

APPENDIX B: Middle Main Eel River TMDL for Sediment
Sediment Source Analysis by PWA

Table 1. Number of grid cells and basin area by stratum and terrain type (geology), Middle Main Stem Eel River TMDL study area						
Watershed	Stratum	Terrain/ Geology Type	# grid cells	Area of grid cells (mi ²)	Proposed grid cell sample	PWA # of grid cells sampled
Middle Main Eel watershed study area	1	Old & Strong	1808	118.06	9	9
	2	Melange	4862	317.49	16	17
	3	Alluvium	157	10.26	3	2
	4	Argillite	216	14.1	4	5
	5	Young & Weak	456	29.78	4	4
	6	Resistant Blocks	477	31.15	4	2
	Total		7,976	520.84	40	39
Spy Rock CALWAA	1	Old & Strong	1,272	83.06	--	4
	2	Melange	3,336	217.84	--	8
	3	Alluvium	50	3.27	--	0
	4	Argillite	0	0	--	0
	5	Young & Weak	0	0	--	0
	6	Resistant Blocks	456	29.78	--	2
	Total		5,114	333.95	--	14
Sequoia CALWAA	1	Old & Strong	536	35	--	5
	2	Melange	1,526	99.65	--	9
	3	Alluvium	107	6.99	--	2
	4	Argillite	216	14.11	--	5
	5	Young & Weak	456	29.78	--	4
	6	Resistant Blocks	21	1.37	--	0
	Total		2,862	186.9	--	25

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Table 2 illustrates the distribution of erosion feature types by ownership and geology type for plot features <3,000 yds³. These numbers reflect actual plot data. The erosion and delivery volumes have not been extrapolated to the entire basin.

Table 2. Total measured erosion and sediment delivery within the 39 field sample plots by ownership, terrain type and erosional feature type, Middle Main Stem Eel River watershed study area.								
Erosional Feature Type	Number of Field Measured Features by Terrain Type (#)						Total measured erosion (yds³)	Total estimated sediment delivery (yds³)
	1. Old & Strong	2. Melange	3. Alluvium	4. Argillite	5. Young & Weak	5. Resistant Blocks		
<i>Spy Rock (plots/mi²)</i>	<i>4/83.06</i>	<i>8/217.84</i>	<i>0/3.27</i>	<i>0/0</i>	<i>0/0</i>	<i>2/29.78</i>	<i>14/333.95</i>	<i>14/333.95</i>
Debris Slide (DL)	4	71	0	0	0	0	20,261	12,109
Earthflow (EF)	0	1	0	0	0	0	500	500
Bank Erosion (BE)	7	91	0	0	0	1	2,806	2,619
Road related gully (GU)	0	5	0	0	0	0	173	151
Non road related gully (GU)	0	9	0	0	0	1	644	623
Stream Crossing (XI)	0	8	0	0	0	0	1,463	1,463
Channel Incision (CI)	1	21	0	0	0	1	469	469
Surface Erosion (SE)	0	5	0	0	0	1	370	286
Subtotals	12	211	0	0	0	4	26,686	18,220
<i>Sequoia (plots/mi²)</i>	<i>5/35</i>	<i>9/99.65</i>	<i>2/6.99</i>	<i>5/14.11</i>	<i>4/29.78</i>	<i>0/1.37</i>	<i>25/186.9</i>	<i>25/186.9</i>
Debris Slide (DL)	18	42	6	10	2	0	10,116	5,951
Earthflow (EF)	0	0	0	0	0	0	0	0
Bank Erosion (BE)	13	32	5	10	11	0	1,241	1,173

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Erosional Feature Type	Number of Field Measured Features by Terrain Type (#)						Total measured erosion (yds³)	Total estimated sediment delivery (yds³)
	1. Old & Strong	2. Melange	3. Alluvium	4. Argillite	5. Young & Weak	5. Resistant Blocks		
Road related gully (GU)	2	3	0	2	0	0	423	412
Non road related gully (GU)	2	6	0	1	2	0	593	417
Stream Crossing (XI)	5	3	0	0	2	0	389	389
Surface Erosion (SE)	0	2	0	0	0	0	193	185
Channel Incision (CI)	7	7	5	4	3	0	355	355
Subtotals	47	95	16	27	20	0	13,310	8,882
Total # of features, erosion and delivery volumes for all domains	59	306	16	27	20	4	39,996	27,102
Total # of plots/terrain type area in mi²	9/118.06	17/317.49	2/10.26	5/14.11	4/29.78	2/31.15	39/520.84	39/520.84

