DATA RELEASE: REDWOOD CREEK CHANNEL CROSS SECTION CHANGES, 1985-1986

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ABSTRACT

A total of 61 channel cross sections were surveyed in Redwood Creek, northwestern California, during the summers of 1985 and 1986. This report summarizes channel changes at cross sections on Redwood Creek between 1985 and 1986. Scour and fill, change in thalweg elevation, mean change in streambed elevation and absolute change were calculated at cross sections. In addition, plots of all cross sections are presented.

The winter of 1985-1986 had a peak flow with a recurrence interval of 4-5 years. In general, surveys showed scour or little change in the upstream reaches of the creek, and the channel appeared to be stable. Along the downstream aggraded reach, more scour, fill and channel shifting occurred.

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I. INTRODUCTION

Redwood National Park was established in 1968, and originally consisted of a half mile wide corridor along Redwood Creek in the lower one-third of the basin. The Park was created to protect old-growth redwood forest and particularly the Tall Trees Grove, a pristine old-growth stand that contains several of the world's tallest known trees.

Following the establishment of the Park, political controversy arose over the damaging effects of logging upstream and adjacent to Redwood Creek. The U.S. Geological Survey (U.S.G.S) documented significant aggradation in Redwood Creek and the impacts of clearcut logging on forest ecology and the aesthetic value of the park (Janda and others, 1975). A decade of political unrest, industry negotiation and scientific research culminated in the expansion of Redwood National Park in March, 1978.

The new park included the lower 197 km^2 of the basin, from the watershed divides to the creek. Federal legislation (P.L. 95-250) that expanded Redwood National Park included provisions for watershed rehabilitation, continued scientific research and monitoring of erosion and sedimentation in the basin. Section 101 (a) (6) of the law directs the Secretary of the Interior to "undertake and publish studies on erosion and sedimentation" within the Redwood Creek watershed, to "identify sources and causes, including differentiation between natural and man-aggravated conditions," and to "adapt his general management plan to benefit from the results of such studies."

Since 1978 the National Park Service has worked to quantify sediment inputs to Redwood Creek and to investigate geomorphic processes involved in the transportation and storage of sediment throughout the watershed. These studies benefit from the use of cross section surveys, which document changes in channel geometry. This report is an update of channel changes at 61 cross sections on the mainstem of Redwood Creek from 1985 to 1986. Net changes in streambed elevation were quantified; plots of all cross sections are included.

II. STUDY AREA

A. Geology and Physiography

The 720 km^2 Redwood Creek watershed is located in the Coast Ranges of northwestern California (Figure 1). For much of its length, the creek flows along the trend of the Grogan Fault. The elongate shape of the basin and the linear course of Redwood Creek are controlled by the fault.

Strike-slip movement along the Grogan Fault has brought two distinct rock types of the Franciscan Assemblage into contact. Hillslopes west of the fault are underlain by a well foliated quartz-mica schist; while the east side is underlain predominantly by unmetamorphosed sandstone and siltstone with minor outcrops of melange.

Rocks of the Franciscan Assemblage are closely fractured and pervasively sheared. Weathering has generated noncohesive soils that are highly susceptible to fluvial erosion, and clayey soils that are susceptible to mass movement when wet (Janda, 1977). Melange terrain is characterized by large earthflow complexes which are also highly erodable.

Redwood Creek's channel gradient ranges from 0.10 to 12 percent. Average hillslope gradient in the basin is 26 percent. Elevation in the basin ranges from sea level to 1615 m. Hillslopes adjacent to Redwood Creek are often steep, and decrease at middle and upper slope positions. This produces an incised inner valley near the creek which is particularly susceptible to mass wasting by shallow debris slides and debris avalanches (Harden and others, 1978).

B. Vegetation

Prior to commercial timber harvesting, much of the basin supported old-growth coniferous forest. The northern one-third of the basin contained primarily mixed stands of redwood and Douglas-fir while the southern two-thirds of the basin supported mixed Douglas-fir and hardwood forests. Patches of oak woodlands and prairie grasslands occupied hillslopes throughout the basin, particularly on slopes east of Redwood Creek. Clearcut logging has reverted much of the forest to early successional phases. Although the basin continues to be dominated by native tree species, their distribution and relative abundance has changed significantly.

