throughout the monitoring period were most extreme lower in the watershed as well. Table 2 shows the total fluctuation in temperature, from the highest and lowest temperatures recorded for each location, during the entire 2001 measurement period.

Table 3 lists by station the most extreme fluxuations in temperature within one day during the 2001 monitoring period. The largest water temperature fluctuation within one day was 13.05ºF at the Long Ridge Crossing location. Spanish Ranch Air fluxuated 35.02ºF in one day. Temperature fluctuations were greatest during heat waves from the beginning of July through August, and began to decrease at the beginning of September.

Table 2. Temperature Extremes (ºF) by Station for 2001

Site	High Temp	Low Temp	Fluctuation
East Boundary	64.91	51.08	13.83
Spanish Ranch	70.22	50.84	19.38
Long Ridge Crossing	70.39	51.79	18.6
Southwest Boundary	N/A	N/A	N/A
Fern Gulch Creek	61.48	50.38	11.1
Amaya Creek	68.73	50	18.73
Spanish Ranch Air	85.52	43.28	42.24

Table 3. Most Extreme Temperature (ºF) Fluctuation within One Day by Station in 2001

Site	Date	High	Low	Difference
East Boundary	6/16/01	60.11	55.28	4.83
Spanish Ranch	7/01/01	69.32	60.07	9.25
Long Ridge Crossing	6/14/01	69.02	55.97	13.05
Southwest Boundary	N/A	N/A	N/A	N/A
Fern Gulch Creek	9/06/01	57.35	52.49	4.86
Amaya Creek	6/15/01	66.7	58.09	8.61
Spanish Ranch Air	6/13/01	80.3	45.28	35.02

Water temperatures above 70ºF make it difficult for coho and steelhead to extract oxygen from the water. Optimal rearing temperatures for juveniles are 45-58ºF for steelhead and 53-58ºF for coho (Resner and Bjornn, 1979). For the sake of comparison, it is interesting to note the number of days recorded at 70°F or higher and 58°F or higher (see Tables 4 and 5, respectively). Since the monitoring period varies from year to year, these tables' comparisons have been adjusted to reflect the same time period in 2000 and 2001. Table 5 shows that compared to 2000, there were several more days in 2001 above 58ºF at the Amaya and Spanish Ranch sites. Table 6 presents a comparison of the peak high temperatures from 1997 to the present. The most notable temperature increase is the air temperature for the Spanish Ranch location.

Table 4. Comparison of Number of Days above 70ºF by Station for the Same Time Period in 2000 and 2001

Site	No. of Days at or above 70º in 2000	No. of Days at or above 70º in 2001
East Boundary	N/A	0
Spanish Ranch	0	2
Long Ridge Crossing	N/A	3
Southwest Boundary	N/A	N/A
Fern Gulch Creek	N/A	0
Amaya Creek	0	0
Spanish Ranch Air	46	80

Table 5. Comparison of Number of Days above 58ºF by Station for the Same Time Period in 2000 and 2001

Site	No. of Days at or above 58º in 2000	No. of Days at or above 58º in 2001
East Boundary	N/A	89
Spanish Ranch	73	117
Long Ridge Crossing	N/A	111
Southwest Boundary	N/A	N/A
Fern Gulch Creek	N/A	66
Amaya Creek	67	99
Spanish Ranch Air	90	98

Table 6. Comparisons of Maximum High Temperatures by Site for 1997, 1998, 1999, 2000, and 2001

Site	High Temp. (°F) 1997	High Temp. (°F) 1998	High Temp. (°F) 1999	High Temp. (°F) 2000	High Temp. (°F) 2001
East Boundary	67.45	67.45	63.68	N/A	64.91
Spanish Ranch	67.86	70.22	66.41	66.90	70.82
Long Ridge Crossing	N/A	N/A	N/A	N/A	70.39
Southwest Boundary	73.80	76.35	71.28	N/A	N/A
Fern Gulch Creek	N/A	N/A	N/A	N/A	61.48
Amaya Creek	66.41	68.44	66.99	62.36	68.73
Spanish Ranch Air	75.06	79.01	83.55	81.59	85.52

Suggestions for Next Year

Comparisons and trends can best be monitored when methods are repeated closely, particularly matching start and stop dates for monitoring. Brad Valentine, Fisheries Biologist for the California Department of Fish and Game, suggested putting the data loggers in June 1 and taking them out in mid to late October, since water temperatures can be highest as early as June 1. Heavy winter rains will probably rearrange the monitoring sites and make them hard to find again. Another site can be substituted as long as it has similar habitat type and cover. It would be helpful to have canopy cover data for each site. To accurately locate sites, measure the distances referenced in the site description.

02/8/02

Soquel Demonstration State Forest
Instream Temperature Monitoring 2002
East Branch of Soquel Creek, Fern Gulch Creek and Amaya Creek

METHODS

Hobo and Stow-Away temperature data loggers (Hobos) were installed at various locations in Soquel Demonstration State Forest (SDSF) in order to continuously monitor stream water and air temperatures throughout the dry season. Hobos recorded temperatures from May 31, 2002 to October 25, 2002.

Locations and Installation

Monitoring locations were chosen based on the following criteria:

- Locations that would demonstrate stream temperature variations of Soquel Creek as it flows through the forest, as well as the temperature of Amaya Creek and Fern Gulch Creek;
- Locations of fish refugia (deeper, shaded areas with cover).

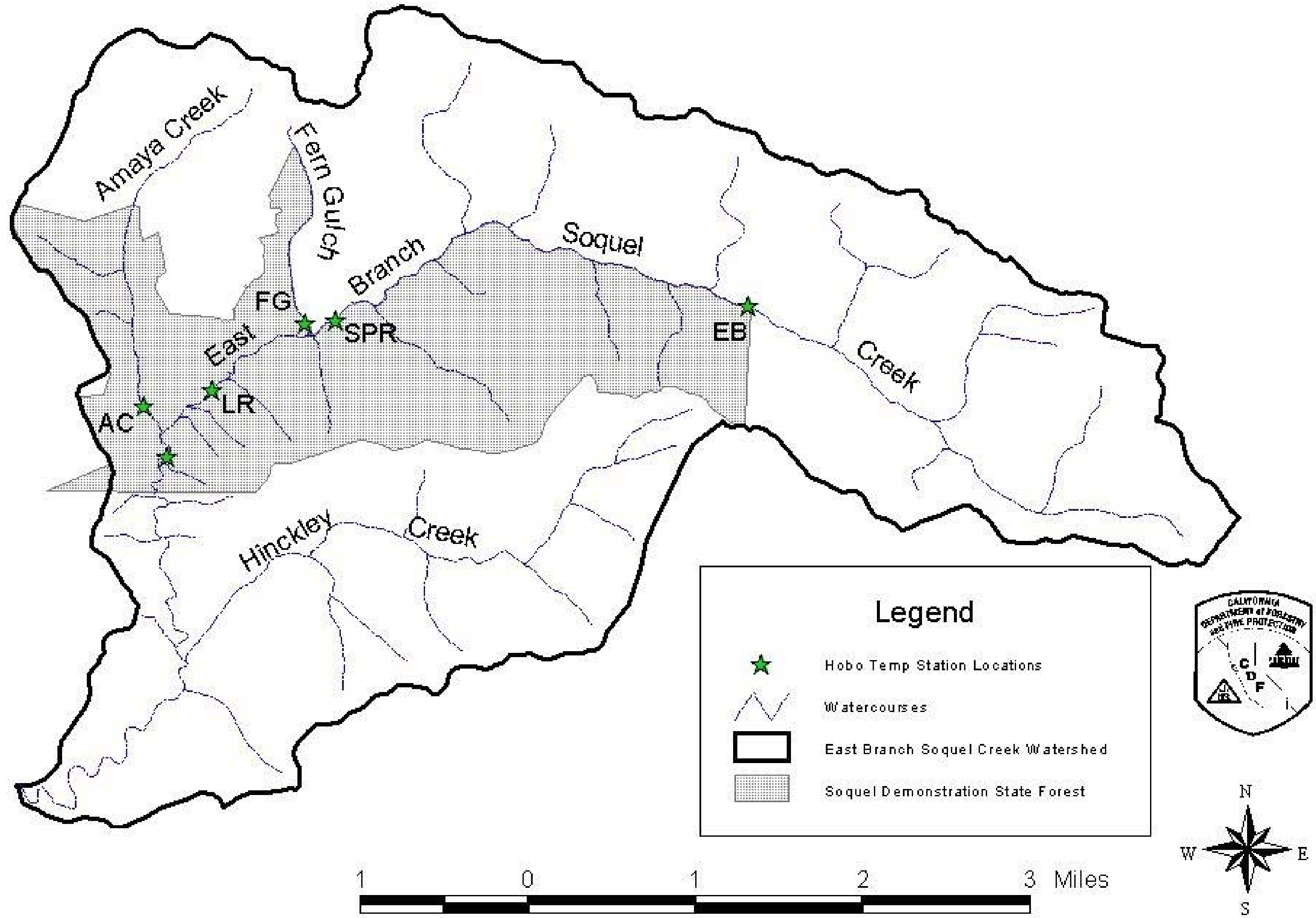
The last criterion was especially important because high water temperatures contribute to lower salmonid survival rates, and fish retreat to these locations to escape warm water temperatures.

Each Hobo was sealed in a clear plastic canister full of clean dry gravel and (except where otherwise indicated) tightly attached to a rock with baling wire, placed in the stream, and covered with cobbles. This method of attachment was used to keep the Hobos submerged throughout the dry season and to hide them to avoid tampering. Included in the canisters were the name of the site and an SDSF business card with "if found please call" written on it. The Hobos were placed in the canisters so that the red light (which indicates it is recording) could be seen from the outside. Red polka dotted flagging was hung at each site to facilitate relocation.

This year canopy readings were made by an ocular estimation at each Hobo site. Hobo locations were the same approximate sites as previous years (see map). Hobo locations were as follows:

> East Boundary - on the east branch of Soquel Creek near the boundary between SDSF and Redwood Empire lands. A green sign on Hihn's Mill Road indicates the property boundary. From there, the pink flagging can be followed downhill to the creek. At the creek are two pink flags tied to a tree. Downstream from the pink flags is a slide descending from Highland Way, a car body and a large debris jam (about 75 feet long and 12 feet high). The data logger was placed 115 feet downstream from the two pink flags at the

Hobo Temperature Data Logger Stations Map



upper end of the debris jam in a small pool (about one foot deep) formed by large woody debris. This site had roughly 20% shade canopy. The Hobo was under large woody debris and did not receive any solar radiation.

Spanish Ranch - on the east branch of Soquel Creek at Spanish Ranch Crossing. Approximately 78 feet upstream from the bottom of the electro-fishing station, under the roots of a clump of redwood trees in a pool on the left bank (looking downstream). This site had almost 100% shade canopy and received no direct sunlight.

Spanish Ranch Air - in redwood clump (mentioned above) approximately 12 feet above the creek level.

Longridge Crossing - approximately 500 feet downstream from Longridge Crossing where a redwood log has fallen across Soquel Creek creating a small bridge that is used as a trail crossing. Approximately 10 feet downstream from the fallen redwood log on the left side of a large pool, the Hobo temp was tucked under some downed woody debris, which was marked with red polka dotted flagging. This location has approximately 70% shade canopy. The Hobo received no solar radiation because it is tucked under a log with cobbles placed on top.

Southwest Boundary - east branch of Soquel Creek 965 feet below the bridge crossing. Placed in an undercut bank under the third alder root wad, about 30 feet downstream from where the rock face ends on the right bank. This site is mostly riffle habitat with very little water deeper than ten inches. The shade canopy at this location was estimated at 85% with no solar radiation reaching the Hobo logger.

Fern Gulch Creek - approximately 472 feet upstream from the confluence of Soquel Creek and Fern Gulch Creek. The Hobo temp was placed in a small pool (created by a log across the creek) on the right side beneath the undercut bank, which is marked with red polka dotted flagging.   This site had approximately 80% shade canopy and the Hobo received no solar radiation. To reach the confluence, head towards Soquel Creek from Hihn's Mill Road approximately 200 feet west of Sawpit Trail. This spot is marked on Hihn's Mill Road with red polka dotted flagging.

Amaya Creek - approximately 245 feet upstream from the confluence with the east branch of Soquel Creek. Two large redwood slabs form a shallow pool; one slab forms a spillway, and the other forms the overhanging left bank. The Hobo was placed under the latter log and was fully protected from solar radiation. This location had approximately 30% shade canopy.

Interval

All Hobos were "launched" to record for six months, which BoxCar Pro 4.3 automatically sets for a two-hour interval depending on the make of the Hobo temp. Longridge Crossing, East Boundary, and Fern Gulch Creek were automatically set on half-hour interval readings.

Data Analysis

All data were downloaded in BoxCar Pro 4.3 and exported to Excel for graphing and analysis. Temperature measurements taken during transport to and from monitoring sites were eliminated. A rolling seven-day average was calculated and graphed over the raw temperature readings. This number was calculated for each data point as the average temperature for the previous 3.5 days and following 3.5 days. With twelve temperature measurements taken in a 24-hour period (or 48 if the Hobo temp was taking half-hour readings), the resulting number is an average of 84 (or 336) data points. The seven-day rolling average historically has more closely corresponded with fish success than straight temperature readings, because it reflects the duration of high temperatures. All temperature data displayed in the following tables is from absolute data, not from the 7-day rolling average.

RESULTS

Results are shown on graphs in the appendix. These graphs were taken from the data tables, which are too large to be printed but can be viewed on a computer screen. All Hobo data are on the SDSF computer hard drive - C:\FILE CABNET\Hobo Reports\Hobo Temps 2002\2002 Hobo Excel Data.

Data for the Southwest boundary were not recorded and are depicted in each table by N/A. The Southwest boundary Hobo temp was launched with a new battery, but must have experienced an internal malfunction during the four months. In previous years the Hobo temps have not always recorded data for the full four to six months. When reviewing data from prior years, N/A indicates that the Hobo temp did not record the data properly or no data were collected for the site.

DISCUSSION

The highest temperatures were recorded from the middle of July to the middle of August. High temperatures (ºF) for each site are shown below in Table 1 for 2001 and 2002.

Table 1. High Temperatures (°F), Date, and Time by Site for 2001 and 2002

Site	High Temp. 2001	Date(s)	Time	High Temp. 2002	Date(s)	Time
East Boundary	64.91	7/03,7/04	15:59	62.85	7/14	15:24
Spanish Ranch	70.82	7/03	17:04	68.73	7/10	17:20
Longridge Crossing	70.39	6/19,6/21,6/29	16:00	61.48	7/(10,11,13,14,17, 19,24,25,26,27,28, 29,30,31) 8/01	All times of the day
Southwest Boundary	N/A	N/A	N/A	N/A	N/A	N/A
Fern Gulch Creek	61.48	7/03,7/04	13:00	60.80	7/9,7/10,7/12,7/13	15:24 to 19:24
Amaya Creek	68.73	7/03	15:05	66.12	7/10	15:18
Spanish Ranch Air	85.52	7/02	13:00	85.52	7/09,8/10	15:19

Maximum water temperatures were lower in 2002 than 2001. In both 2001 and 2002, temperatures were higher at the Spanish Ranch site. The Longridge Crossing site had the greatest decrease in temperature from 2001 to 2002. Temperature fluctuations throughout the monitoring period were extreme in both the lower and upper portions of the watershed. In the past, the most extreme temperature fluctuations were in the lower portions of the watershed. Table 2 shows the total fluctuation in temperature, from the highest and lowest temperatures recorded for each location, during the entire 2002 measurement period.

Table 2. Temperature Extremes (ºF) by Station for 2002

Site	High Temp	Low Temp	Fluctuation
East Boundary	62.85	47.53	15.32
Spanish Ranch	68.73	50	8.73
Longridge Crossing	61.48	53.19	8.29
Southwest Boundary	N/A	N/A	N/A
Fern Gulch Creek	60.8	48.96	11.84
Amaya Creek	66.12	47.76	18.36
Spanish Ranch Air	85.52	43.95	41.57

Table 3 lists by station the most extreme fluctuations in temperature within one day during the 2002 monitoring period. The largest water temperature fluctuation within one day was 8.73°F at the Spanish Ranch location. Spanish Ranch Air temperature fluctuated 31.74ºF in one day. Temperature fluctuations were greatest during heat waves from the beginning of July through August, and began to decrease at the end of September.

Table 3. Most Extreme Temperature (ºF) Fluctuation within One Day by Station in 2002

Site	Date	High	Low	Difference
East Boundary	9/13/02	55.97	51.08	4.89
Spanish Ranch	7/9/02	67.86	50	8.73
Longridge Crossing	6/5/02	60.8	55.97	4.83
Southwest Boundary	N/A	N/A	N/A	N/A
Fern Gulch Creek	7/9/02	60.8	55.28	5.52
Amaya Creek	7/9/02	65.54	57.25	8.29
Spanish Ranch Air	8/12/02	79.01	47.27	31.74

Water temperatures above 70ºF make it difficult for coho salmon and steelhead trout to extract oxygen from the water. Optimal rearing temperatures for juveniles are 45-58ºF for steelhead and 53-58ºF for coho (Resner and Bjornn, 1979). For the sake of comparison, it is interesting to note the number of days recorded at 70°F or higher and 58°F or higher (see Tables 4 and 5, respectively). Since the monitoring period varies from year to year, these tables' comparisons have been adjusted to reflect the same time period in 2001 and 2002. Table 4 shows that in 2002 the Hobos recorded no days with water temperatures above 70°F, while in 2001 there were five days with temperatures over 70°F. Table 5 shows that compared to 2001, there were several more days in 2002 above 58ºF at the Spanish Ranch, Longridge Crossing, and Amaya Creek sites. Table 6 presents a comparison of the peak high temperatures from 1997 to the present. The most notable temperature increase is the air temperature for the Spanish Ranch location.

Table 4. Comparison of Number of Days above 70ºF by Station for the Same Time Period in 2001 and 2002

Site	No. of Days at or above 70º in 2001	No. of Days at or above 70º in 2002
East Boundary	0	0
Spanish Ranch	2	0
Longridge Crossing	3	0
Southwest Boundary	N/A	N/A
Fern Gulch Creek	0	0
Amaya Creek	0	0
Spanish Ranch Air	80	91

Table 5. Comparison of Number of Days above 58ºF by Station for the Same Time Period in 2001 and 2002

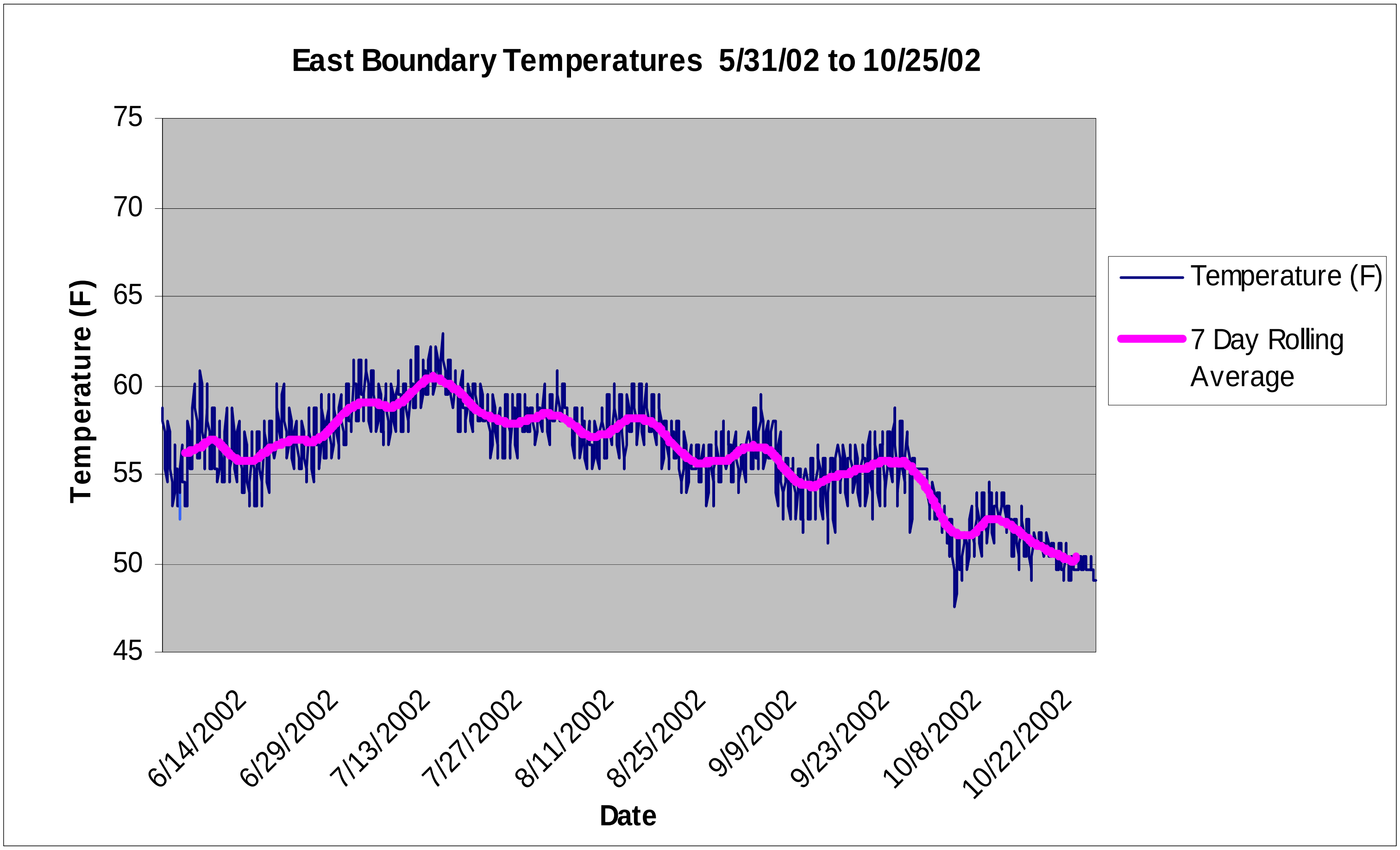
Site	No. of Days at or above 58º in 2001	No. of Days at or above 58º in 2002
East Boundary	89	82
Spanish Ranch	117	123
Longridge Crossing	111	121
Southwest Boundary	N/A	N/A
Fern Gulch Creek	66	44
Amaya Creek	99	118
Spanish Ranch Air	98	145

Table 6. Comparisons of Maximum High Temperatures by Site for 1997, 1998,1999, 2000, 2001 and 2002

	Temperature (F)					
Site	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
East Boundary	67.45	67.45	63.68	N/A	64.91	62.85
Spanish Ranch	67.86	70.22	66.41	66.9	70.82	68.73
Longridge Crossing	N/A	N/A	N/A	N/A	70.39	61.48
Southwest Boundary	73.8	76.35	71.28	N/A	N/A	N/A
Fern Gulch Creek	N/A	N/A	N/A	N/A	61.48	60.8
Amaya Creek	66.41	68.44	66.99	62.36	68.73	66.12
Spanish Ranch Air	75.06	79.01	83.55	81.59	85.52	85.52

Suggestions for Next Year

Comparisons and trends can best be monitored when methods are repeated closely, particularly matching start and stop dates for monitoring. In 2001 Brad Valentine, Fisheries Biologist for the California Department of Fish and Game, suggested putting the data loggers in June 1 and taking them out in mid to late October, since water temperatures can be highest as early as June 1. In 2002, the Hobos were placed in the watershed in late May and were not removed until the end of October. In the future, the Hobos will continue to be placed in the watershed during these months. Heavy winter rains can rearrange the monitoring sites and make them hard to find again. Another site can be substituted as long as it has similar habitat type and cover. The winter rainstorms for 2002/2003 have already been very intense. The Longridge Crossing location has been drastically changed. As a result, it may be necessary to find a new Hobo location for this site and possibly for some of the other Hobo sites in May.


East Boundary Temperatures 5/31/02 to 10/25/02
75
70
65
60
55
50
45
Temperature (F)
6/14/2002
6/29/2002
7/13/2002
7/27/2002
8/11/2002
8/25/2002
9/9/2002
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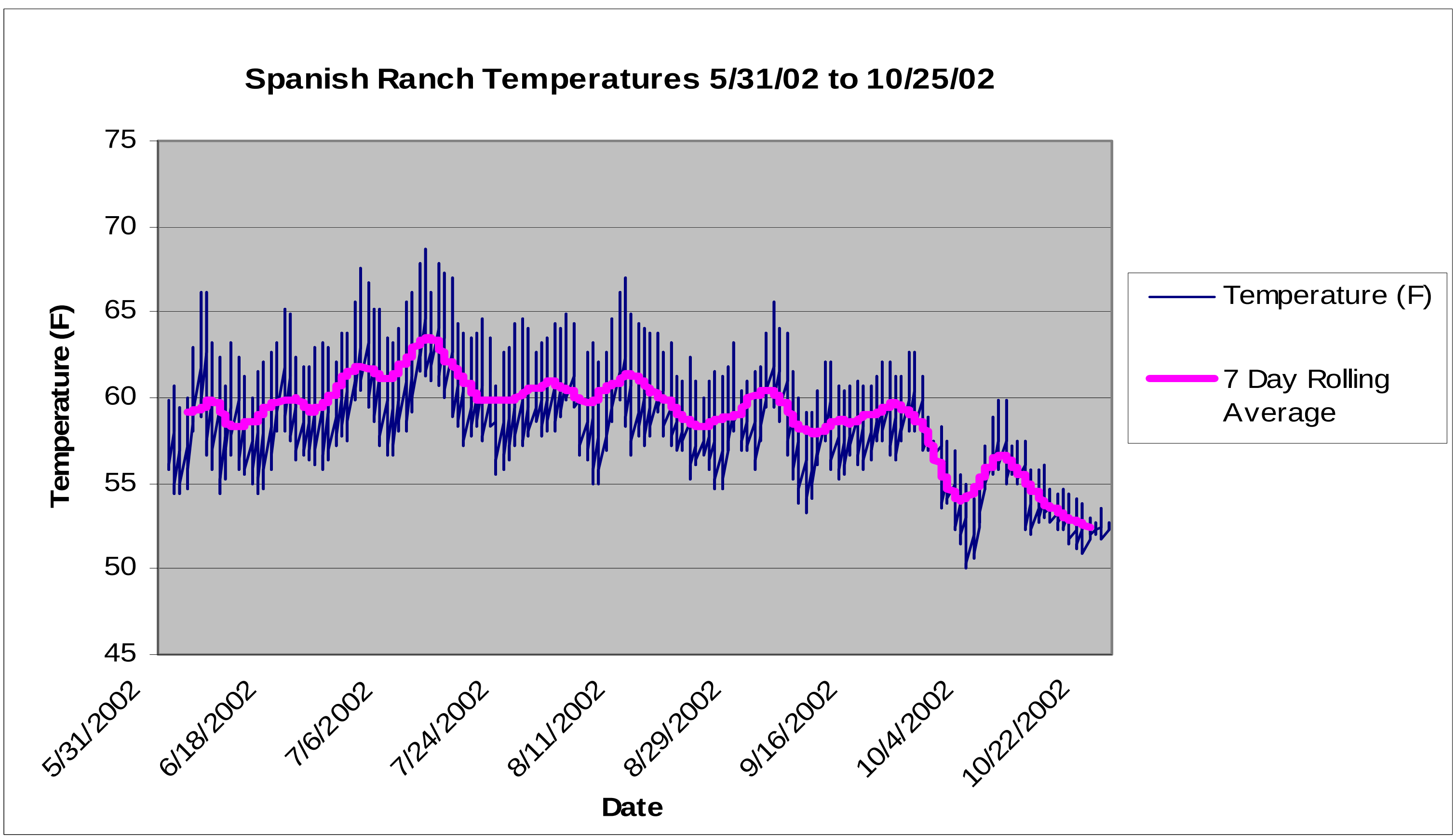
10/8/2002
10/22/2002
Date
Temperature (F)
7 Day Rolling Average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60
55
50
45
Temperature (F)
5/31/2002
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7/6/2002
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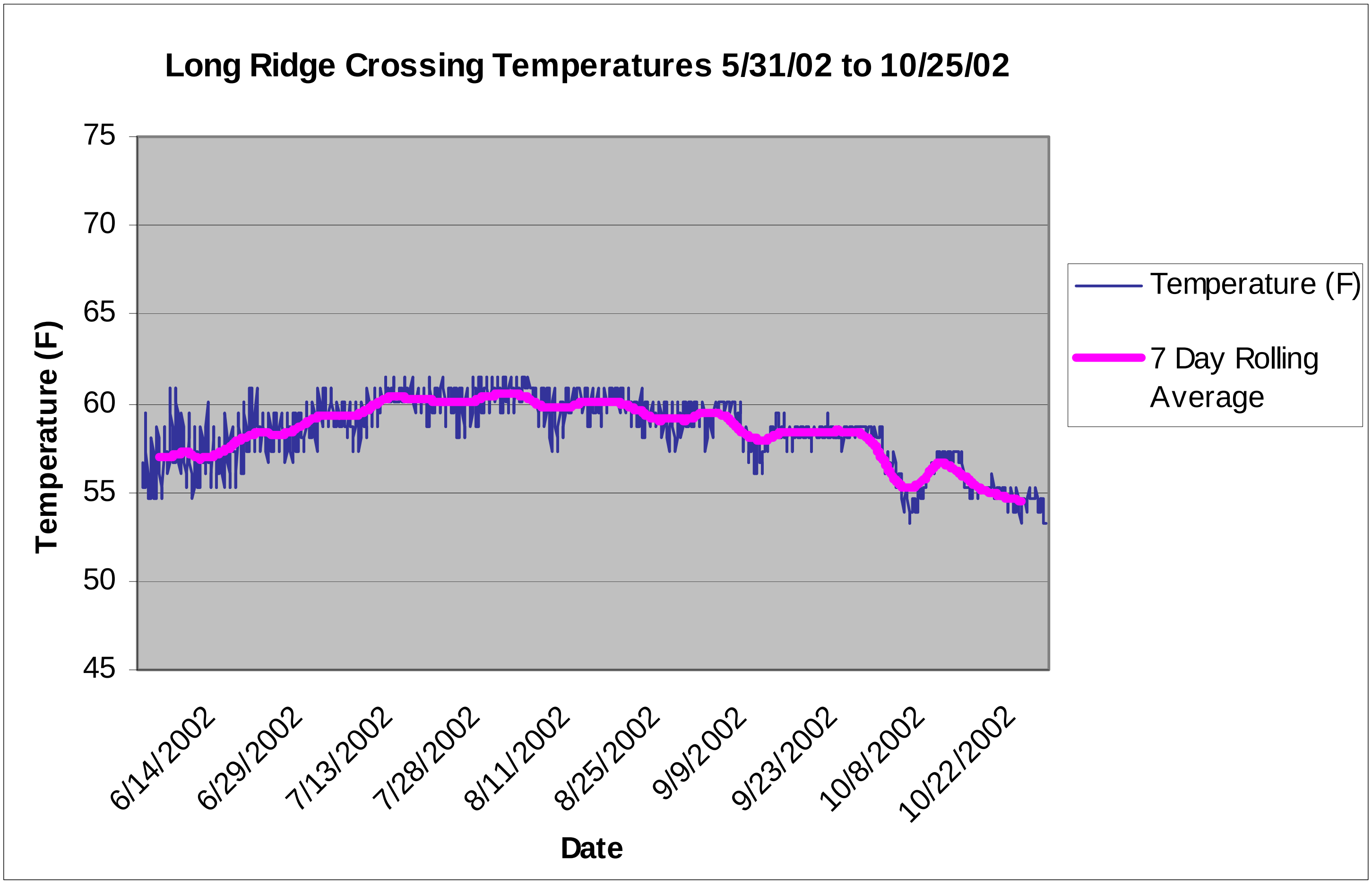
Date
Temperature (F)
7 Day Rolling Average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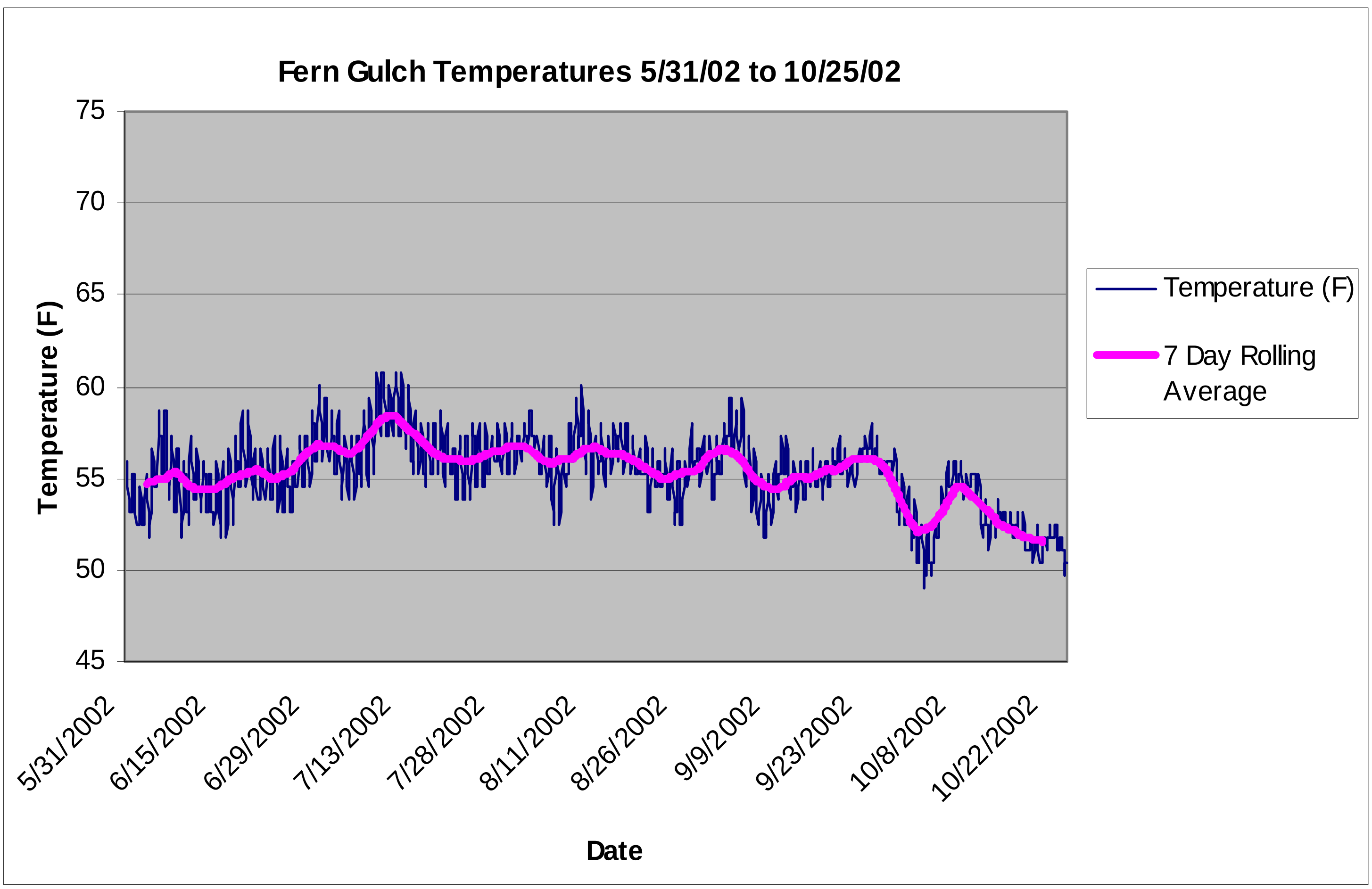
Date
Temperature (F)
7 Day Rolling Average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70
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60
55
50
45
Temperature (F)
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6/15/2002
6/29/2002
7/13/2002
7/28/2002
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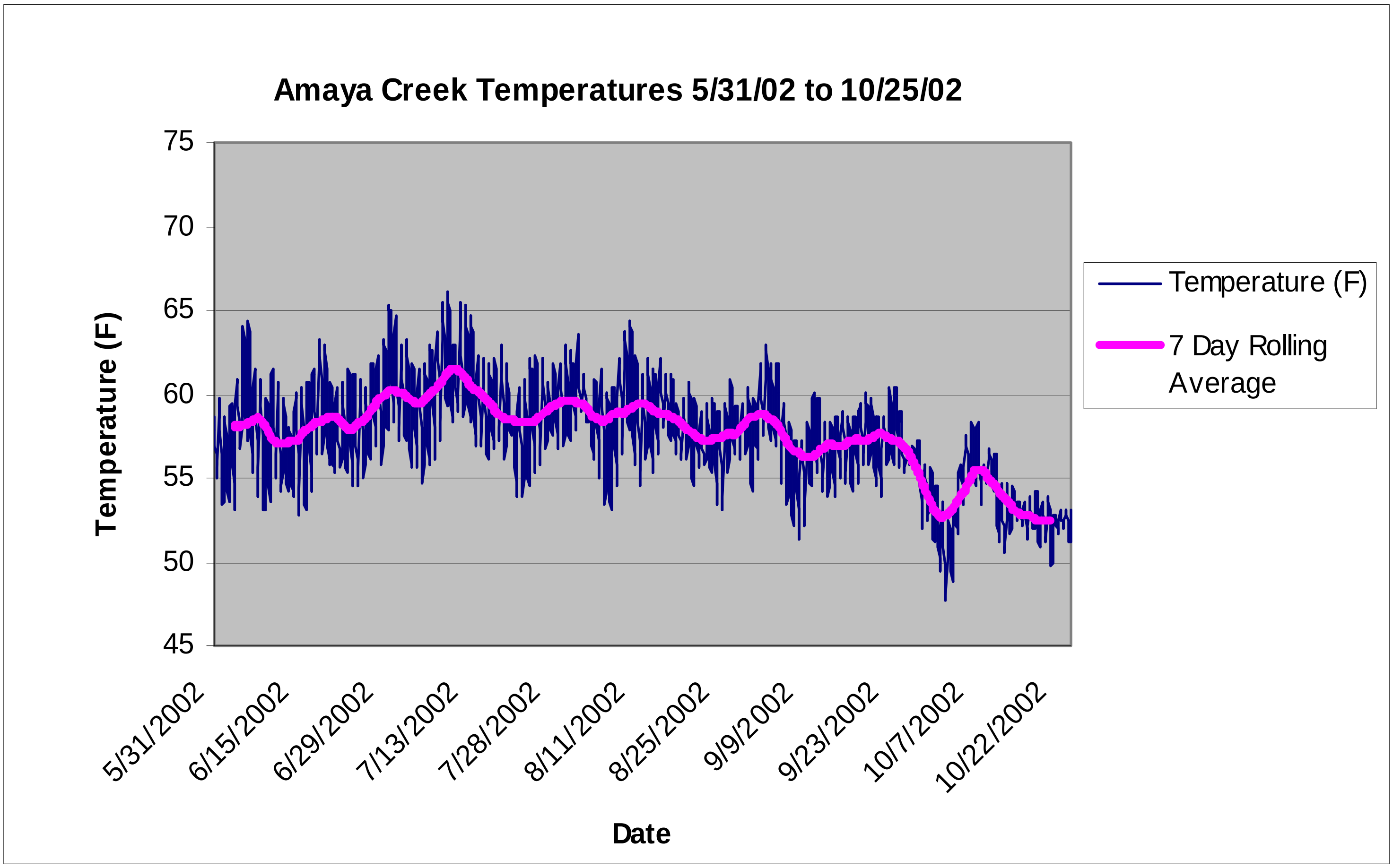
10/22/2002
Date
Temperature (F)
7 Day Rolling Average


Amaya Creek Temperatures 5/31/02 to 10/25/02
Temperature (F)
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70
65
60
55
50
45
5/31/2002
6/15/2002
6/29/2002
7/13/2002
7/28/2002
8/11/2002
8/25/2002
9/9/2002
9/23/2002
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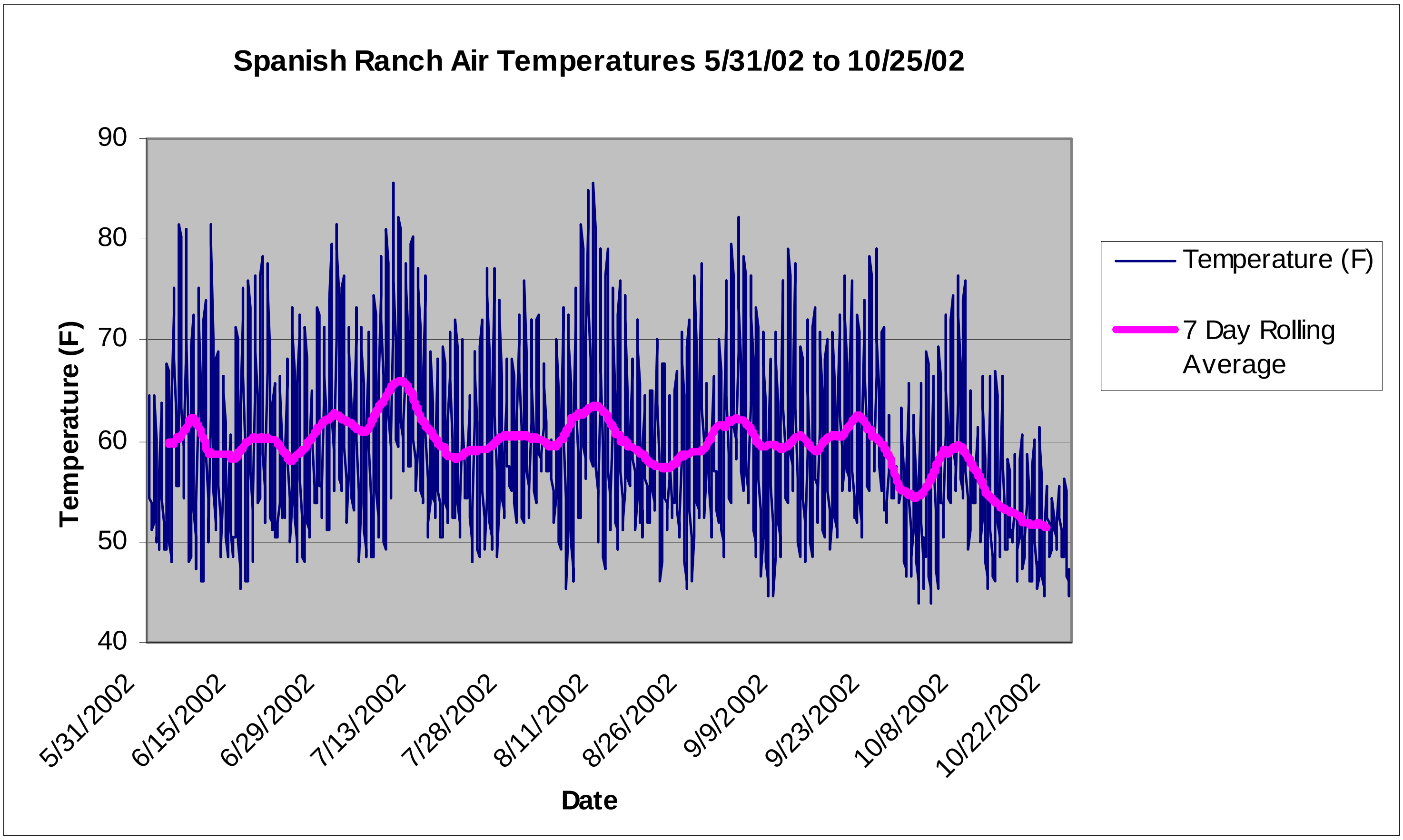
10/22/2002
Date
Temperature (F)
7 Day Rolling Average


Spanish Ranch Air Temperatures 5/31/02 to 10/25/02
Temperature (F)
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70
60
50
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5/31/2002
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7/13/2002
7/28/2002
8/11/2002
8/26/2002
9/9/2002
9/23/2002
10/8/2002
10/22/2002
Date
Temperature (F)
7 Day Rolling Average

Soquel Demonstration State Forest
Instream Temperature Monitoring 2003
East Branch of Soquel Creek, Fern Gulch Creek and Amaya Creek

METHODS

Hobo and Stow-Away temperature data loggers (Hobos) were installed at various locations in Soquel Demonstration State Forest (SDSF) in order to continuously monitor stream water and air temperatures throughout the dry season. Hobos recorded temperatures from June 2, 2003 to October 28, 2003.

Locations and Installation

Monitoring locations were chosen based on the following criteria:

- Locations that would demonstrate stream temperature variations of Soquel Creek as it flows through the forest, as well as the temperature of Amaya Creek and Fern Gulch Creek;
- Locations of fish refugia (deeper, shaded areas with cover).