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Table 3 outlines the erosion and sediment delivery by geology for plot features <3,000 yds³ and PWA air photo identified landslides >3,000 yds³ by CALWAA and TMDL study area. The erosion and sediment delivery from plot features <3,000 yds³ were extrapolated to the entire Middle Main Eel River study area using the stratified random sampling method. Volume estimates for geology type. Erosion and sediment delivery for >3,000 yds³ are from actual measurements from the air photo analysis.

Table 3. Total past erosion and sediment delivery from plot features <3,000 yds³ and PWA identified landslides >3000, by terrain type, to each of the two CalWAAs in the Middle MainStem Eel River watershed study area.							
Watershed/ CALWAA	Terrain Type/ Geology	Feature <3,000 yds³ (plots)²			Feature >3,000 yds³ (PWA air photo identified)³		
		Non earthflow Erosion (yds³)	Non earthflow Sediment Delivery (yds³)	Earthflow Erosion (yds³)	Non earthflow erosion (yds³)	Non earthflow sediment Delivery (yds³)	Earthflow erosion (yds³)
Entire Middle Main Eel River study area	1	634,407	493,383	0	2,490,446	2,025,484	65,484
	2	9,006,712	5,947,942	143,000	3,916,823	3,151,910	784,763
	3	139,573	92,551	0	86,007	63,219	2,709
	4	119,405	82,944	0	2,581,932	1,836,748	4,977
	5	20,748	16,986	0	548,215	431,333	0
	6	29,097	24,089	0	336,188	297,296	7,287
	Totals	9,949,942	6,657,895	143,000	9,959,611	7,805,990	865,220
Spy Rock	1	446,331	347,115	0	1,630,988	1,328,889	56,154
	2	6,179,842	4,081,105	98,118	2,800,208	2,215,747	421,239
	3	44,450	29,475	0	50,064	42,595	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	27,816	23,028	0	315,961	277,537	3,003
	Totals	6,698,438	4,480,723	98,118	4,797,221	3,864,768	480,396
Sequoia	1	188,076	146,268	0	859,458	696,595	9,330
	2	2,826,870	1,866,837	44,882	1,116,615	936,163	363,524
	3	95,123	63,076	0	35,943	20,624	2,709
	4	119,405	82,944	0	2,581,932	1,836,748	4,977
	5	20,748	16,986	0	548,215	431,333	0
	6	1,281	1,061	0	20,227	19,759	4,284
	Totals	3,251,504	2,177,172	44,882	5,162,390	3,941,222	384,824

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Table 4. Sediment yield (in yds ³ /mi ² /year, tons/mi ² /year and %) by domain and primary land use association, Middle Main Stem Eel River watershed.													
CALWAA			Non Earthflow					Earthflow					Total sediment yield (non EF+ EF)
			No land use	Field Measured Road Related	Timber Harvest	Graze/ Homestead Activity	Total non EF sediment yield	No land use	Road Related	Timber harvest	Graze/ Homestead Activity	Total EF sediment yield	
Spy Rock	Plot <3,000 yds ³ sediment sources	yds ³ /mi ² /yr	159	37	8	2	206	5	0	0	0	5	211
		tons/mi ² /yr	245	57	13	3	318	7	0	0	0	7	325
	AP >3,000 yds ³ sediment sources ⁵	yds ³ /mi ² /yr	113	46	17	2	178	22	0	0	0	22	200
		tons/mi ² /yr	174	71	27	3	275	34	0	0	0	34	309
	Sub-total/ %	yds ³ /mi ² /yr	272	83	25	4	384	27	0	0	0	27	411
		tons/mi ² /yr	419	128	40	6	593	41	0	0	0	41	434
Sequoia	Plot <3,000 yds ³ sediment sources	yds ³ /mi ² /yr	137	33	7	3	180	4	0	0	0	4	184
		tons/mi ² /yr	210	51	11	4	276	6	0	0	0	6	282
	AP >3000 yds ³ sediment sources ⁵	yds ³ /mi ² /yr	227	63	34	0.3	324	31	0	0.5	0	31	355
		tons/mi ² /yr	349	97	53	1	500	48	0	0.7	0	48	548
	Sub-total/ %	yds ³ /mi ² /yr	364	96	41	3	504	35	0	0.5	0	35	539