C. Climate

The Redwood Creek basin has a moist, mild climate characteristic of the northern California Coast Ranges. Average rainfall in the basin is 200 cm; however, altitude, proximity to the ocean and slope aspect profoundly influence the amount of precipitation. This results in high variability between locations. At least 80% of the rainfall occurs

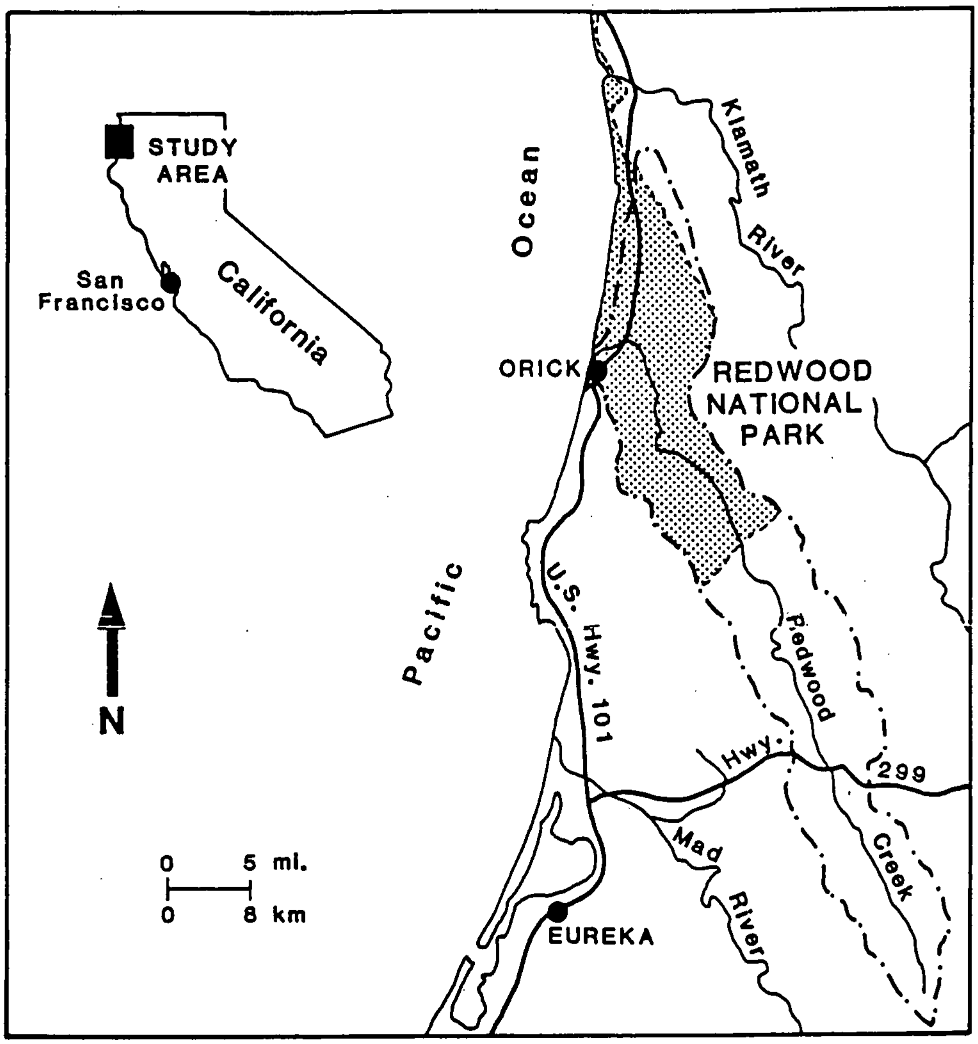


Figure 1. Location map of the Redwood Creek Basin and Redwood National Park (shaded).

during prolonged, moderately intense winter storms between October and March; rainfall during the summer months is rare. Precipitation and discharge are measured and recorded by water years (a water year is from October to September; that is, Water Year 1986 began on October 1, 1985 and ended on September 30, 1986).

Major floods occurred throughout northern California in 1953, 1955, 1964, 1972 and 1975. Peak discharges greater than 1282 m^3/s were recorded near the mouth of Redwood Creek during these floods (Harden and others, 1978). The flood of December 1964 was especially significant because it resulted in widespread landsliding, gullying and changes in channel morphology. Floods which occurred after 1964, although similar in magnitude, did not cause as much erosion as the 1964 flood.

D. Cross Section Network

A total of 61 main channel cross sections are located on Redwood Creek between the headwaters (Cross Section 45) and the upstream end of flood control levees (Cross Section 1) (Figure 2). Figure 3 is a longitudinal profile of Redwood Creek showing cross section locations.

Prior to park expansion, the National Park Service and the U.S.G.S. initiated a sediment study on Redwood Creek. The earliest cross section data on Redwood Creek is at Cross Section 40 (the Blue Lake gaging station at Hwy 299) which was surveyed in 1953. In 1972 three cross sections were established and surveyed at the Tall Trees Grove. An additional 47 cross sections were installed in September and October, 1973; three in the winter of 1974; five in autummn 1978 and three in 1984. In the summer of 1982, the Park Service acquired responsibility for the cross section network. At this time, unstable monuments were surveyed for accuracy and where conditions permitted, cross section end points were re-occupied. Unstable hillslopes at two cross sections (18a and 21a) made it necessary to relocate the end points.