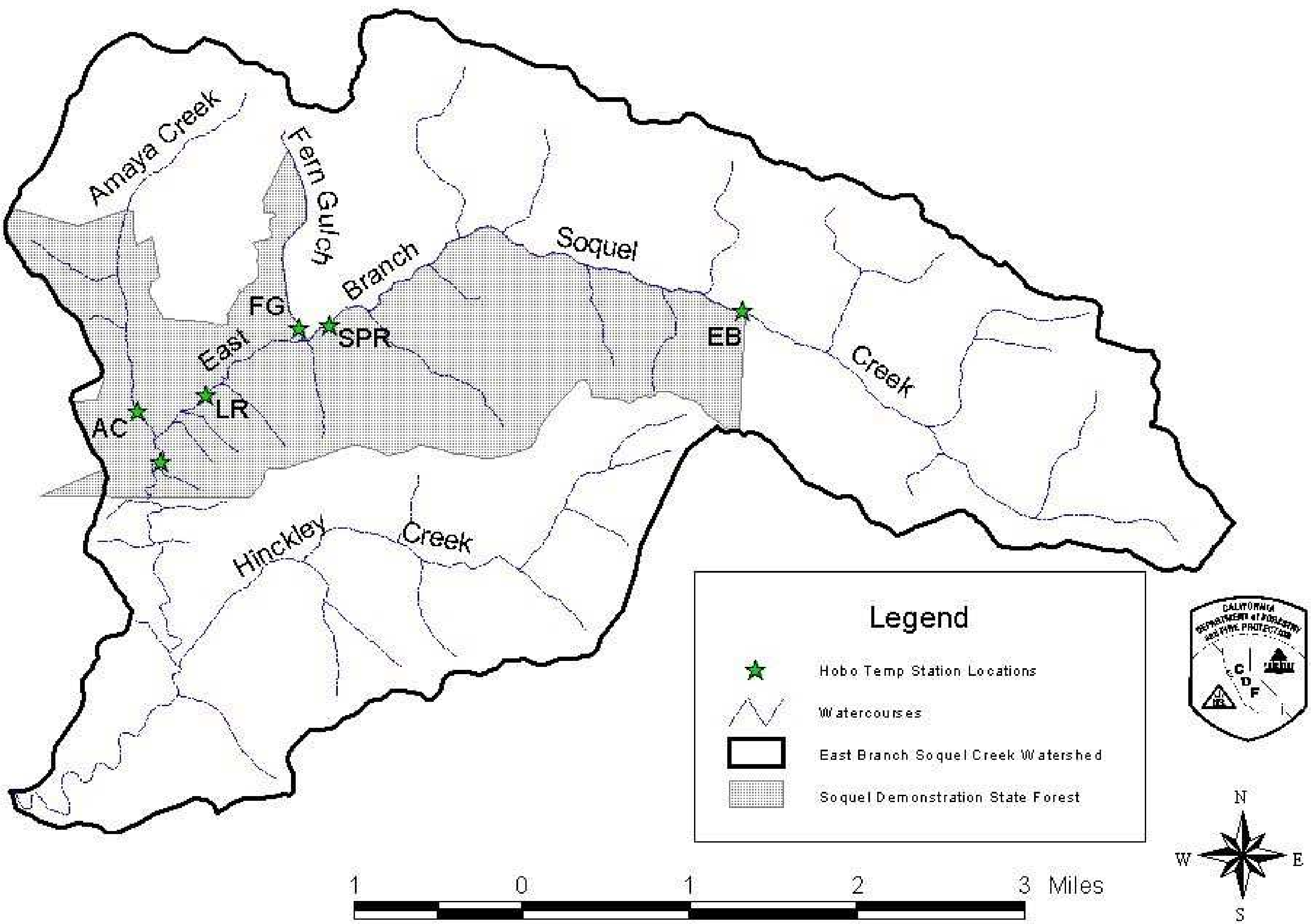
The last criterion was especially important because high water temperatures contribute to lower salmonid survival rates, and fish retreat to these locations to escape warm water temperatures.

Each Hobo was sealed in a clear plastic canister full of clean dry gravel and (except where otherwise indicated) tightly attached to a rock with baling wire, placed in the stream, and covered with cobbles. This method of attachment was used to keep the Hobos submerged throughout the dry season, to hide them to avoid tampering and to protect them from solar radiation. Included in the canisters were the name of the site and an SDSF business card with "if found please call" written on it. The Hobos were placed in the canisters so that the red light (which indicates it is recording) could be seen from the outside. Red polka dotted flagging was hung at each site to facilitate relocation.

Canopy readings were made by an ocular estimation at each Hobo site. Hobo locations were the same approximate sites as previous years (see map), and were as follows:

> <u>East Boundary</u> - on the east branch of Soquel Creek near the boundary between SDSF and Redwood Empire lands. A green sign on Hihn's Mill Road indicates the property boundary. From there, the pink flagging can be followed downhill to the creek. At the creek are two pink flags tied to a 10-inch diameter alder tree. Downstream from the pink flags are a slide descending from Highland Way, a car body, and a large debris jam (about 75 feet long and 12 feet high). The data

Hobo Temperature Data Logger Stations Map



logger was placed 109 feet downstream from the two pink flags attached to the alder tree. The Hobo was completely covered by rocks and placed under a large log. This site is marked with red polka dotted flagging. This station had 0% shade canopy. The site remained undisturbed during the four months the Hobo was deployed.

Spanish Ranch - on the east branch of Soquel Creek at Spanish Ranch Crossing. Approximately 79 feet upstream from the bottom of the electro-fishing station. The Hobo was placed under the roots of a clump of redwood trees in a pool on the left bank (looking downstream). During the hydrological season of 2002-03 this pool was partially filled with sediment, resulting in a smaller, shallower area to place the Hobo under the bank. This site had 100% redwood and alder shade canopy and received no direct sunlight.

Spanish Ranch Air - in redwood clump (mentioned above) approximately 12 feet above the creek level.

Longridge Crossing - approximately 391 feet downstream from Longridge Crossing. During the 2002-03 hydrological season, this part of Soquel Creek changed dramatically, requiring a new Hobo location. The new location is roughly 109 feet upstream from last year's site. The Hobo was placed under the right bank (looking downstream) and the site was marked with red polka dotted flagging. This location had approximately 100% shade canopy consisting of alders, redwoods, oaks, and sycamores. The Hobo received no solar radiation because it was tucked under the bank with cobbles placed on top of it.

Southwest Boundary - east branch of Soquel Creek 965 feet below the bridge crossing. Placed in an undercut bank under the third alder root wad, about 30 feet downstream from where the rock face ends on the right bank. This site is mostly riffle habitat with very little water deeper than ten inches. The shade canopy at this location was estimated at 90% with no solar radiation reaching the Hobo logger.

Fern Gulch Creek Lower - approximately 472 feet upstream from the confluence of Soquel Creek and Fern Gulch Creek. The Hobo temp was placed in a small pool (created by a log across the creek) on the right side beneath the undercut bank, which is marked with red polka dotted flagging. This pool was partially filled during the 2002-03 hydrological season, resulting in a smaller, shallower area to place the Hobo. A new Hobo location may be necessary after the 2003-04 hydrological season if pool filling continues. When extracting the Hobo from this location, a steelhead trout was observed. This site had approximately 100% shade canopy and the Hobo received no solar radiation. To reach the confluence, head towards Soquel Creek from Hihn's Mill Road approximately 200 feet west of Sawpit Trail. This spot is marked on Hihn's Mill Road with red polka dotted flagging.

Fern Gulch Creek Upper - this Hobo location was added in 2003. Fern Gulch Creek runs through the next planned timber harvest area. Having an additional Hobo location on the upper portion of Fern Gulch Creek will aid in the temperature monitoring of this creek before and after the timber harvest. To locate this Hobo site, take the new seasonal road built on the Rapp/Field property boundary until the road intersects the trail to the white bridge. This trail is where Spanish Ranch Road was previously located. The white bridge crosses Fern Gulch Creek, and just under the bridge is pipe for domestic water intake to supply neighboring properties with water. The Hobo was placed 80 feet below the white bridge on the left bank (looking downstream) next to a very small pool created by a step in the creek, and tucked under the left undercut bank. This location is flagged with red and white polka dotted flagging. This site had 100% redwood canopy, and the Hobo received no solar radiation because it was under the cut bank and covered with rocks.

Amaya Creek - approximately 245 feet upstream from the confluence with the east branch of Soquel Creek. Two large redwood slabs form a shallow pool; one slab forms a spillway, and the other forms the overhanging left bank. The Hobo was placed under the latter log and was fully protected from solar radiation. This location had approximately 65% shade canopy consisting of alders and redwoods.

Interval

All Hobos, with the exception of Fern Gulch Creek Upper, were "launched" to record for six months at two-hour intervals. Fern Gulch Creek Upper was set at half-hour intervals. This can be changed before launching this Hobo in 2004.

Data Analysis

All data were downloaded in BoxCar Pro 4.3 and exported to Excel for graphing and analysis. Temperature measurements taken during transport to and from monitoring sites were eliminated. A rolling seven-day average was calculated and graphed over the raw temperature readings. This number was calculated for each data point as the average temperature for the previous 3.5 days and following 3.5 days. With twelve temperature measurements taken in a 24-hour period (or 48 if the Hobo temp was taking half-hour readings), the resulting number is an average of 84 (or 336) data points. The seven-day rolling average historically has more closely corresponded with fish success than straight temperature readings because it reflects the duration of high temperatures. All temperature data displayed in the following tables is from absolute data, not from the 7-day rolling average.

RESULTS

Results are shown on graphs in Appendix A. These graphs were taken from the data tables, which are too large to be printed but can be viewed on a computer screen. All Hobo data are on the SDSF computer hard drive - C:\FILE CABNET\Hobo Reports\Hobo Temps 2003\2003 Hobo Excel Data.

A new Hobo logger was placed in upper Fern Gulch Creek. The Fern Gulch Creek Upper Hobo recorded data from June 24 to October 29. The Southwest Boundary Hobo only recorded data from June 9 to September 1. After the Southwest Boundary Hobo failed to record data in 2002 it was sent to ONSET for a full tune up. ONSET found no malfunctions in the Hobo logger and said it was working properly. When the Southwest Boundary Hobo was pulled out of its location in October 2003, the light was not blinking and it appeared that it had not recorded data. After the Hobo battery was replaced, most of the data was recovered. This data will be included in this report since it covers most of the measuring period. The Longridge Crossing Hobo only recorded temperatures from June 2 to June 15. This Hobo had an internal malfunction and currently is not working. The data from the Longridge Crossing Hobo will not be included in this report and will be depicted by N/A, since it would be misleading to compare 13 days of data with the data from the other sites where temperatures were recorded for the entire measuring period. The Longridge Crossing data can be found on the SDSF computer hard drive C:\FILE CABNET\Hobo Reports\Hobo Temps 2003\2003 Hobo Excel Data. When reviewing data from prior years, N/A indicates that the Hobo temp did not record the data properly or no data were collected for the site.

DISCUSSION

After extracting the Hobo loggers in October, a calibration test was performed. The Hobos remained launched inside the SDSF office for an additional 24 hours. The greatest discrepancy in recorded temperatures was 1.66 degrees with an average difference of .65 degrees. The Spanish Ranch Air Hobo recorded temperatures on a different time interval than the other Hobos and thus a direct comparison cannot be made. Table 1 shows the results from the Hobo calibration test.

Table 1. Hobo Temperatures in SDSF Office for Calibration Test

Hobo	Date	Time	Temperature (F)
East Boundary	10/29/03	15:36	69.71
Spanish Ranch	10/29/03	15:36	70.52
Longridge Crossing	N/A	N/A	N/A
Southwest Boundary	N/A	N/A	N/A
Fern Gulch Creek Lower	10/29/03	15:39	70.39
Fern Gulch Creek Upper	10/29/03	15:39	70.39
Amaya Creek	10/29/03	15:36	70.82
Spanish Ranch Air	10/29/03	16:06	71:37

The highest temperatures were recorded from the end of June to the end of August with the exception of Fern Gulch Creek Upper, which had minimal fluctuations in temperature for the entire four months. High temperatures (ºF) for each site are shown below in Table 2 for both 2002 and 2003.

Table 2. High Temperatures (°F), Date, and Time by Site for 2002 and 2003

Site	High Temp. 2002	Date(s)	Time	High Temp. 2003	Date(s)	Time
East Boundary	62.85	7/14	15:24	63.54	7/(20-24) 7/(28-29)	Between the hours of 14:36-20:36
Spanish Ranch	68.73	7/10	17:20	68.15	7/17	16:36
Longridge Crossing	61.48	7/(10,11,13, 14,17,19,24, 25,26,27,28, 29,30,31) 8/01	Between the hours of 17:22-23:22	N/A	N/A	N/A
Southwest Boundary	N/A	N/A	N/A	70.67	7/12, 7/14, 7/17	16:38
Fern Gulch Creek Lower	60.80	7/9,7/10, 7/12,7/13	15:24 to 19:24	62.17	8/24, 8/25, 8/26	Between the hours of 15:00-20:00
Fern Gulch Creek Upper	N/A	N/A	N/A	61.48	6/27, 7/14, 7/(16-19), 7/(21-22), 7/28, 8/(24-26), 9/(12-14), 9/(21-23), 10/21	Between the hours of 10:05-01:35
Amaya Creek	66.12	7/10	15:18	65.83	6/27	14:36
Spanish Ranch Air	85.52	7/09,8/10	15:19	85.52	6/27,7/12	15:06

In both 2002 and 2003, temperatures were highest at the Spanish Ranch site, with the exception in 2003 of the Southwest Boundary location, which had the highest recorded temperature at 70.67º. The Southwest Boundary Hobo had been tampered with at some point during its four months in Soquel Creek. The Hobo had been pulled out from under the bank and the rocks were no longer on top of the logger. This site receives 90% shade canopy, allowing only partial light during certain times of the day to reach this Hobo location. Past temperatures recorded for the Southwest Boundary have typically been higher when compared to other Hobo locations. Even though the Hobo container had been moved a few feet from its original location, the Hobo was not taken out of its container, so it did not receive any water damage. Also, there were no unusual spikes in temperature recordings, suggesting that the Hobo was not taken out of the water.

The Fern Gulch Creek Lower site had the greatest overall temperature increase from 2002 to 2003. Temperature fluctuations throughout the monitoring period were extreme in both the lower and upper portions of the watershed, but, as in past years, the most extreme temperature fluctuations were in the lower areas of the watershed. Fern Gulch Creek Upper only had a 2.75° difference for the entire four months. This was the first year this Hobo was launched, so there are no comparison data. This location is closer to the source (an underground spring) of Fern Gulch Creek, so possibly the water coming from the source has a relatively invariable temperature. When compared with the other Hobo data, the tiny fluctuation in temperature at Fern Gulch Creek Upper might lead one to believe that the Hobo malfunctioned, but during the calibration test, the Hobo recorded accurate data (Table 1).

Table 3 shows the total fluctuation in temperature, from the highest and lowest temperatures recorded for each location, during the entire 2003 measurement period.

Table 3. Temperature Extremes (ºF) by Station for 2003

Site	High Temp	Low Temp	Range in Extremes
East Boundary	63.54	51.08	12.46
Spanish Ranch	68.15	51.40	16.75
Longridge Crossing	N/A	N/A	N/A
Southwest Boundary	70.67	52.99	17.68
Fern Gulch Creek Lower	62.17	50.38	11.79
Fern Gulch Creek Upper	61.48	58.73	2.75
Amaya Creek	65.83	50.28	15.55
Spanish Ranch Air	85.52	43.95	41.57

Table 4 lists by station the most extreme fluctuations in temperature within one day during the 2003 monitoring period. The largest water temperature fluctuation within one day was 11.98°F at the Southwest Boundary location. In 2002, the greatest fluctuation was at the Spanish Ranch location. Spanish Ranch Air temperature fluctuated 31.8ºF in one day. Temperature fluctuations varied throughout the measurement season; surprisingly, a most extreme fluctuation occurred every month the Hobos were operating. In the past, the most extreme fluctuations were limited to June through August.

Table 4. Most Extreme Temperature (ºF) Fluctuation within One Day by Station in 2003

Site	Date	High	Low	Difference
East Boundary	6/15, 6/(26-27), 7/(1-2), 7/(4-7)	57.35	52.49	4.86
Spanish Ranch	7/14	67.28	58.65	8.63
Longridge Crossing	N/A	N/A	N/A	N/A
Southwest Boundary	6/25	67.53	55.55	11.98
Fern Gulch Creek Lower	10/25	57.35	52.49	4.86
Fern Gulch Creek Upper	7/(8-9), 7/26,8/(7-8), 8/(13-14), 8/(17-18), 8/20,8/23, 8/28, 8/31, 9/6, 9/16, 10/4, 10/(10-11)	60.11 60.8	58.73 59.42	1.38 1.38
Amaya Creek	6/25	62.94	54.46	8.48
Spanish Ranch Air	7/12	85.52	53.72	31.8

Water temperatures above 70ºF make it difficult for coho salmon and steelhead trout to extract oxygen from the water. Optimal rearing temperatures for juveniles are 45-58ºF for steelhead and 53-58ºF for coho (Resner and Bjornn, 1979). For the sake of comparison, it is interesting to note the number of days recorded at 70°F or higher and 58°F or higher (see Tables 5 and 6, respectively). Since the monitoring period varies from year to year, these tables' comparisons have been adjusted to reflect the same time period in 2002 and 2003. Table 5 shows that in 2002 no location recorded temperatures over 70º. In 2003, the Southwest Boundary Hobo recorded 11 days of temperatures at or above 70°F. In 2001, there were five days with water temperatures 70° or above. Table 6 shows that the number of days with temperatures over 58° in 2002 and 2003 is similar except at the Fern Gulch Creek Lower site, where in 2003 there were 48 more days over 58º than in 2002. Table 7 presents a comparison of the peak high temperatures from 1997 to the present. This table shows that there have not been any notable trends in temperature fluctuations over the last 7 years.

Table 5. Comparison of Number of Days above 70ºF by Station for the Same Time Period in 2002 and 2003

Site	No. of Days at or above 70º in 2002	No. of Days at or above 70º in 2003
East Boundary	0	0
Spanish Ranch	0	0
Longridge Crossing	0	N/A
Southwest Boundary	N/A	11
Fern Gulch Creek Lower	0	0
Fern Gulch Creek Upper	N/A	0
Amaya Creek	0	0
Spanish Ranch Air	91	144

Table 6. Comparison of Number of Days above 58ºF by Station for the Same Time Period in 2002 and 2003

Site	No. of Days at or above 58º in 2002	No. of Days at or above 58º in 2003
East Boundary	82	85
Spanish Ranch	123	120
Longridge Crossing	121	N/A
Southwest Boundary	N/A	82
Fern Gulch Creek Lower	44	92
Fern Gulch Creek Upper	N/A	128
Amaya Creek	118	125
Spanish Ranch Air	145	104

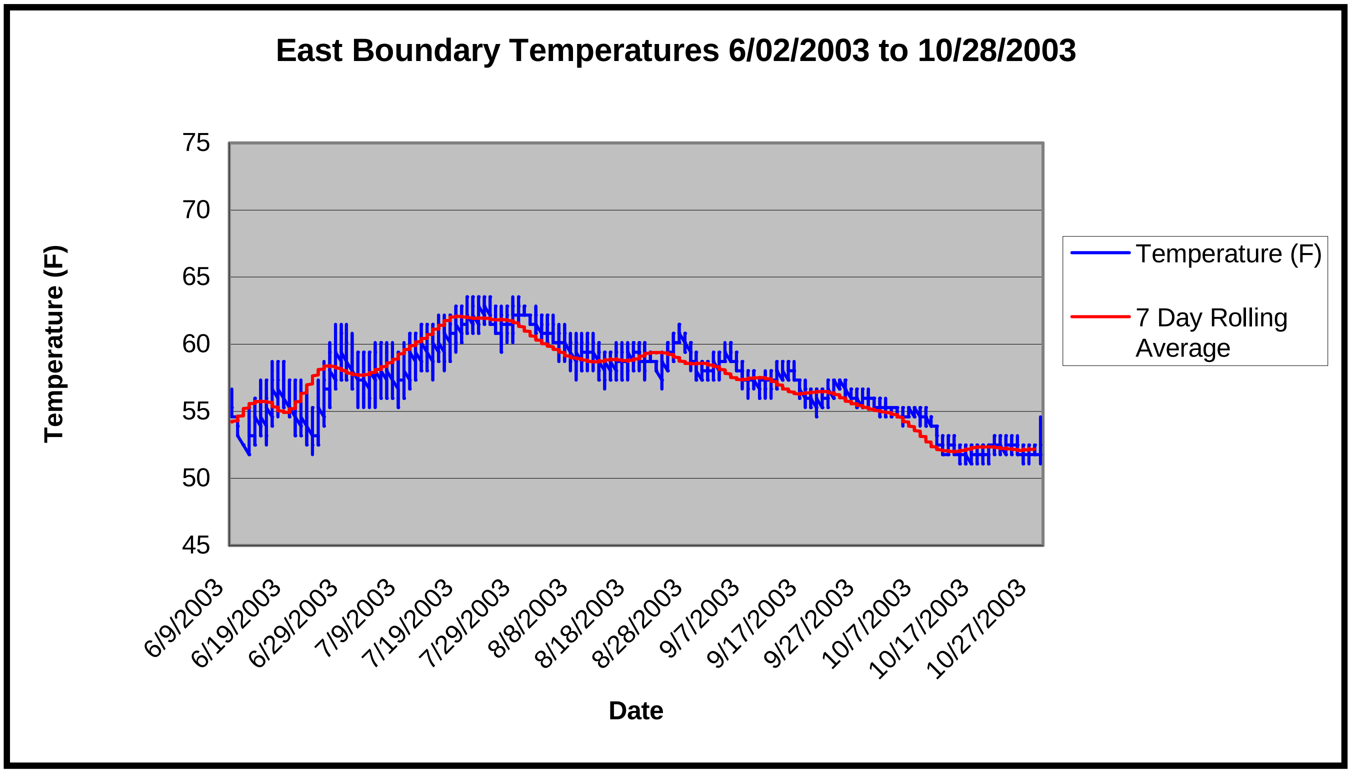
Table 7. Comparisons of Maximum High Temperatures by Site for 1997, 1998, 1999, 2000, 2001, 2002, and 2003

	Temperature (F)						
Site	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
East Boundary	67.45	67.45	63.68	N/A	64.91	62.85	63.54
Spanish Ranch	67.86	70.22	66.41	66.9	70.82	68.73	68.15
Longridge Crossing	N/A	N/A	N/A	N/A	70.39	61.48	N/A
Southwest Boundary	73.8	76.35	71.28	N/A	N/A	N/A	70.67
Fern Gulch Creek Lower	N/A	N/A	N/A	N/A	61.48	60.8	62.17
Fern Gulch Creek Upper	N/A	N/A	N/A	N/A	N/A	N/A	61.48
Amaya Creek	66.41	68.44	66.99	62.36	68.73	66.12	65.83
Spanish Ranch Air	76.45	79.01	83.55	81.59	85.52	85.52	85.52

Suggestions for Next Year

Comparisons and trends can best be monitored when methods are repeated closely, particularly matching start and stop dates for monitoring. In 2001 Brad Valentine, Fisheries Biologist for the California Department of Fish and Game, suggested putting the data loggers in June 1 and taking them out in mid to late October, since water temperatures can be highest as early as June 1. In 2002 and 2003 the Hobos were placed in the watershed in late May to early June and were not removed until the end of October. This schedule should continue to be used. Heavy winter rains can rearrange the monitoring sites and make them hard to find again. Another site can be substituted as long as it has similar habitat type and cover. This season, the Longridge Crossing and East Boundary sites were moved due to changes in the creek from the previous hydrological year.

Appendix A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70
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Temperature (F)
6/9/2003
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7/9/2003
7/19/2003
7/29/2003
8/8/2003
8/18/2003
8/28/2003
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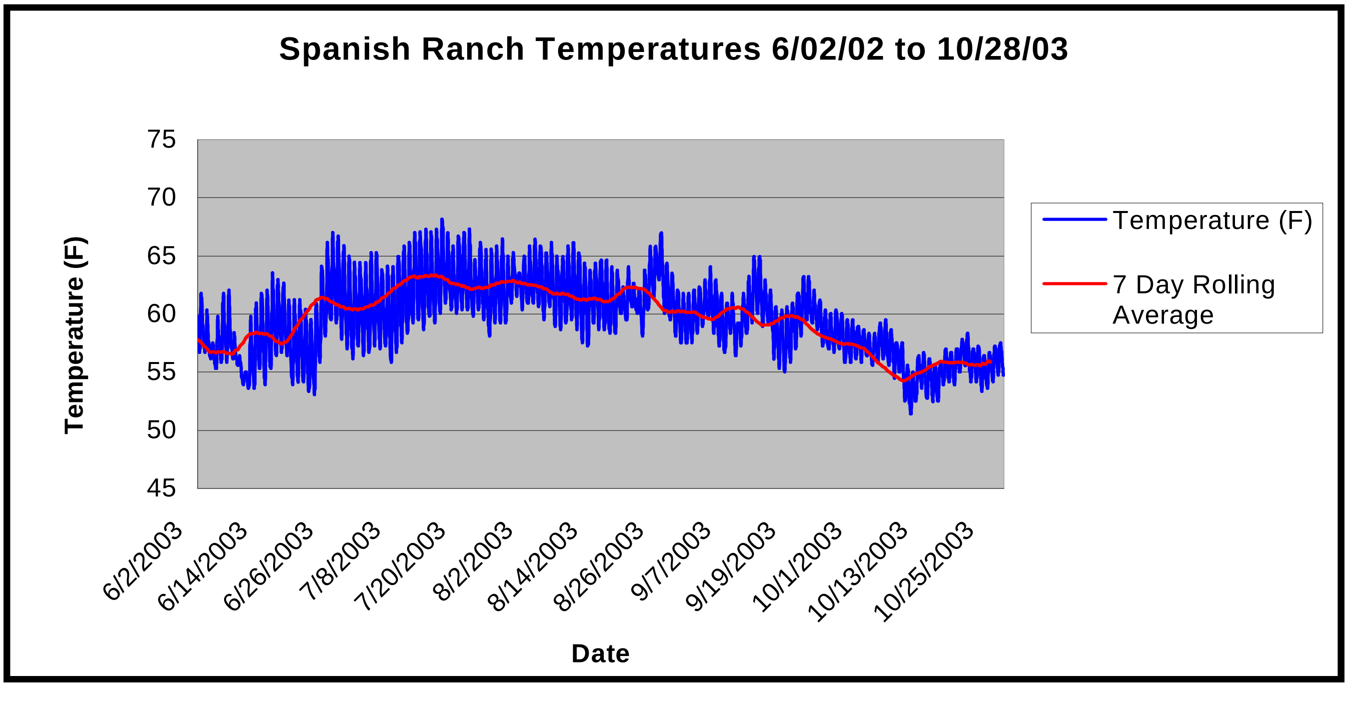
Date
Temperature (F)
7 Day Rolling Average


Spanish Ranch Temperatures 6/02/02 to 10/28/03
75
70
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45
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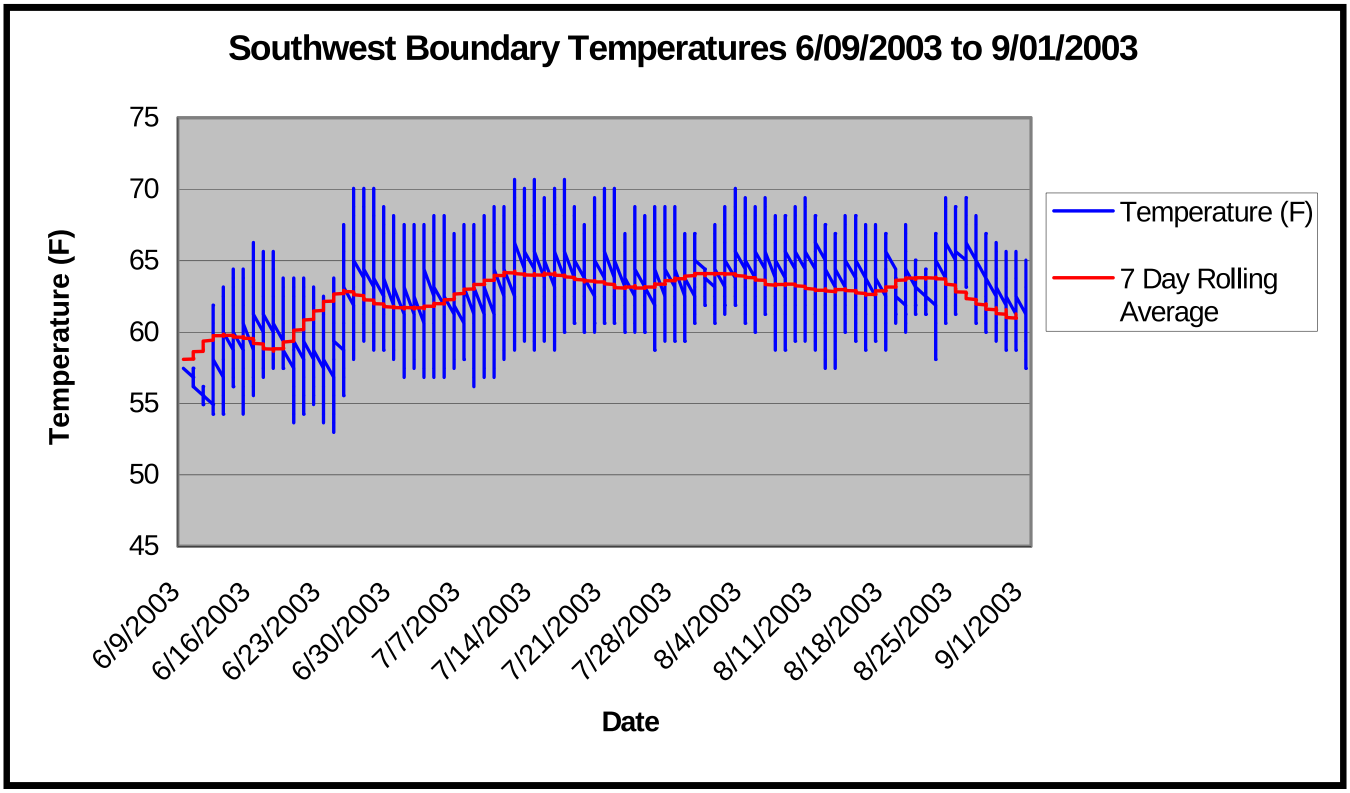
Date
Temperature (F)
7 Day Rolling Average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Temperature (F)
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70
65
60
55
50
45
6/9/2003
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7/7/2003
7/14/2003
7/21/2003
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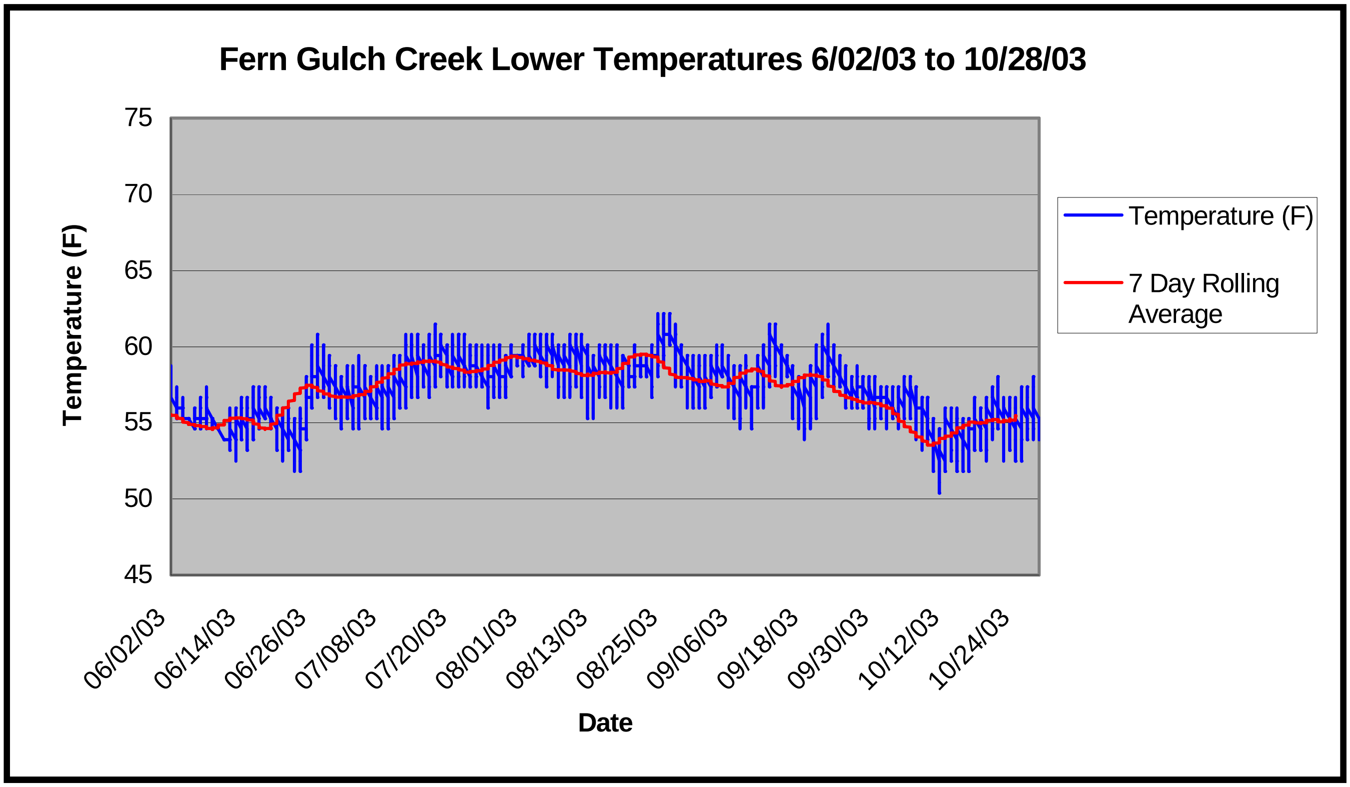
Date
Temperature (F)
7 Day Rolling Average


Fern Gulch Creek Lower Temperatures 6/02/03 to 10/28/03
Temperature (F)
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70
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60
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45
06/02/03
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06/26/03
07/08/03
07/20/03
08/01/03
08/13/03
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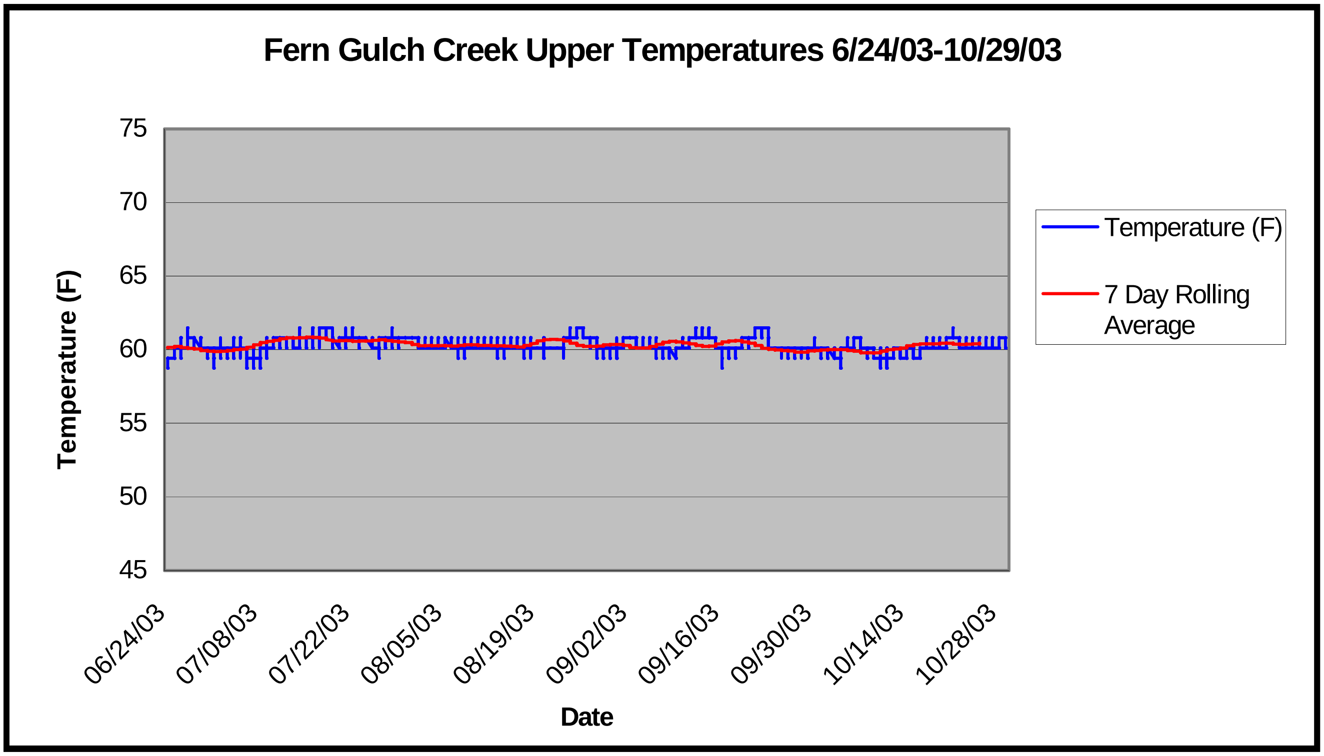
10/24/03
Date
Temperature (F)
7 Day Rolling Average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07/22/03
08/05/03
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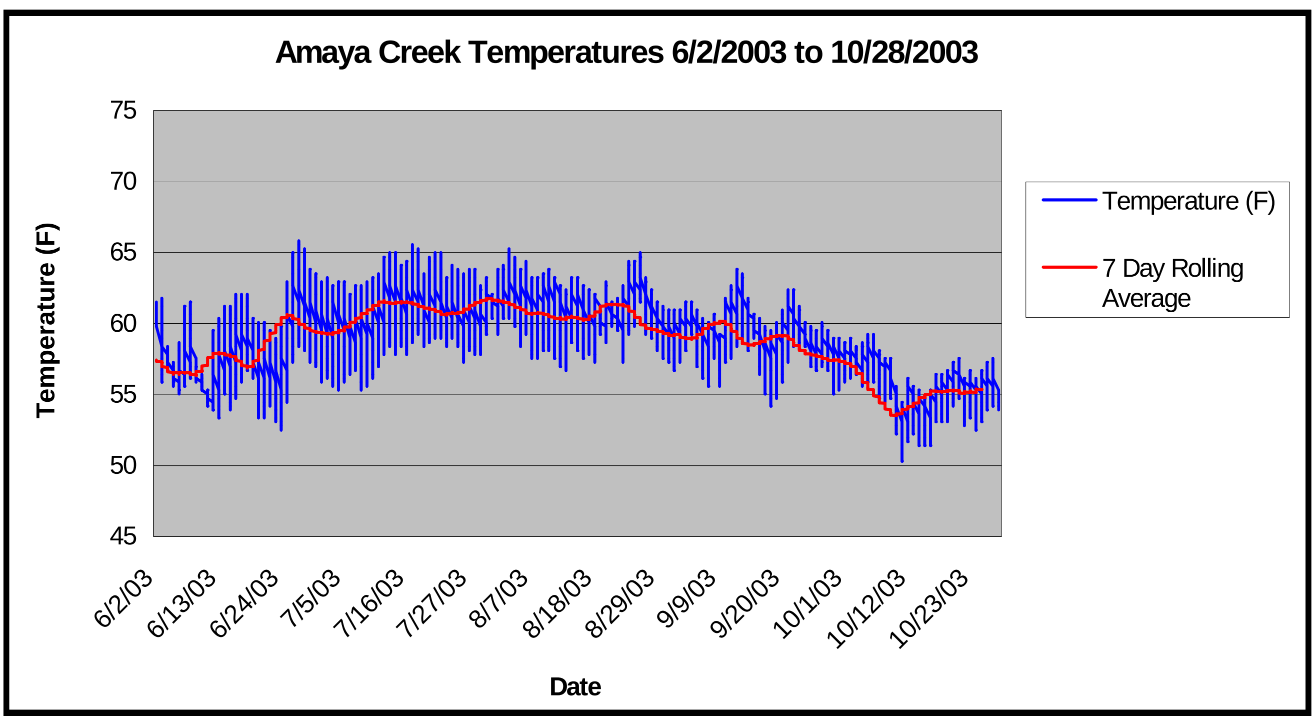
09/16/03
09/30/03
10/14/03
10/28/03
Date
Temperature (F)
7 Day Rolling Average


Amaya Creek Temperatures 6/2/2003 to 10/28/2003
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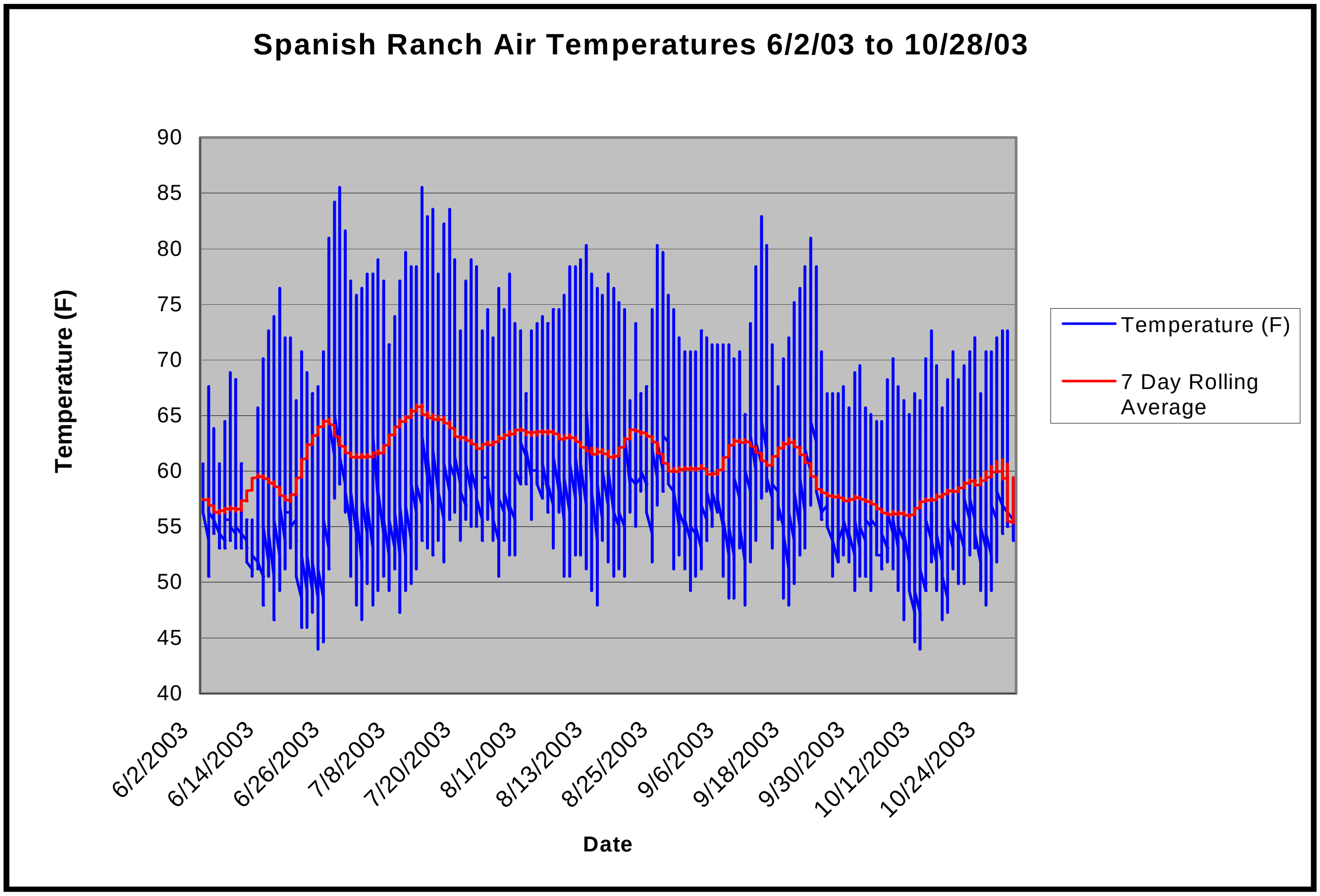
10/1/03
10/12/03
10/23/03
Date
Temperature (F)
7 Day Rolling Average



Spanish Ranch Air Temperatures 6/2/03 to 10/28/03
Temperature (F)
90
85
80
75
70
65
60
55
50
45
40
6/2/2003
6/14/2003
6/26/2003
7/8/2003
7/20/2003
8/1/2003
8/13/2003
8/25/2003
9/6/2003
9/18/2003
9/30/2003
10/12/2003
10/24/2003
Date
Temperature (F)
7 Day Rolling Average

Soquel Demonstration State Forest
Instream Temperature Monitoring 2005
East Branch of Soquel Creek, Fern Gulch Creek and Amaya Creek

METHODS

Hobo and Stow-Away temperature data loggers (Hobos) were installed at various locations in Soquel Demonstration State Forest (SDSF) in order to continuously monitor stream water and air temperatures throughout the dry season. Hobos recorded temperatures from June 15, 2005 to November 03, 2005.