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CALWAA			Non Earthflow					Earthflow					Total sediment yield (non EF+ EF)
			No land use	Field Measured Road Related	Timber Harvest	Graze/ Homestead Activity	Total non EF sediment yield	No land use	Road Related	Timber harvest	Graze/ Homestead Activity	Total EF sediment yield	
		tons/mi ² /yr	559	148	64	5	776	54	0	0.7	0	55	831
Total for the Middle Main Stem Eel River study area	Plot <3,000 yds ³ sediment sources	yds ³ /mi ² /yr	151	36	8	2	197	4	0	0	0	4	201
		tons/mi ² /yr	233	55	12	3	303	7	0	0	0	7	310
		%	77	18	4	1	100	100	0	0	0	100	100
	AP >3,000 yds ³ sediment sources ⁵	yds ³ /mi ² /yr	154	52	24	1	231	25	0	0.16	0	25	256
		tons/mi ² /yr	237	80	36	2	355	39	0	0.25	0	39	394
		%	66	23	10	1	100	99	0	1	0	100	100
	Sub-total/ %	yds ³ /mi ² /yr	305	88	32	3	428	29	0	0.16	0	29	457
		tons/mi ² /yr	470	135	48	5	658	46	0	0.25	0	46	704
		%	71	21	7	1	100	100	0	0	0	100	100

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Table 5 outlines the sediment yield rates by time period for <3000 yds³ plot features and PWA identified >3000 yds³ landslides. The sediment delivery from plot features <3,000 yds³ was extrapolated to the entire Middle Main Stem Eel River basin using the stratified random sampling method. The time period reflects the approximate time of changes to the Forest Practice Rules.

Table 5. Sediment yield (in yds³/mi²/year, tons/mi²/year and %) by calwaa and time frames, for plot features <3,000 yds³ and PWA identified landslides >3,000 yds³, Middle Main Stem Eel River watershed study area.											
Watershed	Sediment Delivery Rate	Pre -1970					Post-1970				
		Plot features <3,000 yds³		Feature >3,000 yds³ (air photo identified)³		Total	Plot features <3,000 yds³		Feature >3,000 yds³ (air photo identified)³		Total
		nonEf	EF	non Ef	EF		non Ef	EF	nonEf	EF	
Entire Middle Main Stem Eel River watershed study area	yds ³ /mi ² /yr	342	9	311	50	712	73	0	162	4	239
	tons/mi ² /yr	526	14	478	77	1,095	112	0	250	7	369
Spy Rock	yds ³ /mi ² /yr	363	10	287	41	701	72	0	85	6	163
	tons/mi ² /yr	559	15	441	64	1,079	111	0	131	9	251
Sequoia	yds ³ /mi ² /yr	303	8	353	66	730	73	0	300	2	375
	tons/mi ² /yr	467	12	544	102	1,125	113	0	462	3	578

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Table 6 outlines the sediment yield from field plot data for features <3,000 yds³ and PWA air photo identified >3,000 yds³ landslides. The table compares the pre-1970 and post 1970 time frames to management versus non management land use association.

Table 6. Total PWA sample plot and aerial photograph determined sediment delivery by time frames and potential controllability.					
CALWAA/Basin		Total Yield by Time Period for Management Sediment Yield (yds³ & %)		Total Yield by Time Period for Non-Management Sediment Yield (yds³ & %)	
		Non Earthflow	Earthflow	Non Earthflow	Earthflow
Spy Rock	Pre-1970 (30 years)	2,074,384	5,439	4,433,568	512,574
	Post-1970 (35 years)	364,672	0	1,472,868	65,940
	Subtotals	2,439,056	5,439	5,906,436	578,514
Sequoia	Pre-1970 (30 years)	1,417,964	0	2,260,310	410,051
	Post-1970 (35 years)	287,698	0	2,152,421	14,216
	Subtotals	1,705,662	0	4,412,731	424,267
Totals for the whole basin	Pre-1970 (30 years)	3,492,348	5,439	6,693,878	922,625
	Post-1970 (35 years)	652,370	0	3,625,289	80,156
	Total	4,144,718	5,439	10,319,167	1,002,781