Analyses of the Redwood Creek cross section network are provided by several researchers. Iwatsubo and others (1975) and (1976) present main channel cross section data for WY 1974. Nolan and Janda (1979) interpret cross section data from 1973 to 1978. Channel changes in WY 1982 are documented by Varnum (1984). Varnum and Ozaki (1986) interpret data from WY 1983 and WY 1984 and compare it with previous years. Nolan and Marron (in press) present cross section data from 1973 to 1981.

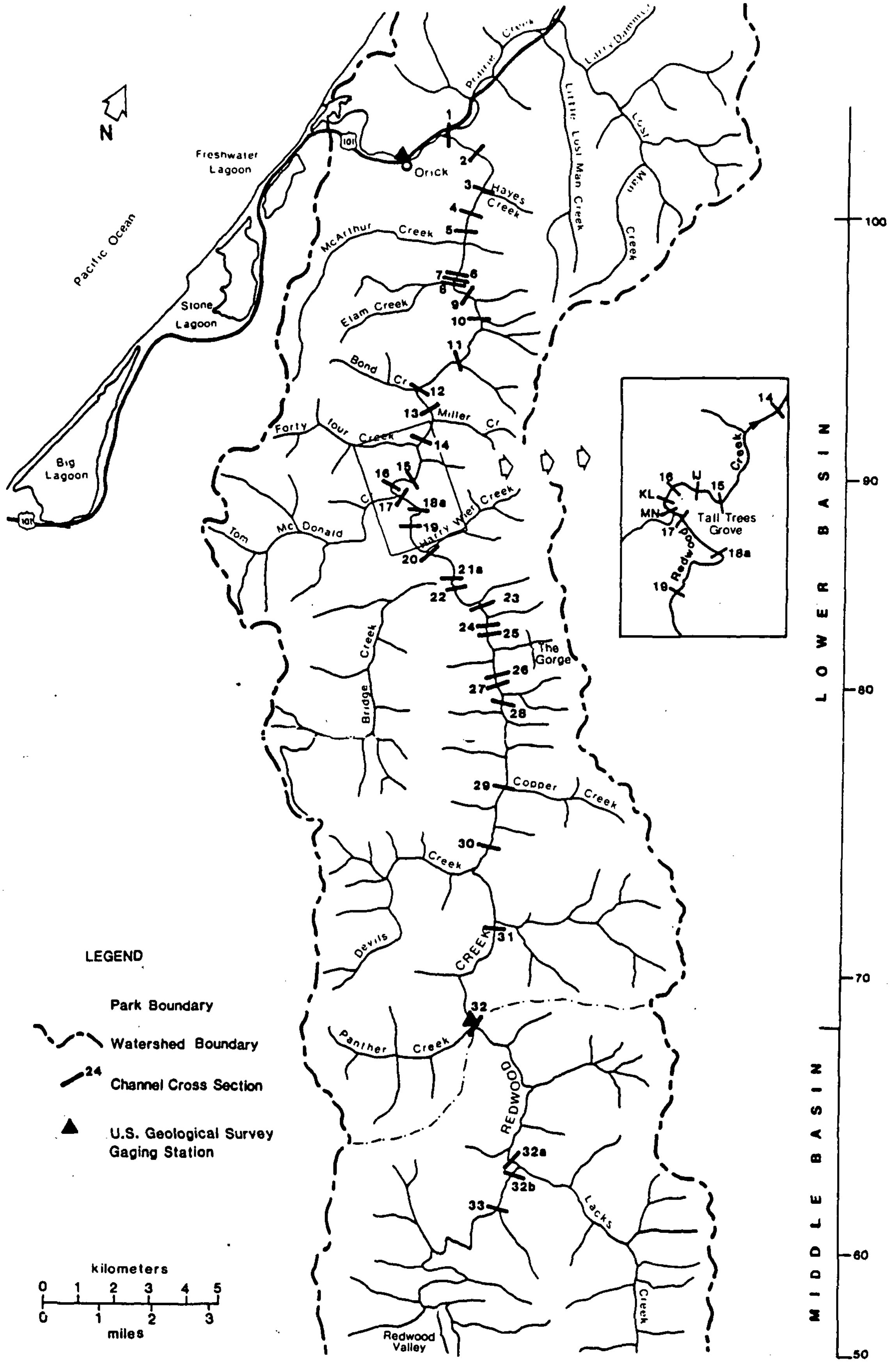


Figure 2. Location map of channel cross sections on Redwood Creek, CA.