Locations and Installation

Monitoring locations were chosen based on the following criteria:

- Locations that would demonstrate stream temperature variations of Soquel Creek as it flows through the Forest, as well as the temperature of Amaya Creek and Fern Gulch Creek;
- Locations of fish refugia (deeper, shaded areas with cover).

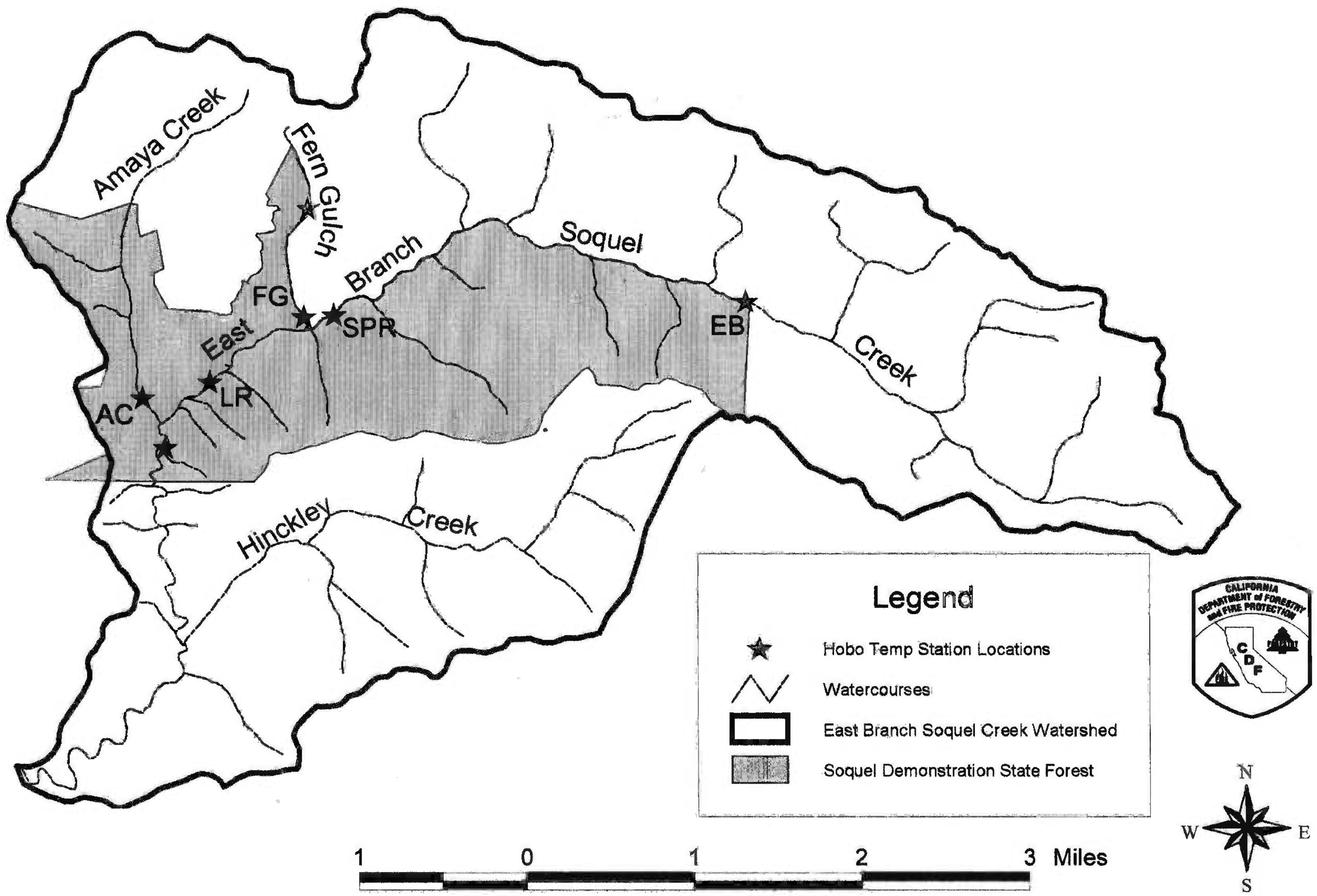
The last criterion was especially important because high water temperatures contribute to lower salmonid survival rates, and fish retreat to these locations to escape warm water temperatures.

Each Hobo was sealed in a clear plastic canister full of clean dry gravel and (except where otherwise indicated) tightly attached to a rock with baling wire, placed in the stream, and covered with cobbles. This method of attachment was used to keep the Hobos submerged throughout the dry season, to hide them to avoid tampering and to protect them from solar radiation. Included in the canisters were the name of the site and an SDSF business card with "if found please call" written on it. The Hobos were placed in the canisters so that the red light (which indicates it is recording) could be seen from the outside. (Batteries for the HoboTemps are replaced each year to ensure proper working order.) Red polka dotted flagging was hung at each site to facilitate relocation.

Canopy readings were made by an ocular estimation at each Hobo site. Hobo locations were the same approximate sites as previous years (see map), and were as follows:

> East Boundary - on the east branch of Soquel Creek near the boundary between SDSF and Redwood Empire lands. A green sign on Hihn's Mill Road indicates the property boundary. From there, the pink flagging can be followed downhill to the creek. At the creek are two pink flags tied to a 10-inch diameter alder tree. Downstream from the pink flags is a slide descending from Highland Way, a car body, and a large debris jam (about 75 feet long and 12 feet high). The data

Hobo Temperature Data Logger Stations Map



logger was placed 109 feet downstream from the two pink flags attached to the alder tree. The Hobo was completely covered by rocks and placed under a large log. This site is marked with red polka dotted flagging. This station had 0% shade canopy.

Spanish Ranch - on the east branch of Soquel Creek at Spanish Ranch Crossing, approximately 79 feet upstream from the bottom of the electro-fishing station. The Hobo was placed under the roots of a clump of redwood trees in a pool on the left bank (looking downstream). The Hobo was placed in water depth of about two feet. This site had 90-100% shade canopy, consisting of redwood and alder covering.

Spanish Ranch Air - in redwood clump (mentioned above) approximately 12 feet above the creek level.

Longridge Crossing - approximately 391 feet downstream from Longridge Crossing. The Hobo was placed under the right bank (looking downstream) and the site was marked with red polka dotted flagging. This location had approximately 90% shade canopy consisting of alders, redwoods, oaks, and sycamores. Water levels at the time of placement were about 1.5 feet deep. The Hobo received no solar radiation because it was tucked under the bank with cobbles placed on top of it.

Southwest Boundary - east branch of Soquel Creek 965 feet below the bridge crossing. The Hobo was placed in an undercut bank under the third alder root wad and covered with numerous cobble stones. Location is about 30 feet downstream from where the rock face ends on the right bank. New flagging was added to the alder tree to more easily spot the location from above stream. Water levels were approximately 1.5 feet deep. The shade canopy at this location was estimated at 80% with no solar radiation reaching the Hobo logger.

Fern Gulch Creek Lower - (Same spot as previous years but new directions on getting to location.) Approximately 472 feet upstream from the confluence of Soquel Creek and Fern Gulch Creek. The HoboTemp was placed in a small pool (created by a log across the creek) on the right side beneath the undercut bank, which is marked with red polka dotted flagging. This site had approximately 100% shade canopy and the Hobo received no solar radiation. To reach the confluence, head towards Soquel Creek from Hihn's Mill Road approximately 323 feet west of Sawpit Trail. This spot is marked on Hihn's Mill Road with red polka dotted flagging. New flagging was placed along the trail to aid in finding the location.

Fern Gulch Creek Upper - Fern Gulch Creek runs through the next planned timber harvest area. Having an additional Hobo location on the upper portion of Fern Gulch Creek will aid in the temperature monitoring of this creek before and after the timber harvest. To locate this Hobo site, take the seasonal road on the Rapp/Howard property boundary until the road intersects the trail to the white bridge. This trail is where Spanish Ranch Road was previously located. The white bridge crosses Fern Gulch Creek, and just under the bridge is pipe for domestic water intake to supply neighboring properties with water. The Hobo was placed 80 feet below the white bridge on the left bank (looking downstream) next to a very small pool (about six inches deep) created by a step in the creek, and tucked under the left undercut bank. This location is flagged with red and white polka dotted flagging. This site had 100% redwood canopy, and the Hobo received no solar radiation because it was under the cut bank and covered with rocks.

Amaya Creek - approximately 245 feet upstream from the confluence with the east branch of Soquel Creek. Two large redwood slabs form a deep pool (approximately 3 feet deep); one slab forms a spillway, and the other forms the overhanging left bank. Water levels were noticeably high this year. The Hobo was placed under the latter log and was fully protected from solar radiation. This location had approximately 65-70% shade canopy consisting of alders and redwoods.

Interval

The four older HoboTemps were "launched" to record for six months at two-hour intervals: Spanish Ranch, Southwest Boundary, Amaya Creek, and Spanish Ranch Air. The four newer HoboTemps were “launched” to record for six months at one-hour intervals: East Boundary, Longridge Crossing, Fern Gulch Lower and Fern Gulch Upper.

Data Analysis

All data were downloaded in BoxCar Pro 4.3 and exported to Excel for graphing and analysis. Temperature measurements taken during transport to and from monitoring sites were eliminated. A rolling seven-day average was calculated and graphed over the raw temperature readings. This number was calculated for each data point as the average temperature for the previous 3.5 days and following 3.5 days. With twelve temperature measurements taken in a 24-hour period (or 24 if the Hobo temp was taking hourly readings), the resulting number is an average of 84 (or 168) data points. The seven-day rolling average historically has more closely corresponded with fish success than straight temperature readings because it reflects the duration of high temperatures. All temperature data displayed in the following tables are from absolute data, not from the seven-day rolling average.

RESULTS

Results are shown on graphs in Appendix A. These graphs were taken from the data tables, which are too large to be printed but can be viewed on a computer screen. All Hobo data are on the SDSF computer hard drive - D:\FILE CABNET\Hobo Reports\Hobo Temps 2005\2005 Hobo Excel Data.

No HoboTemps failed during this monitoring season. All HoboTemps were placed in the same locations as previous years (2002 and 2003) and no noticeable tampering of HoboTemps was detected.

When viewing data from prior years, N/A indicates that the HoboTemp did not record the data properly or no data were collected for the site.

DISCUSSION

Before placing the HoboTemps (Data Loggers) in their intended sites on June 15th, a calibration test was performed on June 10th. The HoboTemps were launched on June 9th and placed within the Soquel office. They were allowed to record air temperature within the office for several days before being placed in their actual sites. The greatest discrepancy in recorded temperatures was 0.50 degrees. Table 1 shows the results from the Hobo calibration test.

Table 1. Hobo Temperatures in SDSF Office for Calibration Test

Hobo	Date	Time	Temperature (F)
East Boundary	6/10/2005	15:00	71.83
Spanish Ranch	6/10/2005	15:00	72.07
Longridge Crossing	6/10/2005	15:00	71.83
Southwest Boundary	6/10/2005	15:00	72.24
Fern Gulch Creek Lower	6/10/2005	15:00	71.86
Fern Gulch Creek Upper	6/10/2005	15:00	71.83
Amaya Creek	6/10/2005	15:00	72.30
Spanish Ranch Air	6/10/2005	15:00	71.80

The highest temperatures were recorded from the end of June to the end of August. This is as expected since June, July and August are the three hottest months of the year. High temperatures (ºF) for each site are shown below in Table 2 for 2005.

Table 2. High Temperatures (°F), Date, and Time by Site for 2005

Site	High Temp. 2005	Date(s)	Time
East Boundary	63.54	7/16-20, 7/31, 8/1, 8/7, 8/8	Between the hours of 15:00-19:00
Spanish Ranch	66.70	7/12, 8/07	17:26
Longridge Crossing	69.02	7/12, 7/24	16:00
Southwest Boundary	69.41	7/12	16:00
Fern Gulch Creek Lower	60.80	7/12, 7/23, 7/24, 8/6-7	Between the hours of 15:00-19:00
Fern Gulch Creek Upper	63.54	7/11-12	Between the hours of 15:00-19:00
Amaya Creek	66.70	7/12	15:29
Spanish Ranch Air	82.24	7/23	16:00

In 2005, water temperatures were highest at the Southwest Boundary site. This is very similar to temperature readings in the past. Although water temperatures varied from site to site, there were no drastic temperature spikes in 2005. In 2003, the Southwest Boundary site was tampered with at some point during its monitoring season. In 2005, no tampering of HoboTemps was detected. (There was no water temperature monitoring in 2004.)

Table 3 shows the total fluctuation in temperature, from the highest and lowest temperatures recorded for each location, during the entire four month measurement period in 2005.

Table 3. Temperature Extremes (ºF) by Station for 2005

Site	High Temp	Low Temp	Range in Extremes
East Boundary	63.54	46.82	16.72
Spanish Ranch	66.70	48.60	18.10
Longridge Crossing	69.02	46.82	22.20
Southwest Boundary	69.41	47.83	21.58
Fern Gulch Creek Lower	60.80	48.25	12.55
Fern Gulch Creek Upper	63.54	55.28	8.26
Amaya Creek	66.70	47.21	19.49
Spanish Ranch Air	82.24	40.57	41.67

Table 4 lists by station the most extreme fluctuations in temperature within one day during the 2005 monitoring period. The largest water temperature fluctuation within one day was 10.33°F at the Longridge Crossing location. Spanish Ranch Air temperature fluctuated 29.8ºF in one day. Air temperature fluctuations can be more drastic when compared to water temperatures. This is due to the fact that bodies of water tend to moderate temperate fluctuations, therefore we rarely see any dramatic differences. Temperature fluctuations varied throughout the measurement season as in previous years.

Table 4. Most Extreme Temperature (ºF) Fluctuation within One Day by Station in 2005

Site	Date	High	Low	Difference
East Boundary	6/22	56.66	51.79	4.87
Spanish Ranch	8/26	62.07	54.74	7.33
Longridge Crossing	8/26	64.22	53.89	10.33
Southwest Boundary	7/23	68.16	58.08	10.08
Fern Gulch Creek Lower	7/23	60.80	55.97	4.83
Fern Gulch Creek Upper	7/3, 7/6	60.11	55.28	4.83
Amaya Creek	7/23	65.54	56.69	8.85
Spanish Ranch Air	7/23	82.24	52.44	29.8

Water temperatures above 70ºF make it difficult for coho salmon and steelhead trout to extract oxygen from the water. Optimal rearing temperatures for juveniles are 45-58ºF for steelhead and 53-58ºF for coho (Resner and Bjornn, 1979). For the sake of comparison, it is interesting to note the number of days recorded at 70°F or higher and 58°F or higher (see Tables 5 and 6, respectively). Since the monitoring period varies from year to year, these tables' comparisons have been adjusted to reflect the same time period in 2005. Table 5 shows that in 2005 no location recorded temperatures over 70. Table 6 shows the number of days with temperatures over 58° in 2005. Upper Fern Gulch Creek had the most days at or above 58ºF, which was a total of 142 days. Southwest Boundary and Longridge Crossing came in second and third, respectively. This can be explained by water depth. The shallower the water levels the easier it is to heat up the water temperature (the opposite is also true, deeper pools stay cooler). These three HoboTemp sites have noticeably shallower water depths when compared to other HoboTemp sites. Table 7 presents a comparison of the peak high temperatures from 1997 to the present (with the exception of 2004, when there was no water temperature monitoring). This table shows that there have not been any notable trends in temperature fluctuations over the last 9 years.

Table 5. Comparison of Number of Days above 70ºF by Station for the Same Time Period in 2005

Site	No. of Days at or above 70º in 2005
East Boundary	0
Spanish Ranch	0
Longridge Crossing	0
Southwest Boundary	0
Fern Gulch Creek Lower	0
Fern Gulch Creek Upper	0
Amaya Creek	0
Spanish Ranch Air	58

Table 6. Comparison of Number of Days above 58ºF by Station for the Same Time Period in 2005

Site	No. of Days at or above 58º in 2005
East Boundary	69
Spanish Ranch	94
Longridge Crossing	108
Southwest Boundary	109
Fern Gulch Creek Lower	61
Fern Gulch Creek Upper	142
Amaya Creek	92
Spanish Ranch Air	135

Table 7. Comparisons of Maximum High Temperatures by Site for 1997, 1998, 1999, 2000, 2001, 2002, 2003, and 2005

Temperature (F) Site	1997	1998	1999	2000	2001	2002	2003	2005
East Boundary	67.45	67.45	63.68	N/A	64.91	62.85	63.54	63.54
Spanish Ranch	67.86	70.22	66.41	66.9	70.82	68.73	68.15	66.7
Longridge Crossing	N/A	N/A	N/A	N/A	70.39	61.48	N/A	69.02
Southwest Boundary	73.8	76.35	71.28	N/A	N/A	N/A	70.67	69.41
Fern Gulch Creek Lower	N/A	N/A	N/A	N/A	61.48	60.8	62.17	60.8
Fern Gulch Creek Upper	N/A	N/A	N/A	N/A	N/A	N/A	61.48	63.54
Amaya Creek	66.41	68.44	66.99	62.36	68.73	66.12	65.83	66.7
Spanish Ranch Air	76.45	79.01	83.55	81.59	85.52	85.52	85.52	82.24

Suggestions for Next Year

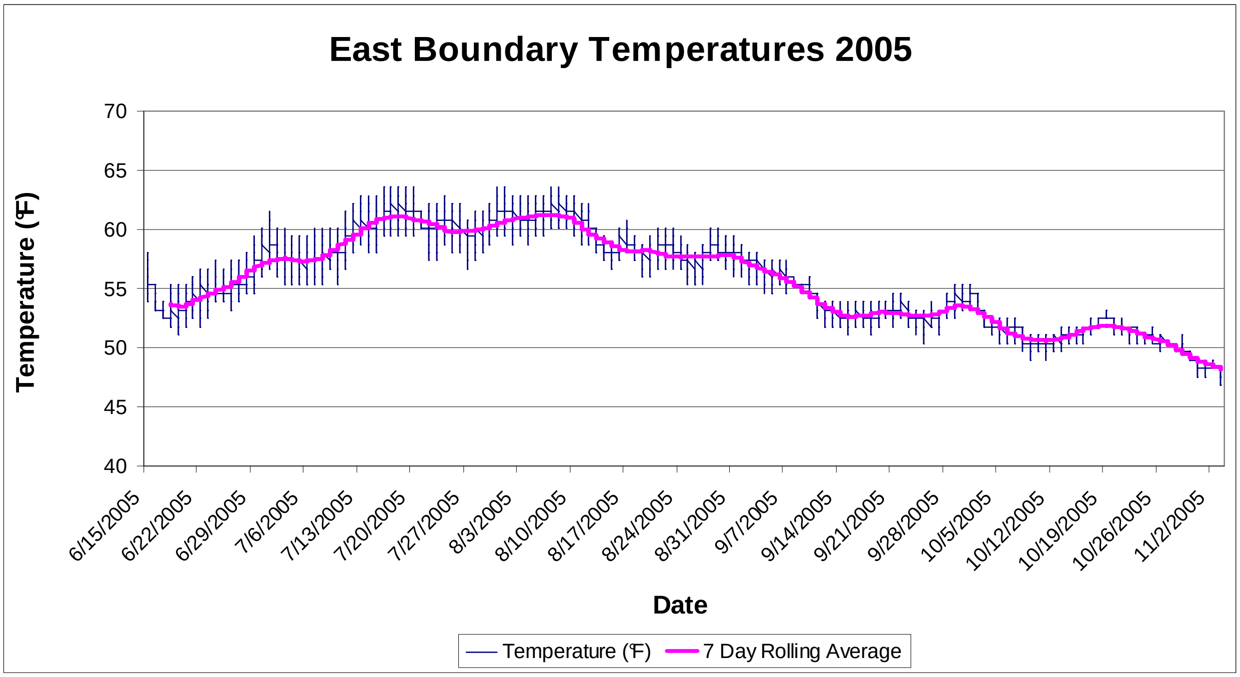
Comparisons and trends can best be monitored when methods are repeated closely, particularly matching start and stop dates for monitoring. In 2001 Brad Valentine, Fisheries Biologist for the California Department of Fish and Game, suggested putting the data loggers in June 1st and taking them out in mid to late October, since water temperatures can be highest as early as June 1st.

In 2006, the California Regional Water Quality Control Board (for the Central Coast Region) released a set of protocols for continuous water temperature monitoring. The standard operating procedures state that monitor season shall begin at the onset of timber harvest operations and shall be consistent with their Monitoring and Report Program (MRP). It goes on to say that continuous temperature monitoring should occur for the five and a half month period starting May 1st and ending October 15th, at all temperature monitoring locations established in the MRP. If a site becomes dry at any point during the monitoring season, the logger shall be relocated further downstream where monitoring can continue.

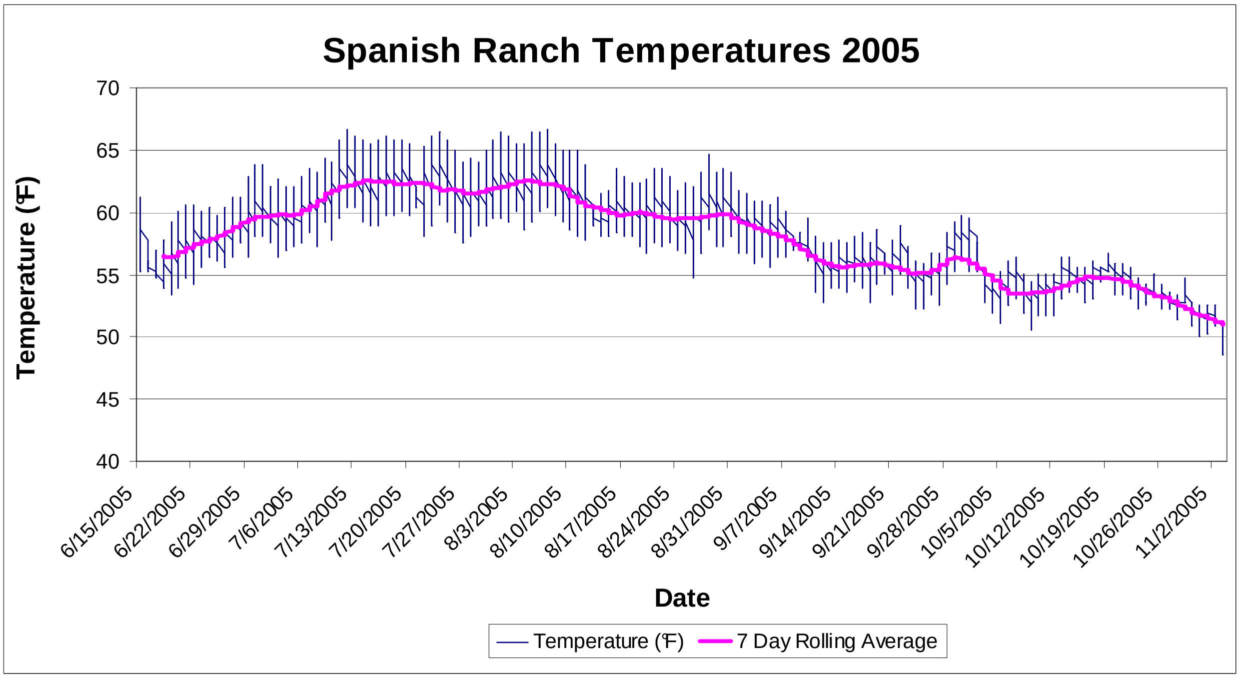
Also if timber operations commence during the period of October 16th through April 30th, temperature monitoring shall begin the subsequent May 1st. If timber harvest operations commence during the period of May 1st through October 15th, temperature monitoring shall begin and continue the day operations begin until October 15th of that same year. Temperature monitoring shall then continue in the subsequent years as prescribed in the MRP.

For further information on the California Regional Water Quality Control Board's monitoring protocol, please read the Standard Operating Procedures Continuous Temperature Monitoring document released by the Water Control Board. A copy of this document can be found online.

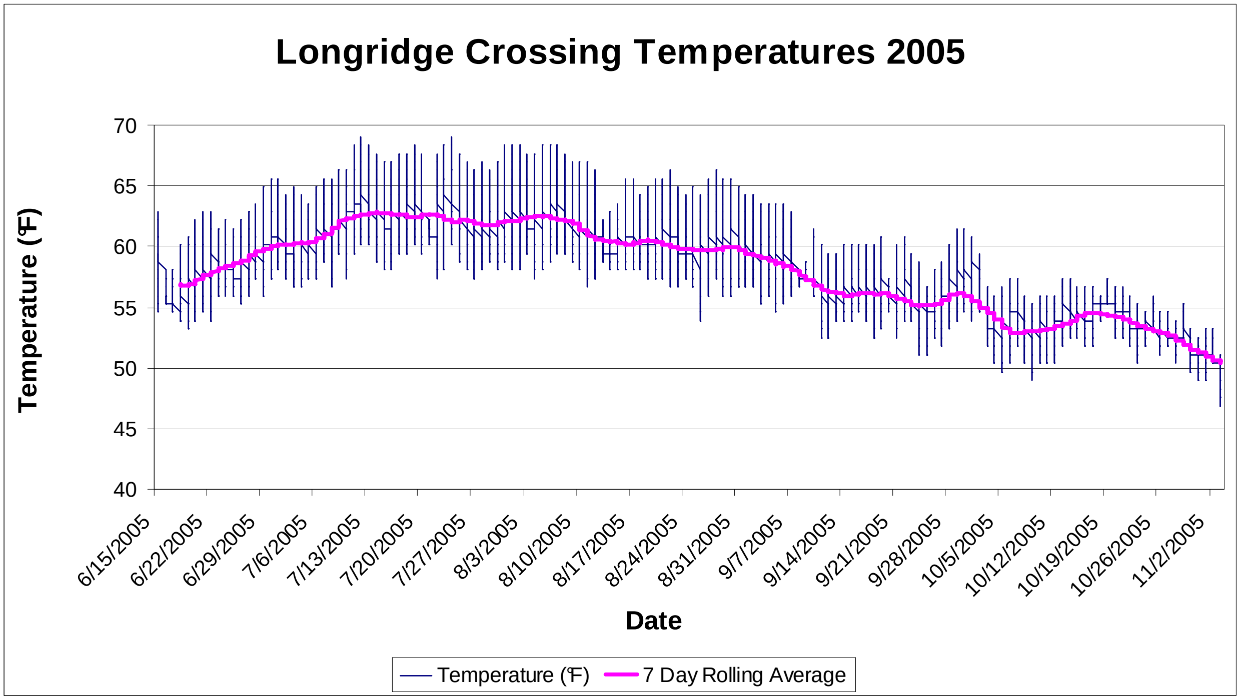
Appendix A

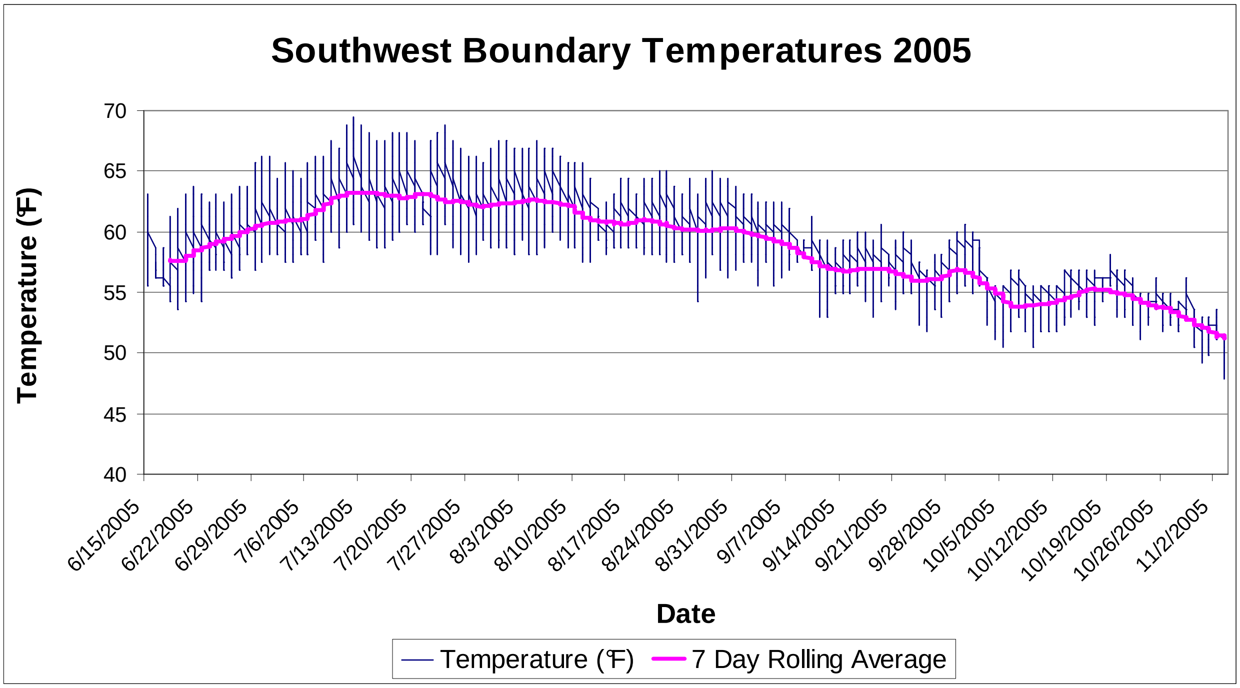


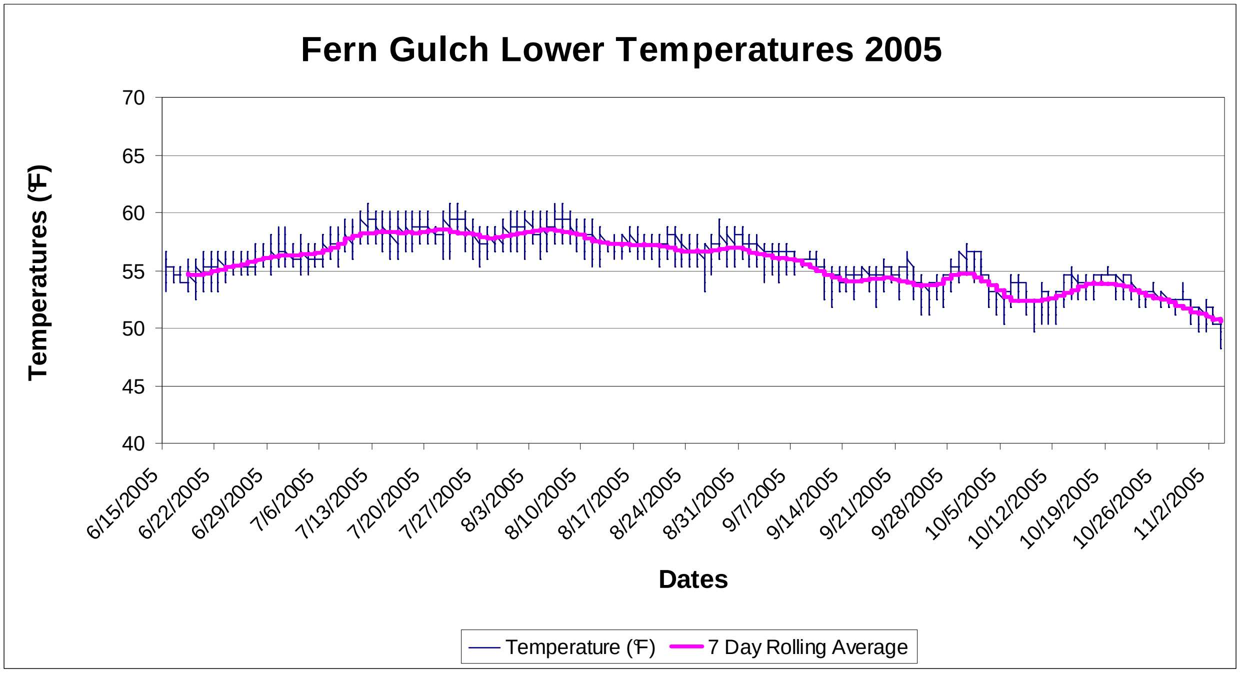
East Boundary Temperatures 2005
Temperature (°F)
70
65
60
55
50
45
40
6/15/2005
6/22/2005
6/29/2005
7/6/2005
7/13/2005
7/20/2005
7/27/2005
8/3/2005
8/10/2005
8/17/2005
8/24/2005
8/31/2005
9/7/2005
9/14/2005
9/21/2005
9/28/2005
10/5/2005
10/12/2005
10/19/2005
10/26/2005
11/2/2005
Date
Temperature (°F)
7 Day Rolling Average



Spanish Ranch Temperatures 2005
Temperature (°F)
70
65
60
55
50
45
40
6/15/2005
6/22/2005
6/29/2005
7/6/2005
7/13/2005
7/20/2005
7/27/2005
8/3/2005
8/10/2005
8/17/2005
8/24/2005
8/31/2005
9/7/2005
9/14/2005
9/21/2005
9/28/2005
10/5/2005
10/12/2005
10/19/2005
10/26/2005
11/2/2005
Date
Temperature (°F)
7 Day Rolling Average


Longridge Crossing Temperatures 2005
70
65
60
55
50
45
40
Temperature (°F)
6/15/2005
6/22/2005
6/29/2005
7/6/2005
7/13/2005
7/20/2005
7/27/2005
8/3/2005
8/10/2005
8/17/2005
8/24/2005
8/31/2005
9/7/2005
9/14/2005
9/21/2005
9/28/2005
10/5/2005
10/12/2005
10/19/2005
10/26/2005
11/2/2005
Date
Temperature (°F)
7 Day Rolling Average


Southwest Boundary Temperatures 2005
70
65
60
55
50
45
40
Temperature (°F)
6/15/2005
6/22/2005
6/29/2005
7/6/2005
7/13/2005
7/20/2005
7/27/2005
8/3/2005
8/10/2005
8/17/2005
8/24/2005
8/31/2005
9/7/2005
9/14/2005
9/21/2005
9/28/2005
10/5/2005
10/12/2005
10/19/2005
10/26/2005
11/2/2005
Date
Temperature (°F)
7 Day Rolling Average


Fern Gulch Lower Temperatures 2005
Temperatures (°F)
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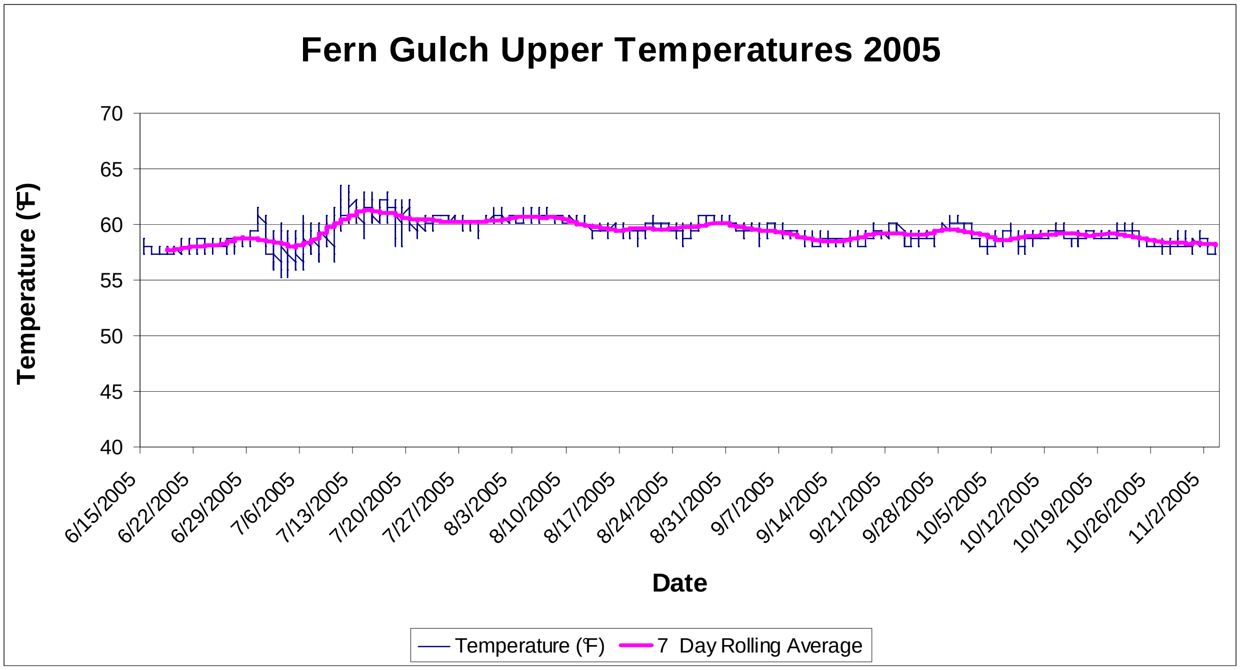
65
60
55
50
45
40
6/15/2005
6/22/2005
6/29/2005
7/6/2005
7/13/2005
7/20/2005
7/27/2005
8/3/2005
8/10/2005
8/17/2005
8/24/2005
8/31/2005
9/7/2005
9/14/2005
9/21/2005
9/28/2005
10/5/2005
10/12/2005
10/19/2005
10/26/2005
11/2/2005
Dates
Temperature (°F)
7 Day Rolling Average


Fern Gulch Upper Temperatures 2005
Temperature (°F)
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65
60
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50
45
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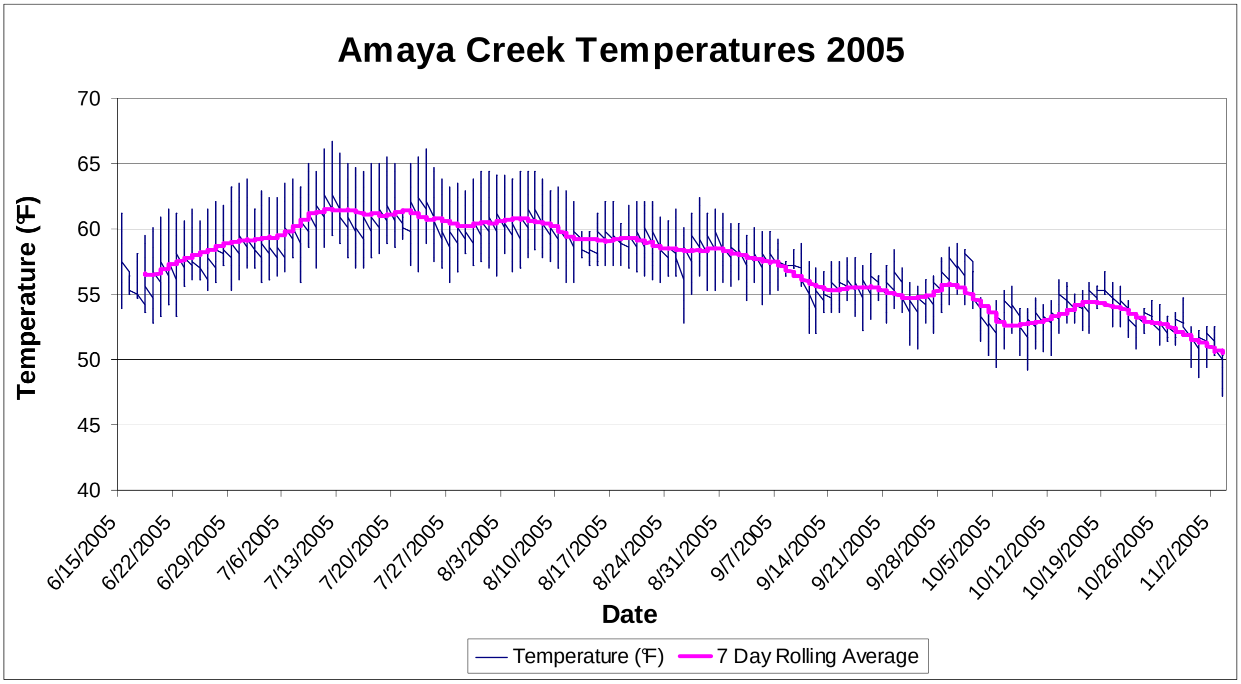
6/15/2005
6/22/2005
6/29/2005
7/6/2005
7/13/2005
7/20/2005
7/27/2005
8/3/2005
8/10/2005
8/17/2005
8/24/2005
8/31/2005
9/7/2005
9/14/2005
9/21/2005
9/28/2005
10/5/2005
10/12/2005
10/19/2005
10/26/2005
11/2/2005
Date
Temperature (°F)
7 Day Rolling Average


Amaya Creek Temperatures 2005
Temperature (°F)
70
65
60
55
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45
40
6/15/2005
6/22/2005
6/29/2005
7/6/2005
7/13/2005
7/20/2005
7/27/2005
8/3/2005
8/10/2005
8/17/2005
8/24/2005
8/31/2005
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9/14/2005
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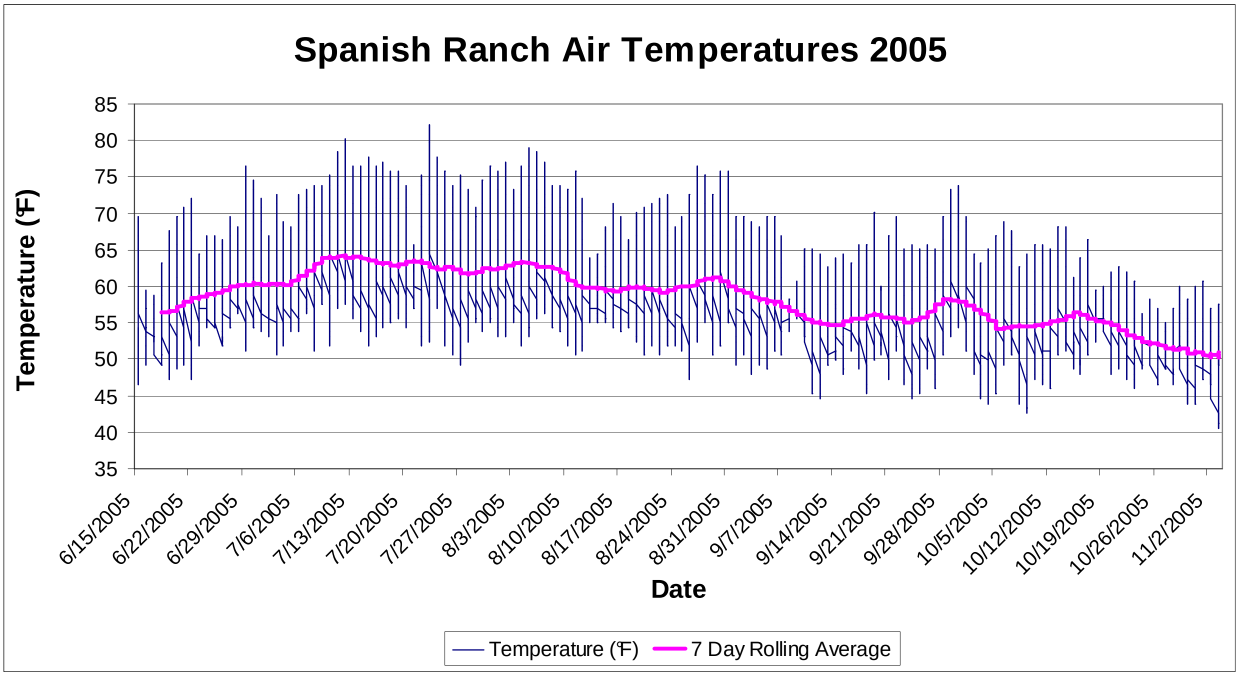
10/26/2005
11/2/2005
Date
Temperature (°F)
7 Day Rolling Average


Spanish Ranch Air Temperatures 2005
Temperature (°F)
85
80
75
70
65
60
55
50
45
40
35
6/15/2005
6/22/2005
6/29/2005
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10/19/2005
10/26/2005
11/2/2005
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Instream Temperature Monitoring 2006
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Monitoring locations were chosen based on the following criteria:

- Locations that would demonstrate stream temperature variations of Soquel Creek as it flows through the forest, as well as the temperature of Amaya Creek and Fern Gulch Creek;
- Locations of fish refugia (deeper, shaded areas with cover).