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Table 7 (Note this is old table 3) Total past erosion and sediment delivery from plot features <3,000 yds ³ and PWA identified features >3000, by terrain type for the 2 CALWAAs and the entire Middle Main Stem Eel River study area (includes SEDMODL road-related sediment delivery)								
Ownership	Terrain Type/ Geology	Feature <3,000 yds ³ (plots) ²				Landslides >3,000 yds ³ (PWA air photo identified)		
		Non earthflow Erosion (yds ³)	Non earthflow Sediment Delivery (yds ³)	SEDMODL Road Related Sediment Delivery (yds ³)	Earthflow Erosion (yds ³)	Non earthflow erosion (yds ³)	Non earthflow sediment Delivery (yds ³)	Earthflow erosion (yds ³)
Entire Upper Eel River study area	1	634,407	493,383	144,011	0	2,490,446	2,025,484	65,484
	2	9,006,712	5,947,942	880,293	143,000	3,916,823	3,151,910	784,763
	3	139,573	92,551	61,293	0	86,007	63,219	2,709
	4	119,405	82,944	33,222	0	2,581,932	1,836,748	4,977
	5	20,748	16,986	102,363	0	548,215	431,333	0
	6	29,097	24,089	20,077	0	336,188	297,296	7,287
	Totals	9,949,942	6,657,895	1,241,259	143,000	9,959,611	7,805,990	865,220
Spy Rock	1	446,331	347,115	103,230	0	1,630,988	1,328,889	56,154
	2	6,179,842	4,081,105	519,278	98,118	2,800,208	2,215,747	421,239
	3	44,450	29,475	18,441	0	50,064	42,595	0
	4	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0
	6	27,816	23,028	18,633	0	315,961	277,537	3,003
	Totals	6,698,438	4,480,723	659,581	98,118	4,797,221	3,864,768	480,396
Sequoia	1	188,076	146,268	40,781	0	859,458	696,595	9,330
	2	2,826,870	1,866,837	361,015	44,882	1,116,615	936,163	363,524
	3	95,123	63,076	42,852	0	35,943	20,624	2,709
	4	119,405	82,944	33,222	0	2,581,932	1,836,748	4,977
	5	20,748	16,986	102,363	0	548,215	431,333	0
	6	1,281	1,061	1,444	0	20,227	19,759	4,284
	Totals	3,251,504	2,177,172	581,678	44,882	5,162,390	3,941,222	384,824

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Table 8 (note this is old table 4). Sediment Delivery Rates (in yds³/mi²/year, tons/mi²/year) by primary land use association for the 2 CALWAAs and the entire Middle Main Stem Eel River TMDL study area (includes SEDMODL road-related sediment delivery).

CALWAA			Non Earthflow						Earthflow					Total sediment yield (non EF+ EF)
			No land use	Field Measured Road Related	SED MODL Input Road-related	Timber Harvest	Graze/ Homestead Activity	Total non EF sediment yield	No land use	Road Related	Timber harvest	Graze/ Homestead Activity	Total EF sediment yield	
Spy Rock	Plot <3,000 yds ³ sediment sources	yds ³ /mi ² /yr	159	37	30	8	2	236	5	0	0	0	5	241
		tons/mi ² /yr	245	57	41	13	3	359	7	0	0	0	7	366
	AP >3,000 yds ³ sediment sources ⁵	yds ³ /mi ² /yr	113	46	0	17	2	178	22	0	0	0	22	200
		tons/mi ² /yr	174	71	0	27	3	275	34	0	0	0	34	309
	Sub-total/ %	yds ³ /mi ² /yr	272	83	30	25	4	414	27	0	0	0	27	441
		tons/mi ² /yr	419	128	41	40	6	634	41	0	0	0	41	675
Sequoia	Plot <3,000 yds ³ sediment sources	yds ³ /mi ² /yr	137	33	48	7	3	228	4	0	0	0	4	232
		tons/mi ² /yr	210	51	65	11	4	341	6	0	0	0	6	347
	AP >3000 yds ³ sediment sources ⁵	yds ³ /mi ² /yr	227	63	0	34	0.3	324	31	0	0.5	0	31	355
		tons/mi ² /yr	349	97	0	53	1	500	48	0	0.7	0	48	548