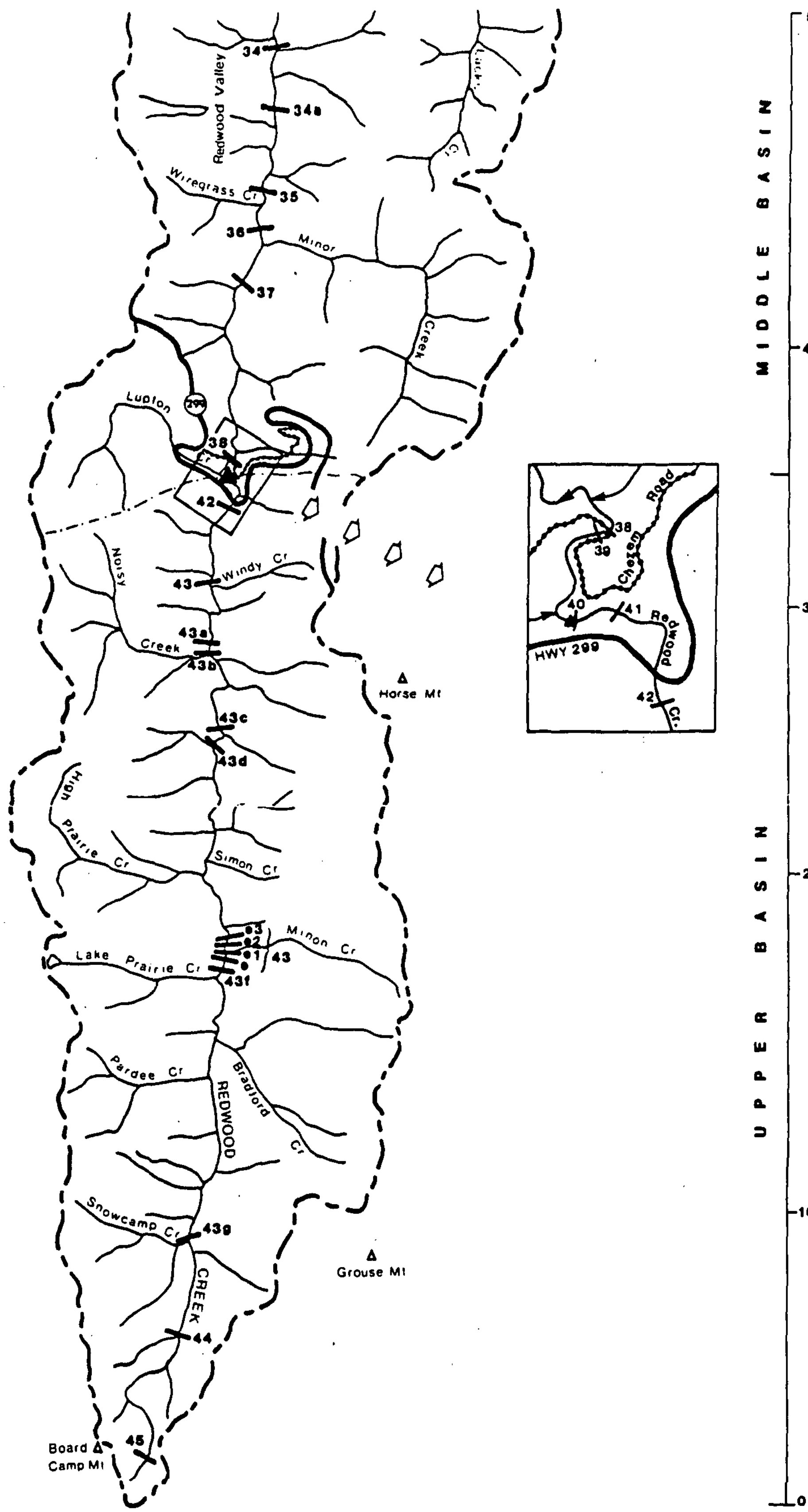


Figure 2. Location map of channel cross sections on Redwood Creek, CA.