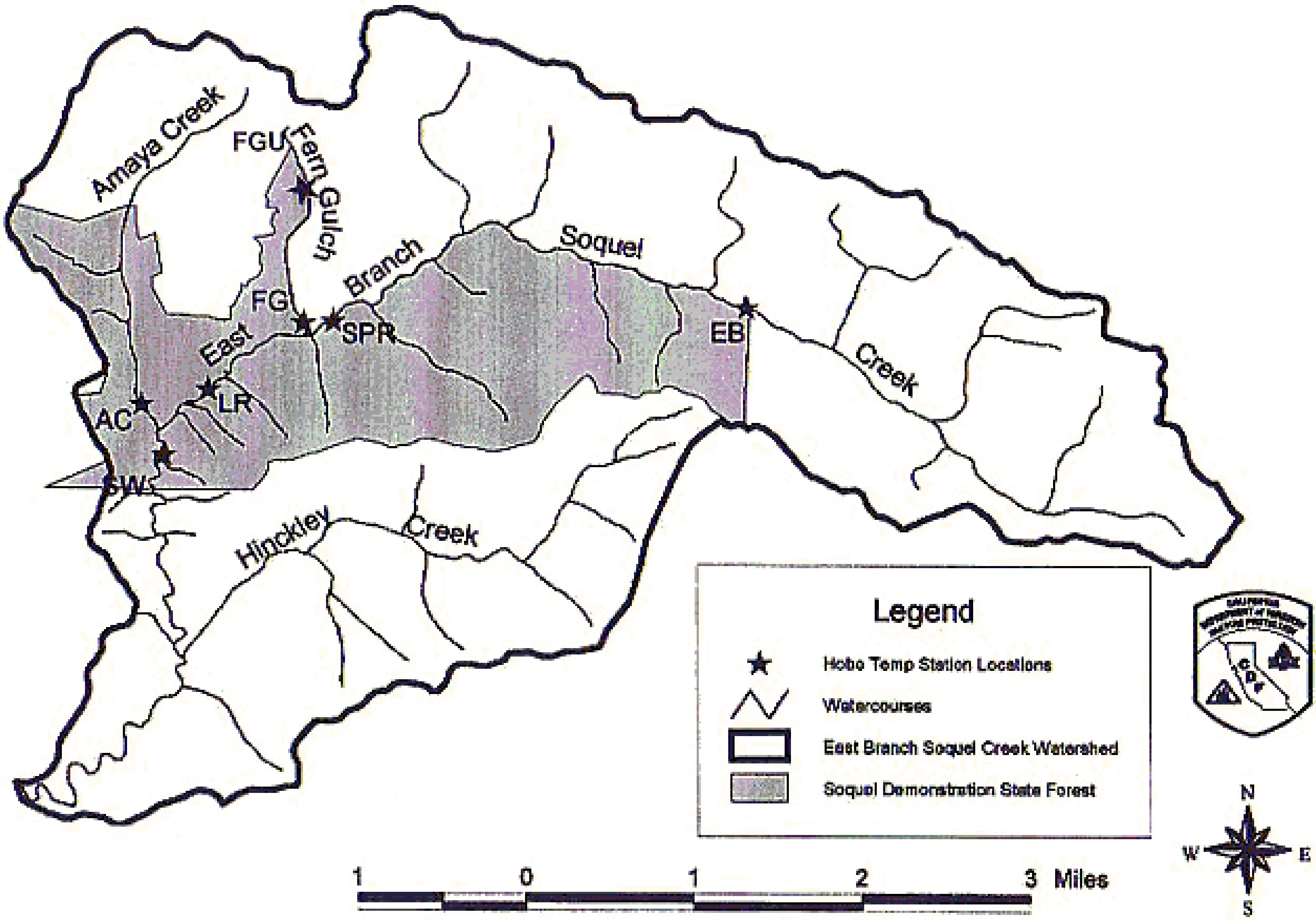
The last criterion was especially important because high water temperatures contribute to lower salmonid survival rates, and fish retreat to these locations to escape warm water temperatures.

Each Hobo was sealed in a clear plastic canister full of clean dry gravel and (except where otherwise indicated) tightly attached to a rock with baling wire, placed in the stream, and covered with cobbles. This method of attachment was used to keep the Hobos submerged throughout the dry season, to hide them to avoid tampering and to protect them from solar radiation. Included in the canisters were the name of the site and an SDSF business card with "if found please call" written on it. The Hobos were placed in the canisters so that the red light (which indicates it is recording) could be seen from the outside. Red polka dotted flagging was hung at each site to facilitate relocation.

Canopy readings were made by an ocular estimation at each Hobo site. Hobo locations were the same approximate sites as previous years (see map), and were as follows:

> East Boundary - on the east branch of Soquel Creek near the boundary between SDSF and Redwood Empire lands. A green sign on Hihn's Mill Road indicates the property boundary. From there, pink and/or red polka dot flagging can be followed downhill to the creek. At the creek are two pink and red polka dot flags tied to a 10-inch diameter alder tree. Downstream from the pink flags is a slide descending from Highland Way, a car body, and a large debris jam (about 75 feet long and 12 feet high). The data

Hobo Temperature Data Logger Stations Map



logger was placed 109 feet downstream from the two pink flags attached to the alder tree. The Hobo was completely covered by rocks and placed under a large log. This site is marked with red polka dotted flagging. This station had 50% shade canopy. The site remained undisturbed during the three months the Hobo was deployed.

Spanish Ranch - on the east branch of Soquel Creek at Spanish Ranch Crossing. Approximately 79 feet upstream from the bottom of the electro-fishing station. The Hobo was placed under the roots of a clump of redwood trees in a pool on the left bank (looking downstream). Large cobble stones where placed on the HoboTemp for more cover. This site had the deepest pool with a measured depth of 2.5 ft. (A chest wader is highly recommended when placing or retrieving HoboTemp from this site.) This site had 100% redwood and alder shade canopy and received no direct sunlight.

Spanish Ranch Air - in redwood clump (mentioned above) approximately 12 feet above the creek level.

Longridge Crossing - approximately 391 feet downstream from Longridge Crossing. The Hobo was placed under the right bank (looking downstream) and the site was marked with red polka dotted flagging. The water depth at the site where the Hobo was placed measured at 1.5 ft in depth. This location had approximately 80% shade canopy consisting of alders, redwoods, oaks, and sycamores. The Hobo received no solar radiation because it was tucked under the bank with cobbles placed on top of it. No signs of tampering where notice.

Southwest Boundary - east branch of Soquel Creek 965 feet below the bridge crossing. Placed in an undercut bank under the third alder root wad, about 30 feet downstream from where the rock face ends on the right bank. In previous years this site was mostly riffle habitat with very little water deeper than ten inches. This was not the case this year, the water depth measured at close to two feet. The shade canopy at this location was estimated at 80% with no solar radiation reaching the Hobo logger. The Hobo Logger at this location moved two feet from its original location. Tampering might have occurred at this location.

Fern Gulch Creek Lower - approximately 472 feet upstream from the confluence of Soquel Creek and Fern Gulch Creek. The Hobo temp was placed in a small pool (created by a log across the creek) on the right side beneath the undercut bank, which is marked with red polka dotted flagging. The small pool measured two feet in depth. This site had approximately 80% shade canopy and the Hobo received no solar radiation. To reach the confluence, head towards Soquel Creek from Hihn's Mill Road approximately 200 feet west of Sawpit Trail. This spot is marked on Hihn's Mill Road with red polka dotted flagging.

Fern Gulch Creek Upper - Fern Gulch Creek runs through the next planned timber harvest area. Having an additional Hobo location on the upper portion of Fern Gulch Creek will aid in the temperature monitoring of this creek before and after the timber harvest. To locate this Hobo site, take the new seasonal road built on the Rapp/Field property boundary until the road intersects the trail to the white bridge. This trail is where Spanish Ranch Road was previously located. The white bridge crosses Fern Gulch Creek, and just under the bridge is pipe for domestic water intake to supply neighboring properties with water. The Hobo was placed 80 feet below the white bridge on the left bank (looking downstream) next to a very small pool created by a step in the creek, and tucked under the left undercut bank. The pool of water measured six inches in depth during this season. This location is flagged with red and white polka dotted flagging. This site had 100% redwood canopy, and the Hobo received no solar radiation because it was under the cut bank and covered with rocks.

Amaya Creek - approximately 245 feet upstream from the confluence with the east branch of Soquel Creek. Two large redwood slabs form a shallow pool; one slab forms a spillway, and the other forms the overhanging left bank. The shallow pool of water measured 2ft in depth. The Hobo was placed under the latter log and was fully protected from solar radiation. Three large cobble stones were used to cover the Hobos from direct sunlight. This location had approximately 100% shade canopy consisting of alders and redwoods.

Interval

The four older HoboTemps were "launched" to record for six months at two-hour intervals; Spanish Ranch, Southwest Boundary, Amaya Creek, and Spanish Ranch Air. The four newer HoboTemps were "launched" to record for six months at one-hour intervals; East Boundary, Longridge Crossing, Fern Gulch Lower and Fern Gulch Upper.

Data Analysis

All data were downloaded in BoxCar Pro 4.3 and exported to Excel for graphing and analysis. Temperature measurements taken during transport to and from monitoring sites were eliminated. A rolling seven-day average was calculated and graphed over the raw temperature readings. This number was calculated for each data point as the average temperature for the previous 3.5 days and following 3.5 days. With twelve temperature measurements taken in a 24-hour period (or 48 if the Hobo temp was taking half-hour readings), the resulting number is an average of 84 (or 336) data points. The seven-day rolling average historically has more closely corresponded with fish success than straight temperature readings because it reflects the duration of high temperatures. All temperature data displayed in the following tables is from absolute data, not from the 7-day rolling average.

RESULTS

Results are shown on graphs in Appendix A. These graphs were taken from the data tables, which are too large to be printed but can be viewed on a computer screen. All Hobo data are on the SDSF computer hard drive - C:\FILE CABNET\Hobo Reports\Hobo Temps 2006\2006 Hobo Excel Data.

There were no failures of any HoboTemps during this monitoring season. All Hobo data are on SDSF computer hard drive-D:\FILE CABNET\Hobo Reports\Hobo Temps 2006\2006 Hobo Excel Data.

DISCUSSION

Before placing the HoboTemps (Data Loggers) in its intended sites during July 7th, a calibration test was performed on July 5th. The HoboTemps were launched on June 5 and placed within the Soquel office. They were allowed to record air temperatures within the station for one day before being placed in their actual sites. The greatest discrepancy in recorded temperatures was less than 0.55 degrees. Table 1 shows the results from the Hobo calibration test.

Table 1. Hobo Temperatures in SDSF Office for Calibration Test.

Hobo	Date	Time	Temperature (*C)
East Boundary	7/5/2006	15:00	24.29
Spanish Ranch	7/5/2006	15:00	24.13
Longridge Crossing	7/5/2006	15:00	23.85
Southwest Boundary	7/5/2006	15:00	24.20
Fern Gulch Creek Lower	7/5/2006	15:00	23.74
Fern Gulch Creek Upper	7/5/2006	15:00	24.29
Amaya Creek	7/5/2006	15:00	24.23
Spanish Ranch Air	7/5/2006	15:00	24.21

Just like the previous years before, the highest temperatures were recorded from the beginning of July to the end of August with the exception of Fern Gulch Creek Upper, which had minimal fluctuations in temperature for the entire three months. High temperatures (ºC) for each site are shown below in Table 2 for 2006.

Table 2. High Temperatures (°C), Date, and Time by Site for 2006.

Site	High Temp.	Date(s)	Time
East Boundary Spanish Ranch	21.33 22.73	7/24, 7/25 7/24	16:00 15:59
Longridge Crossing	23.24	7/24	16:00
Southwest Boundary	22.52	7/22-7/25	17:00
Fern Gulch Creek Lower	18.66	7/23-7/25	15:00-19:00
Fern Gulch Creek Upper	16.76	7/24-7/25	13:00-23:00
Amaya Creek	21.23	7/23-7/24	15:58-17:58
Spanish Ranch Air	31.21	7/24	15:00

For 2006, water temperatures were highest at the Longridge Crossing site, unlike previous years where the Southwest Boundary site usually had the highest temperature readings. The differences in temperature between the two sites were very small, less than one degree Celsius. Besides Longridge Crossing HoboTemp having the highest temperature reading this year, all the other HoboTemps had readings that were very similar to readings recorded in the past. Water temperatures varied from site too site, there were no real drastic temperature spikes that occurred in 2006. In 2003, Southwest Boundary site was tampered with at some point during its monitoring season, there is a possibility that tampering might have happen again this year at the same site. When retrieving the HoboTemp from the Southwest Boundary site, I noticed that the HoboTemp was moved approximately two feet from its original location. There was no noticeable fluctuation in the data recovered from the HoboTemp so everything worked out fine.

Table 3 shows the total fluctuation in temperature, from the highest and lowest temperatures recorded for each location, during the entire 2006 measurement period.

Table 3. Temperature Extremes (ºC) by Station for 2006.

Site	High Temp	Low Temp	Range in Extremes
East Boundary	21.33	10.21	11.12
Spanish Ranch	22.73	10.92	11.81
Longridge Crossing	23.24	10.60	13.13
Southwest Boundary	22.52	11.30	11.22
Fern Gulch Creek Lower	18.66	10.99	7.67
Fern Gulch Creek Upper	16.76	14.09	2.67
Amaya Creek	21.23	10.46	10.87
Spanish Ranch Air	31.21	6.26	24.95

Table 4 lists by station the most extreme fluctuations in temperature within one day during the 2006 monitoring period. The largest water temperature fluctuation within one day was 5.61°C at the Southwest Boundary location. In 2006, the greatest fluctuation was at the Spanish Ranch location. Spanish Ranch Air temperature fluctuated 16.58ºC in one day. Temperature fluctuations varied throughout the measurement season; not surprisingly the most extreme fluctuation occurred in the month of July. July was unusually hot this year and this showed in the temperature readings for that month.

Table 4. Most Extreme Temperature (ºC) Fluctuation within One Day by Station in 2006.

Site	Date	High	Low	Difference
East Boundary	7/7	16.38	12.93	3.45
Spanish Ranch	7/7	17.66	13.41	4.25
Longridge Crossing	7/7	18.28	12.93	5.35
Southwest Boundary	7/7	18.68	13.07	5.61
Fern Gulch Creek Lower	7/7	15.23	12.55	2.68
Fern Gulch Creek Upper	8/19, 8/27, 9/26	15.62	14.47	1.15
Amaya Creek	7/7	17.02	12.47	4.55
Spanish Ranch Air	7/7	24.69	8.11	16.58

Water temperatures above 21.1ºC make it difficult for coho salmon and steelhead trout to extract oxygen from the water. Optimal rearing temperatures for juveniles are 7.22-14.4ºC for steelhead and 11.67-14.4ºC for coho (Resner and Bjornn, 1979). For the sake of comparison, it is interesting to note the number of days recorded at 21.1°C or higher and 14.4°C or higher (see Tables 5 and 6, respectively). Since the monitoring period varies from year to year, these tables' comparisons have been adjusted to reflect the same time period in 2006. Table 5 shows that in 2006 Fern Gulch Creek Lower and Upper were the only two HoboTemp sites that had no temperatures recorded over 21.1ºC. Southwest Boundary Hobo recorded 6 days of temperatures at or above 21.1°C followed by Longridge Crossing which recorded 5 days at or above 21.1ºC. In 2005, no water temperature readings were recorded over 21.1ºC. Table 6 shows the number of days with temperatures at or over 14.4°C in 2006. Fern Gulch Creek recorded 100 days of temperatures at or above 14.4ºC. Table 7 presents a comparison of the peak high temperatures from 1997 to the present. This table shows that there have not been any notable trends in temperature fluctuations over the last 7 years. Although 2006 HoboTemp temperature readings are above average this is just a fluke because July was an exceptionally warm month this year.

Table 5. Comparison of Number of Days above 21.1ºC by Station for the Same Time Period in 2006.

Site	No. of Days at or above 21.1ºC in 2006
East Boundary	2
Spanish Ranch	4
Longridge Crossing	5
Southwest Boundary	6
Fern Gulch Creek Lower	0
Fern Gulch Creek Upper	0
Amaya Creek	4
Spanish Ranch Air	53

Table 6. Comparison of Number of Days above 14.4ºC by Station for the Same Time Period in 2006.

Site	No. of Days at or above 14.4ºC in 2006
East Boundary	68
Spanish Ranch	78
Longridge Crossing	86
Southwest Boundary	83
Fern Gulch Creek Lower	56
Fern Gulch Creek Upper	100
Amaya Creek	71
Spanish Ranch Air	99

Table 7. Comparisons of Maximum High Temperatures by Site for 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2005, and 2006.

Temperature (°C) Site	1997	1998	1999	2000	2001	2002	2003	2005	2006
East Boundary	19.69	19.69	17.60	N/A	18.28	17.14	17.52	17.52	21.33
Spanish Ranch	19.92	21.23	19.12	19.39	21.57	20.41	20.08	19.28	22.73
Longridge Crossing	N/A	N/A	N/A	N/A	21.33	16.38	N/A	20.57	23.24
Southwest Boundary	23.22	24.64	21.82	N/A	N/A	N/A	21.48	20.78	22.52
Fern Gulch Creek Lower	N/A	N/A	N/A	N/A	16.38	16.00	16.76	16.00	18.66
Fern Gulch Creek Upper	N/A	N/A	N/A	N/A	N/A	N/A	16.38	17.52	16.76
Amaya Creek	19.12	20.24	19.44	16.87	20.41	18.96	18.79	19.28	21.23
Spanish Ranch Air	24.69	26.12	28.64	27.55	29.73	29.73	29.73	27.91	31.21

Suggestions for Next Year

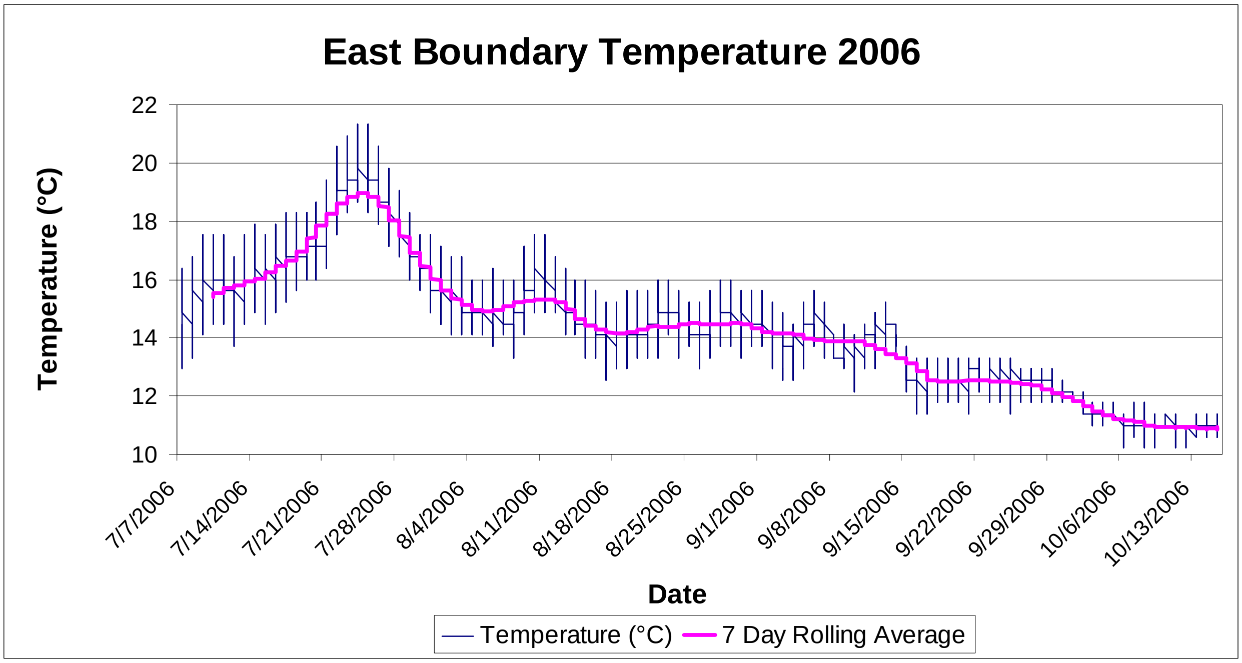
Comparisons and trends can best be monitored when methods are repeated closely, particularly matching start and stop dates for monitoring. In 2001 Brad Valentine, Fisheries Biologist for the California Department of Fish and Game, suggested putting the data loggers in June 1 and taking them out in mid to late October, since water temperatures can be highest as early as June 1.

In 2006, the California Regional Water Quality Control Board (for the Central Coast Region) released a set of protocols for continuous water temperature monitoring. The standard operating procedures states that monitor season shall begin at the onset of timber harvest operations and shall be consistent with the Monitoring and Report Program (MRP). It goes on to say that continuous temperature monitoring should occur for the five and a half month period starting May 1 and ending October 15, at all temperature monitoring locations established in the MRP. If a site becomes dry at any point during the monitoring season, the logger shall be relocated further downstream where monitoring can continue.

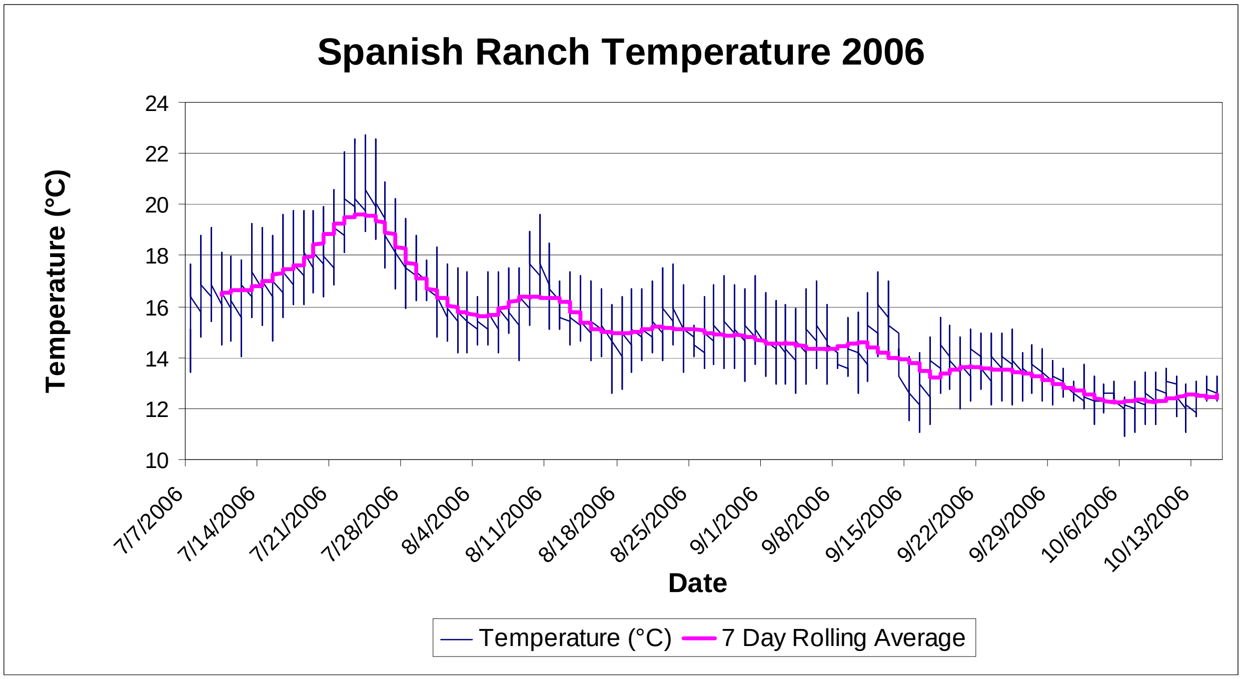
Also if timber operations commence during the period of October 16 through April 30, temperature monitoring shall begin the subsequent May 1. If timber harvest operations commence during the period of May 1 through October 15, temperature monitoring shall begin and continue the day operations begin until October 15 of that same year. Temperature monitoring shall then continue in the subsequent years as prescribed in the MRP.

For further info on the California Regional Water Quality Control Board ‘s monitoring protocol, please read the Standard Operating Procedures Continuous temperature Monitoring released by the Water Control Board .

Appendix A



East Boundary Temperature 2006
Temperature (°C)
22
20
18
16
14
12
10
7/7/2006
7/14/2006
7/21/2006
7/28/2006
8/4/2006
8/11/2006
8/18/2006
8/25/2006
9/1/2006
9/8/2006
9/15/2006
9/22/2006
9/29/2006
10/6/2006
10/13/2006
Date
Temperature (°C)
7 Day Rolling Average



Spanish Ranch Temperature 2006
Temperature (°C)
24
22
20
18
16
14
12
10
7/7/2006
7/14/2006
7/21/2006
7/28/2006
8/4/2006
8/11/2006
8/18/2006
8/25/2006
9/1/2006
9/8/2006
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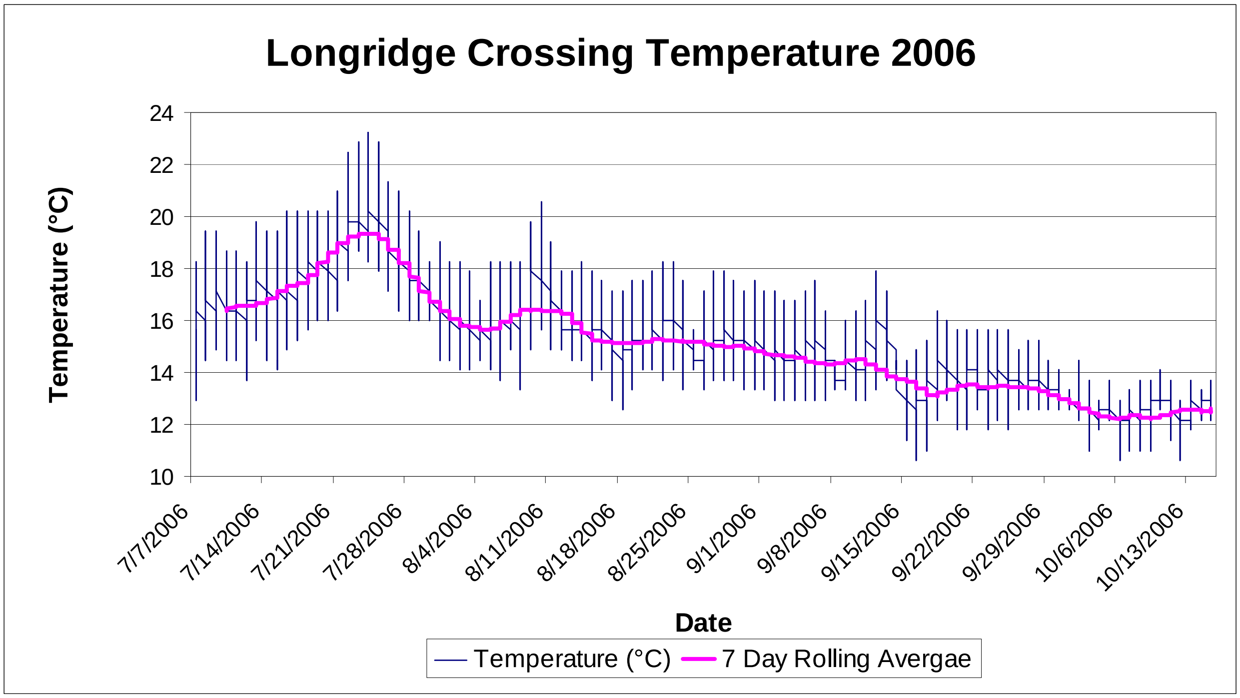
10/13/2006
Date
Temperature (°C)
7 Day Rolling Average


Longridge Crossing Temperature 2006
Temperature (°C)
24
22
20
18
16
14
12
10
7/7/2006
7/14/2006
7/21/2006
7/28/2006
8/4/2006
8/11/2006
8/18/2006
8/25/2006
9/1/2006
9/8/2006
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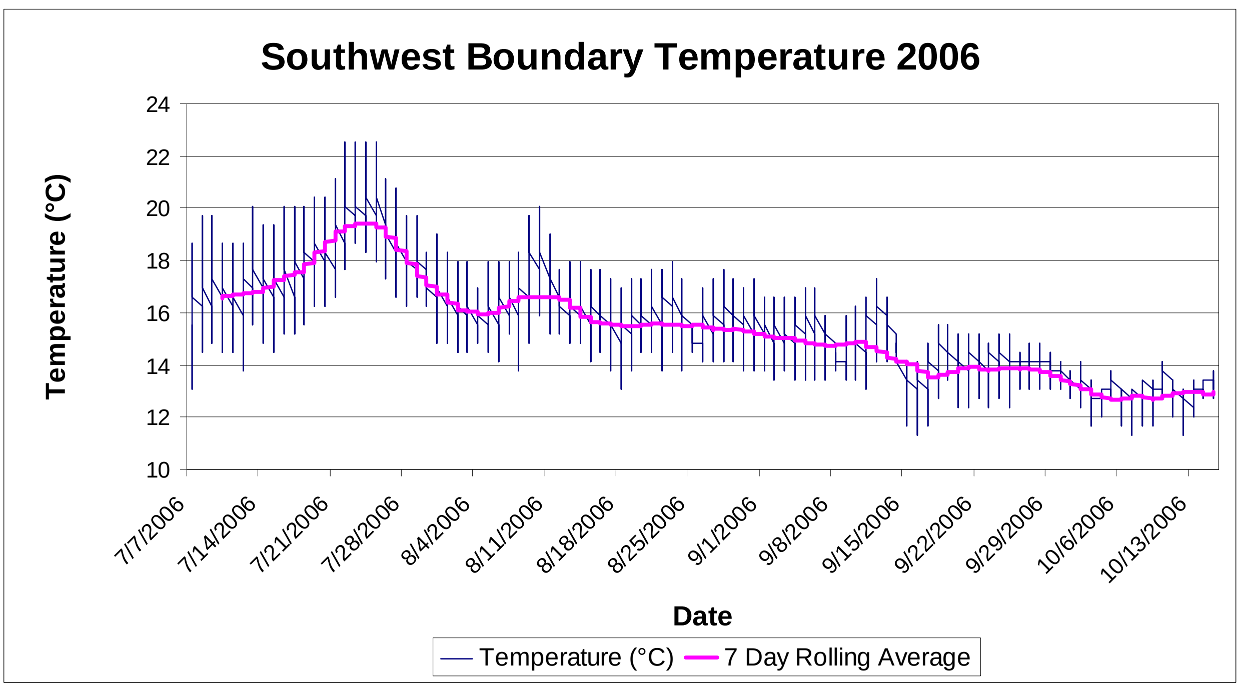
9/22/2006
9/29/2006
10/6/2006
10/13/2006
Date
Temperature (°C)
7 Day Rolling Avergae


Southwest Boundary Temperature 2006
Temperature (°C)
24
22
20
18
16
14
12
10
7/7/2006
7/14/2006
7/21/2006
7/28/2006
8/4/2006
8/11/2006
8/18/2006
8/25/2006
9/1/2006
9/8/2006
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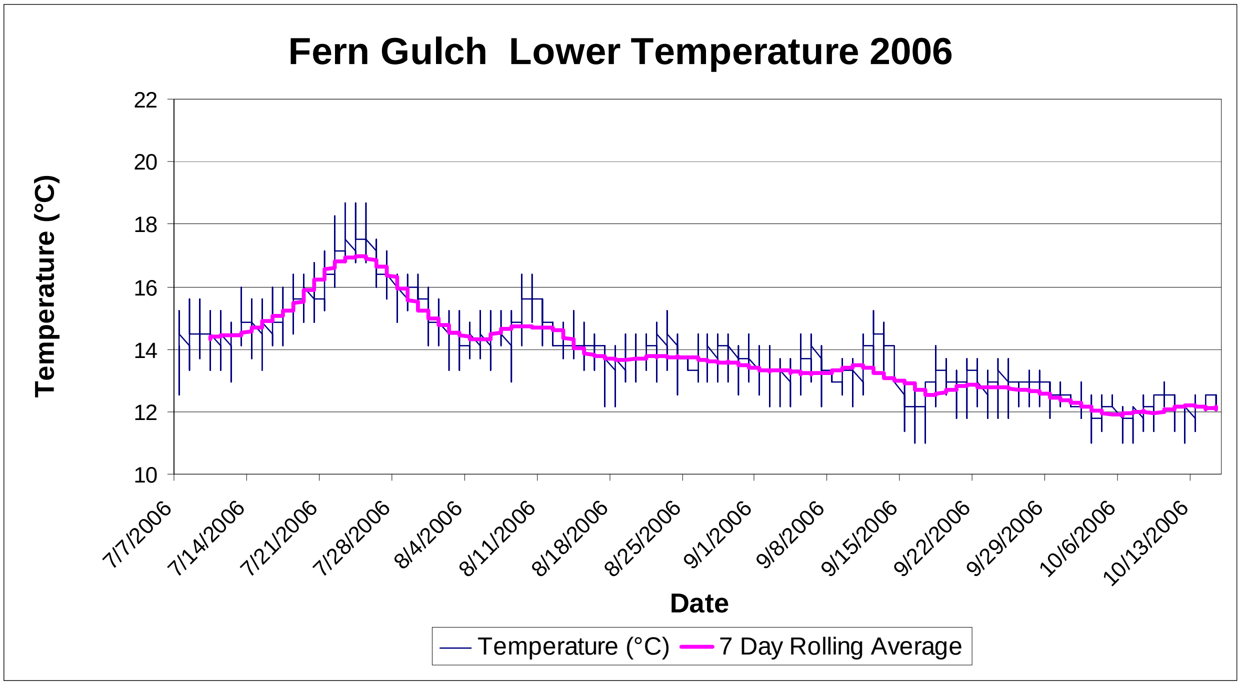
9/22/2006
9/29/2006
10/6/2006
10/13/2006
Date
Temperature (°C)
7 Day Rolling Average


Fern Gulch Lower Temperature 2006
Temperature (°C)
22
20
18
16
14
12
10
7/7/2006
7/14/2006
7/21/2006
7/28/2006
8/4/2006
8/11/2006
8/18/2006
8/25/2006
9/1/2006
9/8/2006
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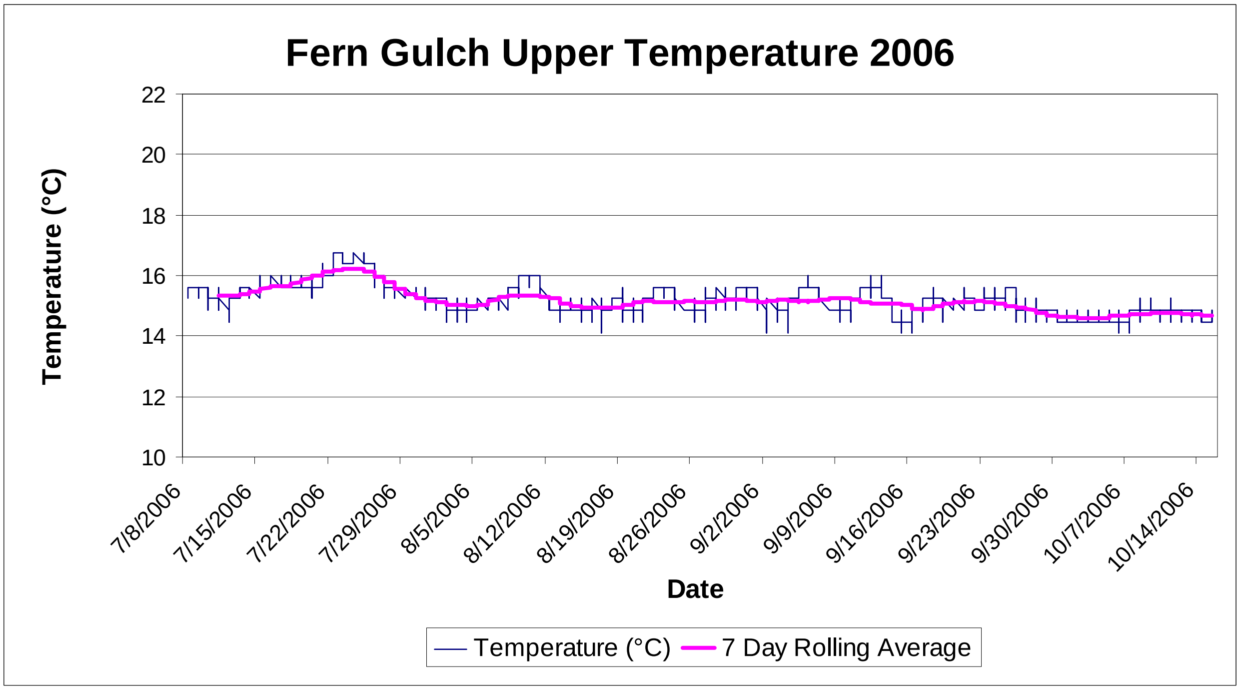
9/22/2006
9/29/2006
10/6/2006
10/13/2006
Date
Temperature (°C)
7 Day Rolling Average


Fern Gulch Upper Temperature 2006
Temperature (°C)
22
20
18
16
14
12
10
7/8/2006
7/15/2006
7/22/2006
7/29/2006
8/5/2006
8/12/2006
8/19/2006
8/26/2006
9/2/2006
9/9/2006
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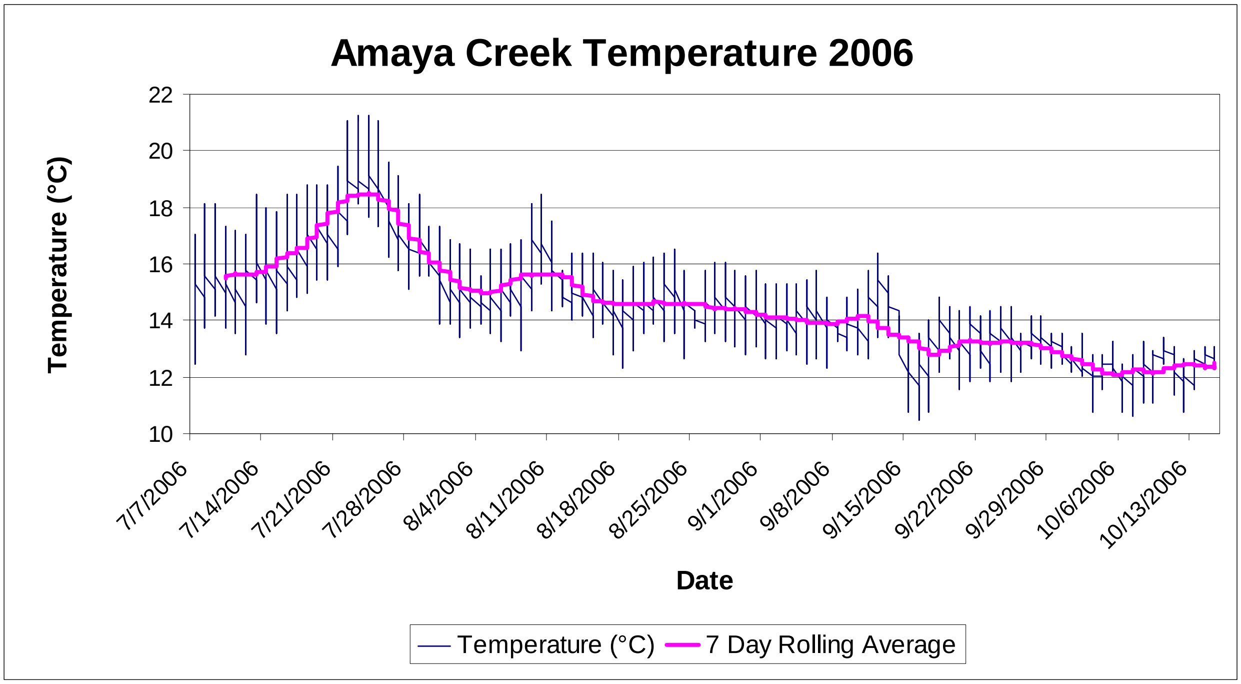
9/23/2006
9/30/2006
10/7/2006
10/14/2006
Date
Temperature (°C)
7 Day Rolling Average


Amaya Creek Temperature 2006
Temperature (°C)
22
20
18
16
14
12
10
7/7/2006
7/14/2006
7/21/2006
7/28/2006
8/4/2006
8/11/2006
8/18/2006
8/25/2006
9/1/2006
9/8/2006
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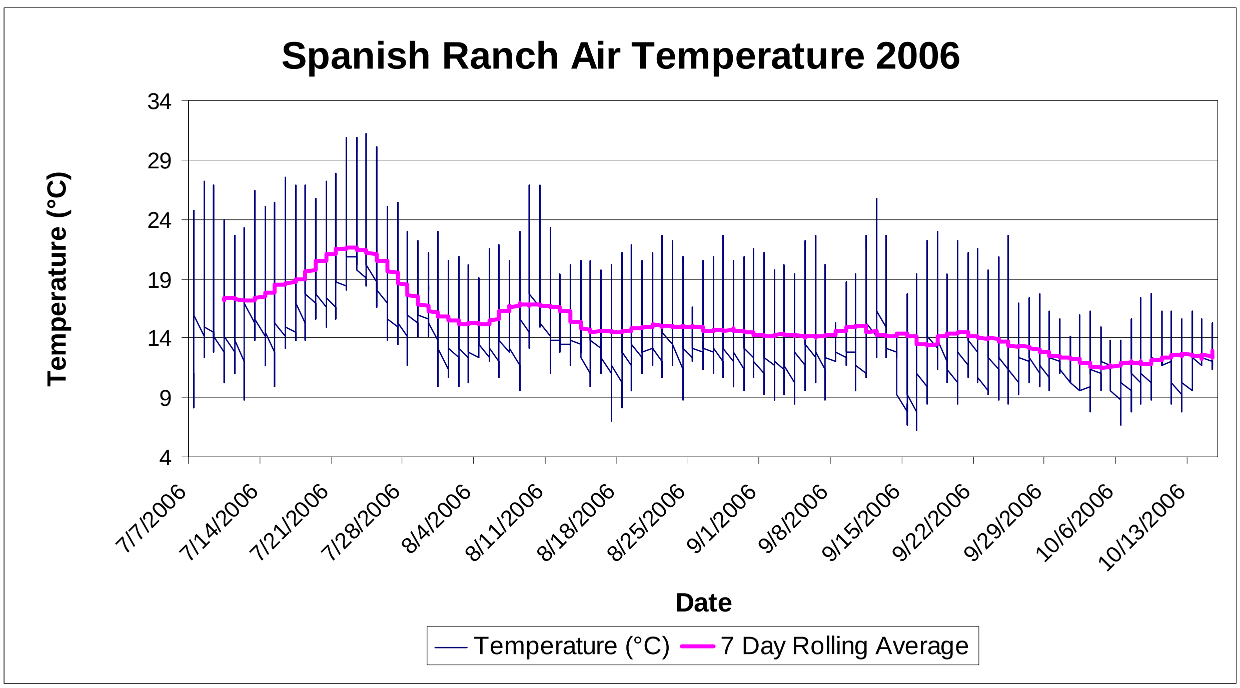
9/22/2006
9/29/2006
10/6/2006
10/13/2006
Date
Temperature (°C)
7 Day Rolling Average


Spanish Ranch Air Temperature 2006
Temperature (°C)
34
29
24
19
14
9
4
7/7/2006
7/14/2006
7/21/2006
7/28/2006
8/4/2006
8/11/2006
8/18/2006
8/25/2006
9/1/2006
9/8/2006
9/15/2006
9/22/2006
9/29/2006
10/6/2006
10/13/2006
Date
Temperature (°C)
7 Day Rolling Average

10/29/08

Soquel Demonstration State Forest
Instream Temperature Monitoring 2007
East Branch of Soquel Creek, Fern Gulch Creek and Amaya Creek

METHODS

Hobo and Stow-Away temperature data loggers (Hobos) were installed at various locations in Soquel Demonstration State Forest (SDSF) in order to continuously monitor stream water and air temperatures throughout the dry season. Hobos recorded temperatures from June 26, 2007 to November 2, 2007.