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CALWAA			Non Earthflow						Earthflow					Total sediment yield (non EF+ EF)
			No land use	Field Measured Road Related	SED MODL Input Road-related	Timber Harvest	Graze/ Homestead Activity	Total non EF sediment yield	No land use	Road Related	Timber harvest	Graze/ Homestead Activity	Total EF sediment yield	
	Sub-total/ %	yds ³ /mi ² /yr 39	364	96	48	41	3	552	35	0	0.5	0	35	587
		tons/mi ² /yr	559	148	65	64	5	841	54	0	0.7	0	55	896
Total for the Middle Main Stem Eel River study area	Plot <3,000 yds ³ sediment sources	yds ³ /mi ² /yr	151	36	37	8	2	234	4	0	0	0	4	238
		tons/mi ² /yr	233	55	49	12	3	352	7	0	0	0	7	359
		%	65	15	16	3	1	100	100	0	0	0	100	100
	AP >3,000 yds ³ sediment sources ⁵	yds ³ /mi ² /yr	154	52	0	24	1	231	25	0	0.16	0	25	256
		tons/mi ² /yr	237	80	0	36	2	355	39	0	0.25	0	39	394
		%	67	22	0	10	1	100	99	0	1	0	100	100
	Sub-total/ %	yds ³ /mi ² /yr	305	88	37	32	3	465	29	0	0.16	0	29	494
		tons/mi ² /yr	470	135	49	48	5	707	46	0	0.25	0	46	753
		%	65	19	8	7	1	100	100	0	0	0	100	100

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Middle Main Eel Sediment TMDL Table Assumptions

1) Air Photos used in analysis: 1960, 1965, 1966, 1980, 1984, 1985, 2000, 2003

2) Conversion factor for yds³ to tons = 1.54 yds³/ton

3) Time period = 65 years (1940-2005)

4) The following equations were used to compute volumes for each feature type

a) Depth for landslides, debris flow sources (excluding earthflows) was calculated using a power equation developed from field verified air photo identified landslides =

$$\text{Depth} = 0.5068 * \text{Area}^{0.2381}$$

b) Torrent tracks and gullies were calculated using an equation developed from studies conducted in the Jordan Creek and Bear Creek watersheds (flow into the lower Eel) Torrent track erosion or gully erosion = Length * 2.91 yds³/ft

c) Bank erosion was calculated using an equation developed from studies conducted in the Jordan Creek and Bear Creek watersheds (flow into the lower Eel). Bank erosion volume = Length of channel * 1.42 yds³/ft

d) Earthflow erosion was calculated using an average earthflow toe retreat rate applied to the width of the toe of the earthflow and an average toe depth.

$$\text{Earthflow erosion} = \text{Width of EF toe} * 16 \text{ ft average depth} * 1.82 \text{ ft retreat per year.}$$

This yields a volume/year. We applied this rate to each air photo period assuming that earthflow activity is in response to high annual rainfall. Earthflow activity is found to continue for years after heavy rainfall years. This is based on Iverson's work on earthflows (Iverson, R. M., 1984. Unsteady, nonuniform landslide motion: theory and measurement. Unpublished PhD thesis, Stanford University, CA. 303p.)

For estimates of earthflow sediment delivery we applied 21 years of activity for the 1960 decade of photos (spans back to 1940), 14 years of activity for the 1980 decade of air photos and 6 years of activity for the 2000 decade of air photos. This was derived from annual rainfall data collected in Scotia, California.

5) The middle main stem component was derived from selecting landslides delivering to the main stem Eel and to main stem interfluvies within a 1500' buffer along the main stem Eel. Although the main stem component appears low, this is not surprising. We just finished a watershed analysis in the Eel River just downstream of the Middle Main TMDL study area. We found that landslide rates were much higher in streams that are more affected by channel migration zone shifts. The Larabee Creek watershed which drains to the Eel showed very high landslide rates where the channel migration was more of an influence due to the channel confinement. The section of the Eel River in the watershed analysis area did not show the same rate of landsliding. It appears that the wider channel was better at accommodating the channel migration shifts and resulted in less streamside landslides.

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