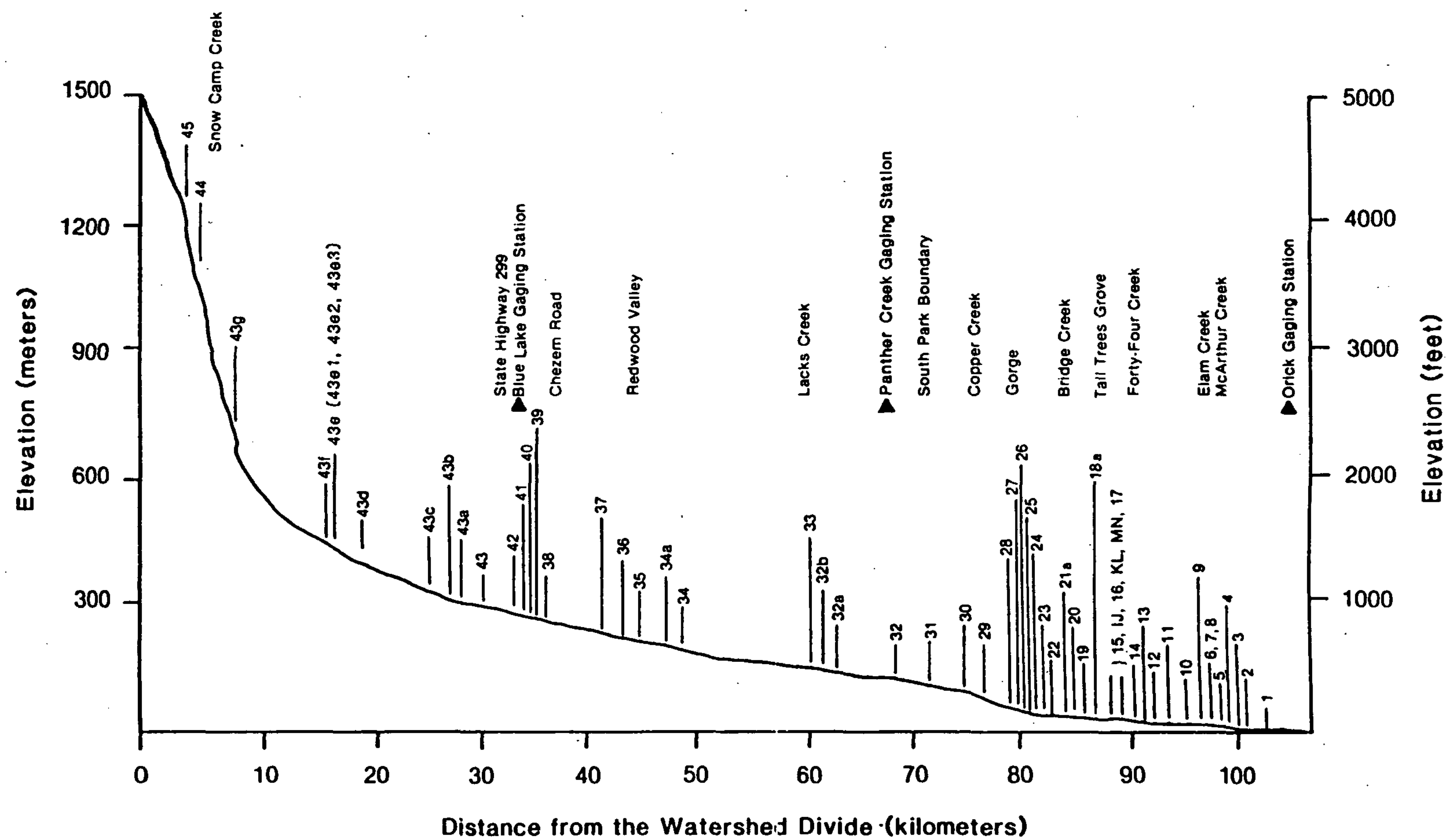


Figure 3. Longitudinal profile of Redwood Creek showing cross section locations, major tributaries and gaging stations.

III. METHODS

Cross sections are surveyed between two permanent end points of known elevation. Annual surveys at cross sections document changes in channel width, bed elevations and thalweg position (Figure 4). Fifteen years of data currently exist to quantify channel response to hydrologic and physical variables and to describe the movement of streambed sediment.

Cross section end points were monumented with 1.2 m lengths of 9.5 mm steel rebar or by reference marks on concrete bridge abutments. Steel rebar was driven 1 meter into the ground, reinforced with concrete, and referenced to at least two other triangulation points. Relative elevations between end points were established by leveling (Emmett, 1974; Nolan, 1979). Cross sections were surveyed during the summer months with either an automatic level and stadia rod or a theodolite and electronic distance meter.

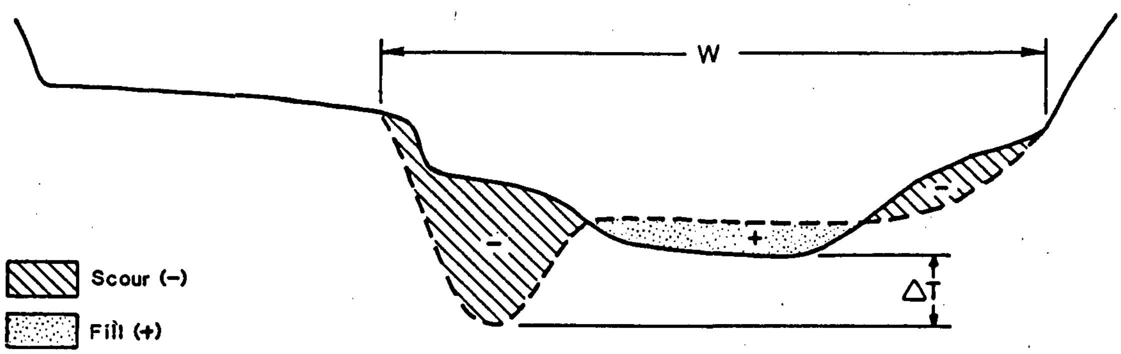
Comparing successive cross section surveys requires monumented end points of known elevation for each survey. Landslides and soil creep cause monuments to shift both laterally and vertically. When a monument is lost due to landslides or bank erosion, it is reestablished the following year using distance and bearing data from known reference points. However, when monuments shift only a small amount, discretion must be used in reestablishing "true" elevation. Small amounts of shifting often occurs at all monuments, and therefore, some uncontrollable survey error exists between successive surveys.