Locations and Installation
Monitoring locations were chosen based on the following criteria:

- Locations that would demonstrate stream temperature variations of Soquel Creek as it flows through the forest, as well as the temperature of Amaya Creek and Fern Gulch Creek
- Locations of fish refugia (deeper, shaded areas with cover)

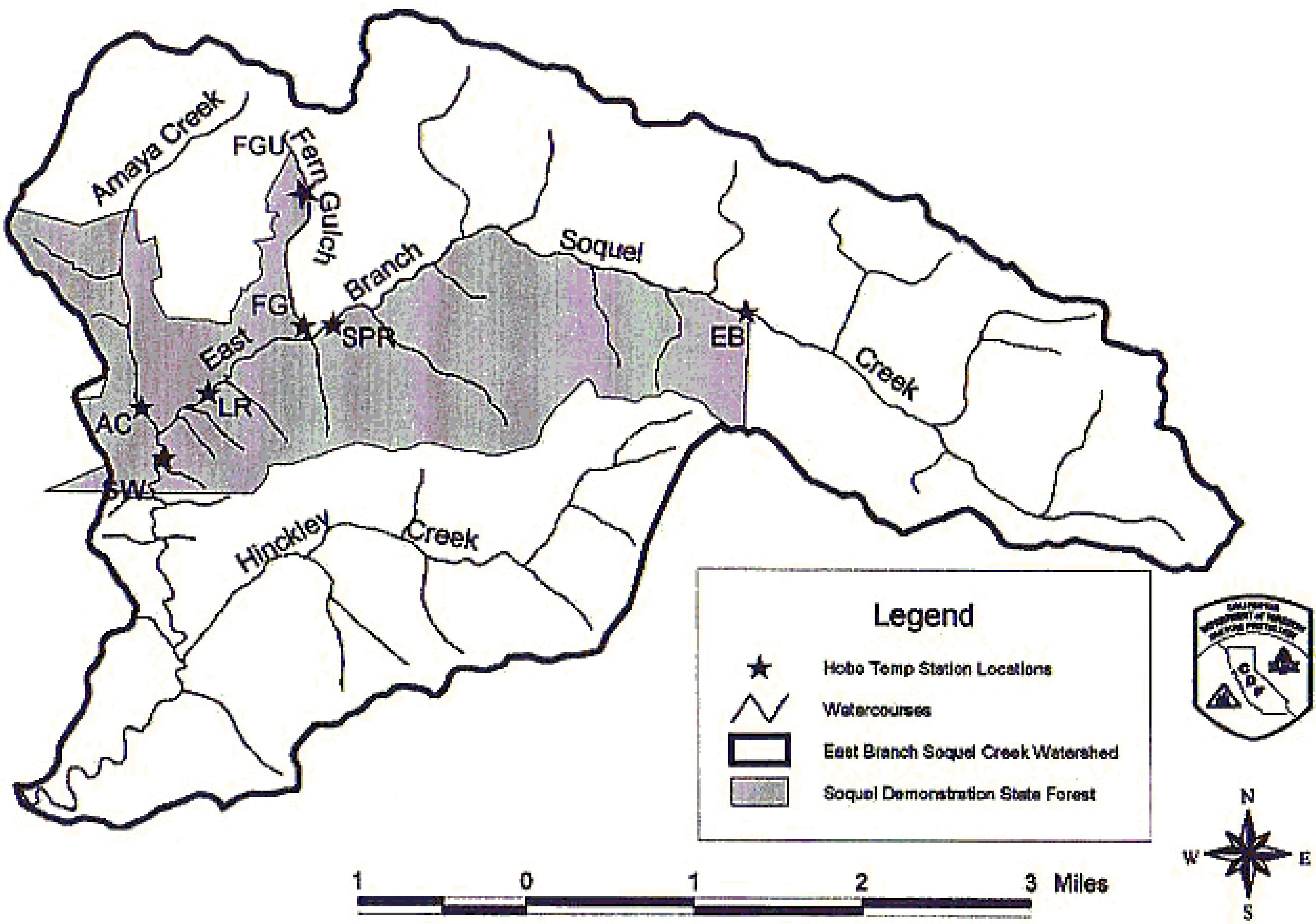
The last criterion was especially important because high water temperatures contribute to lower salmonid survival rates, and fish retreat to these locations to escape warm water temperatures.

Each Hobo was sealed in a clear plastic canister full of clean dry gravel and (except where otherwise indicated) tightly attached to a rock with baling wire, placed in the stream, and covered with cobbles. This method of attachment was used to keep the Hobos submerged throughout the dry season, avoid tampering, and provide protection from solar radiation. Included in the canisters were the name of the site and an SDSF business card with "if found please call" written on the card. The Hobos were placed in the canisters so that the red light (which indicates it is recording) could be seen from the outside. Red polka-dot flagging was hung at each site to facilitate relocation.

Shade density observations are from 2006 (none were recorded in 2007.) Hobo locations were the same approximate sites as previous years (see map), and were as follows:

> East Boundary - Located on the East Branch of Soquel Creek near the boundary between SDSF and Redwood Empire lands. A green sign on Hihn's Mill Road indicates the property boundary. From there, pink and/or red polka-dot flagging can be followed downhill to the creek. At the creek are two pink and red polka-dot flags tied to a 10-inch diameter alder tree. Downstream from the pink flags is a slide descending from Highland Way, a car body, and a large debris jam (about 75 feet long and 12 feet high). The data logger was placed 130 feet downstream

Hobo Temperature Data Logger Stations Map



from the two pink flags attached to the alder tree. The Hobo was placed 10 inches below the surface of the water underneath a log jam. This site is marked with red polka-dot flagging. The site remained undisturbed during the four months the Hobo was deployed.

Spanish Ranch – Located on the East Branch of Soquel Creek at Spanish Ranch Crossing, approximately 79 feet upstream from the bottom of the electro-fishing station. The Hobo was placed under the roots of a clump of redwood trees in a pool on the left bank (looking downstream). Large cobble stones where placed on the HoboTemp for more cover. The Hobo was placed 18 inches below the surface of the water. (Chest waders are highly recommended when placing or retrieving HoboTemp from this site.) This site had 100% redwood and alder shade canopy and received no direct sunlight.

Spanish Ranch Air – Located in a redwood clump (mentioned above) approximately 15 feet above the creek level.

Longridge Crossing – Located approximately 391 feet downstream from Longridge Crossing on the East Branch of Soquel Creek. The Hobo was placed under the right bank (looking downstream) and the site was marked with red polka-dot flagging. The Hobo was placed 12 inches below the surface of the water. This location had approximately 80% shade canopy consisting of alders, redwoods, oaks, and sycamores. The Hobo received no solar radiation because it was tucked under the bank with cobbles placed on top of it. No signs of tampering were noticed.

Southwest Boundary – Located on the East Branch of Soquel Creek 965 feet below the Hihn Bridge crossing. Placed in an undercut bank under the third alder root wad, about 30 feet downstream from where the rock face ends on the right bank. The Hobo was placed 15 inches below the surface of the water. The shade canopy at this location was estimated at 80% with no solar radiation reaching the Hobo logger. The Hobo Logger at this location moved two feet from its original location.

Fern Gulch Creek Lower – Located in Fern Gulch Creek approximately 472 feet upstream from the confluence of Soquel Creek. The Hobo temp was placed in a small pool (created by a log across the creek) on the right side beneath the undercut bank, which is marked with red polka-dot flagging. The Hobo was placed 16-18 inches below the surface of the water. This site had approximately 80% shade canopy and the Hobo received no solar radiation. In order to, reach the confluence, head towards Soquel Creek from Hihn's Mill Road approximately 200 feet west of Sawpit Trail. This spot is marked on Hihn's Mill Road with red polka-dot flagging.

Fern Gulch Creek Upper - Fern Gulch Creek runs through the next planned timber harvest area. Having an additional Hobo location on the upper portion of Fern Gulch Creek will aid in the temperature monitoring of this creek before and after the timber harvest. To locate this Hobo site, take the seasonal road built on the Rapp/Field property boundary until the road intersects the trail to the white bridge. This trail is where Spanish Ranch Road was previously located. The white bridge crosses Fern Gulch Creek, and just under the bridge is pipe for domestic water intake to supply neighboring properties with water. The Hobo was placed 80 feet below the white bridge on the left bank (looking downstream) next to a very small pool created by a step in the creek, and tucked under the left undercut bank. The Hobo was placed 8 inches below the surface of the water. This location is flagged with red and white polka-dot flagging. This site had 100% redwood canopy, and the Hobo received no solar radiation because it was under the cut bank and covered with rocks.

Amaya Creek – Located in Amaya Creek approximately 245 feet upstream from the confluence with the east branch of Soquel Creek. Two large redwood slabs form a shallow pool; one slab forms a spillway, and the other forms the overhanging left bank. The Hobo was placed 12 inches below the surface of the water. The Hobo was placed under the overhanging left bank and was fully protected from solar radiation. Three large cobble stones were used to cover the Hobos from direct sunlight. This location had approximately 100% shade canopy consisting of alders and redwoods.

Temperature Recording Interval

The four older HoboTemps were "launched" to record for six months at two-hour intervals; Spanish Ranch, Southwest Boundary, Amaya Creek, and Spanish Ranch Air. The four newer HoboTemps were "launched" to record for six months at one-hour intervals; East Boundary, Longridge Crossing, Fern Gulch Lower and Fern Gulch Upper.

Data Analysis

All data was downloaded in BoxCar Pro 4.3 and exported to Excel for graphing and analysis. Temperature measurements taken during transport to and from monitoring sites were eliminated. A rolling seven-day average was calculated and graphed over the raw temperature readings. Refer to Appendix A for graphs of the rolling seven-day average. This number was calculated for each data point as the average temperature for the previous 3.5 days and following 3.5 days. With 12 temperature measurements taken in a 24-hour period (or 24 if the Hobo temp was taking hourly readings), the resulting number is an average of 84 (or 168) data points. The seven-day rolling average historically has more closely corresponded with fish success than straight temperature readings because it reflects the duration of high temperatures. All temperature data displayed in the following tables is from absolute data, not from the 7-day rolling average.

RESULTS

Results for temperatures and seven-day rolling averages are shown on graphs in Appendix A. These graphs were taken from the data tables, which are too large to be printed but can be viewed on a computer screen. There were no failures of any Hobos during this monitoring season. All Hobo data are on the SDSF computer hard drive - C:\FILE CABNET\Hobo Reports\Hobo Temps 2007\2007 Hobo Excel Data.

DISCUSSION

Before placing the HoboTemps (Data Loggers) in its intended sites during June 26th 2007, a calibration test was performed on June 25th. The HoboTemps were launched on June 25 and placed within the Soquel office. They were allowed to record air temperatures within the station for one day before being placed in their actual sites. The greatest discrepancy in recorded temperatures was less than 2 degrees. Table 1 shows the results from the Hobo calibration test.

Table 1. Hobo Temperatures in SDSF Office for Calibration Test.

Hobo	Date	Time	Temperature (*C)
East Boundary	6/25/2007	15:00	23.24
Spanish Ranch	6/25/2007	15:00	23.57
Longridge Crossing	6/25/2007	15:00	23.63
Southwest Boundary	6/25/2007	15:00	23.93
Fern Gulch Creek Lower	6/25/2007	15:00	24.01
Fern Gulch Creek Upper	6/25/2007	15:00	26.73
Amaya Creek	6/25/2007	15:00	23.74
Spanish Ranch Air	6/25/2007	15:00	23.62

Just like the previous years before, the highest temperatures were recorded from the beginning of July to the end of August with the exception of Fern Gulch Creek Upper, which had minimal fluctuations in temperature for the entire three months. High temperatures (ºC) for each site are shown below in Table 2 for 2007.

Table 2. High Temperatures (°C), Date, and Time by Site for 2007.

Site	High Temp.	Date(s)	Time
East Boundary	17.90	7/5, 7/24	15:00
Spanish Ranch	20.08	7/23	18:57
Longridge Crossing	22.48	7/22	17:27
Southwest Boundary	21.13	7/23, 7/24	15:36
Fern Gulch Creek Lower	17.14	9/4	14:00
Fern Gulch Creek Upper	16.38	8/29, 9/3	14:00-20:00
Amaya Creek	19.76	7/23	15:44
Spanish Ranch Air	30.47	7/4	14:58

For 2007, water temperatures were highest at the Longridge Crossing site. In years preceding 2006, the Southwest Boundary site usually had the highest temperature readings. The differences in temperature between the two sites were very small. All the other HoboTemps had readings that were very similar the past. Water temperatures varied from site to site and there were no significant temperature spikes in 2007. While tampering at the Southwest Boundary has occurred in the past, the temperature readings did not indicate any abnormal fluctuation caused by tampering in 2007.

Table 3 shows the total fluctuation in temperature, from the highest and lowest temperatures recorded for each location, during the entire 2007 measurement period.

Table 3. Temperature Extremes (ºC) by Station for 2007.

Site	High Temp	Low Temp	Range in Extremes
East Boundary	17.90	9.03	8.87
Spanish Ranch	20.08	9.22	10.86
Longridge Crossing	22.48	8.23	14.25
Southwest Boundary	21.13	9.51	11.62
Fern Gulch Creek Lower	17.14	8.23	8.91
Fern Gulch Creek Upper	16.38	14.09	2.29
Amaya Creek	19.76	8.91	10.85
Spanish Ranch Air	30.47	3.99	26.48

Table 4 lists by station the most extreme fluctuations in temperature within one day during the 2007 monitoring period. The largest water temperature fluctuation within one day was 7.25°C at the Longridge Crossing location. In 2006, the greatest fluctuation was 5.61°C at the Spanish Ranch location. Temperature fluctuations varied throughout the measurement season; not surprisingly the most extreme fluctuation occurred in the month of July.

Table 4. Most Extreme Temperature (ºC) Fluctuation within One Day by Station in 2007.

Site	Date	High	Low	Difference
East Boundary	7/4	17.52	14.85	2.67
Spanish Ranch	7/2	18.47	14.18	4.29
Longridge Crossing	7/2	20.95	13.70	7.25
Southwest Boundary	7/2 7/4	19.73, 20.78	14.13, 15.18	5.60
Fern Gulch Creek Lower	9/4	17.14	13.70	3.44
Fern Gulch Creek Upper	8/1	15.62	14.47	1.15
Amaya Creek	7/2	18.31	12.94	5.37
Spanish Ranch Air	7/2	29.36	10.28	19.08

Water temperatures above 21.1ºC make it difficult for coho salmon and steelhead trout to extract oxygen from the water. Optimal rearing temperatures for juveniles are 7.22-14.4ºC for steelhead and 11.67-14.4ºC for coho (Resner and Bjornn, 1979). It is interesting to note the number of days recorded at 21.1°C or higher and 14.4°C or higher (see Tables 5 and 6, respectively). Table 5 and Table 6 can then be compared to previous monitoring seasons. The comparison of the number of days with temperatures exceeding 21.1°C and 14.4°C to those of previous years will show any trends in adverse conditions occurring throughout the entire temperature monitoring project for each monitoring site. Missing data and variation in the monitoring period start and finish dates limit the amount of data available for the comparison.

Table 5 shows that in 2007 East Boundary, Spanish Ranch, Fern Gulch Creek Lower, Fern Gulch Creek Upper and Amaya Creek have temperature readings under 21.1ºC for the entire monitoring season. The Longridge crossing recorded 11 days with readings above 21.1ºC and Southwest Boundary recorded 2 days with readings above 21.1ºC.

Table 5. Number of Days When Temperature Readings Exceeded 21.1ºC

Site	No. of Days Above 21.1ºC in 2007
East Boundary	0
Spanish Ranch	0
Longridge Crossing	11
Southwest Boundary	2
Fern Gulch Creek Lower	0
Fern Gulch Creek Upper	0
Amaya Creek	0

Table 6 shows the number of days with temperatures at or over 14.4°C in 2007. Although Fern Gulch Creek Upper recorded 127 days with readings above14.4°C, the highest among all monitoring sites, this site recorded the lowest overall high temperature, range in extremes, and one day fluctuation compared to all other monitoring sites.

Table 6. Number of Days When Temperature Readings Exceeded 14.4ºC

Site	No. of Days at or above 14.4ºC in 2007
East Boundary	80
Spanish Ranch	86
Longridge Crossing	86
Southwest Boundary	90
Fern Gulch Creek Lower	39
Fern Gulch Creek Upper	127
Amaya Creek	85

Table 7 presents a comparison of the peak high temperatures from 1997 to the present. This table shows that there have not been any notable trends in temperature fluctuations over the last 7 years. The highest temperatures are witnessed in 2006 due to warm temperatures occurring into the month of July. Rainfall during the winter of '06/'07 was 17.94 inches, approximately 40% of average. This resulted in significantly lower stream flows during the 2007 monitoring season.

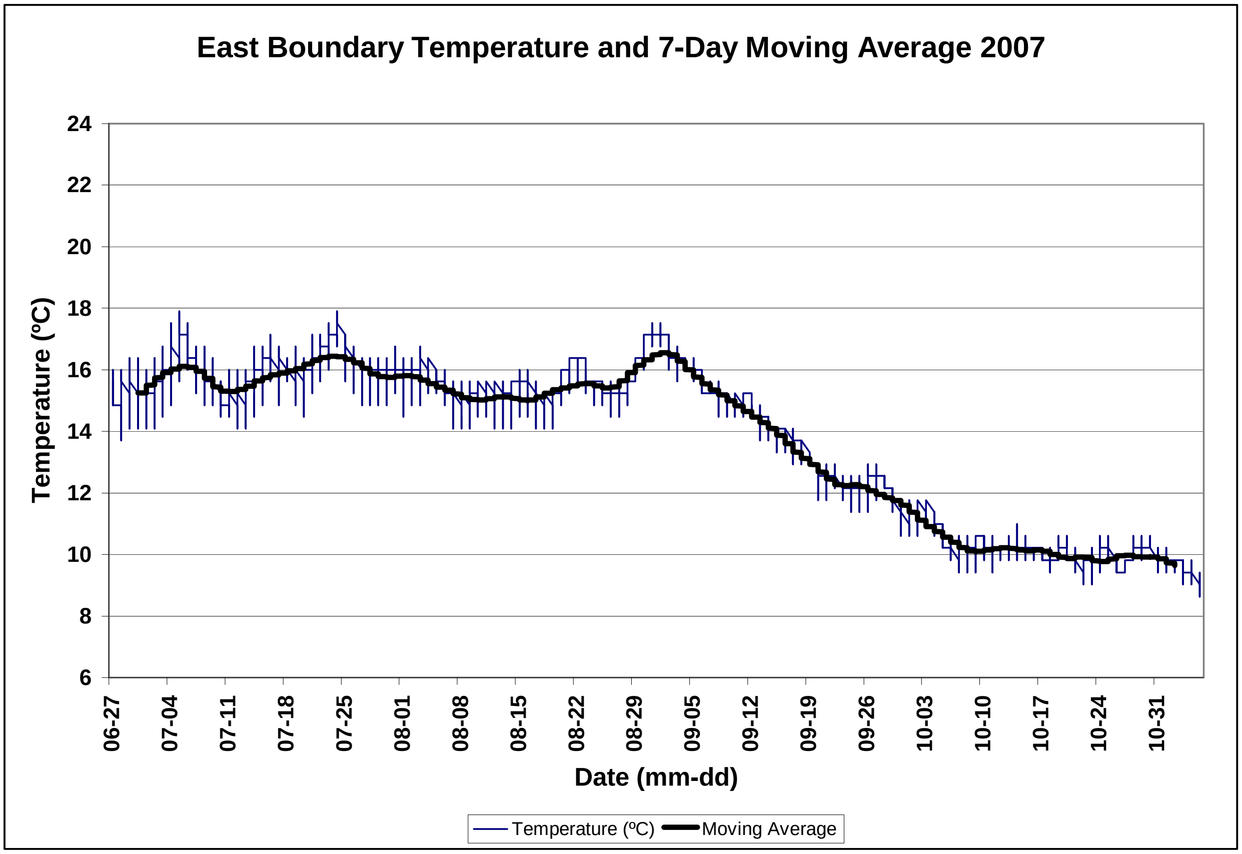
Table 7. Comparison of High Temperatures from 1997 to 2007

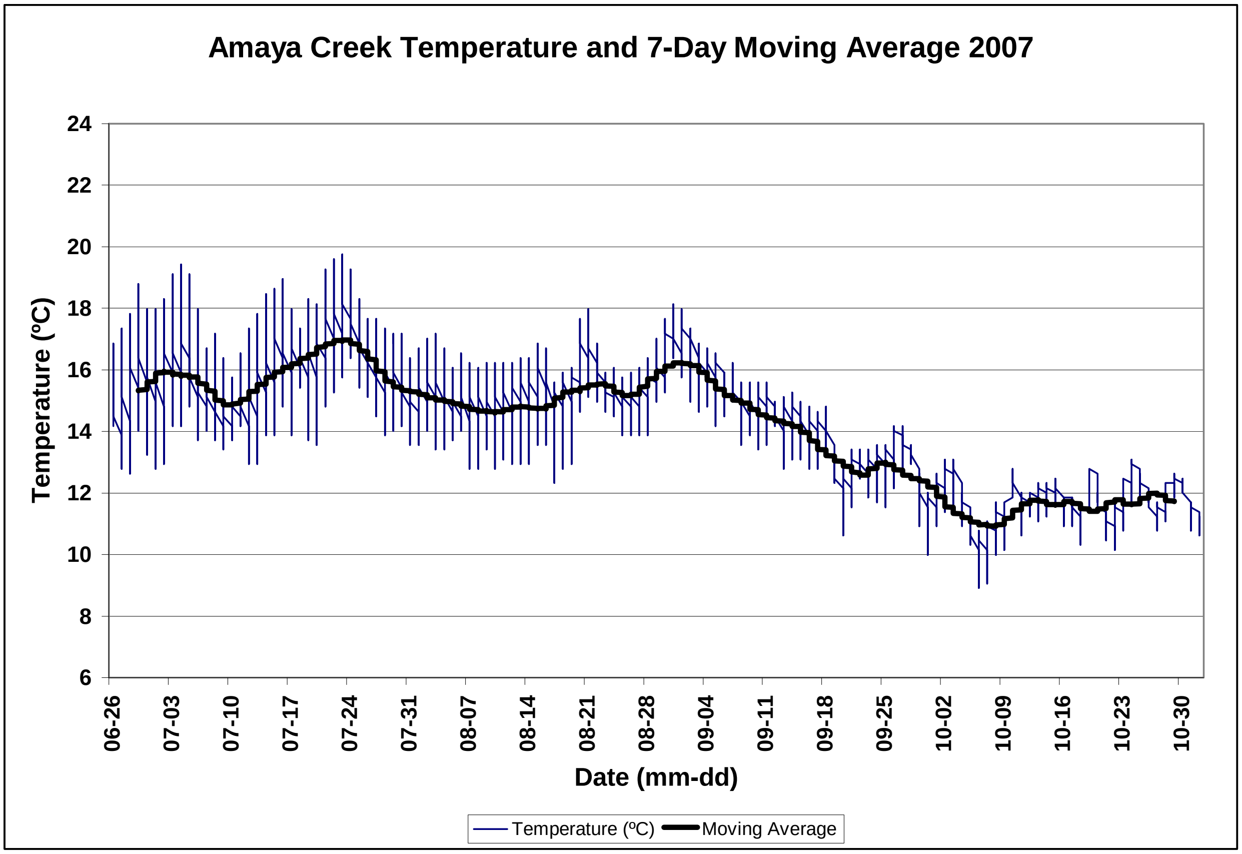
High Temperatures (°C)										
Site	Year									
	1997	1998	1999	2000	2001	2002	2003	2005	2006	2007
East Boundary	19.69	19.69	17.60	N/A	18.28	17.14	17.52	17.52	21.33	17.90
Spanish Ranch	19.62	21.23	19.12	19.39	21.57	20.41	20.08	19.28	22.73	20.08
Longridge Crossing	N/A	N/A	N/A	N/A	21.33	16.38	N/A	20.57	23.24	22.48
Southwest Boundary	23.22	24.64	21.82	N/A	N/A	N/A	21.48	20.78	22.52	21.13
Fern Gulch Creek Lower	N/A	N/A	N/A	N/A	16.38	16.00	16.76	16.00	18.66	17.14
Fern Gulch Creek Upper	N/A	N/A	N/A	N/A	N/A	N/A	16.38	17.52	16.76	16.38
Amaya Creek	19.12	20.24	19.44	16.87	20.41	18.96	18.79	19.28	21.23	19.76
Spanish Ranch Air	24.69	26.12	28.64	27.55	29.73	29.73	29.73	27.91	31.21	30.47

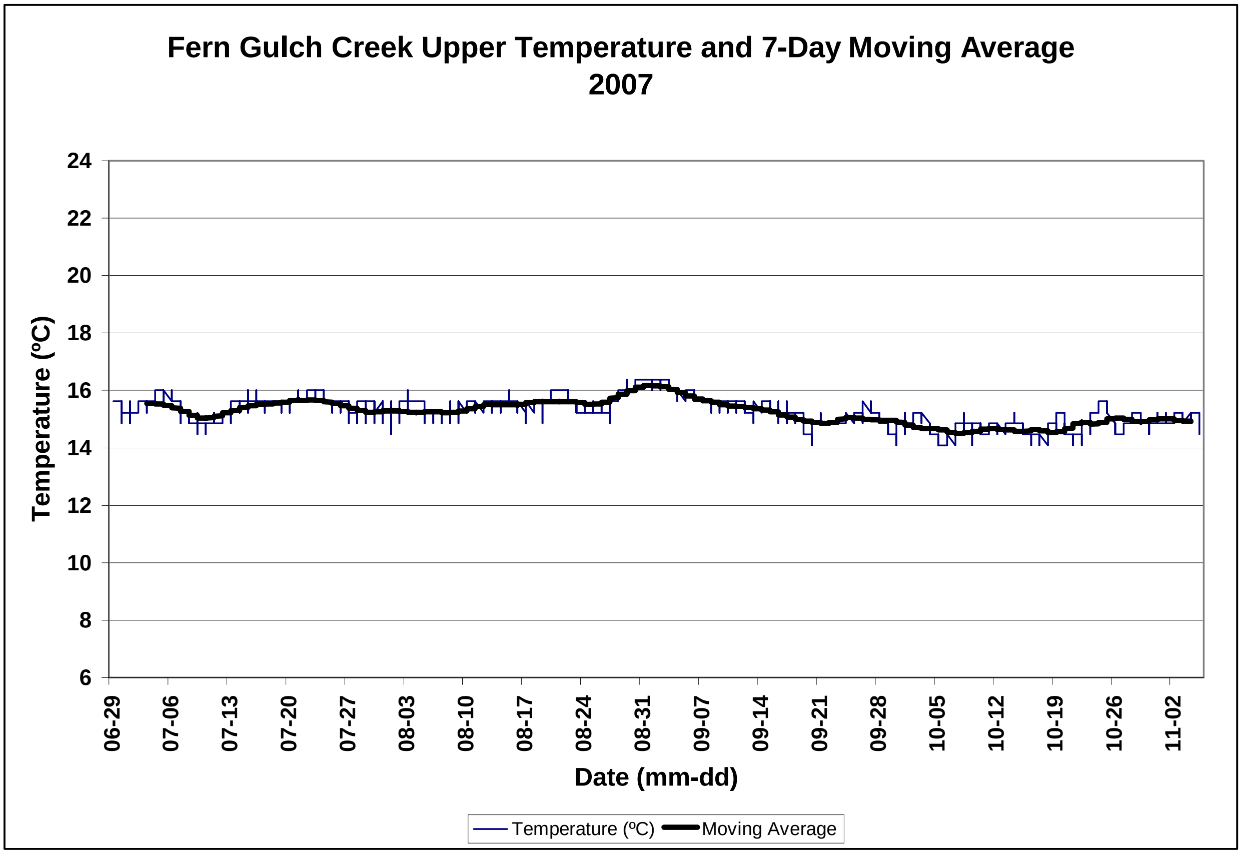
Suggestions for Next Year

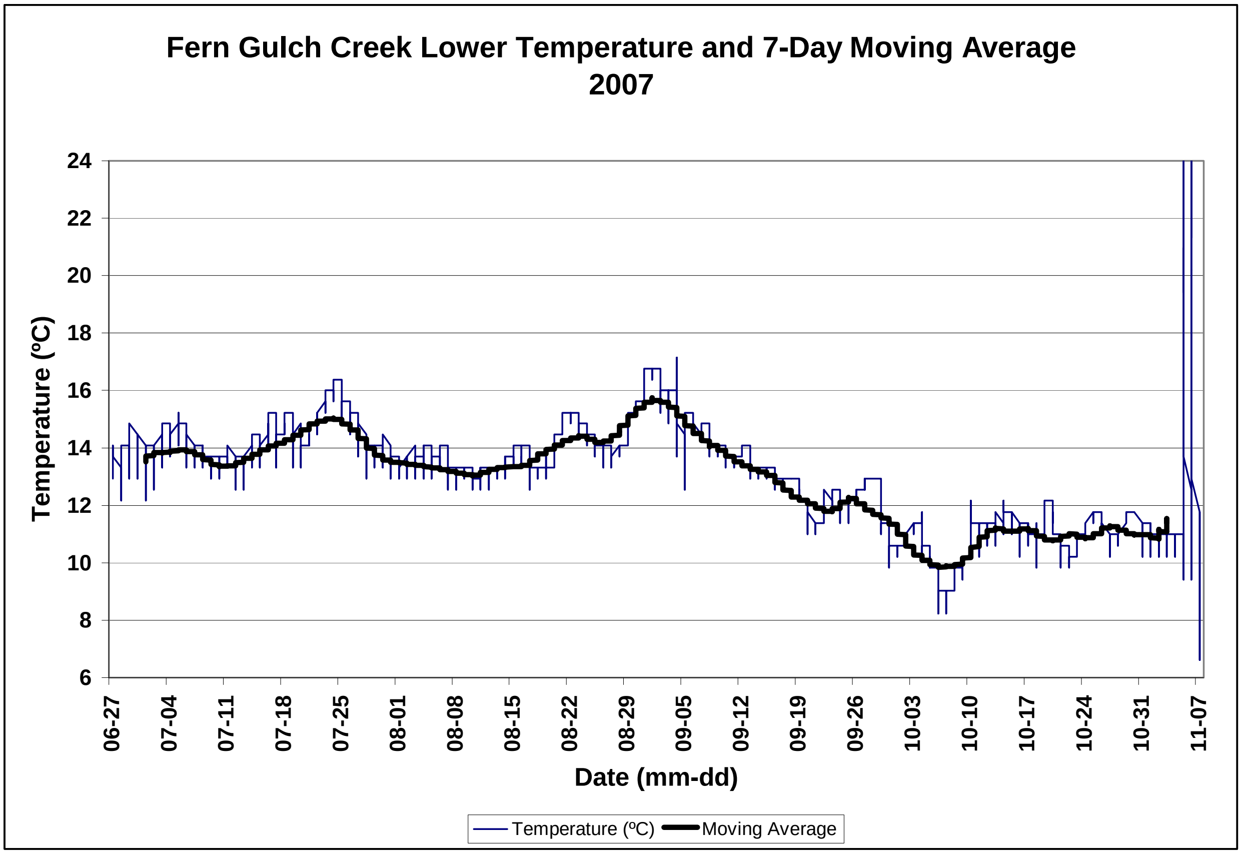
Comparisons and trends can best be monitored when methods are repeated closely, particularly matching start and stop dates for monitoring. In 2006, the California Regional Water Quality Control Board for the Central Coast Region released a set of protocols for continuous water temperature monitoring for their timber harvesting water quality waiver program. These protocols indicate continuous temperature monitoring should occur for the five and a half month period starting May 1 and ending October 15. To be consistent with these protocols, it is recommended that water temperatures be monitored during this same time period.

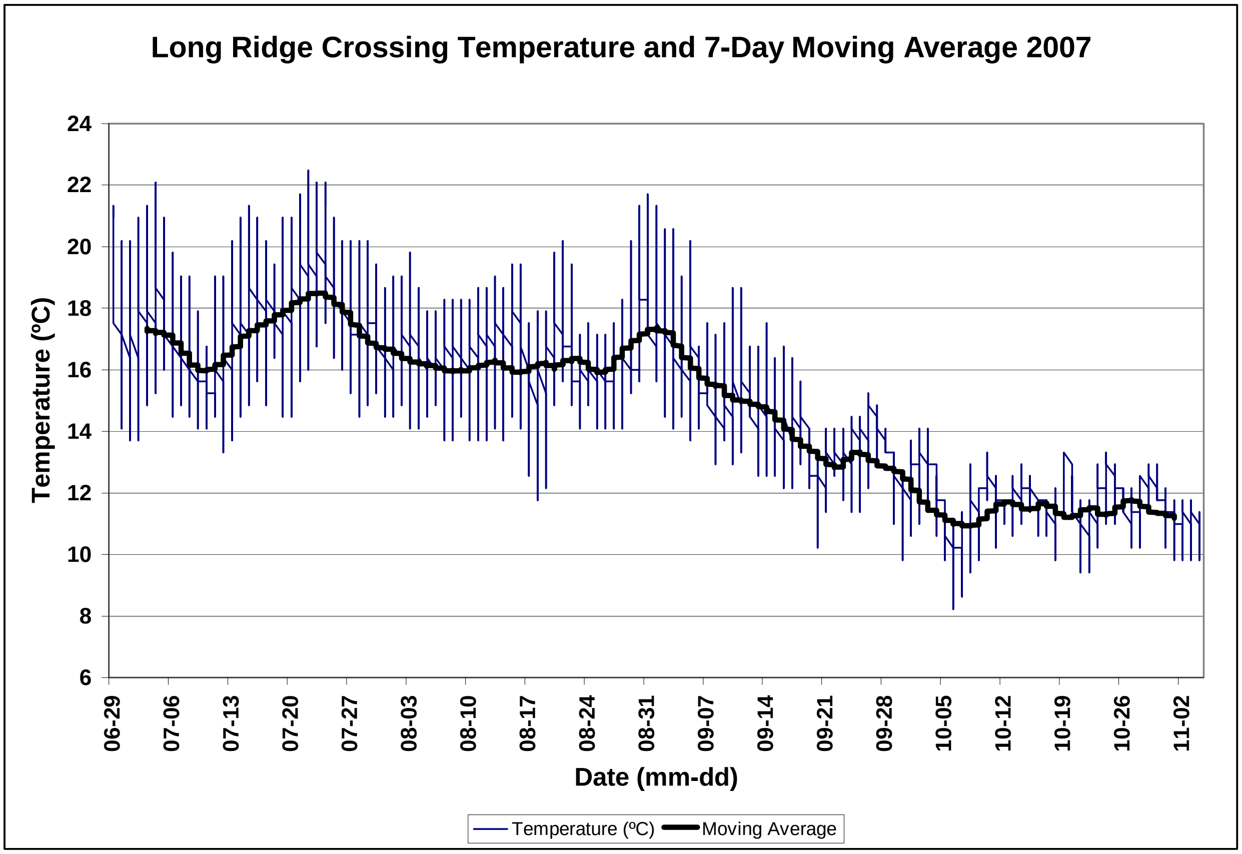
Appendix A

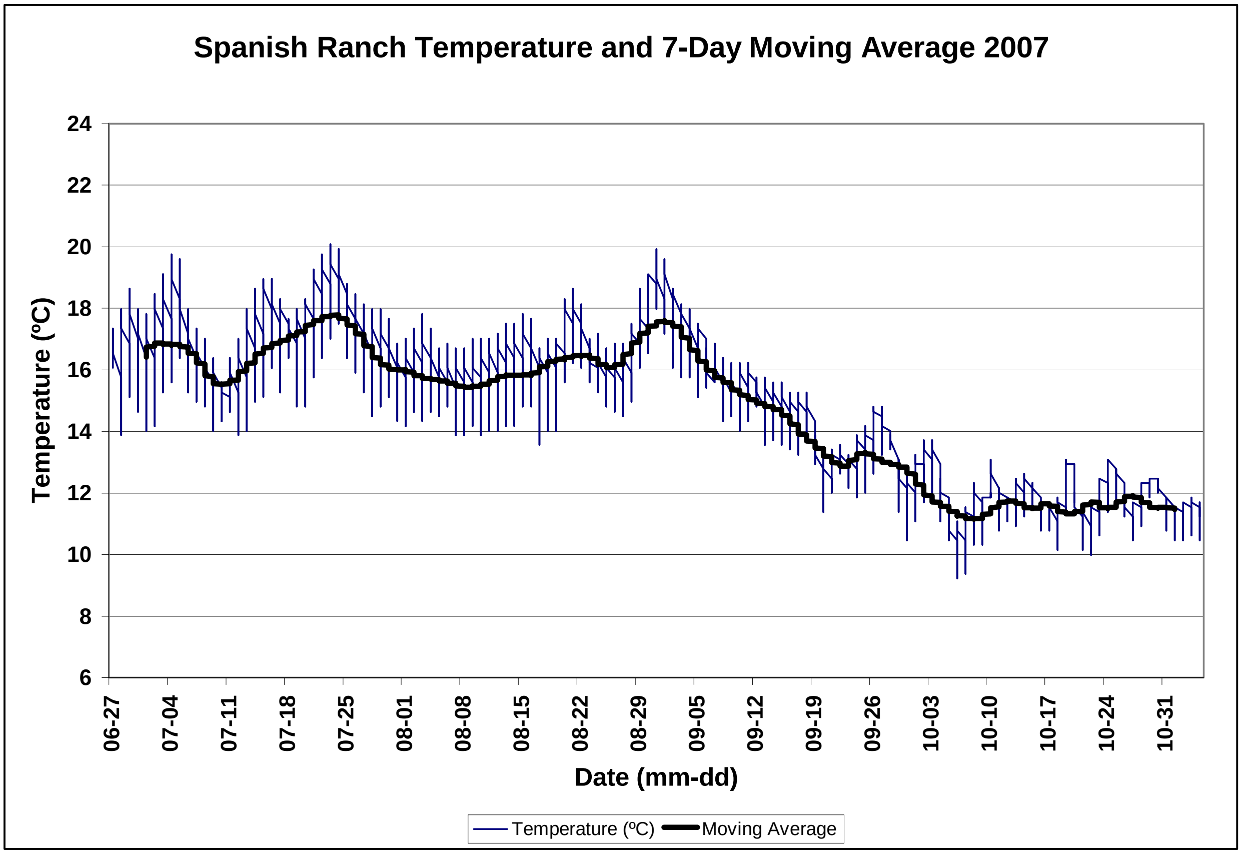

East Boundary Temperature and 7-Day Moving Average 2007
Temperature (ºC)
Date (mm-dd)
24
22
20
18
16
14
12
10
8
6
06-27
07-04
07-11
07-18
07-25
08-01
08-08
08-15
08-22
08-29
09-05
09-12
09-19
09-26
10-03
10-10
10-17
10-24
10-31
Temperature (ºC)
Moving Average

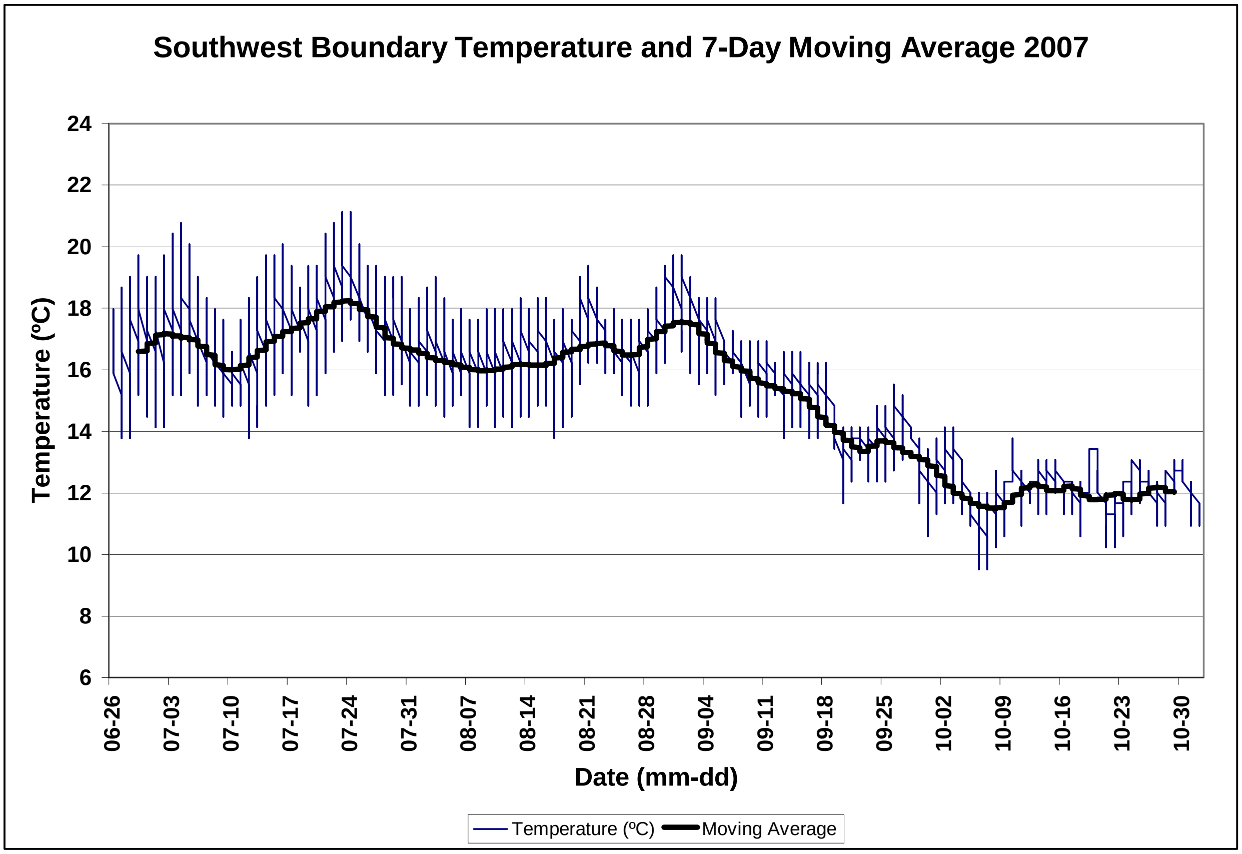

Amaya Creek Temperature and 7-Day Moving Average 2007
Temperature (ºC)
Date (mm-dd)
24
22
20
18
16
14
12
10
8
6
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02
10-09
10-16
10-23
10-30
Temperature (ºC)
Moving Average

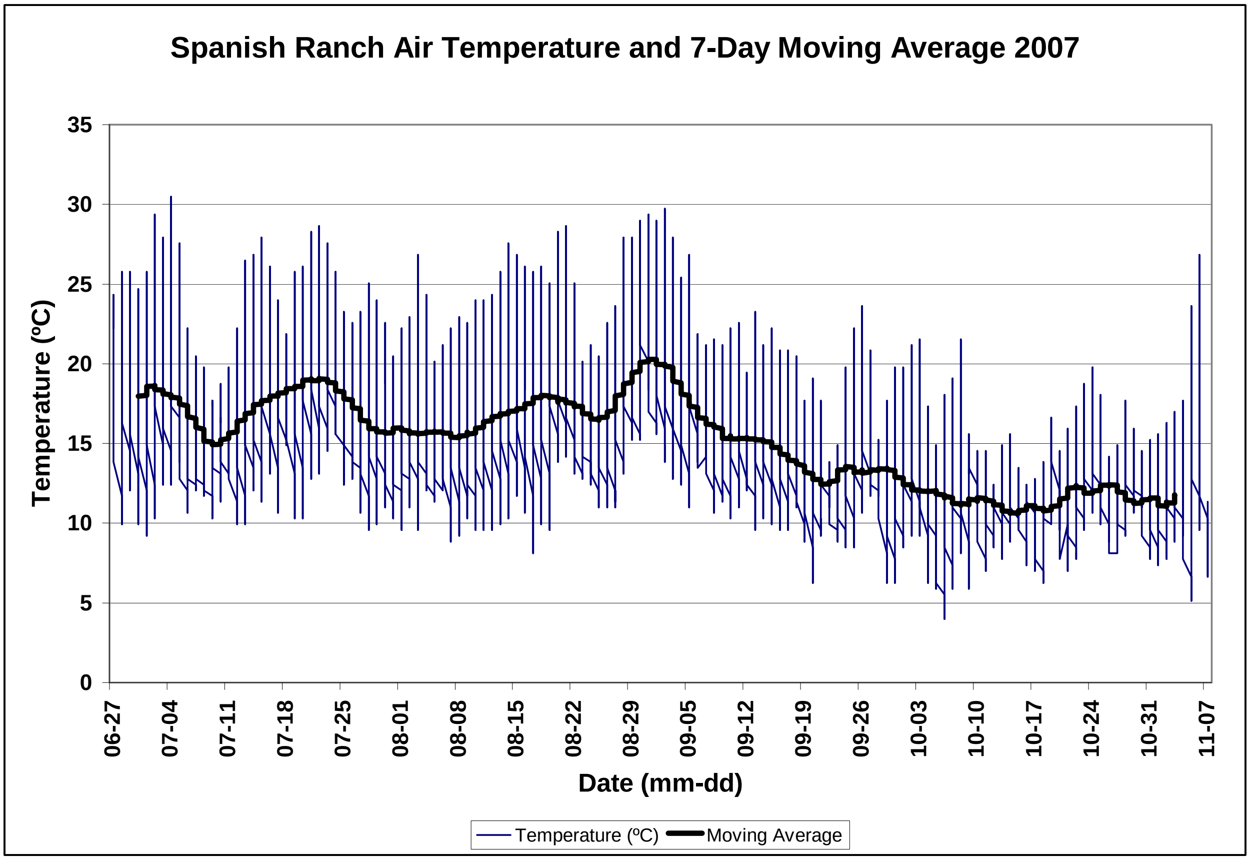

Fern Gulch Creek Upper Temperature and 7-Day Moving Average
2007
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
06-29
07-06
07-13
07-20
07-27
08-03
08-10
08-17
08-24
08-31
09-07
09-14
09-21
09-28
10-05
10-12
10-19
10-26
11-02
Date (mm-dd)
Temperature (ºC)
Moving Average


Fern Gulch Creek Lower Temperature and 7-Day Moving Average
2007
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
06-27
07-04
07-11
07-18
07-25
08-01
08-08
08-15
08-22
08-29
09-05
09-12
09-19
09-26
10-03
10-10
10-17
10-24
10-31
11-07
Date (mm-dd)
Temperature (ºC)
Moving Average


Long Ridge Crossing Temperature and 7-Day Moving Average 2007
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
06-29
07-06
07-13
07-20
07-27
08-03
08-10
08-17
08-24
08-31
09-07
09-14
09-21
09-28
10-05
10-12
10-19
10-26
11-02
Date (mm-dd)
Temperature (ºC)
Moving Average


Spanish Ranch Temperature and 7-Day Moving Average 2007
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
06-27
07-04
07-11
07-18
07-25
08-01
08-08
08-15
08-22
08-29
09-05
09-12
09-19
09-26
10-03
10-10
10-17
10-24
10-31
Date (mm-dd)
Temperature (ºC)
Moving Average


Southwest Boundary Temperature and 7-Day Moving Average 2007
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02
10-09
10-16
10-23
10-30
Date (mm-dd)
Temperature (ºC)
Moving Average


Spanish Ranch Air Temperature and 7-Day Moving Average 2007
Temperature (ºC)
35
30
25
20
15
10
5
0
06-27
07-04
07-11
07-18
07-25
08-01
08-08
08-15
08-22
08-29
09-05
09-12
09-19
09-26
10-03
10-10
10-17
10-24
10-31
11-07
Date (mm-dd)
Temperature (ºC)
Moving Average

Soquel Demonstration State Forest
Instream Temperature Monitoring 2008
East Branch of Soquel Creek, Fern Gulch Creek and Amaya Creek

INTRODUCTION

Instream temperature loggers are installed at various locations in Soquel Demonstration State Forest (SDSF) in order to measure and record stream water temperatures throughout the dry season. During the 2008 dry season, instream temperatures were recorded from May 1, 2008 to October 15, 2008. An additional temperature logger is located at the Spanish Ranch site on the East Branch of Soquel Creek to measure and record air temperature in the same time period.