A tolerance value of 2.5 cm was selected to detect unstable monuments and permanent change of a cross section end point. Cross section surveys with less than 2.5 cm error between monument elevations were considered acceptable. At cross sections with greater than 2.5 cm error, monument elevations were adjusted (using reference points, previous survey elevations and field notes). New monument elevations were assigned to correct for shifting monuments and eliminate survey error. Roughly 75% of the cross sections had less than 2.5 cm error and monument elevations were not changed.

Since 1982, streamside landslides and widespread bank erosion removed the monumented end point from 15 percent of the cross sections. In most cases, end points were reestablished by triangulating from monument reference points. In some cases, long term instability required minor realignment of the cross section.

IV. TERMINOLOGY

The terminology of Varnum and Ozaki (1986) was used in this report. Figure 4 is a summary from their report. The thalweg (T) is defined as the lowest point in the streambed in cross-sectional profile. Channel width (W) is defined by the channel width occupied by the effective discharge. The effective discharge defined by Nolan and others (1987) transports the majority of sediment due to its high frequency of occurrence. This discharge is identified in Redwood Creek by highwater marks, vegetation breaks and breaks-in-slope. Recurrence interval (RI) for the effective discharge (425 m^3/s) is 1.8 years on Redwood Creek (Nolan and others, 1987).



———	Cross section profile at time of initial survey
- - - - -	Cross section profile at time of resurvey
W	Channel width
ΔT	Change in thalweg
ΔA_s	Net change in streambed area is the sum of scour (−) and fill (+) at a cross section. (not shown)
ΔE_c	Change in mean streambed elevation $\Delta E_c = \Delta A_s / W$ (not shown)
Absolute change	Absolute change in area is the sum of the absolute value of scour (−) and fill (+). (not shown)

Figure 4. Terms and symbols used to describe changes at cross sections.

Net change in streambed area (ΔA_s) is the difference between fill and scour in the streambed. Mean change in streambed elevation (ΔE_c) is a normalized value that compares the relative importance of changes at cross sections of different widths. This variable is derived by dividing the net change in streambed area (ΔA_s) by channel width (W).

$$\Delta E_c = \Delta A_s / W$$

Thus, lowering the mean streambed elevation by 0.15 m (ΔE_c = -0.15 m) produces the same percent change in a 10 m wide cross section as it does in a 100 m wide cross section, even though more material has moved through the wider cross section.

To evaluate the amount of change at a cross section, the absolute value of streambed area change was normalized. This value was derived by summing the absolute value of scour and fill at a cross section and dividing it by channel width.

V. RESULTS AND DISCUSSION

All 61 cross sections on Redwood Creek were surveyed during the summers of 1985 and 1986. Approximately 90 percent of the cross sections were surveyed using an automatic level and a stadia rod. Remaining cross sections were surveyed with an electronic distance meter and theodolite. Measured and calculated values for changes at cross sections are summarized in Table 1.

Redwood Creek, like many streams in north coastal California, has experienced dramatic changes in channel configuration and sediment load since the mid-1950's. A series of major floods and the advent of widespread timber harvest were recognized as a cause of these major channel changes (Hickey, 1969; Denton, 1974; Kelsey, 1977; Kennedy and Malcolm, 1979; Lisle, 1981).

Anderson (1976) and Janda (1977) suggest that the suspended sediment discharge rates measured on Redwood Creek in the late 1960's and early 1970's are at least seven times higher than pre-logging rates. Madej (1984) documents a 45 percent increase in the volume of sediment stored in the mainstem of Redwood Creek since 1947. Channel characteristics reflecting this increase in stored sediment include channel widening, increased streambed elevation, increased channel braiding and decreased streambed material size (Janda and others, 1975). These changes reflect the tendency of the stream to reestablish-equilibrium to carry the load supplied by a given discharge.

Climatic conditions in the Redwood Creek basin result in periodic major flood-producing storm events accompanied by accelerated erosion. These storm events have occurred in the past and will continue to occur. The last major flood occurred in 1975 (RI = 25-30 years)(Coghlan, 1984). Consequently, the cross section network has been in operation under relatively low flow conditions. Although changes since 1975 have been significant, they have not been as dramatic as the changes that occurred during the period from 1964 to 1975. The National Park Service continues to monitor the cross section network to provide a thorough data base and to document the effects of the next major flood.

During WY 1986, the Redwood Creek basin received normal annual rainfall, of which 22 percent fell in February. In particular, the February 13-February 22 storm had a long duration and was of low intensity, consequently, only minor channel changes occurred. The peak flow of 869 m^3/s was estimated to have a RI = 4-5 years at Orick, California.

Channel changes in WY 1986 follow trends observed in previous years. Varnum and Ozaki (1986) discuss previous changes in detail. The channel exhibited minor scour or no change from the headwaters (Cross Section 45) to below Copper Creek (Cross Section 29)(Table 1). Cross sections near Slide Creek (Cross Sections 26, 27 and 28) aggraded. Aggradation at these cross sections was probably due to a major channel constriction immediately downstream of Cross Section 26 and the relatively wide

Table 1. Summary of channel changes on Redwood Creek Cross Sections, 1985 - 1986.

Cross Section Number	Year Estab.	Cross Section Dist. (m)	Change in Thalweg Elev. (m)	Change in Streambed Area: Scour (-) (m^2)	Change in Streambed Area: Fill (+) (m^2)	Change in Streambed Area: Net Change in Area (m^2)	Channel Width (m)	ΔE_c* (m)	Absolute Change (m)
1	10/73	140.82	-0.10	44.63	69.99	25.36	139	0.18	0.82
2	10/73	168.42	-0.11	43.64	14.18	-29.46	154	-0.19	0.38
3	9/73	143.60	-0.16	24.37	40.33	15.96	134	0.12	0.48
4	10/73	163.37	-0.13	16.67	10.29	-6.38	132	-0.05	0.20
5	10/73	114.30	0.11	20.28	15.02	-5.26	114	-0.05	0.31
6	10/73	116.13	0.13	17.07	29.42	12.35	112	0.11	0.42
7	9/73	65.23	-1.49	10.68	12.78	2.10	65	0.03	0.36
8	9/73	97.97	-1.54	26.64	16.90	-9.74	91	-0.11	0.48
9	9/73	129.24	0.16	32.02	21.03	-10.99	112	-0.10	0.47
10	10/73	107.60	0.41	21.10	23.55	2.45	99	0.02	0.45
11	10/73	74.98	-0.15	9.25	7.71	-1.54	71	-0.02	0.24
12	10/73	84.43	0.32	4.70	16.45	11.75	75	0.16	0.28
13	10/73	78.65	0.35	9.30	6.84	-2.46	70	-0.04	0.23
14	10/73	61.24	0.12	1.88	1.16	-0.72	61	-0.01	0.05
15	10/73	70.35	0.02	12.97	5.79	-7.18	62	-0.12	0.30
IJ	11/72	160.00	0.50	104.32	88.32	-16.00	155	-0.10	1.24
16	10/73	93.27	0.22	4.58	17.08	12.50	82	0.15	0.26
KL	11/72	86.26	0.18	19.23	33.63	14.40	81	0.18	0.65
MN	12/72	122.83	-0.18	51.22	28.77	-22.45	120	-0.19	0.67

17	10/73	92.66	1.09	8.32	21.87	13.55	90	0.15	0.34
18a	10/82	71.93	0.23	10.69	6.01	-4.68	66	-0.07	0.25
19	10/73	144.78	0.80	52.51	34.73	-17.78	128	-0.14	0.68
20	10/73	61.27	0.43	8.47	11.82	3.35	58	0.06	0.35
21a	10/82	78.90	0.00	12.36	4.77	-7.59	71	-0.11	0.24
22	10/73	61.27	0.29	14.14	4.16	-9.98	57	-0.18	0.32
23	10/73	103.33	0.79	19.86	22.87	3.01	83	0.04	0.51
24	7/79	68.28	0.14	17.77	3.96	-13.81	62	-0.22	0.35
25	10/73	64.01	-0.20	14.37	7.30	-7.07	49	-0.14	0.44
26	10/73	56.38	0.12	4.50	13.12	8.62	47	0.18	0.37
27	10/73	76.20	0.41	5.55	13.17	7.62	43	0.18	0.44
28	10/73	97.84	-0.09	2.52	6.15	3.63	59	0.06	0.15
29	10/73	77.60	-0.03	4.83	4.99	0.16	67	0.00	0.15
30	10/73	45.72	-0.41	6.71	3.40	-3.31	39	-0.08	0.26
31	10/73	27.73	0.24	2.84	1.93	-0.91	28	-0.03	0.17
32	10/73	42.67	-0.10	3.16	1.02	-2.14	35	-0.06	0.12
32a	12/74	92.05	-0.27	22.89	19.03	-3.86	69	-0.06	0.61
32b	10/74	114.90	0.12	14.61	16.17	1.56	97	0.02	0.32
33	10/73	47.55	-0.28	12.30	0.70	-11.60	44	-0.26	0.30
34	10/73	111.15	-0.02	12.13	3.55	-8.58	75	-0.11	0.21
34a	10/74	153.62	0.14	16.75	15.16	-1.59	89	-0.02	0.36
35	10/73	65.23	0.03	2.14	2.34	0.20	51	0.00	0.09
36	10/73	44.50	-0.04	2.83	7.25	4.42	40	0.11	0.25
37	10/73	44.20	-0.29	7.92	0.22	-7.70	43	-0.18	0.19
38	10/73	31.00	0.72	4.11	2.46	-1.65	22	-0.08	0.30

* Mean Change in Streambed Elevation

Table 1. Summary of channel changes on Redwood Creek Cross Sections, 1985 - 1986 (Continued).