METHODS

In 2006, the California Regional Water Quality Control Board for the Central Coast Region released a set of protocols for continuous water temperature monitoring for their timber harvesting water quality waiver program. SDSF's methods are consistent with these protocols, although they differ in the calibration procedure. SDSF calibrates the temperature loggers against a scientific thermometer at room temperature, not with an ice bath. If the temperature loggers record accurate measurements at room temperature, they are ready to use for instream temperature monitoring.

Instream Monitoring Locations

Monitoring locations are chosen based on the following criteria:

- Locations that demonstrate stream temperature variations of the East Branch of Soquel Creek, Amaya Creek, and Fern Gulch Creek within the boundaries of SDSF
- Locations of fish refugia (deep pools, shaded areas with cover)

The last criterion is especially important because high water temperatures contribute to lower salmonid survival rates, and fish retreat to these locations to escape warm water temperatures. Shade density observations are carried over from 2006. Red polka-dot flagging is hung to facilitate relocation of each monitoring site. Temperature logger monitoring sites are the same approximate sites as previous years (see map), and are as follows:

> East Boundary – The monitoring site is located on the East Branch of Soquel Creek near the boundary between SDSF and Redwood Empire lands. A green sign on Hihn's Mill Road indicates the property boundary. From there, pink and/or red polka-dot flagging can be followed downhill to the creek. At the creek are two

pink and red polka-dot flags tied to a 10-inch diameter alder tree. Downstream from the pink flags is a slide descending from Highland Way, a car body, and a large debris jam (about 75 feet long and 12 feet high). The monitoring site is 130 feet downstream from the flagged alder tree. In 2008, the temperature logger was placed 1.3 feet below the surface of the water underneath a log jam. This site is marked with red polka-dot flagging. The site had been shaded by the debris jam and received no direct sunlight. The site remained undisturbed during the 5 1/2 months of temperature monitoring.

<u>Spanish Ranch</u> – The monitoring site is located on the East Branch of Soquel Creek at Spanish Ranch Crossing, approximately 79 feet upstream from the bottom of the electro-fishing station. The trail to the site takes off from Hihn's Mill Road 100 feet east of the Weir Creek crossing. There is a patch of French broom standing approximately 8-10 feet high through which the trail begins. The temperature logger is installed under the roots of a clump of redwood trees in a pool on the left bank (looking downstream). In 2008, the temperature logger was placed 1.7 feet below the surface of the water. Chest waders are highly recommended for this site. This site had 100% redwood and alder shade canopy and received no direct sunlight. The site remained undisturbed during the 5 1/2 months of temperature monitoring.

<u>Spanish Ranch Air</u> – The monitoring site is located in a redwood clump (mentioned above) 13 feet above the creek level. The site remained undisturbed during the 5 1/2 months of temperature monitoring.

<u>Longridge Crossing</u> – The monitoring site is located approximately 391 feet downstream from Longridge Crossing on the East Branch of Soquel Creek. The temperature logger is installed under the right bank (looking downstream) and the site is marked with red polka-dot flagging. In 2008, the temperature logger was placed 0.9 feet below the surface of the water. This location had approximately 80% shade canopy consisting of alders, redwoods, oaks, and sycamores and received no direct sunlight. The site remained undisturbed during the 5 1/2 months of temperature monitoring.

<u>Southwest Boundary</u> – The monitoring site is located on the East Branch of Soquel Creek 965 feet below the Hihn Bridge crossing. The temperature logger is installed in an undercut bank under the third alder root wad, about 30 feet downstream from where the rock face ends on the right bank. In 2008, the temperature logger was placed 1.5 feet below the surface of the water. The shade canopy at this location was estimated at 80% with no solar radiation reaching the data logger. The site remained undisturbed during the 5 1/2 months of temperature monitoring.

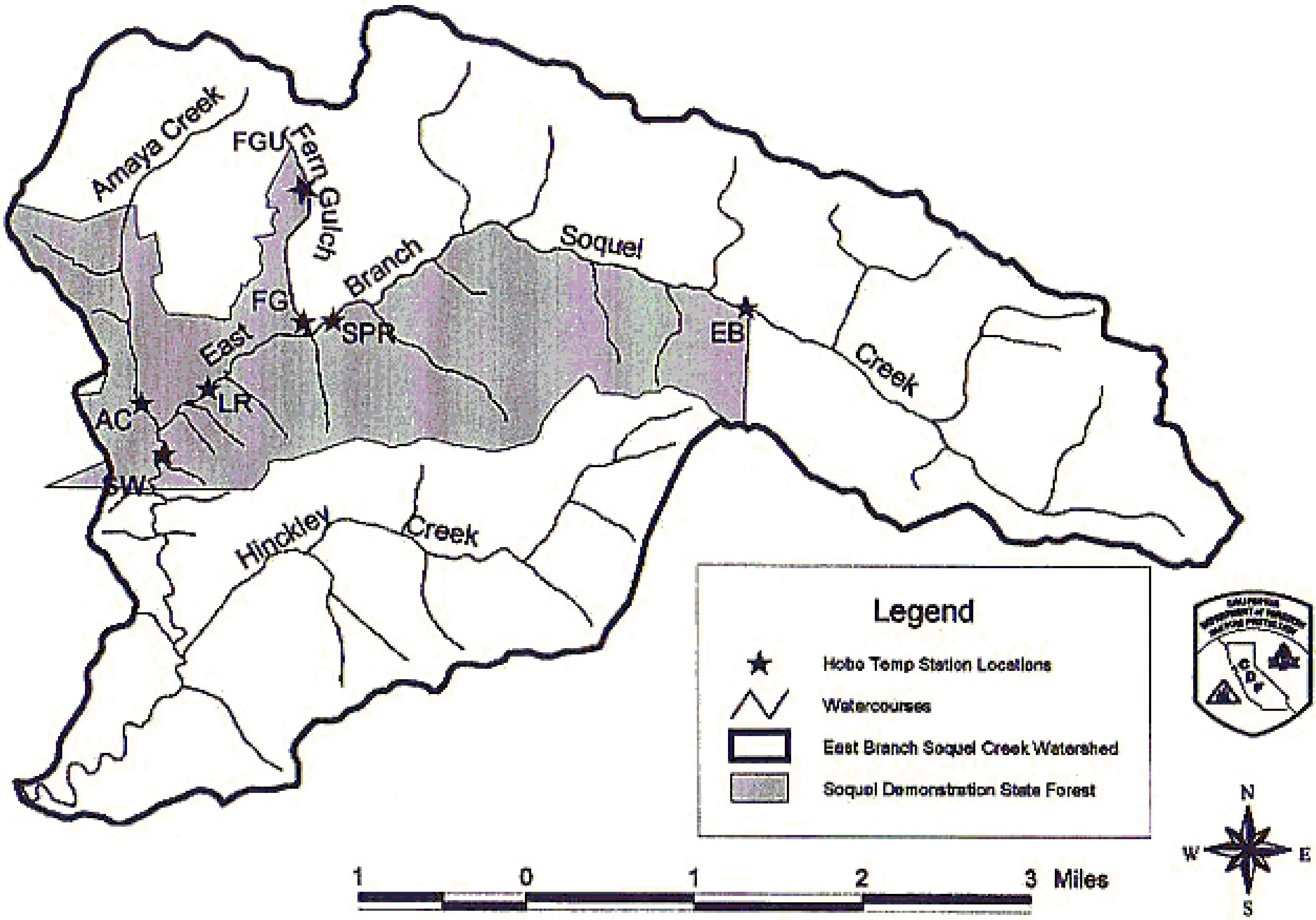
<u>Fern Gulch Creek Lower</u> – The monitoring site is located in Fern Gulch Creek approximately 472 feet upstream from the confluence of Soquel Creek. The temperature logger is installed in a small pool (created by a log across the creek)

on the right side (looking downstream) beneath the undercut bank, which is marked with red polka-dot flagging. In 2008, the temperature logger was placed 1.7 feet below the surface of the water. This site had approximately 80% shade canopy and the temperature logger received no solar radiation. When relocating the site, park at the turnout at the intersection of Hihn's Mill Road and Sawpit Trail. A red polka-dot flag marks the take-off point. Follow the flag line to the west, crossing over the East Branch of Soquel Creek, and ending at the monitoring site. The site remained undisturbed during the 5 1/2 months of temperature monitoring.

<u>Fern Gulch Creek Upper</u> - Fern Gulch Creek runs through the next planned timber harvest area. Having an additional instream temperature logger on the upper portion of Fern Gulch Creek will aid in the temperature monitoring of this creek before and after the timber harvest. To locate the monitoring site, take the seasonal road built on the Rapp/Field property boundary until the road intersects the trail to the white bridge. This trail is where Spanish Ranch Road was previously located. The white bridge crosses Fern Gulch Creek, and just under the bridge is a pipe for domestic water intake to supply neighboring properties with water. The monitoring site is 80 feet below the white bridge on the left bank (looking downstream) next to a very small pool created by a step in the creek, and tucked under the left undercut bank. In 2008, the temperature logger was placed 0.5 feet below the surface of the water. This location is flagged with red polka-dot flagging. This site had 100% redwood canopy, and the temperature logger received no solar radiation. The site remained undisturbed during the 5 1/2 months of temperature monitoring.

<u>Amaya Creek</u> – The monitoring site is located in Amaya Creek approximately 245 feet upstream from the confluence with the East Branch of Soquel Creek. Two large redwood slabs form a shallow pool; one slab forms a spillway, and the other forms the overhanging left bank (looking downstream.) In 2008, the temperature logger was placed 1.5 feet below the surface of the water. The temperature logger was placed under the overhanging left bank and was fully protected from solar radiation. This location had approximately 100% shade canopy consisting of alders and redwoods. The site remained undisturbed during the 5 1/2 months of temperature monitoring.

Hobo Temperature Data Logger Stations Map



Temperature Logger Instream Installation

Begin preparations April 1. Prepare the temperature loggers for installation using the following steps:

- Order new batteries and moisture absorbing packets (silica gel) at least one month in advance. Batteries are available online from Radio Shack and silica gel can be bought over the phone from Onset, the temperature logger manufacturer.
- Prepare the 8 waterproof cases by thoroughly cleaning each with water and a rag.
- Lubricate the seals with the lubricating gel in the box.
- Place a small amount of clean dry gravel in the case for added weight.
- Place a fresh moisture absorbing packet into each case.
- When ready for field installation, launch the temperature loggers with BoxCar Pro 4.3. The cable is connected to the main office computer. Place the temperature loggers into a case so that the red light is visible.
- Place the SDSF business cards in each case and close the cases.

It will take two or three days to install the temperature loggers at all eight sites. Begin installing the temperature loggers in late April and provide sufficient time to complete the installation before May 1. A list of things to bring for data logger field installation can be found in the most recent file. Review the list prior to beginning field installation.

After arriving at the monitoring site, attach the waterproof case to a rock using thick gauge baling wire, place it in the stream, and cover it with cobbles. Use this method to keep the temperature loggers submerged throughout the dry season, to avoid tampering, and to provide protection from solar radiation. In 2008, the following temperature recording intervals were used when launching the temperature loggers.

Temperature Recording Interval:

Amaya Creek………………………………………………………………2 hr 30 min
Southwest Boundary……………………………………………………….2 hr 30 min
Spanish Ranch.. 2 hr 30 min
Spanish Ranch Air………………………………………………………….2 hr 30 min
Longridge………………………………………………………………………1 hr
Upper Fern Gulch……………………………………………………………..1 hr
Lower Fern Gulch……………………………………………………………..1 hr
East Boundary………………………………………………………………… 1 hr

2 hr 30 min intervals are used in the "StowAway" and "HOBO-TEMP" temperature loggers because they have less available memory. The newer "HOBO Temp" temperature loggers have more memory and the capability to store more temperature records. The temperature recording intervals should remain the same for subsequent monitoring season's assuming the length of the monitoring period is 5 ½ months.

DATA ANALYSIS

After retrieving the temperature loggers at the end of the monitoring season, all data is downloaded in BoxCar Pro 4.3 and exported to Excel for graphing and analysis. Temperature measurements taken during transport to and from monitoring sites are eliminated. The analysis checks for high temperatures, temperature extremes, the largest one-day fluctuations, days with temperatures exceeding 21.1ºC, and days with temperatures exceeding 14.4ºC. Additionally, a table showing the high temperature data for each monitoring season is included. Finally, a moving 7-day average is calculated and graphed. Trends over time are valuable information provided in the data analysis, the time available for writing the report and the limited amount of available data make uncovering the trends a challenging task.

RESULTS

Results for temperatures and 7-day moving averages are shown in the following tables and graphs. The raw data and analysis are too large to include in the written report, but can be found on the SDSF computer hard drive. Temperature logger data is on the SDSF computer hard drive - C:\FILE CABNET\Hobo Reports\Hobo Temps 2008\Logger Data. There were no failures of any temperature loggers during this monitoring season. Rainfall for the '07-'08 rainy season was 29.25 inches, improving over '06-'07 season's unusually low 17.94 inches, but still low compared to the 43.2 inch average from '93 to '07. Unfortunately, stream flows during the 2008 dry season did not improve over the 2007 dry season and remained very low throughout the monitoring period. Low stream flows were evidenced by the pool at the Fern Gulch Creek Lower site drying up on 08/10/08, and the temperature records taken on or after 08/10/08 were discarded from the Fern Gulch Creek Lower analysis.

DISCUSSION

The temperature loggers were calibrated prior to launch. In late April, they were allowed to record air temperatures within the station for one day and the recorded temperatures were compared to a scientific thermometer. The greatest discrepancy in recorded temperatures was less than 2 degrees. The results of the calibration test are found in the SDSF computer hard drive under

C:\FILECABNET\HoboReports\HoboTemps2008\Calibration\TemperatureLoggerCalibrationForm2008.xls

High Temperatures

High temperatures (ºC) for each site are shown below in Table 1 for 2008.

Table 1. 2008 High Temperatures (°C), Date, and Time

Site	High Temp.	Date(mm/dd)	Time (24 hr)
East Boundary	18.28	07/09 07/10	17:00-22:00 15:00-21:00
Spanish Ranch	19.76	06/20	20:08
Longridge Crossing	22.09	06/20	16:00
Southwest Boundary	20.43	06/20	17:30
Fern Gulch Creek Lower	16.00	06/21 06/22 07/10	22:00-00:00 00:00-02:00 04:00-05:00
Fern Gulch Creek Upper	16.38	07/08 07/09 07/10 08/28 08/29 09/05 09/06 09/07	14:00-20:00 14:00-21:00 14:00 15:00-20:00 13:00-20:00 16:00-17:00, 20:00 14:00-21:00 14:00-20:00
Amaya Creek	18.79	06/20	17:39
Spanish Ranch Air	34.63	06/20	15:00

Most recorded high temperatures were between late June and early July. The highest temperature recorded was 22.09ºC at the Longridge monitoring site. Longridge also had the highest recorded temperatures for 2006 and 2007. Prior to 2006, the highest temperatures were recorded at the Southwest Boundary. In 2008, the Southwest Boundary recorded the second highest temperature at 20.43ºC. The difference in temperature between the two sites was small. Overall, recorded high temperatures for all sites were similar to the results in previous years. While tampering at the Southwest Boundary had occurred in the past, possibly affecting the recorded high temperature, the temperature records did not indicate any abnormalities caused by tampering in 2008.

Temperature Range

Table 2 shows the total range in temperature between the highest and lowest temperatures recorded for each location, during the entire 2008 monitoring season.

Table 2. 2008 Temperature Extremes (ºC) by Station.

Site	High Temp	Low Temp	Range in Extremes
East Boundary	18.28	8.23	10.05
Spanish Ranch	19.76	8.60	11.16
Longridge Crossing	22.09	7.83	14.26
Southwest Boundary	20.43	8.42	12.01
Fern Gulch Creek Lower	16.00	7.83	8.17
Fern Gulch Creek Upper	16.38	13.32	3.06
Amaya Creek	18.79	7.83	10.96
Spanish Ranch Air	34.63	3.22	31.41

Longridge Crossing had the largest range followed closely by the Southwest Boundary. The results are not surprising given both sites had the highest recorded temperatures over the monitoring season. However, it is notable that in 2008 both sites had a larger range when compared to the 2007 results. The 2007 results show the highest and lowest recorded temperatures at the Longridge Crossing were 22.48ºC and 8.23ºC, with a range of 14.25ºC. The 2007 range was only .01ºC smaller compared to 2008, but the 2007 high and low were both warmer by approximately 0.4ºC.

Temperature Fluctuations in One Day

Table 3 shows the largest temperature fluctuations within one day during the 2008 monitoring period for each site.

Table 3. 2008 Largest One-day Temperature Fluctuations (ºC) by Station.

Site	Date (mm/dd)	High	Low	Difference
East Boundary	05/06	11.38	8.63	2.75
Spanish Ranch	06/09	17.50	13.25	4.25
Longridge Crossing	06/18	20.19	12.93	7.26
Southwest Boundary	06/07	16.58	10.94	5.64
Fern Gulch Creek Lower	06/05	12.93	9.82	3.11
	06/07	12.93	9.82	3.11
Fern Gulch Creek Upper	07/22	15.62	14.47	1.15
Amaya Creek	06/19	17.98	13.09	4.89
Spanish Ranch Air	06/19	31.58	12.42	19.16

Longridge Crossing had the largest one-day fluctuation of 7.26ºC on 6/18/08. The largest one-day fluctuation occurred the day before the largest air temperature fluctuation, and two days before the single highest air temperature recorded in the 2008 monitoring season.

Temperatures Recorded Above 21.1ºC and 14.4ºC

Water temperatures above 21.1ºC make it difficult for coho salmon and steelhead trout to extract oxygen from the water. Optimal rearing temperatures for juveniles are 7.22-14.4ºC for steelhead and 11.67-14.4ºC for coho (Resner and Bjornn, 1979[1]). An analysis of the number of days with temperature readings exceeding 21.1°C and 14.4°C provides valuable information for fisheries management in SDSF.

Table 5 shows the number of days when water temperature exceeds 21.1ºC in 2008.

Table 5. Days Exceeding 21.1ºC in 2008

Site	Days Exceeding 21.1ºC
East Boundary	0
Spanish Ranch	0
Longridge Crossing	2
Southwest Boundary	0
Fern Gulch Creek Lower	0
Fern Gulch Creek Upper	0
Amaya Creek	0

Longridge Crossing recorded only two days with water temperature exceeding 21.1ºC. This is a notable drop from 11 days in 2007. Also, Southwest Boundary recorded 0 days exceeding 21.1ºC, dropping from 2 in 2007.

Table 6 shows the number of days when water temperature exceeds 14.4°C.

Table 6. Days Exceeding 14.4ºC in 2008

Site	Days Exceeding 14.4ºC
East Boundary	104
Spanish Ranch	130
Longridge Crossing	150
Southwest Boundary	145
Fern Gulch Creek Lower	28
Fern Gulch Creek Upper	162
Amaya Creek	116

The Fern Gulch Creek Upper site recorded 162 days exceeding 14.4°C. Although this is the largest number of days exceeding 14.4°C, the Fern Gulch Creek Upper site has the smallest range between high and low temperatures (see Table 2.) The Fern Gulch Creek Lower site recorded only 28 days exceeding 14.4°C due to an abbreviated monitoring season from May through early August when the pool had become

[1] R&B 1979

completely dry. The number of days with temperatures exceeding 14.4°C in 2008 is greater compared to the results for 2007. This was attributed to a shorter monitoring season in 2007.

A comparison of 2007 and 2008 can be made using temperature data collected during the same time period. The same comparison can also be made for the entire duration of the SDSF Instream Temperature Monitoring Project. The findings from such a comparison will uncover trends and provide a clearer picture of the temperature conditions within SDSF fisheries.

1997 to 2008 Comparison of High Temperatures

Table 7 presents a comparison of the peak high temperatures from 1997 to the present.

Table 7. Comparison of High Temperatures (ºC) from 1997 to 2008

	Site							
Year	East Boundary	Spanish Ranch	Longridge Crossing	Southwest Boundary	Fern Gulch Lower	Fern Gulch Upper	Amaya Creek	Spanish Ranch Air
1997	19.69	19.62		23.22			19.12	24.69
1998	19.69	21.23		24.64			20.24	26.12
1999	17.60	19.12		21.82			19.44	28.64
2000		19.39					16.87	27.55
2001	18.28	21.57	21.33		16.38		20.41	29.73
2002	17.14	20.41	16.38		16.00		18.96	29.73
2003	17.52	20.08		21.48	16.76	16.38	18.79	29.73
2004								
2005	17.52	19.28	20.57	20.78	16.00	17.52	19.28	27.91
2006	21.33	22.73	23.24	22.52	18.66	16.76	21.23	31.21
2007	17.90	20.08	22.48	21.13	17.14	16.38	19.76	30.47
2008	18.28	19.76	22.09	20.43	16.00	16.38	18.79	34.63

Table 7 is missing data for several reasons. One involves malfunctioning temperature loggers, including the East Boundary in 2000, Longridge Crossing in 2003, and the Southwest Boundary in 2000, 2001, and 2002. No temperature loggers were installed in 2004. The Longridge Crossing site was added to the project in 2001 along with the Fern Gulch Creek Lower site. Fern Gulch Creek Upper was added in 2003 in anticipation of the Fern Gulch Timber Harvest. An ANOVA can make a valuable interpretation of the data by determining if any trend exists between Year and Temperature, but many more years of recorded high temperatures are required to determine if a statistically significant trend is occurring.

7-Day Moving Average

A 7-day moving average is calculated for each data point as the average temperature for the previous 3.5 days and following 3.5 days. Calculating the number of readings in 3.5 days will depend on the temperature recording interval of the temperature logger.

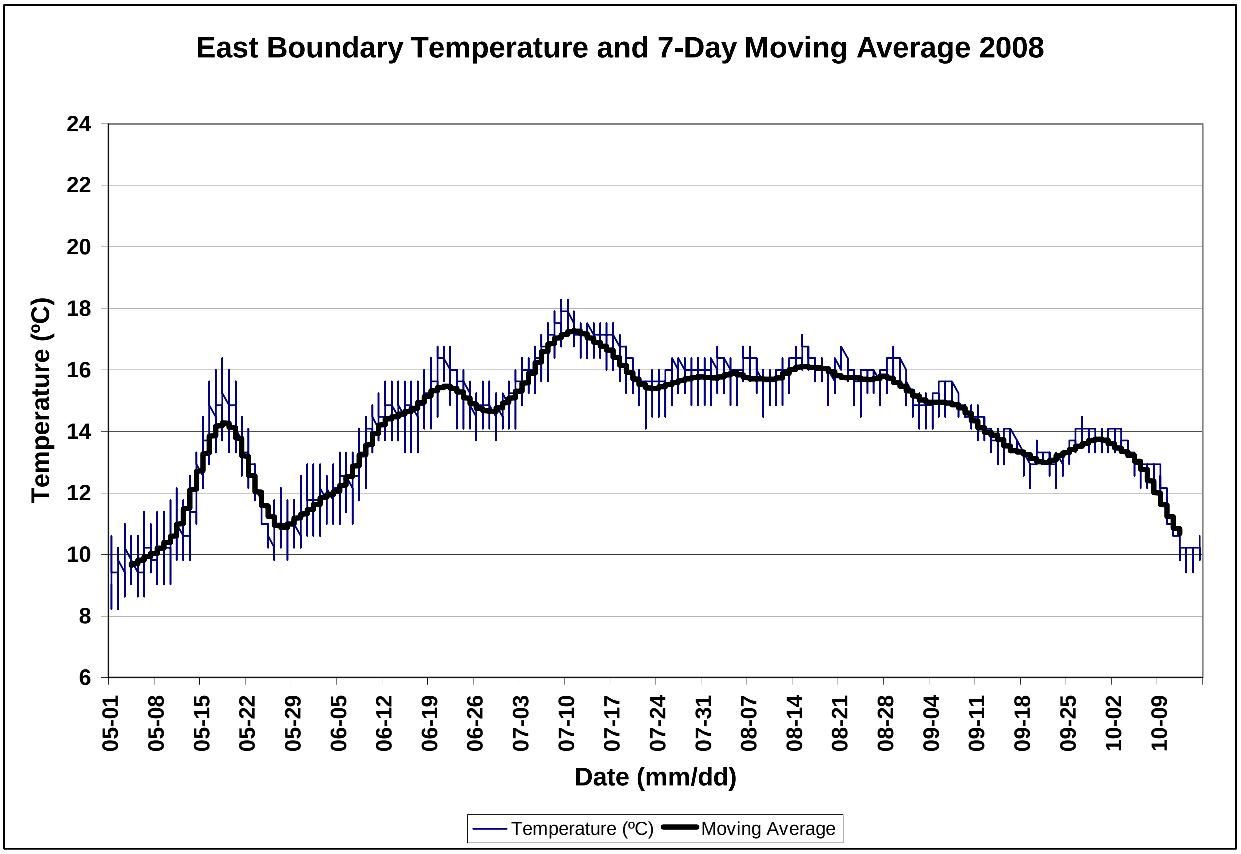
At a one hour interval, there are 168 readings in 7 days. Therefore, 84 readings are in 3.5 days.

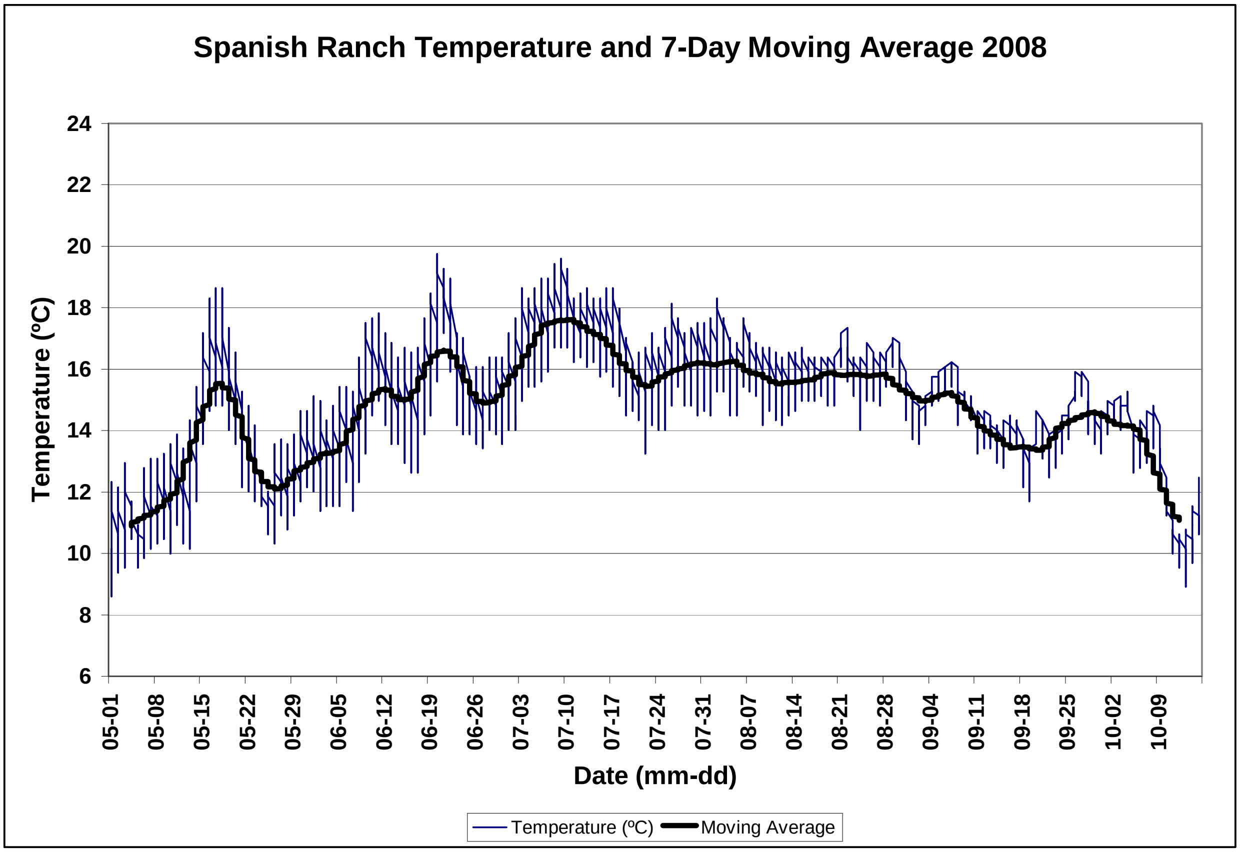
(7 days * 24 hr/1 day * 1 reading/1 hour)

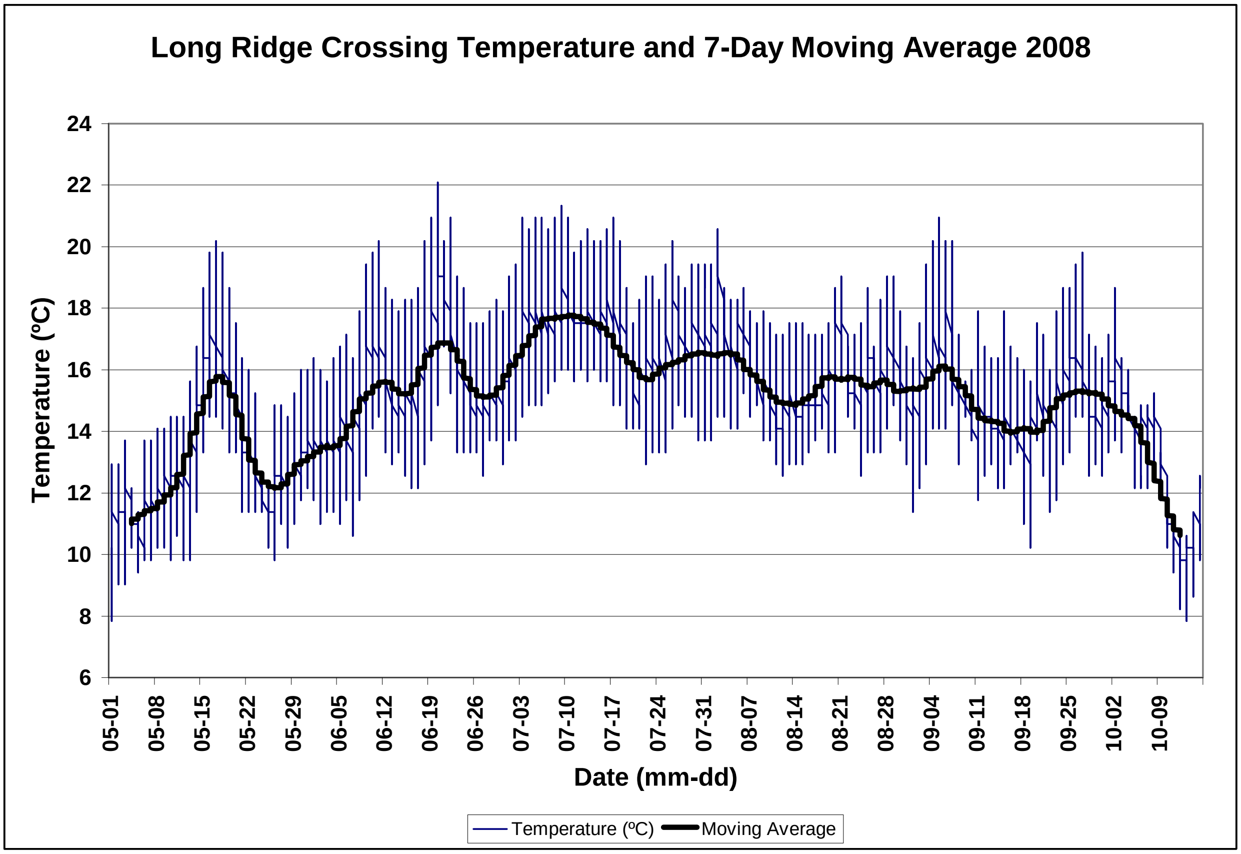
Using a 2.5 hour interval results in 67.2 readings every 7 days.

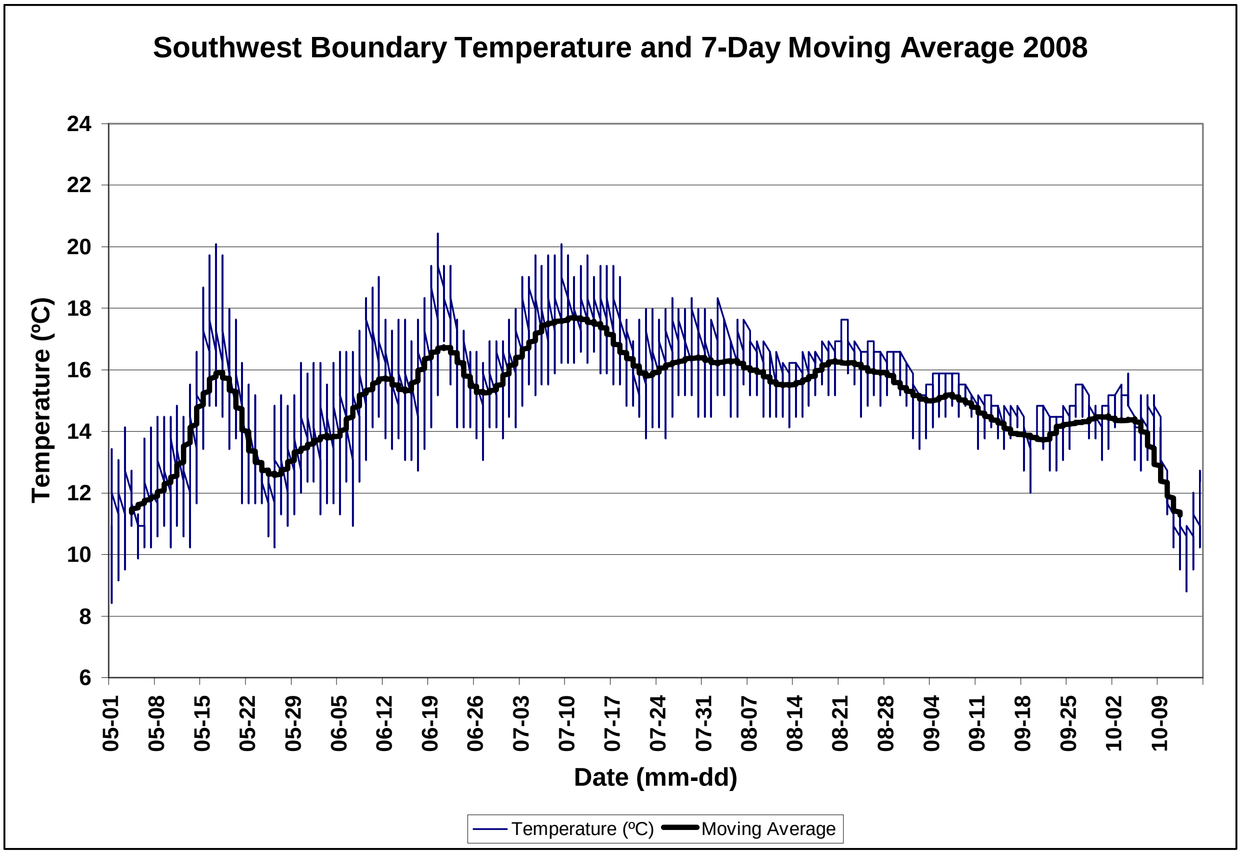
(7 days * 24 hr/day * 1reading/2.5hours)

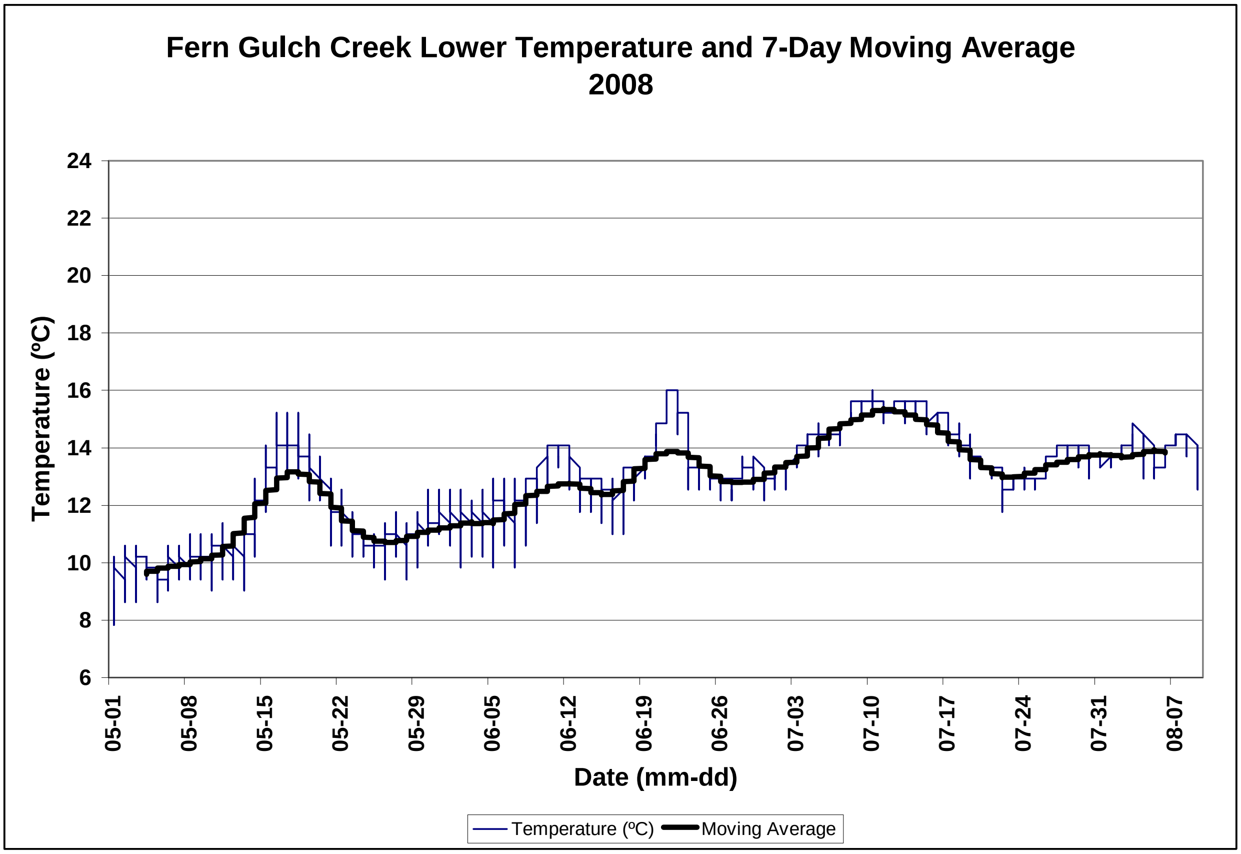
If this interval is used in subsequent monitoring seasons, refer to the Excel spreadsheets for guidance when calculating the moving 7-day average. Compared to straight temperature readings, the 7-day moving average more closely corresponds with fish success than straight temperature readings because it reflects the duration of high temperatures. The definition of a harmful duration is yet to be incorporated into this report. This is an important addition in the 7-day moving average analysis. The connection between the results, both numerically and graphically, and fish success is unclear. Similar to all previous reports, the 2008 report continues without making this connection. Graphs of the results are included in the following pages.


East Boundary Temperature and 7-Day Moving Average 2008
Temperature (ºC)
Date (mm/dd)
24
22
20
18
16
14
12
10
8
6
05-01
05-08
05-15
05-22
05-29
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02
10-09
Temperature (ºC)
Moving Average

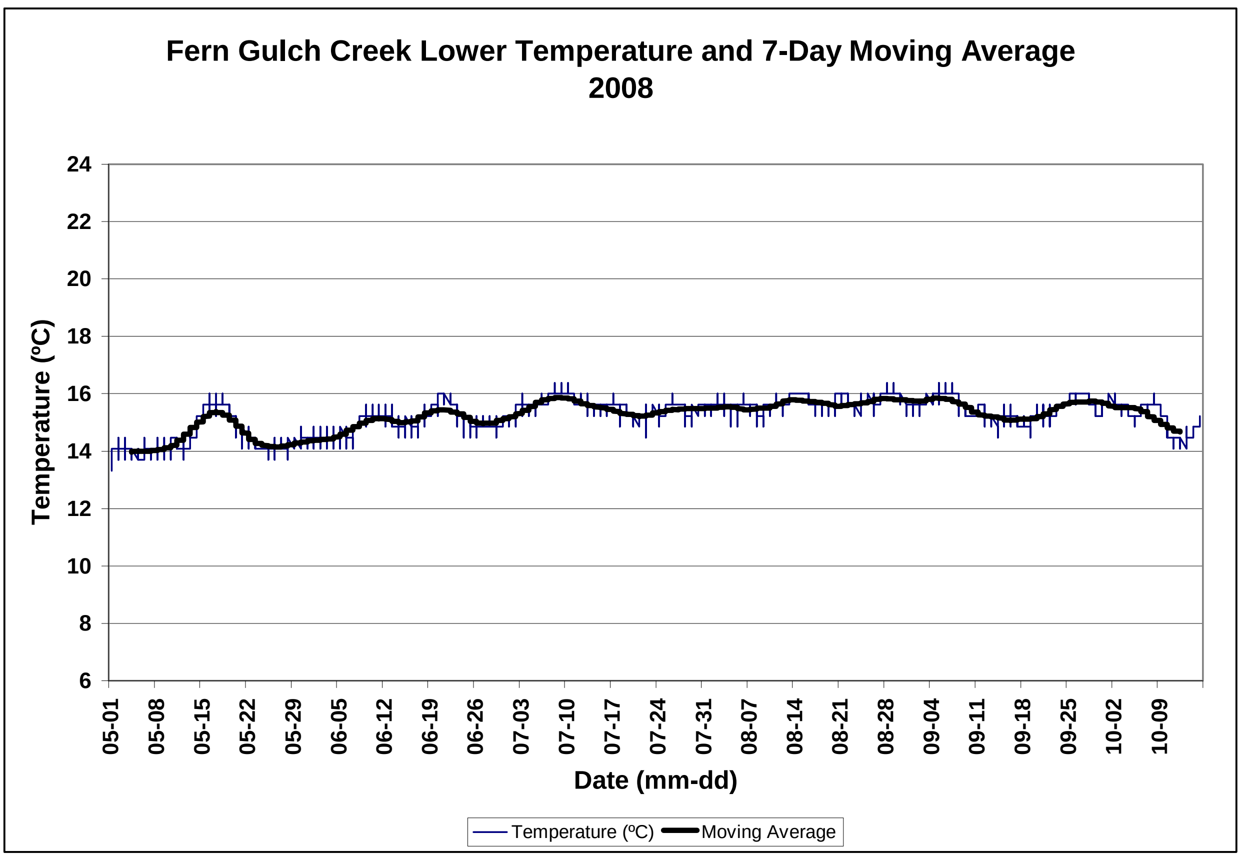

Spanish Ranch Temperature and 7-Day Moving Average 2008
Temperature (ºC)
Date (mm-dd)
24
22
20
18
16
14
12
10
8
6
05-01
05-08
05-15
05-22
05-29
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02
10-09
Temperature (ºC)
Moving Average


Long Ridge Crossing Temperature and 7-Day Moving Average 2008
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
05-01
05-08
05-15
05-22
05-29
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02
10-09
Date (mm-dd)
Temperature (ºC)
Moving Average

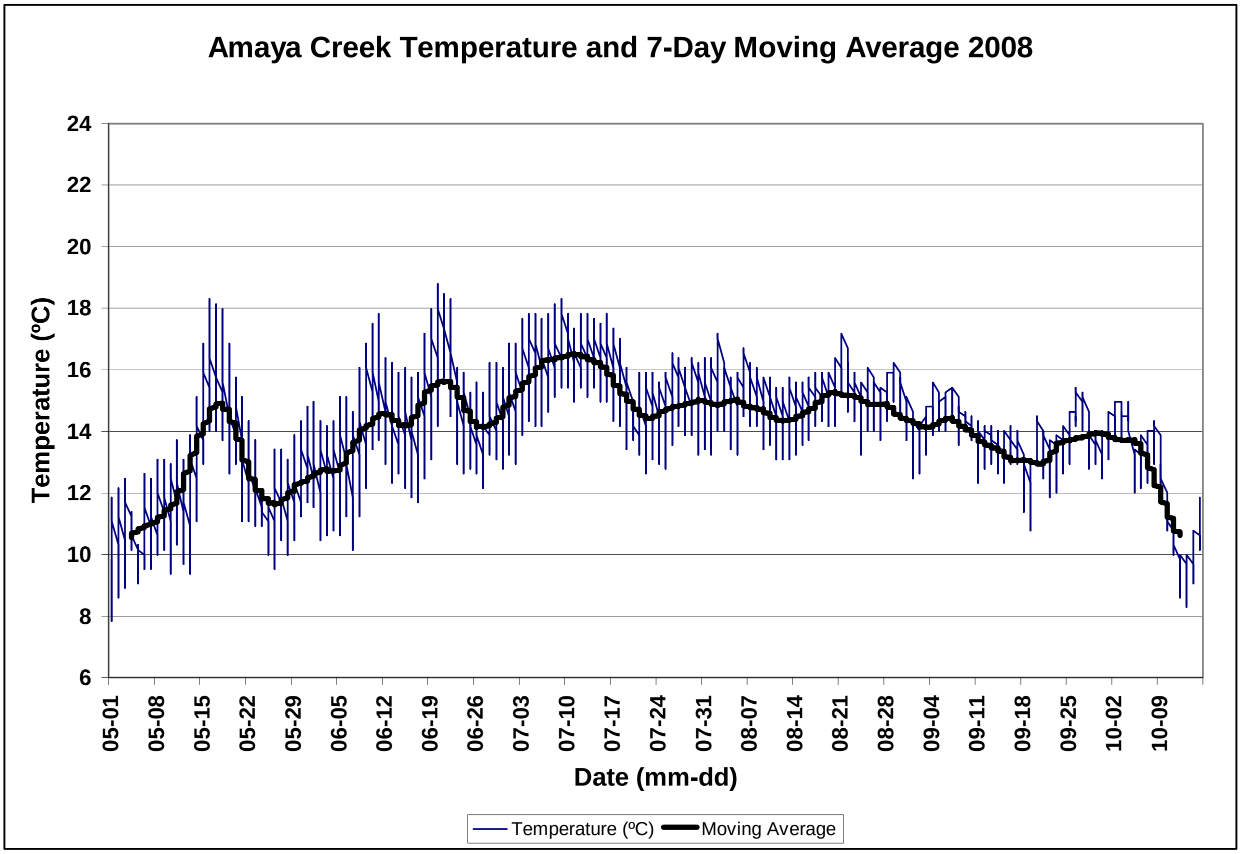

Southwest Boundary Temperature and 7-Day Moving Average 2008
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
05-01
05-08
05-15
05-22
05-29
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02
10-09
Date (mm-dd)
Temperature (ºC)
Moving Average

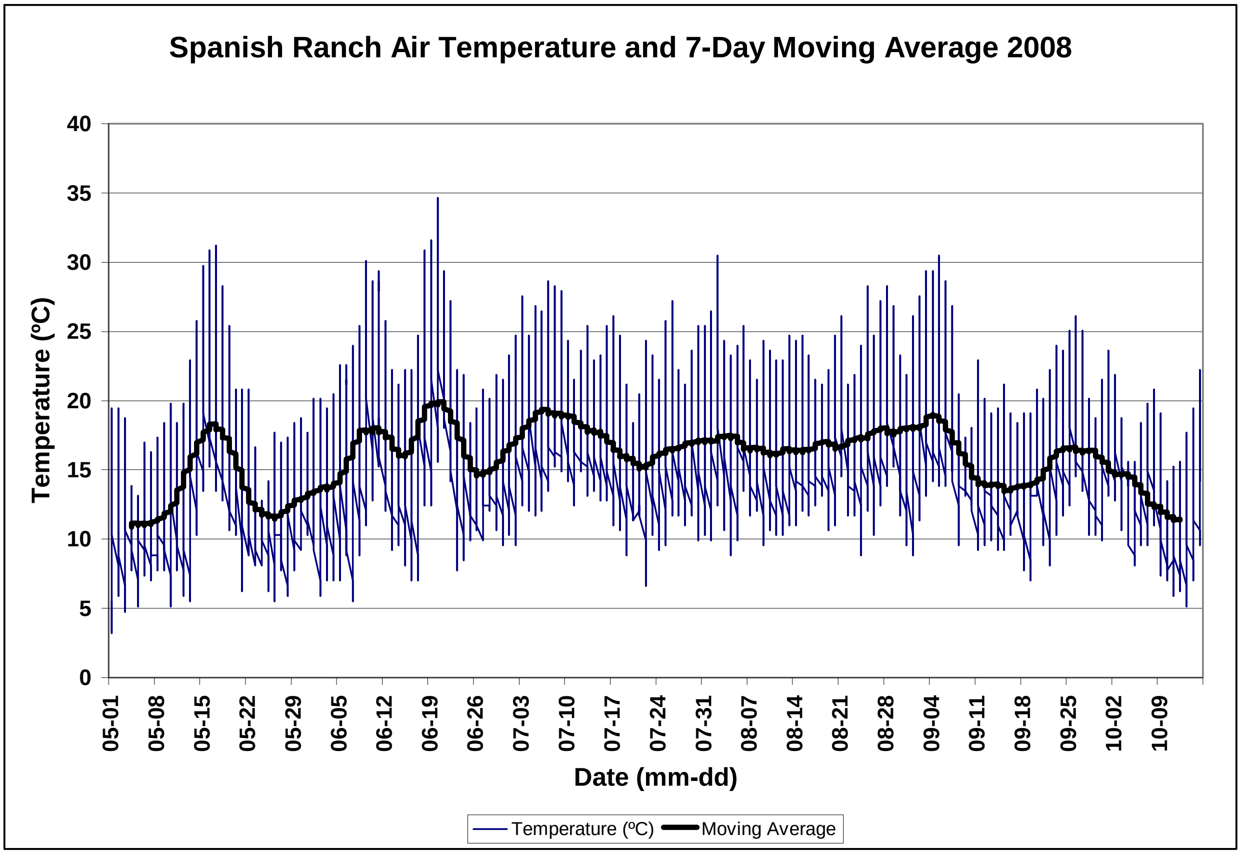


Fern Gulch Creek Lower Temperature and 7-Day Moving Average
2008
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
05-01
05-08
05-15
05-22
05-29
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
Date (mm-dd)
Temperature (ºC)
Moving Average



Fern Gulch Creek Lower Temperature and 7-Day Moving Average
2008
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
05-01
05-08
05-15
05-22
05-29
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02
10-09
Date (mm-dd)
Temperature (ºC)
Moving Average


Amaya Creek Temperature and 7-Day Moving Average 2008
Temperature (ºC)
24
22
20
18
16
14
12
10
8
6
05-01
05-08
05-15
05-22
05-29
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02
10-09
Date (mm-dd)
Temperature (ºC)
Moving Average


Spanish Ranch Air Temperature and 7-Day Moving Average 2008
Temperature (ºC)
40
35
30
25
20
15
10
5
0
05-01
05-08
05-15
05-22
05-29
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02
10-09
Date (mm-dd)
Temperature (ºC)
Moving Average

Suggestions for Next Year

Continue the Instream Temperature Monitoring in 2009 using the same start and finish dates from 2008. Continue the data analysis to determine trends and research the 7-day moving average and relate the results to fish success through a definition of a harmful duration of high temperatures.

Comparisons and trends can best be monitored when methods are repeated closely, particularly matching start and stop dates for monitoring. In 2006, the California Regional Water Quality Control Board for the Central Coast Region released a set of protocols for continuous water temperature monitoring for their timber harvesting water quality waiver program. These protocols indicate continuous temperature monitoring should occur for the five and a half month period starting May 1 and ending October 15. To be consistent with these protocols, it is recommended that water temperatures be monitored during this same time period.

7/15/02

Soquel Demonstration State Forest
Instream Temperature Monitoring 2001
East Branch of Soquel Creek, Fern Gulch Creek and Amaya Creek

METHODS

Hobo and Stow-Away temperature data loggers (Hobos) were installed at various locations in Soquel Demonstration State Forest (SDSF) in order to continuously monitor stream water and air temperatures throughout the dry season. Hobos recorded temperatures from June 12, 2001 to October 19, 2001.

Locations and Installation

Monitoring locations were chosen based on the following criteria:

- Locations that would demonstrate stream temperature variations of Soquel Creek as it flows through the forest, as well as the temperature of Amaya Creek and Fern Gulch Creek;
- Locations of fish refugia (deeper, shaded areas with cover).

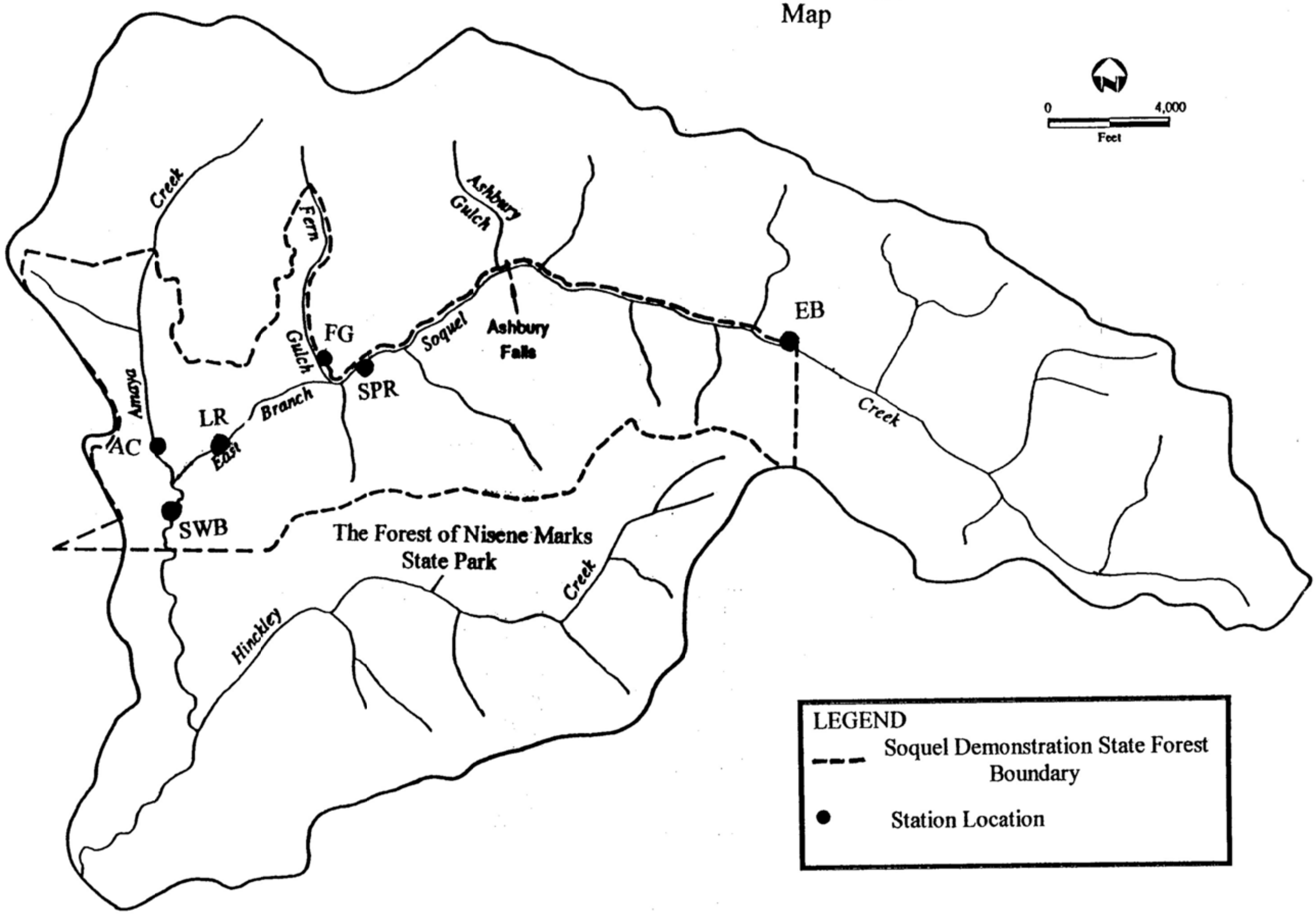
The last criterion was especially important because high water temperatures contribute to lower salmonid survival rates, and fish retreat to these locations to escape warm water temperatures.

Each Hobo was sealed in a clear plastic canister full of clean dry gravel and (except where otherwise indicated) tightly attached to a rock with baling wire, placed in the stream, and covered with cobbles. This method of attachment was used to keep the Hobos submerged throughout the dry season and to hide them to avoid tampering. Included in the canisters were the name of the site and an SDSF business card with "if found please call" written on it. The Hobos were placed in the canisters so that the red light (which indicates it is recording) could be seen from the outside. Red polka dotted flagging was hung at each site to facilitate relocation.

Hobo locations were the same approximate sites as previous years (see map). New Hobos were placed in Fern Gulch Creek and near Long Ridge Crossing in Soquel Creek this year. Hobo locations were as follows:

> <u>East Boundary</u> - on the east branch of Soquel Creek near the boundary between SDSF and Redwood Empire lands. A green sign on Hihn's Mill Road indicates the property boundary. From there, the pink flagging can be followed downhill to the creek. Downstream from the boundary is a slide descending from Highland Way, a car body and a large debris jam (about 75 feet long and 12 feet high). The data logger was placed at the upper end of the debris jam in a small pool (about one foot deep) formed by large woody debris.

Hobo Temperature Data Logger Stations Map



Spanish Ranch - on the east branch of Soquel Creek at Spanish Ranch Crossing. Approximately 50 feet upstream from the bottom of the electro-fishing station, under the roots of a clump of redwood trees on the left bank (looking downstream). This site has almost 100% shade canopy.

Spanish Ranch Air - in redwood clump (mentioned above) approximately 10 feet above the creek level.

Long Ridge Crossing - approximately 200 feet downstream from Long Ridge Crossing where a redwood log has fallen across Soquel Creek creating a small bridge that is used as a trail crossing. Approximately 10 feet downstream from the fallen log on the left side of the creek the Hobo temp was tucked under some downed woody debris, which was marked with red polka dotted flagging.

Southwest Boundary - east branch of Soquel Creek 900 feet below the bridge crossing. Placed in a small pool under the third alder root wad, about 30 feet downstream from where the rock face ends on the left bank. This site is mostly riffle habitat with very little water deeper than six inches.

Fern Gulch Creek - approximately 300 feet upstream from the confluence of Soquel Creek and Fern Gulch Creek. The Hobo temp was placed in a small pool (created by a log across the creek) on the right side beneath the undercut bank. To reach the confluence, head towards Soquel Creek from Hihn's Mill Road approximately 200 feet west of Sawpit Trail.

Amaya Creek - approximately 100 feet upstream from the confluence with the east branch of Soquel Creek. Two large redwood slabs form a shallow pool; one slab forms a spillway, and the other forms the overhanging left bank. The Hobo was placed under the latter log.

Interval

All Hobos were "launched" to record for six months, which BoxCar Pro 4.0 automatically sets for a two-hour or half-hour interval depending on the make of the Hobo temp. Long Ridge Crossing, East Boundary, and Fern Gulch Creek were automatically set on half-hour interval readings.

Data Analysis

All data was downloaded in BoxCar Pro 4.0 and exported to Excel for graphing and analysis. Temperature measurements taken during transport to and from monitoring sites were eliminated. A rolling seven-day average was calculated and graphed over the raw temperature readings. This number was calculated for each data point as the average temperature for the previous 3.5 days and following 3.5 days. With twelve temperature measurements taken in a 24-hour period (or 48 if the Hobo temp was taking half-hour readings), the resulting number is an average of 84 (or 336) data points. The seven-day rolling average historically has more closely corresponded with fish success than straight temperature readings, because it reflects the duration of high temperatures. All temperature data displayed in the following tables is from absolute data, not from the 7-day rolling average.

RESULTS

Results are shown on graphs in the appendix. These graphs were taken from the data tables, which are too large to be printed but can be viewed on a computer screen. All Hobo data are on the SDSF computer hard drive - C:\FILE CABNET\Hobo Reports\Hobo Temps 2001\2001 Hobo Excel Data.

Data for the Southwest boundary were not recorded and are depicted in each table by N/A. The Southwest boundary Hobo temp was launched with a new battery, but must have experienced an internal malfunction during the four months. In previous years the Hobo temps have not always recorded data for the full 4-6 months. When reviewing data from prior years, N/A indicates that the Hobo temp did not record the data properly or no data were collected for the site. In the beginning of October, the Spanish Ranch Air Hobo temp was found on the forest floor instead of its original position (attached 10 feet high in a redwood tree). This may have had an effect on the results of the Spanish Ranch Air temperature readings.

DISCUSSION

The highest temperatures were recorded from late June to the beginning of August. High temperatures (ºF) for each site are shown below in Table 1 for 2000 and 2001.

Table 1. High Temperatures (°F), Date, and Time by Site for 2000 and 2001

Site	High Temp. 2000	Date(s)	Time	High Temp. 2001	Date(s)	Time
East Boundary	N/A	N/A	N/A	64.91	7/03,7/04	15:59
Spanish Ranch	66.9	7/31,8/5	17:28	70.82	7/03	17:04
Long Ridge Crossing	N/A	N/A	N/A	70.39	6/19, 6/21,6/29,	16:00
Southwest Boundary	N/A	N/A	N/A	N/A	N/A	N/A
Fern Gulch Creek	N/A	N/A	N/A	61.48	7/03, 7/04	13:00
Amaya Creek	62.36	6/21,6/26,6/27, 7/23,7/31,8/4, 8/5,812	17:31	68.73	7/03	15.05
Spanish Ranch Air	81.59	7/23	15:29	85.52	7/02	13:00

Maximum water and air temperatures were higher in 2001 than 2000. In both 2000 and 2001, temperatures were higher in Soquel Creek at the sites lower in the watershed. Temperature fluctuations throughout the monitoring period were most extreme lower in the watershed as well. Table 2 shows the total fluctuation in temperature, from the highest and lowest temperatures recorded for each location, during the entire 2001 measurement period.

Table 3 lists by station the most extreme fluxuations in temperature within one day during the 2001 monitoring period. The largest water temperature fluctuation within one day was 13.05ºF at the Long Ridge Crossing location. Spanish Ranch Air fluxuated 35.02ºF in one day. Temperature fluctuations were greatest during heat waves from the beginning of July through August, and began to decrease at the beginning of September.

Table 2. Temperature Extremes (ºF) by Station for 2001

Site	High Temp	Low Temp	Fluctuation
East Boundary	64.91	51.08	13.83
Spanish Ranch	70.22	50.84	19.38
Long Ridge Crossing	70.39	51.79	18.6
Southwest Boundary	N/A	N/A	N/A
Fern Gulch Creek	61.48	50.38	11.1
Amaya Creek	68.73	50	18.73
Spanish Ranch Air	85.52	43.28	42.24

Table 3. Most Extreme Temperature (ºF) Fluctuation within One Day by Station in 2001

Site	Date	High	Low	Difference
East Boundary	6/16/01	60.11	55.28	4.83
Spanish Ranch	7/01/01	69.32	60.07	9.25
Long Ridge Crossing	6/14/01	69.02	55.97	13.05
Southwest Boundary	N/A	N/A	N/A	N/A
Fern Gulch Creek	9/06/01	57.35	52.49	4.86
Amaya Creek	6/15/01	66.7	58.09	8.61
Spanish Ranch Air	6/13/01	80.3	45.28	35.02

Water temperatures above 70ºF make it difficult for coho and steelhead to extract oxygen from the water. Optimal rearing temperatures for juveniles are 45-58ºF for steelhead and 53-58ºF for coho (Resner and Bjornn, 1979). For the sake of comparison, it is interesting to note the number of days recorded at 70°F or higher and 58°F or higher (see Tables 4 and 5, respectively). Since the monitoring period varies from year to year, these tables' comparisons have been adjusted to reflect the same time period in 2000 and 2001. Table 5 shows that compared to 2000, there were several more days in 2001 above 58ºF at the Amaya and Spanish Ranch sites. Table 6 presents a comparison of the peak high temperatures from 1997 to the present. The most notable temperature increase is the air temperature for the Spanish Ranch location.

Table 4. Comparison of Number of Days above 70ºF by Station for the Same Time Period in 2000 and 2001

Site	No. of Days at or above 70º in 2000	No. of Days at or above 70º in 2001
East Boundary	N/A	0
Spanish Ranch	0	2
Long Ridge Crossing	N/A	3
Southwest Boundary	N/A	N/A
Fern Gulch Creek	N/A	0
Amaya Creek	0	0
Spanish Ranch Air	46	80

Table 5. Comparison of Number of Days above 58ºF by Station for the Same Time Period in 2000 and 2001

Site	No. of Days at or above 58º in 2000	No. of Days at or above 58º in 2001
East Boundary	N/A	89
Spanish Ranch	73	117
Long Ridge Crossing	N/A	111
Southwest Boundary	N/A	N/A
Fern Gulch Creek	N/A	66
Amaya Creek	67	99
Spanish Ranch Air	90	98

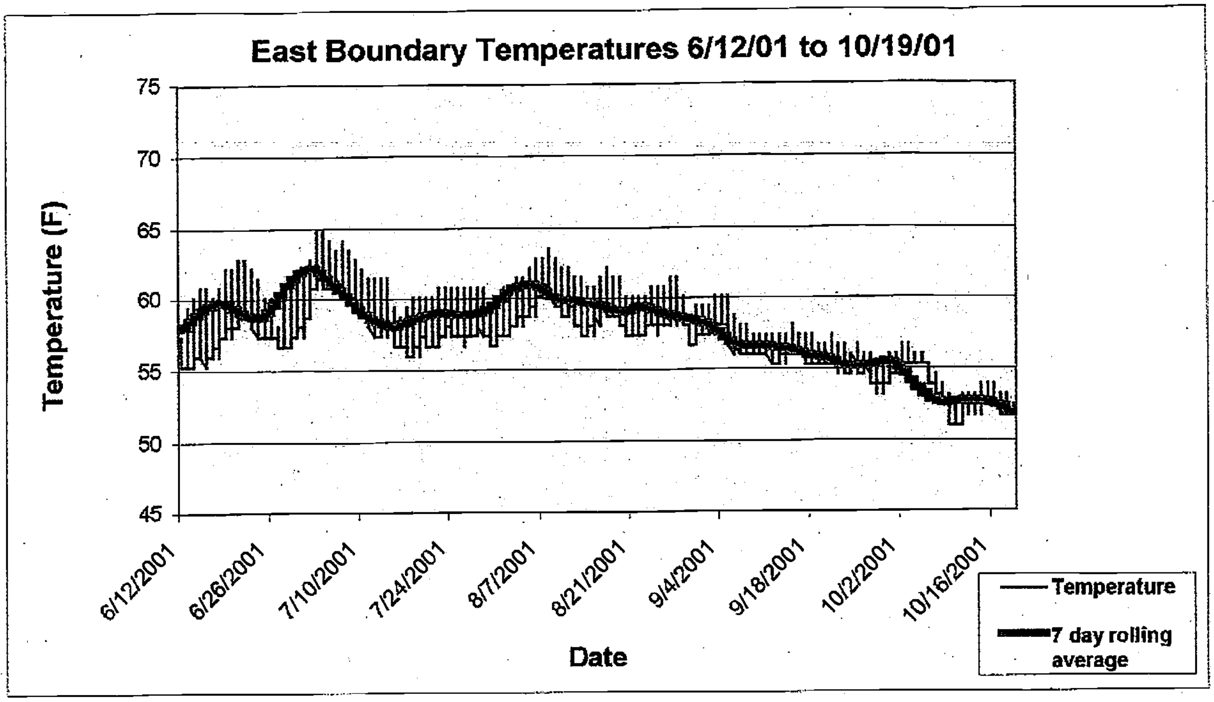
Table 6. Comparisons of Maximum High Temperatures by Site for 1997, 1998, 1999, 2000, and 2001

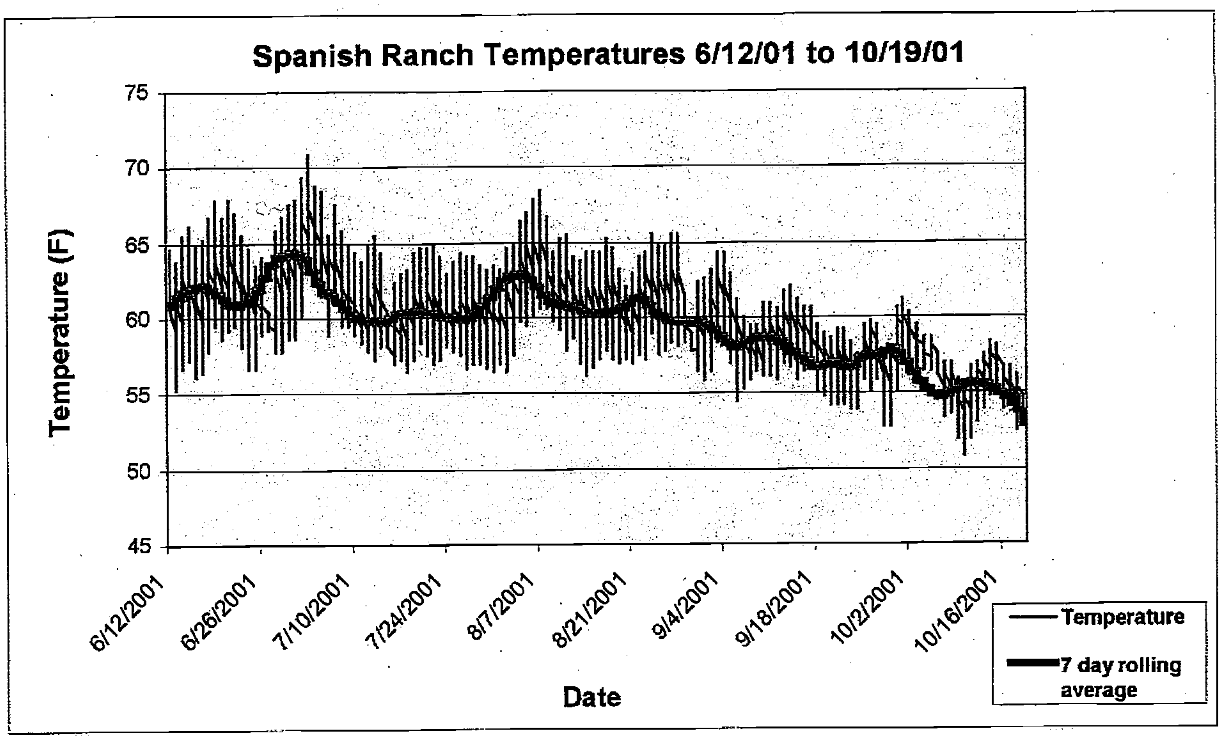
Site	High Temp. (°F) 1997	High Temp. (°F) 1998	High Temp. (°F) 1999	High Temp. (°F) 2000	High Temp. (°F) 2001
East Boundary	67.45	67.45	63.68	N/A	64.91
Spanish Ranch	67.86	70.22	66.41	66.90	70.82
Long Ridge Crossing	N/A	N/A	N/A	N/A	70.39
Southwest Boundary	73.80	76.35	71.28	N/A	N/A
Fern Gulch Creek	N/A	N/A	N/A	N/A	61.48
Amaya Creek	66.41	68.44	66.99	62.36	68.73
Spanish Ranch Air	75.06	79.01	83.55	81.59	85.52

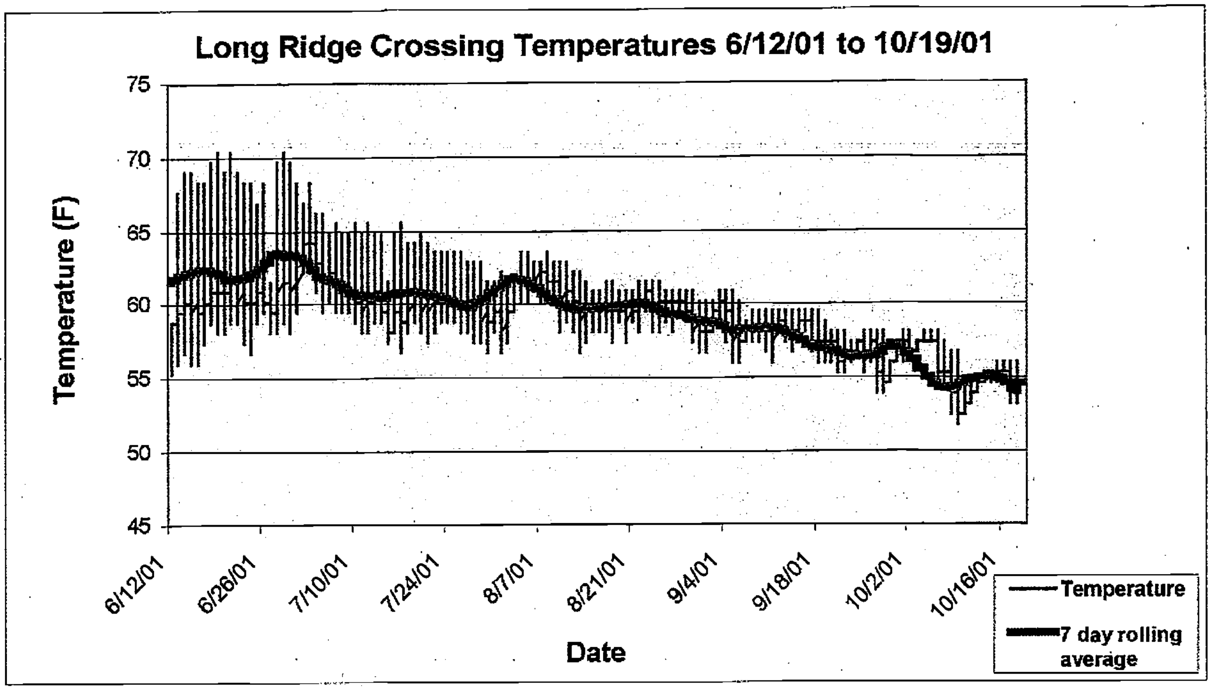
Suggestions for Next Year

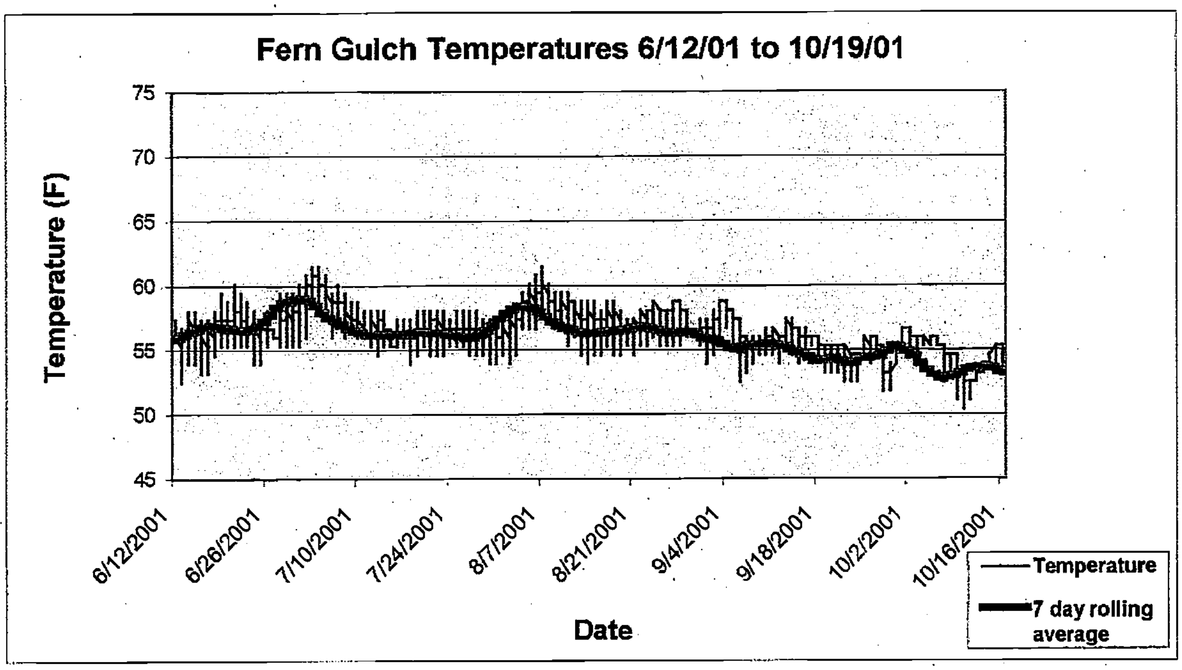
Comparisons and trends can best be monitored when methods are repeated closely, particularly matching start and stop dates for monitoring. Brad Valentine, Fisheries Biologist for the California Department of Fish and Game, suggested putting the data loggers in June 1 and taking them out in mid to late October, since water temperatures can be highest as early as June 1. Heavy winter rains will probably rearrange the monitoring sites and make them hard to find again. Another site can be substituted as long as it has similar habitat type and cover. It would be helpful to have canopy cover data for each site. To accurately locate sites, measure the distances referenced in the site description.

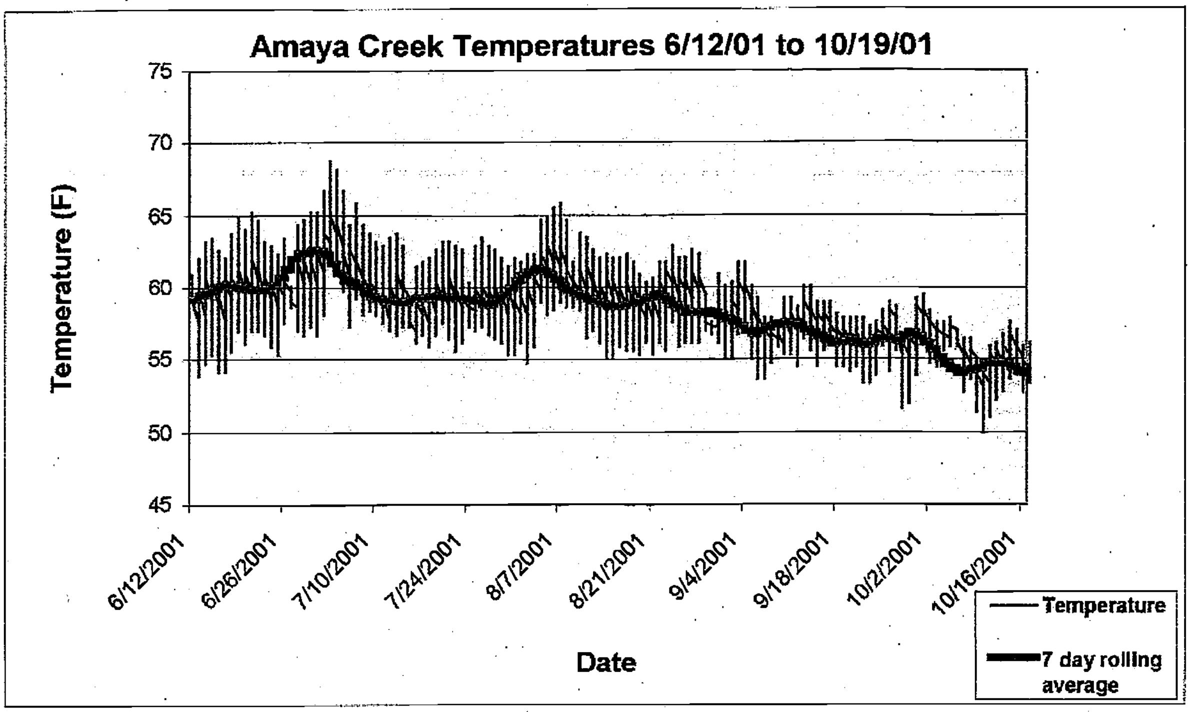
SDSF Hobo Temp Appendix 2001

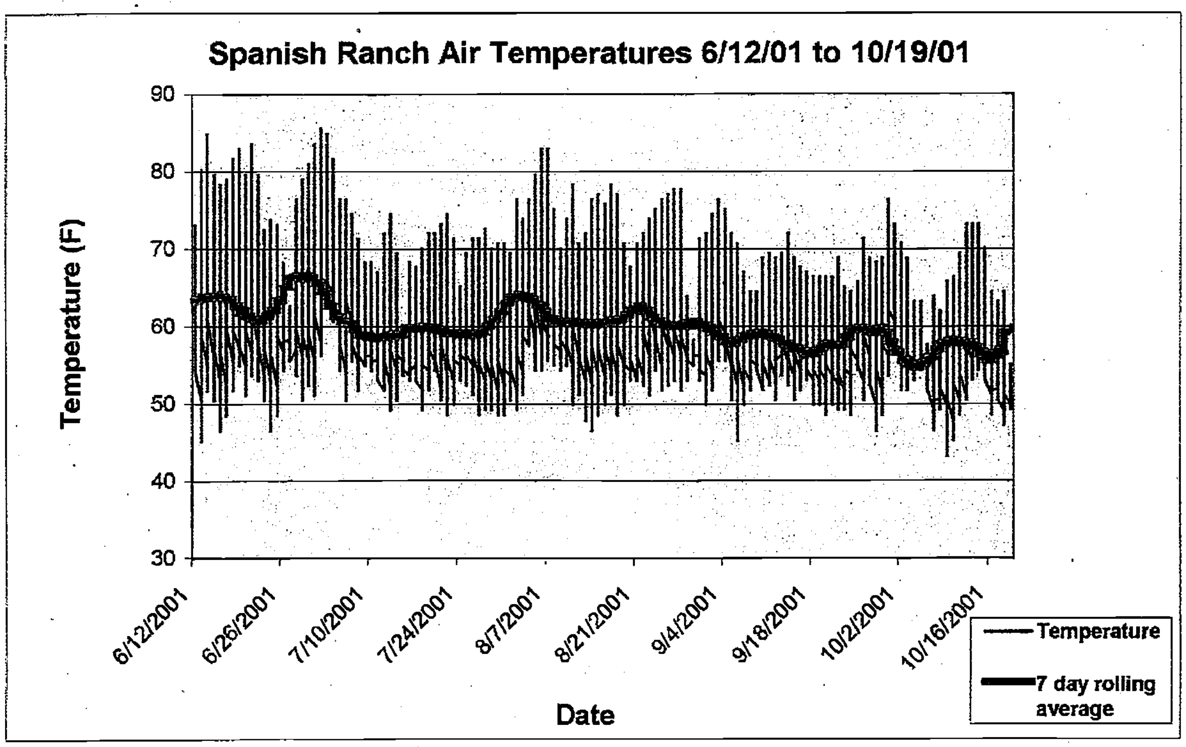





Long Ridge Crossing Temperatures 6/12/01 to 10/19/01
Temperature (F)
75
70
65
60
55
50
45
6/12/01
6/26/01
7/10/01
7/24/01
8/7/01
8/21/01
9/4/01
9/18/01
10/2/01
10/16/01
Date
Temperature
7 day rolling average


Fern Gulch Temperatures 6/12/01 to 10/19/01
Temperature (F)
75
70
65
60
55
50
45
6/12/2001
6/26/2001
7/10/2001
7/24/2001
8/7/2001
8/21/2001
9/4/2001
9/18/2001
10/2/2001
10/16/2001
Date
Temperature
7 day rolling average


Amaya Creek Temperatures 6/12/01 to 10/19/01
Temperature (F)
75
70
65
60
55
50
45
6/12/2001
6/26/2001
7/10/2001
7/24/2001
8/7/2001
8/21/2001
9/4/2001
9/18/2001
10/2/2001
10/16/2001
Date
Temperature
7 day rolling average


Spanish Ranch Air Temperatures 6/12/01 to 10/19/01
Temperature (F)
90
80
70
60
50
40
30
6/12/2001
6/26/2001
7/10/2001
7/24/2001
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Effects of Timber Harvest on Aquatic Vertebrates and Habitat in the North Fork Caspar Creek[1]

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Abstract: *I examined the relationships between timber harvest, creek habitat, and vertebrate populations in the North and South forks of Caspar Creek. Habitat inventories suggested pool availability increased after the onset of timber harvest activities. Increased large woody debris in the channel was associated with an increase in the frequency of blowdown in the riparian buffer zone. This increase in large woody debris volume increased the availability of pools.*

No dramatic changes in the abundance of young-of-the-year steelhead, yearling steelhead, coho, or Pacific giant salamanders were directly related to logging. High interannual variation in the abundance of aquatic vertebrates made it difficult to contrast changes in abundance between pre-logging and post-logging periods. Changes in channel morphology associated with increased volume of large woody debris in the channel suggest that yearling steelhead, coho, and Pacific giant salamanders may benefit from logging in the short-term because of increased living space. However, over a longer time scale these conditions will probably not persist (Lisle and Napolitano, these proceedings).

The impacts of timber harvest on aquatic ecosystems can range from detrimental to beneficial depending on the geology and geomorphology of the watershed, the method of timber harvest, and the presence of other activities in the watershed. Disturbance of hillslope and riparian soils can result in increased sediment delivery to streams. This increased sediment input may result in decreased depth and availability of pools (McIntosh and others 1993), decreased survival of incubating salmonid eggs (Reiser and White 1988), and/or increased turbidity (Burns 1972). Alterations in the routing of surface and subsurface runoff may result in increased peak storm flows (Wright and others 1990). Increased peak flows may scour redds or bury them under sediments (Lisle 1989). Removal of timber from riparian areas decreases the amount of large woody debris available for recruitment into the channel. Within the Pacific Northwest, large woody debris plays a critical role in pool formation, sediment storage, and cover availability (Beechie and Sibley 1997, Bilby and Ward 1991). In contrast, thinning of the riparian canopy allows greater amounts of solar radiation to reach the stream. Increased incident solar radiation has been linked to increased aquatic productivity (Bisson and Sedell 1984, Burns 1972, Holtby 1988, Murphy and Hall 1981, Newbold and others 1980, Thedinga 1989).

During the late 1960's, the abundance of salmonids declined in South Fork Caspar Creek after logging (Burns 1972). This decline was associated with disruption of the streambed by heavy equipment, increased sediment input associated with slope and bank failures, road construction just upslope of the channel, and excessive amounts of slash left in the channel. However, after only 2 years salmonid abundance had returned to near pre-logging levels. Burns (1972) concluded that logging activities were compatible with anadromous fish production as long as adequate attention was given to stream and watershed protection. Unlike the logging which occurred in the South Fork, within the North Fork logging roads were constructed along ridge tops, about 81 percent of the logs were removed by cable yarding, heavy equipment was not operated in the channel, and a riparian buffer strip was maintained to protect the stream. Given this new set of conditions, the goal of this study was to document the effects of logging in the North Fork on the abundance of aquatic vertebrates and their habitat.

Study Site

The North and South forks of Caspar Creek lie approximately 11 km southeast of Fort Bragg, California, on the Jackson State Demonstration Forest. Before this study, the South Fork had been logged twice and the North Fork had been logged once. During the late 1800's the watersheds were clearcut and burned. After logging, the areas were primarily reforested by redwood (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*). Beginning in 1971, the South Fork was divided into three selective-cut logging sales. A network of skid trails was constructed to transport fallen trees by tractor. By the end of the 3-year operation, 15 percent of the watershed was in roads, landings, and skid trails, and 67 percent of the timber volume in the South Fork was removed (Keppeler and Ziemer 1990). Logging activities in the North Fork began in May 1989. The watershed was divided into eight separate clearcut logging units. High-lead (cable) logging was used to remove timber from approximately 44 percent of the watershed area. Thirty- to 60-m-wide riparian buffer zones were maintained along the entire length of the mainstem channel. Logging was completed in January 1992.