Cross Section Number	Year Estab.	Cross Section Dist. (m)	Change in Thalweg Elev. (m)	Change in Streambed Area: Scour (-) (m^2)	Change in Streambed Area: Fill (+) (m^2)	Change in Streambed Area: Net Change in Area (m^2)	Channel Width (m)	ΔE_c* (m)	Absolute Change (m)
39	10/73	35.97	0.09	3.62	1.16	-2.46	33	-0.07	0.14
40	10/73+	41.15	-0.16	2.15	2.26	0.11	34	0.00	0.13
41	10/73	57.91	-0.15	2.66	0.77	-1.89	29	-0.07	0.12
42	10/73	38.10	-0.24	1.99	1.01	-0.98	34	-0.03	0.09
43	10/73	96.93	-0.40	11.82	1.37	-10.45	78	-0.13	0.17
43a	10/78	99.37	0.01	2.57	3.94	1.37	54	0.03	0.12
43b	10/78	77.42	-0.20	4.03	5.77	1.74	59	0.03	0.17
43c	10/78	71.11	0.16	13.02	2.92	-10.10	55	-0.18	0.29
43d	10/78	61.87	-0.14	2.21	1.77	-0.44	50	-0.01	0.08
43e	10/78	59.44	-0.01	1.87	2.68	0.81	54	0.02	0.08
43e1	8/84	17.68	-0.15	0.78	0.79	0.01	16	0.00	0.10
43e2	8/84	24.69	0.03	1.57	0.44	-1.13	13	-0.09	0.15
43e3	8/84	50.82	-0.16	1.92	1.21	-0.71	30	-0.02	0.10
43f	10/78	43.40	0.11	1.37	2.50	1.13	29	0.04	0.13
43g	10/78	61.60	-0.13	4.57	3.63	-1.54	48	-0.03	0.17
44	10/74	19.20	-0.15	5.14	0.09	-5.05	15	-0.34	0.35
45	10/74	17.00	0.02	0.21	0.53	0.32	12	0.03	0.06

* Mean Change in Streambed Elevation.
+ Gaging station records extend cross section data back to 1953.

channel widths in this section of the creek. From the base of the gorge (Cross Section 25) downstream to Elbow Creek (Cross Section 18a), the channel degraded. Channel cross sections from the Tall Trees Grove (Cross Section 17) downstream to the flood control levees (Cross Section 1) exhibited no trend in either aggradation or degradation. This pattern of alternating scour and fill is similar to that seen in previous years. Cross sections in these reaches exhibited relatively higher values for absolute streambed area change than the rest of the creek and indicated that the channel in these reaches was fairly mobile during winter flows. Recent channel aggradation has been documented downstream of the Tall Trees Grove (Varnum and Ozaki, 1986). Channel shifting is common in aggraded sections on lower Redwood Creek and occurred downstream of Elam Creek (Cross Section 8).

In general, channel cross sections reflected similar trends observed in WY 1984. Cross sections in the upper basin appeared very stable while more scour, fill and thalweg shifting occurred in the lower, aggraded reaches. The channel in the upstream portion of the watershed has steeper gradients, larger streambed particles and has bedrock exposed in parts of the channel. Long term records at Cross Section 40 indicate that the streambed has returned to near pre-aggradation levels. The lack of significant changes observed upstream of Cross Section 40 probably reflects a return to pre-aggradation conditions for much of that reach.

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APPENDIX

Each cross section is plotted showing the channel configuration for 1985 (solid line) and 1986 (dashed line). Both axes are plotted in meters. The x-axis is the distance measured from the left end point (i.e. left pin distance = 0 m). Consequently, the channel cross section is viewed looking in the downstream direction. The y-axis is the elevation measured above an arbitrary datum. Lost monuments due to bank erosion or landslides are designated by a ✚ on cross section plots.

The vertical exaggeration (VE) for each plot is either 5x or 10x. The scale on the x-axis (elevation) is five times the y-axis scale (distance) on plots with a vertical exaggeration of five (VE = 5). Likewise, the x-axis scale on plots with VE = 10 is ten times that of the y-axis scale. In addition to vertical exaggeration, a value for horizontal scale (110 meters/inch) is provided. This allows the reader to make measurements directly from the plots.