The study reaches in both creeks began upstream of impoundments created by V-notch weirs. Drainage areas in the study reachs were 473 ha and 424 ha in the North Fork and South Fork, respectively. Slopes in both watersheds are relatively gentle with about 35 percent of the two watersheds having slopes of <30 percent. Both watersheds contain well-drained soils derived from sandstone. The climate is typical of coastal northern California. Winters are mild and wet. Average annual precipitation is about 1,190 mm. Approximately 90 percent of the annual precipitation falls from October through April. Average discharges in the watersheds are similar, varying from less than 0.01 m^3s^{-1} during the summer to 0.71 m^3s^{-1} during the winter. Daily summer water temperatures in both creeks vary between 10 °C and 20 °C and

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average about 13 °C. Winter water temperatures in the creeks vary between 1 °C and 12 °C, averaging approximately 7 °C. Riparian vegetation in the South Fork is composed primarily of red alder (*Alnus rubra*) and tan oak (*Lithocarpus densiflorus*). Riparian vegetation in the North Fork is composed primarily of Douglas-fir, redwood, and grand fir (*Abies grandis*).

Steelhead (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*) spawn in both creeks. Stickleback *(Gasterosteus aculeatus*) occur only in the South Fork. Amphibians inhabiting the North Fork include Pacific giant salamander *(Dicamptdon tenebrosus*), tailed frog (*Ascaphus truei*), and rough-skinned newt (*Taricha granulosa*). Pacific giant salamander and rough-skinned newt are present in the South Fork; however, tailed frogs are absent.

Methods

I categorized habitat units in the North and South forks during the summers of 1986, 1990, 1993, and 1995 according to the classification system described by McCain and others (1990). Habitat inventories were conducted in those years when I perceived changes in habitat availability and distribution associated with high discharge events. The habitat inventories in both creeks began at the upstream ends of the weir ponds and extended to the upstream barrier to fish passage in the North Fork (approximately 2,700 m) and until the stream became intermittent in the South Fork (approximately 3,000 m). Once each habitat unit was identified, I recorded a minimum of three equally spaced width measurements and three equally spaced length measurements for each habitat unit. I measured habitat depth at three equally spaced locations along each of the width transects and maximum habitat depth.

On the basis of the results of the inventory, I randomly selected individual habitat units for sampling of aquatic vertebrates. The units were selected to represent the array of habitat types available in each creek. Selected habitat units were flagged to facilitate relocation during later surveys. New habitat units were randomly selected after successive inventories.

Except for the 1986 survey that took place in August, I surveyed aquatic vertebrates in June and July. Block nets were placed across the upstream and downstream boundaries of the habitat unit. Fish were sampled to depletion using multiple passes with a backpack electrofisher. Salamanders were not sampled to depletion, but few were captured in the final electrofishing pass. Captured vertebrates were anesthetized using tricaine methanesulfonate (trade name MS-222)[3] and identified to species. I recorded fork length (mm) and total length (mm) for each of the fishes and body length from the tip of the snout to the anal vent for salamanders. I recorded maximum body length for all other amphibians. In addition, between 1990 and 1995 I recorded weights for fishes and amphibians using a portable electronic balance (Ohaus CT-200, readability 0.01 g). All fish and amphibians were then returned to the habitat unit from which they were collected. I recorded the dimensions of the unit sampled (i.e., length, width, depth, etc.) using the same protocol as during habitat typing.

I used automated temperature-monitoring equipment to monitor air and water temperatures in the creeks between April 1989 to August 1994. The data recorders were positioned at sites just upstream of the weir ponds. The data recorders were programmed to record temperature at 1-hour intervals.

Data on habitat and vertebrates were summarized by sampling year and grouped into one of two survey periods: pre-logging (1986-1989) or logging (1990-1995) depending on the year in which the survey occurred. Road building and timber falling began in the North Fork in May 1989. Because my sampling took place only one month after the onset of logging, I assumed that there would be no detectable impact during that year. Timber harvest was completed in January 1992. I collected habitat availability data once during the pre-logging period and three times during the logging period. I divided habitat units into either fast (riffle, run, cascade, etc.) or slow (pool) types and calculated the availability of each type on the basis of area. I further determined the proportion of pool habitats in each creek associated with large woody debris (logs, rootwads). Vertebrates were divided into one of four groups: young-of-the-year (YOY), steelhead (≤ 70 mm fl), yearling steelhead (> 70 mm fl); coho; or larval Pacific giant salamanders. I calculated the difference in mean density within each year, between the two creeks and compared the differences before and after logging (Stewart-Oaten and others 1986). I conducted separate analyses for each of the vertebrate groups using Mann-Whitney-Wilcoxon tests to compare pre- and post-logging differences. I used the same method to analyze mean body length. Since the vertebrate biomass and temperature data were collected only during the logging period, the data were not subjected to statistical analysis.

Results

Habitat

The availability of fast and slow water habitat was similar between creeks during the 1986 habitat inventory (*table 1*). Slow water habitat comprised approximately 25 percent of the available

Table 1*—Proportional habitat availability in the North Fork and South Fork Caspar Creek. Fast habitat types include riffles, cascades, runs, and glides. Slow habitat types include all pools. Habitat inventories were conducted during May or June of each assessment year. Pools with large woody debris (LWD) include the proportion of total pool availability that incorporated large woody debris as a critical element in their formation on the basis of frequency of occurrence.*

	North Fork Caspar			South Fork Caspar		
Year	Slow	Fast	Pools with LWD	Slow	Fast	Pools with LWD
1986	0.27	0.73	0.70	0.29	0.71	0.46
1990	0.41	0.59	0.51	0.52	0.48	0.43
1993	0.40	0.60	0.55	0.45	0.55	0.41
1995	0.44	0.56	0.53	0.35	0.65	0.42

3 The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

habitat. However, after the 1990 habitat inventory the percentage of slow water habitat had increased to 41 percent in the North Fork and 52 percent in the South Fork. The 1993 and 1995 habitat inventories suggested that the habitat availability remained relatively stable in the North Fork whereas habitat availability in the South Fork tended to return to the 1986 level.

Large woody debris (LWD), including rootwads from standing trees, were critical in the formation of 70 percent of the pools in the North Fork during the 1986 habitat inventory (*table 1*). In contrast, only 55 percent of the pools in the South Fork incorporated LWD. Later inventories revealed that the percentage in the North Fork was reduced to between 45 percent and 57 percent. The proportion of pools associated with large woody debris in the South Fork ranged between 37 and 46 percent, between 1990 and 1995.

Mean monthly water temperatures in the North Fork were the lowest in December and the highest in July or August (*fig. 1*). Throughout the monitoring period mean monthly water temperatures ranged between 4.6 °C and 14.6 °C. Water temperatures averaged 0.4 °C higher in the North Fork compared to the South Fork. Air temperatures averaged 2.1 °C higher in the North Fork compared to the South Fork (*fig. 2*). The data suggested that air and water temperatures in the North Fork remained greater than temperatures in the South Fork throughout most of the monitoring period. The greatest differences for air and water temperatures between the North and South forks roughly coincided with the annual minimum and maximum monthly temperatures.

Vertebrate Data

Young-of-the-Year Steelhead

Young-of-the-year (YOY) steelhead densities during the pre-logging period were slightly higher in the North Fork (0.93 YOY steelhead m^{-2}, n = 4, 0.12 S.E.) compared to the South Fork (0.78 YOY m^{-2}, n = 4, 0.09 S.E.) (*fig. 3a*). During the logging period, mean YOY steelhead densities in the North Fork (0.85 YOY m^{-2}, n = 6, 0.12 S.E.) were again greater than densities in the South Fork (0.59 YOY m^{-2}, n = 6, 0.04 S.E.), but lower than pre-logging densities. The differences in YOY steelhead density between creeks were not significantly different between survey periods (p = 0.38).

During the logging period YOY steelhead biomass in the North Fork averaged 0.97 g m^{-2} (n = 6, 0.15 S.E.) whereas YOY steelhead biomass in the South Fork averaged 0.80 g m^{-2} (n = 6, 0.07 S.E.) (*fig. 3b*). High interannual variation characterized the mean biomass in both creeks.

Young-of-the-year steelhead fork length averaged 40.6 mm (n = 4, 0.25 S.E.) for the pre-logging period and 45.2 mm (n = 6, 0.18 S.E.) for the post-logging period in the North Fork (*fig. 3c*). Mean fork length for steelhead from the South Fork averaged 42.5 mm (n = 4, 0.25 S.E.) for the pre-logging period and 45.8 mm (n = 6, 0.19 S.E.) for the post-logging period. The differences in mean fork length between creeks was not significantly different between survey periods (p = 0.46).

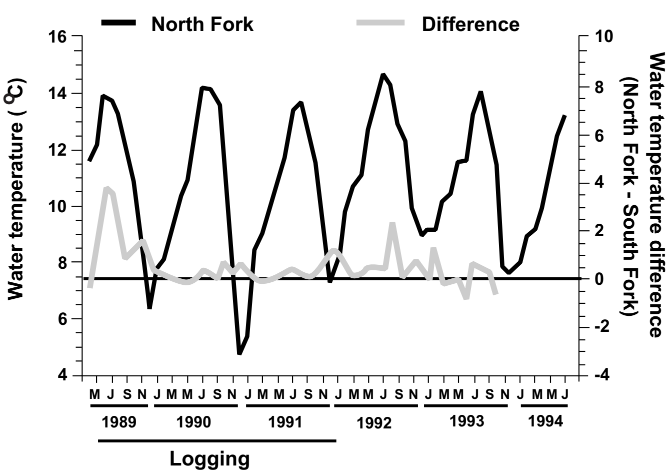

Figure 1—Mean monthly water temperature for the North Fork Caspar Creek and the difference in mean monthly water temperature between the North Fork and South Fork. The data were collected by automated temperature data loggers. The data loggers were programmed to record temperature at 1-hour intervals. The thermisters were accurate to within 0.2 °C.

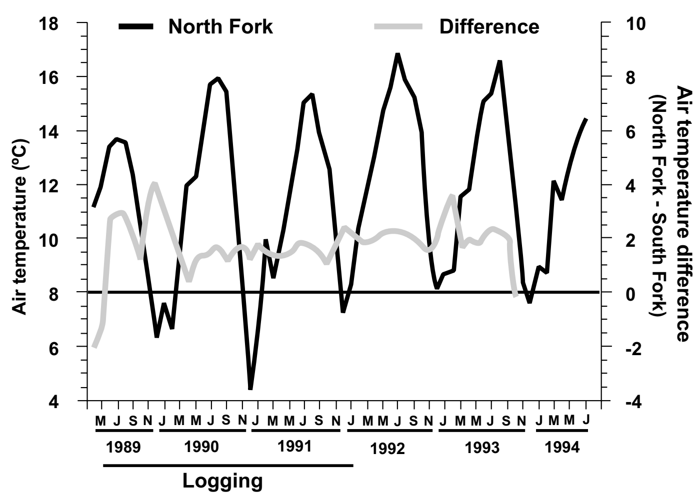

Figure 2—Mean monthly air temperature for the North Fork Caspar Creek and the difference in mean monthly air temperature between the North Fork and South Fork. The data were collected by automated temperature data loggers. The data loggers were programmed to record temperature at 1-hour intervals. The thermisters were accurate to within 0.2 °C

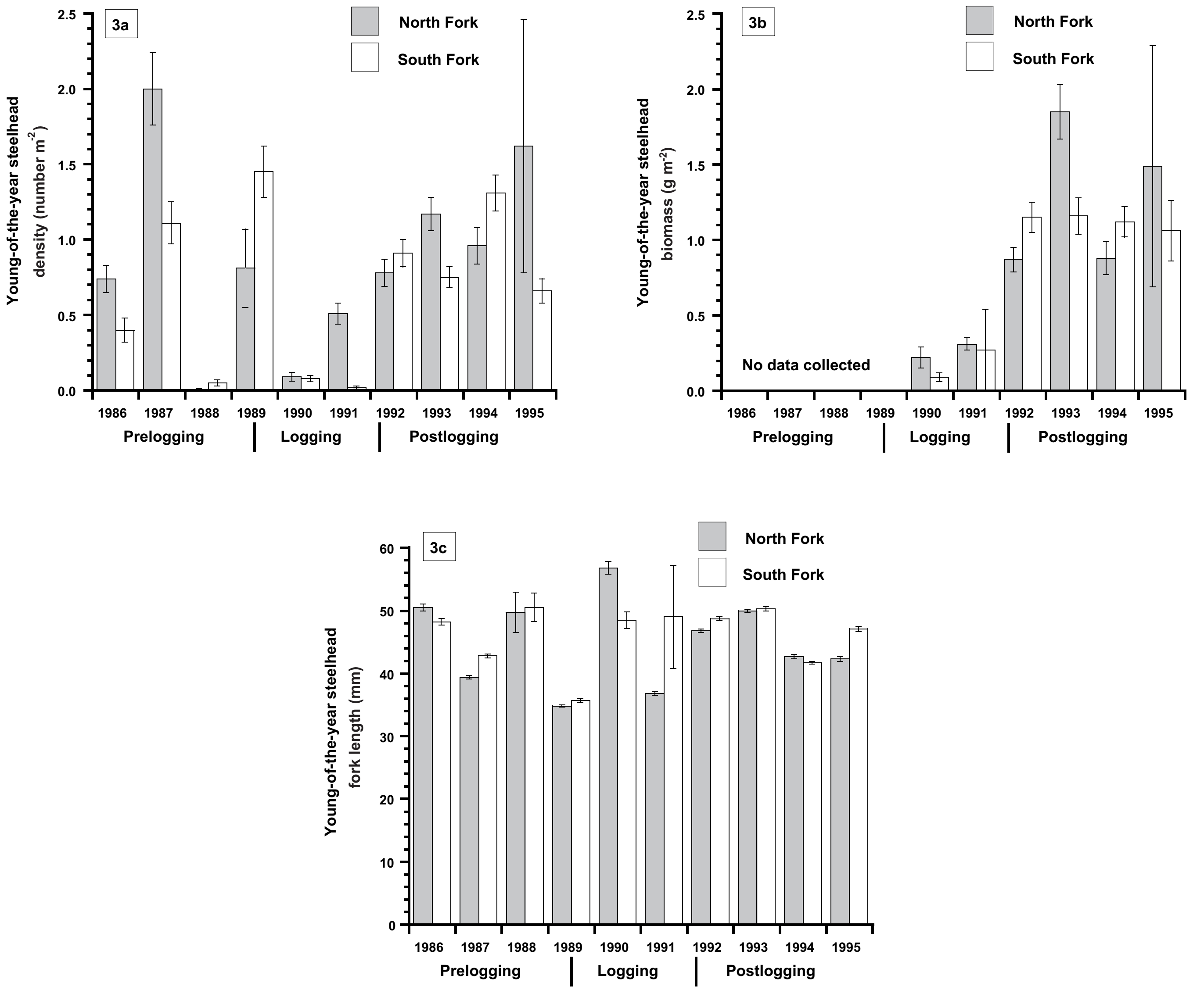

Figure 3—Mean and standard error for annual abundance (a), biomass (b), and fork length (c) for young-of-the-year steelhead in the North Fork and South Fork Caspar Creek, based on summer electrofishing surveys. Timber harvest activities began in May 1989 in the North Fork and were completed by January 1992.

Yearling Steelhead

Yearling steelhead densities during the pre-logging period in the North Fork and South Fork averaged 0.08 fish m^{-2} (0.01 S.E.) and 0.05 fish m^{-2} (0.01 S.E.), respectively (*fig. 4a*). During the logging period, steelhead densities averaged 0.12 fish m^{-2} (0.02 S.E.) in the North Fork, slightly greater than for the pre-logging period. Steelhead densities in the South Fork were also slightly elevated at 0.07 fish m^{-2} (0.01 S.E.). The difference in density between the creeks did not change significantly between pre-logging and logging periods ($p = 0.54$). Yearling steelhead biomass during the logging period averaged 1.31 g m^{-2} ($n = 6$, 0.17 S.E.) in the North Fork and 0.97 g m^{-2} ($n = 6$, 0.13 S.E.) in the South Fork (*fig. 4b*).

Mean fork length for yearling steelhead collected from the North Fork averaged 95.5 mm (2.36 S.E.) for the pre-logging period and 97.5 mm (1.37 S.E.) for the post-logging period (*fig. 4c*). Mean fork lengths for yearling steelhead collected from the South Fork were 104.0 mm (2.22 S.E.) and 97.0 mm (1.58 S.E.) for the pre-logging and post-logging periods, respectively. The differences in mean fork length between creeks were not significantly different between pre-logging and logging periods ($p = 0.46$).

Coho

Young-of-the-year coho densities were variable throughout the monitoring period (*fig. 5a*). Coho densities during the pre-logging

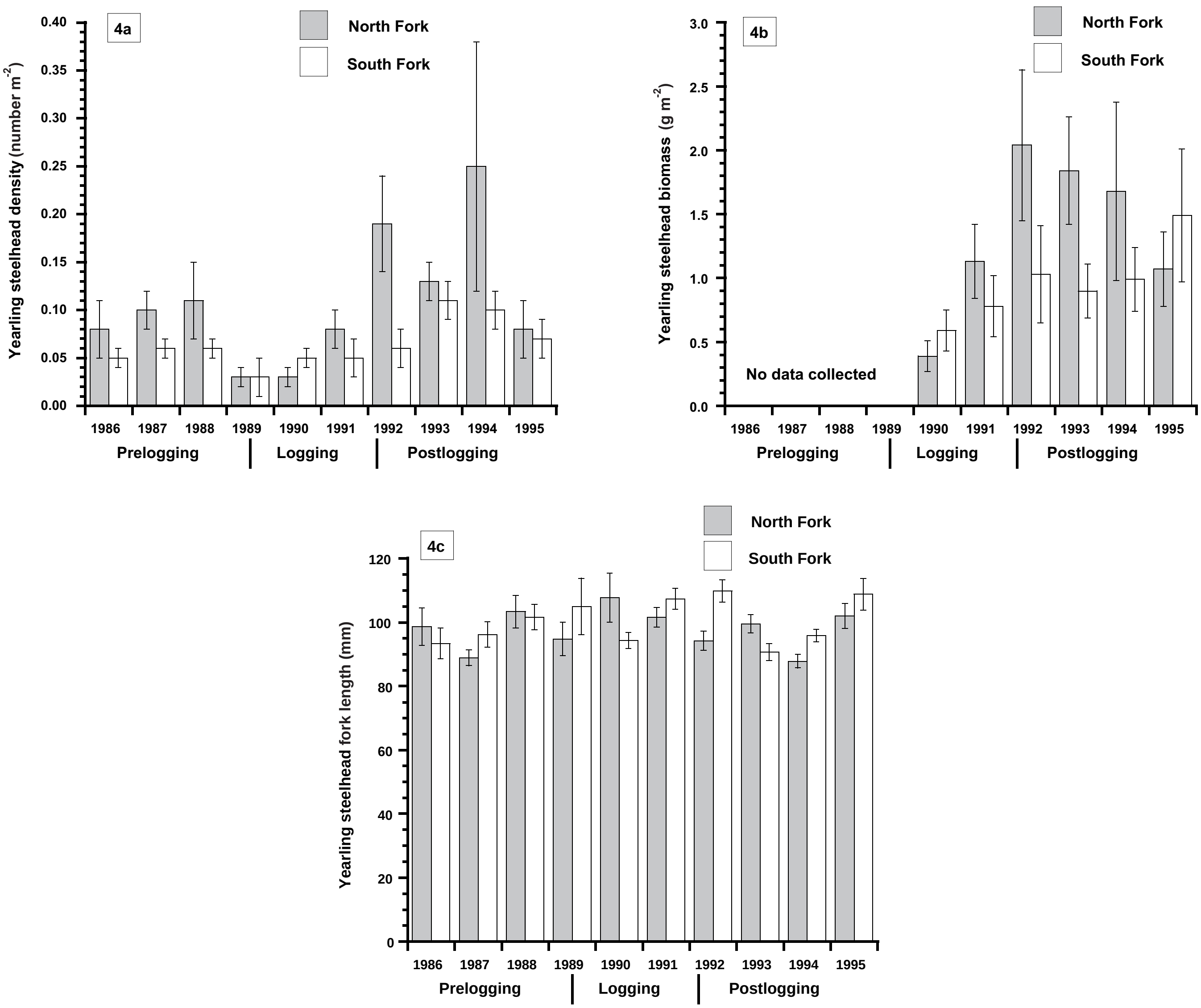

Figure 4—Mean and standard error for (a) annual abundance, (b) biomass, and (c) fork length for yearling steelhead in the North Fork and South Fork Caspar Creek, based on summer electrofishing surveys. Timber harvest activities began in May 1989 in the North Fork and were completed by January 1992.

period averaged 0.57 fish m^{-2} (0.09 S.E.) in the North Fork and 0.65 fish m^{-2}(0.08 S.E.) in the South Fork. Coho densities during the logging period declined significantly to 0.03 fish m^{-2} (0.01 S.E.) in the North Fork and 0.07 fish m^{-2} (0.01 S.E.) in the South Fork. The differences in coho density between creeks were not significantly different across survey periods ($p = 0.18$).

Coho biomass during the logging period declined to 0.07 g m^{-2} (0.02 S.E.) and 0.21 g m^{-2} (0.03 S.E.) in the North Fork and South Fork, respectively (*fig. 5b*). Throughout the logging period coho biomass remained extremely low in both creeks.

Coho from the North Fork averaged 55.7 mm fl (0.29 S.E.) and 59.8 mm fl (1.14 S.E.) for the pre-logging and logging periods, respectively (*fig. 5c*). Coho from the South Fork averaged 54.8 mm fl (0.31 S.E.) during the pre-logging period and 61.9 mm fl (0.57 S.E.) during the logging period. The mean length of coho did not change significantly relative to the South Fork between pre-logging and logging periods ($p=0.34$).

Larval Pacific Giant Salamanders

Mean larval Pacific giant salamander (LPGS) densities throughout the monitoring period were higher in the North Fork compared to the South Fork (*fig. 6a*). Pre-logging densities in the North Fork averaged 1.33 LPGS m^{-2} (0.18 S.E.) while densities in the South Fork averaged 0.93 LPGS m^{-2} (0.09 S.E.) for the same period. Logging period

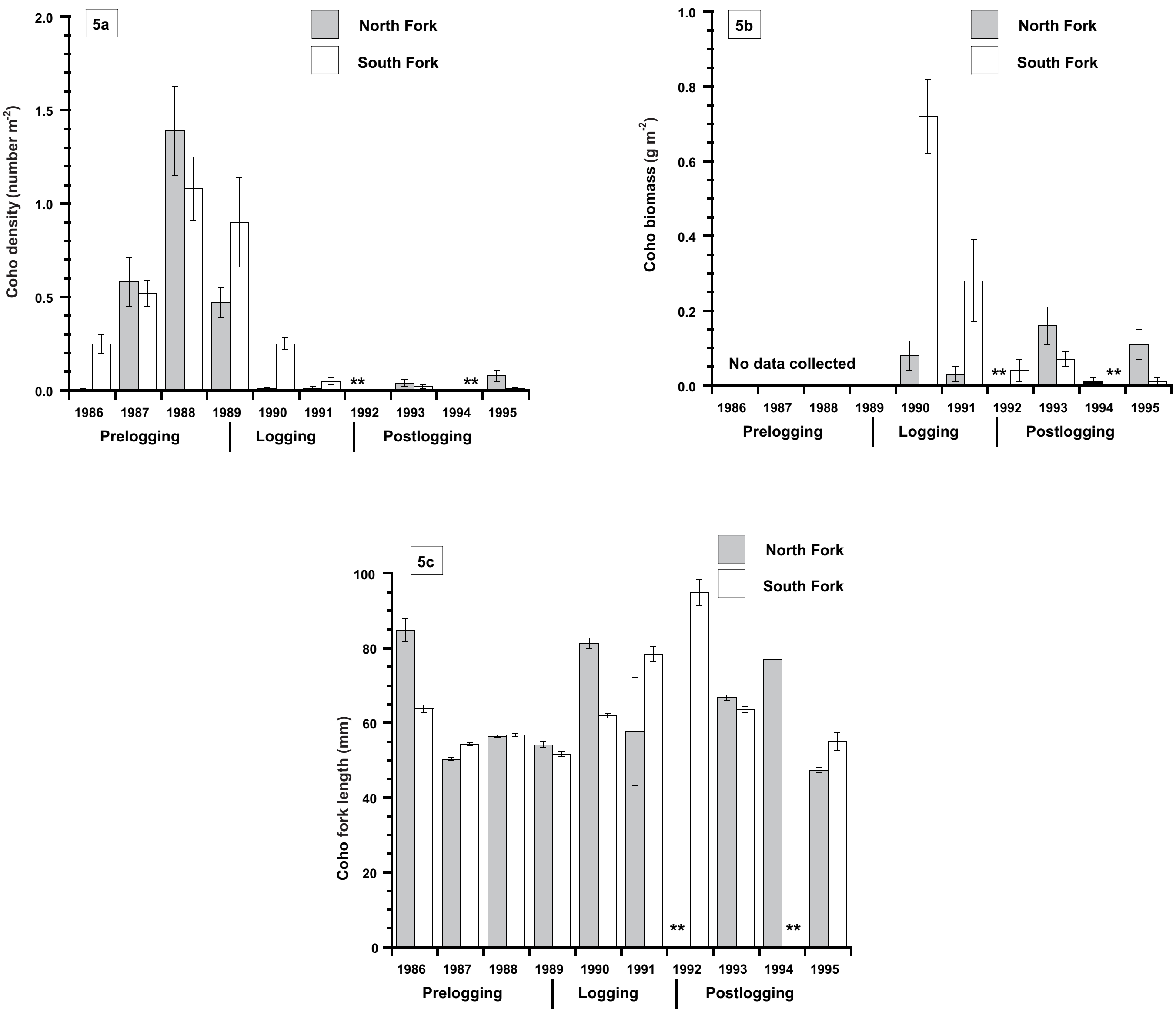

Figure 5—Mean and standard error for (a) annual abundance, (b) biomass, and (c) fork length for young-of-the-year coho in the North Fork and South Fork Caspar Creek, based on summer electrofishing surveys. Timber harvest activities began in May 1989 in the North Fork and were completed by January 1992. ** = no coho collected.

densities were slightly higher than pre-logging densities averaging 1.46 LPGS m^{-2} (0.30 S.E.) in the North Fork and 1.28 LPGS m^{-2} (0.07 S.E.) in the South Fork. No significant change in the mean density of North Fork LPGS was identified after logging (p=0.13).

Larval Pacific giant salamander biomass generally was 1.5 to 2.0 times greater than combined salmonid biomass for both creeks (*fig. 6b*). During 1995, LPGS biomass in the North Fork was estimated to be 10.4 g m^{-2}. Larval Pacific giant salamander biomass during the logging period averaged 5.39 g m^{-2} (n = 6, 1.37 S.E.) in the North Fork and 4.39 g m^{-2} (n = 6, 0.32 S.E.) in the South Fork.

Snout-to-vent length for LPGS collected during the pre-logging period averaged 36.6 mm (n = 3, 0.28 S.E.) in the North Fork and 39.6 mm (n = 3, 0.33 S.E.) in the South Fork (*fig. 6c*). Larval Pacific giant salamander collected during the logging period from the North Fork averaged 38.8 mm long (n = 6, 0.21 S.E.), while LPGS collected from the South Fork averaged 37.8 mm long (n = 6, 0.23 S.E.). The difference in snout-to-vent length between creeks was significantly larger during the logging period compared to the pre-logging period (p = 0.01).

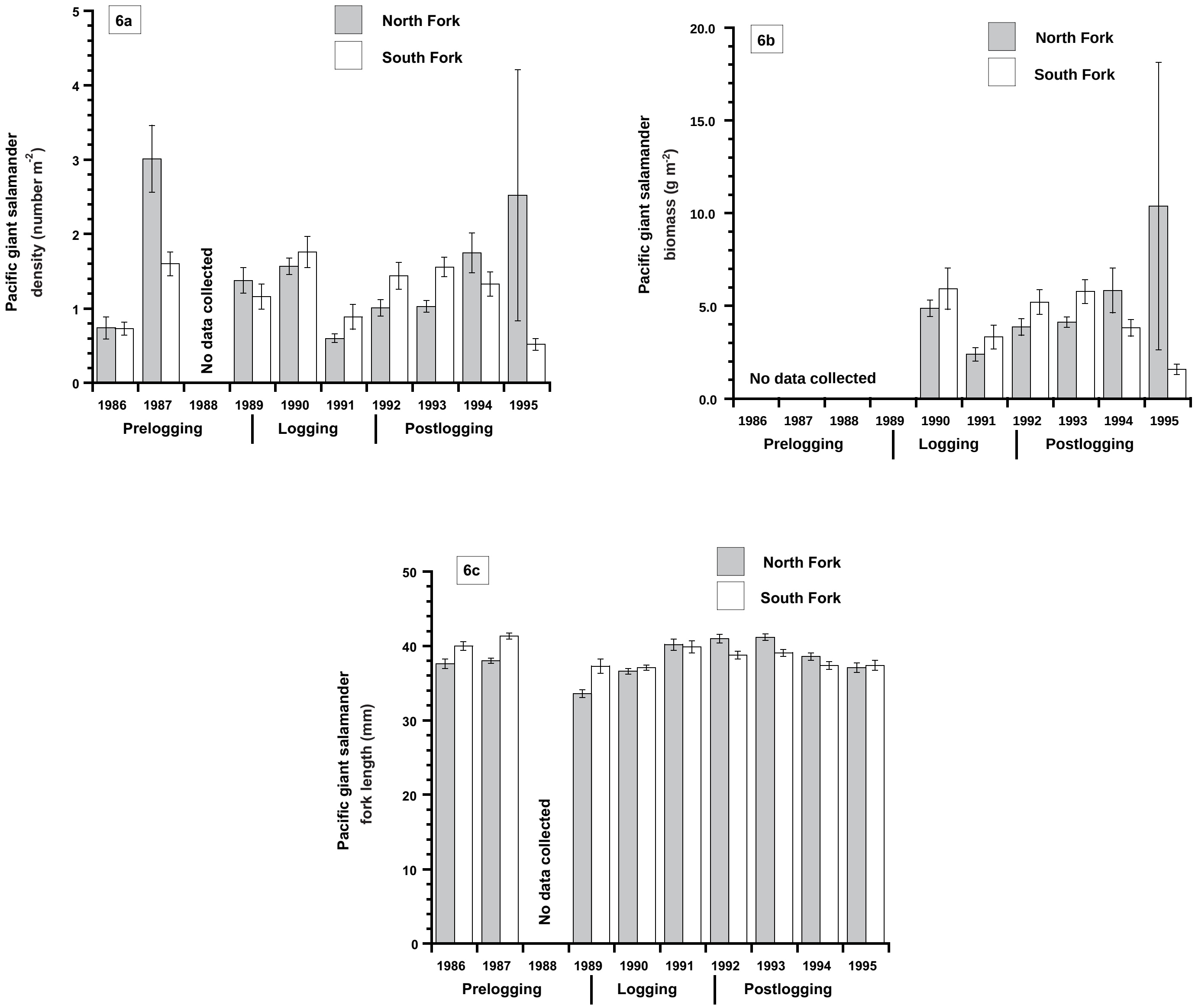

Figure 6—Mean and standard error for (a) annual abundance, (b) biomass, and (c) snout-to-vent length for larval Pacific giant salamanders in the North Fork and South Fork Caspar Creek, based on summer electrofishing surveys. Timber harvest activities began in May 1989 in the North Fork and were completed by January 1992.

Discussion

The effects of timber harvest in the late 1800's in the North Fork were still evident in 1987. Logging techniques used during that period left the channel relatively simple in form, lacking large woody debris (LWD) (Lisle and Napolitano, these proceedings). The increased rate of tree fall has significantly augmented the supply of LWD in the North Fork (Reid and Hilton, these proceedings). This increase in available LWD has been linked to the increase in pool availability observed in this study and by Lisle and Napolitano (these proceedings). However, my data suggested that the availability of pools associated with LWD had not increased after logging. Differences in timing of assessments and differences in methodologies may in part explain this contradiction. Severe winter storms during 1990 and 1994 resulted in elevated rates of tree fall in the North Fork. However, during December 1995, an abnormally severe storm resulted in higher-than-usual tree fall (Reid and Hilton, these proceedings). The final habitat survey included in this report was completed in June 1995. Further, my habitat surveys included only those LWD that were in contact with the wetted perimeter of the channel during the summer low flow period. Reid and Hilton assessed all downed trees both in the riparian buffer strip and to a distance of more than 200 m into uncut units. Exclusion of the LWD from my survey does not suggest that these pieces are not important components of the creek. Although much of the LWD contributed little to summer habitat complexity, this LWD may provide increased habitat complexity during winter high-flow periods, resulting in higher survival of juvenile salmonids and increased pool availability during the summer.

Stream temperatures in the North Fork in general were higher than stream temperature in the South Fork throughout the year. Increases in stream temperature have been widely observed after timber harvest (Brown and Krygier 1970, Holtby 1988, Meehan 1970). However, in the absence of data for pre-logging stream temperatures, it is impossible to determine whether logging resulted in higher temperatures in the North Fork. The increase in water temperature was small and the range of temperatures observed within the North Fork is within the tolerable range for salmonids.

The results of this study identified no dramatic short-term changes in the abundance of aquatic vertebrates directly related to logging. However, these results are far from definitive. The extremely low statistical power of the statistical tests casts some doubt over their conclusions. Burns (1972) concluded that high interannual variation in salmonid numbers made it difficult to separate timber harvest impacts from natural variation. However, changes in habitat suggest possibility of changes in abundance. Decreased availability of shallow water habitat and increases in the density of yearling steelhead may negatively affect YOY steelhead in the North Fork as size-dependent interactions favor yearling steelhead in pool habitats (Harvey and Nakamoto 1997). Larval Pacific giant salamander density is strongly influenced by substrate composition and cover availability (Parker 1991). Changes in sediment storage associated with increased LWD input could benefit LPGS. Reduced amounts of sediment transported past debris jams promote scour downstream. Transport of fine sediments from these downstream areas will increase the availability of interstitial space between cobbles. Increased cover area provided by LWD and the scour of fine materials create habitat conditions favoring LPGS.

The abundance of coho in both creeks was variable until 1990 after which coho virtually disappeared. The extremely low population levels in both creeks combined with the low statistical power of the comparison results in a low probability of detecting logging-associated changes in the coho population. However, current increases in LWD and pool availability in the North Fork should benefit coho (Bisson and others 1988, Murphy and others 1986, Reeves and others 1989) although, competition between juvenile coho and steelhead in Caspar Creek may slow the recovery of coho (Harvey and Nakamoto 1996). Depressed population levels in both creeks suggest that conditions in both watersheds will not support coho and/or that factors outside the watersheds are influencing coho reproduction. Some of these factors may include poor winter and/or summer rearing habitat, or early emigration from the study reach. During those years when creek discharge was not sufficient for operation of the fish ladder over the V-notch weirs, the creeks were largely inaccessible to adults.

The increase in pool availability is closely related to the increased amount of LWD in the channel. The price of the significant increases in LWD input associated with severe winter storms may be that fewer logs are left to contribute in future years. The volume of LWD may be reduced as current LWD decays and is transported downstream. The current rate of LWD input from the riparian zone may decrease as reserves are depleted and trees become more wind firm. Other trees in the riparian zone may reach sizes large enough to form pools (> 20 cm diameter) within 25 years (Beechie and Sibley 1997). However, it is unlikely that these small trees will contribute enough LWD to offset losses. Increased summer flow is expected to disappear within 5 years after logging (Keppeler and Ziemer 1990). It would appear that over a longer time scale, habitat conditions and the aquatic vertebrates have not benefited from logging operations in the North Fork.

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State of California The Resources Agency

M E M O R A N D U M

To: Marc Jameson
Forest Manager
Jackson Demonstration State Forest

Date : July 2, 1997
Ref. : IMD 7-2

From: Department of Forestry and Fire Protection
Coast-Cascade Region

Subject: Water Temperatures on Jackson Demonstration State Forest During the Summer of 1996

During the summer of 1996, I deployed continuous water temperature monitors in each major drainage on Jackson Demonstration State Forest (JDSF). In addition to the monitors I used in 1996, the data from monitors deployed by JDSF are also presented in this memo.

This makes the fourth year of water temperature studies that I have undertaken on JDSF. Unlike the more thorough analysis I prepared on previous years efforts, this memo will simply present the results in tabular and graphical format. A diskette is also enclosed with the ".pic" files to enable your staff to incorporate them in documents as appropriate.

Stowaway® temperature monitors were programmed to start either when triggered or upon a specified date, to record either 15 or 20 records/day, and to use the multiple sampling mode with the maximum option. In the multiple sampling (maximum) mode, the monitors measure temperature about 100 times during the sampling interval but record the maximum during that time interval. Monitors were placed in different situations to represent different conditions:

- Within the stream, monitors were situated at locations intended to represent the "commonly" available temperatures. That is, in riffles that were deep enough to assure that monitors would remain submerged during the entire summer, or between 0.5 and 1 foot below the residual pool surface in the channel thalweg at the pool's head.
- At a sub-sample of stations with in-stream monitors, a second monitor was submersed in an un-capped, 5-gallon bucket filled with water in a well-shaded part of the forest adjacent to the stream. Care was taken to avoid direct sunlight on the bucket yet avoid substantial topographic shading. This placement was intended to represent the "equilibrium" temperature of water in good canopy conditions.
- At a sub-sample of sites with in-stream monitors, another monitor was suspended from vegetation in a well-shaded area of the stream side-zone to observe air temperatures. Care was

taken to place avoid direct sunlight and yet avoid topographic shading.

- One monitor was placed within the seep supporting the only known Torrent Salamander site on JDSF.
- One monitor was placed in Montgomery Creek, a small perennial creek in Montgomery Woods State Preserve that is managed by State Parks. This creek drains a watershed which has not, to my knowledge, had any timber harvesting near the watercourse. A one-lane dirt road does approximate it for some distance. This location is in the Big Creek drainage and is about 8 miles east-south-east of the eastern-most portions of JDSF.

Figure 1 maps the approximate locations of the sampling stations.

The period of coverage differed among the monitors. Deployment started as early as June 8 and retrieval ended as late as October 31. In the office, monitors were down-loaded, converted to Lotus 123 files, and evaluated for erroneous data. When such data was detected (e.g., data recorded prior or subsequent to placement in-stream), the erroneous data was deleted.

Maximum instantaneous stream temperatures ranged from 12.94° C to 23.23° C (Table 1).

The maximum weekly average temperature (MWAT) is a parameter which is useful to assess water temperature conditions for fishes (Brungs and Jones 1977, Armour 1991). For coho salmon, MWAT thresholds fall between 17.1° C and 18.3° C (Anon. 1997). Following Brungs and Jones' (1977) definition of MWAT as

> *"...the mathematical mean of multiple, equally spaced, daily temperatures over a 7-day consecutive period,"*

I calculated the weekly average temperature as a moving mean of temperature records for data sets with adequately long records. The calculated weekly average temperature can then be compared with the MWAT threshold to assess stress conditions on JDSF. For JDSF in-stream monitors, the maximal value and date of weekly average temperatures on JDSF during 1996 ranged from 12.56° C to 18.91° C, and 06 July to 31 August, respectively (Table 1). On the graphs, the time of the maximal weekly average temperature is depicted as a short (1 week long) horizontal line with a vertical line at the peak point.

To further portray the water temperature conditions on JDSF, I also calculated a monthly (4-week) average temperature using a moving mean temperature for records of adequate duration. The maximal values and dates of monthly average temperatures on JDSF during 1996 ranged from 12.33° C to 18.45° C and July 17 to

August 20, respectively (Table 1). On the graphs, the time of the maximal monthly average temperature is depicted as a long (28-day month long) horizontal line with a vertical line at the peak monthly maximum.

The Torrent Salamander site's peak temperature was 12.47° C, its weekly average temperature was 11.92° C, and its monthly average temperature was 11.52° C. The weekly average temperature peaked on 30 August and its monthly average temperature peaked on 26 July.

CRAIG E. ANTHONY
Deputy Director for
Resource Management

By: Bradley E. Valentine
Regional Biologist

Enclosures: Diskettes

attachments: Figures and Tables

cc: Region files (w/o enclosures)
Pete Caferatta (CDF Sacramento; w/o enclosures)
Wendy Jones (DFG; w/o enclosures)
A.J. Kieth (Stillwater Sciences; w/ enclosures)

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Table 1. Results of temperature monitoring on Jackson Demonstration State Forest during 1996. Information in ***bold italics*** is for situations other than in-stream monitoring.

Stream Name & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
Hare Ck. Stream	Down Bunker Gulch	July 06	14.03	July 19	13.83	15.43
Hare Ck. Stream	Hare Ck. Ck. below bndry SFHC'97	July 10	13.86	July 17	13.69	15.27
Hare Ck. Stream	Down trail	July 11	13.79	July 17	13.64	15.27
Hare Ck. Stream	Upper Bunker Gulch	July 29	13.07	July 19	12.91	13.87
Hare Ck. Stream	Bunker Gulch above Hare Ck. Ck.	July 28	14.55	July 17	14.34	16.54
Hare Ck. SPRING	***Torrent Sal. Site***	***August 30***	***11.92***	***July 26***	***11.52***	***12.47***
SF Noyo AIR	***Down Limits***	***August 28***	***15.34***	***July 17***	***14.85***	***24.43***
SF Noyo BUCKET	***Down Boundary***	***August 27***	***13.82***	***July 17***	***13.45***	***16.07***

Stream Name & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
SF Noyo Stream	Downstream Limit	July 12	16.23	July 18	16.01	17.98
SF Noyo AIR	***SF, Upstream Limits***	***August 14***	***15.37***	***August 24***	***14.26***	***27.59***
SF Noyo BUCKET	***Upper Limits***	***August 13***	***15.76***	***July 18***	***15.23***	***19.43***
SF Noyo Stream	SF, Upstream Limits	July 29	14.62	July 19	14.37	15.59
SF Noyo Stream	SF above Rd 320	July 29	16.92	August 03	16.56	19.92
SF Noyo Stream	SF, ca 50 m below Parlin	July 29	15.94	July 19	15.69	17.34
SF Noyo Stream	SF between 23 G and Parlin	July 10	15.21	July 18	15	16.54
SF Noyo Stream	Between Parlin and NF,SF	August 13	15.37	August 19	14.77	16.38
SF Noyo	SF, 300' downstream of Bear Gulch	July 29	15.95	July 18	15.73	18.47

Stream Name & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
SF Noyo Stream	Between Parlin and NF,SF	August 14	15.94	August 20	15.42	18.31
SF Noyo Stream	Between Parlin and NF,SF	August 14	15.84	August 20	15.29	17.82
SF Noyo Stream	SF upstream of confluence with NF of SF	July 29	15.55	July 19	15.32	17.98
SF Noyo Stream	Egg Station	July 10	15.85	July 18	15.63	17.82
SF Noyo Stream	Parlin above Frolic	July 30	14.7	August 04	14.41	16.7
SF Noyo Stream	Parlin above Camp 7	July 29	15.14	July 19	14.9	16.86
SF Noyo Stream	Parlin below Camp 7	July 29	15.47	July 19	15.14	17.34
SF Noyo Stream	Parlin ca 10 m above SF	July 29	16.26	July 19	15.97	18.31

Stream Name Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
SF Noyo BUCKET	***Bear Gulch***	***July 28***	***15.51***	***July 18***	***15.14***	***19.43***
SF Noyo Stream	Bear Gulch beneath Rd. 300 bridge	July 29	14.03	July 20	13.74	15.27
SF Noyo Stream	Petersen Gulch	July 29	13.03	July 20	13.02	14.02
SF Noyo Stream	NF, SF at end of road	July 29	14.9	July 20	14.64	16.38
SF Noyo Stream	NF,SF above Brandon Gulch	July 10	15.28	July 18	15.06	17.34
SF Noyo Stream	NF of SF upstream of confluence with SF	July 10	16.07	July 18	15.87	17.5
NF Big River Stream	NF, upper limits of road 911	July 28	18.91	July 18	18.3	23.23
NF Big River Stream	NF, ca. 30m above James Ck.	July 28	18.85	July 18	18.35	21.73

Stream & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
NF Big River Stream	NF, ca. 40m below James Creek	July 28	18.49	July 18	17.93	21.73
NF Big River Stream	NF, ca 20 m above Chamberlin	July 28	18.48	July 18	18.04	21.56
NF Big River Stream	NF below Chamberlin	July 28	17.92	July 18	17.38	20.89
NF Big River AIR	***NF lower limits***	***July 04***	***19.63***	***August 02***	***18.45***	***33.63***
NF Big River BUCKET	***NF lower limits***	***July 28***	***14.99***	***July 19***	***14.38***	***16.38***
NF Big River Stream	Downstream Limits	July 09	17.95	July 18	17.61	19.59
NF Big River Stream	NF James Ck. at upper Rd. 100 crossing	July 28	15.09	August 03	14.58	17.18
NF Big River Stream	James, ca 30m below N and Main Forks of James	July 28	16.76	August 02	16.1	19.76