

Redwood Creek Estuary Monitoring 2002 Annual Progress Report

David G. Anderson
Redwood National and State Parks

Introduction

This annual report summarizes Redwood National and State Parks (RNSP) Fish and Wildlife Branch monitoring activities in the Redwood Creek estuary for the calendar year 2002. Monitoring has occurred in the Redwood Creek estuary since 1980. The purpose of the monitoring is to determine fish utilization of the estuary, monitor estuary water quality and water and sand berm elevations, and document breaching incidents. This report serves as the annual report for RNSP Division of Resource Management and Science and the U.S. Army Corps of Engineers (Corps). The annual report fulfills special condition seven of Corps permit No. 21881N. The permit authorizes breaching the mouth of Redwood Creek. The eight special conditions of the permit are addressed in this report. A copy of the Corps permit is in Appendix I. The permit ended on December 31, 2002.

Location

Redwood Creek estuary is located 2.5 miles west of Orick, California at the mouth of Redwood Creek at the Pacific Ocean (Figure 1). Redwood Creek is 108 km long and the basin is 720 km² in area. The U.S. Army Corps of Engineers constructed 3.4 miles of flood control levees in 1968 on lower Redwood Creek, which bisect and terminate in the estuary. The estuary consists of the north and south sloughs, and the embayment. The south slough was the last meander of the river bypassed by the south levee.

Methods

Fish Monitoring

Population Estimates - The Peterson mark and recapture method (Youngs and Robson 1978) was used to estimate numbers of juvenile salmonid fish in the Redwood Creek embayment. Fish were seined with a 150-foot long, 15-foot wide, ¼ inch mesh beach seine net deployed off the bow of a 16-foot motor boat. A blue dye mark was applied to the upper, middle, or lower caudal fin or anal fin of captured fish using a Panjet needleless injector and Alcian Blue dye. Captured fish were marked the first two days, allowed to mix the third day, and seined on the fourth day to determine the ratio of marked to unmarked fish. Population and 95 percent confidence interval (95% CI) estimates are rounded off to the nearest 10. Four population estimates were conducted during the summer/fall 2002.

Growth Estimates - Fish fork lengths (mm) were measured, to the nearest 1-mm, from 200 each of chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*), and weight (g) measurements were taken from 30 juveniles of each species. Two electronic balances were used, a 200 g ± 0.01g capacity balance for smaller fish, and a 5,000 g ± 2g capacity for larger fish. All other salmonid species, coastal cutthroat trout (*O. clarki*) and coho salmon (*O. kisutch*), though not as numerous as chinook or steelhead, were measured and weighed. Seven growth estimates were conducted in 2002, four in conjunction with the population estimates, and three single day estimates between or after the population estimates.

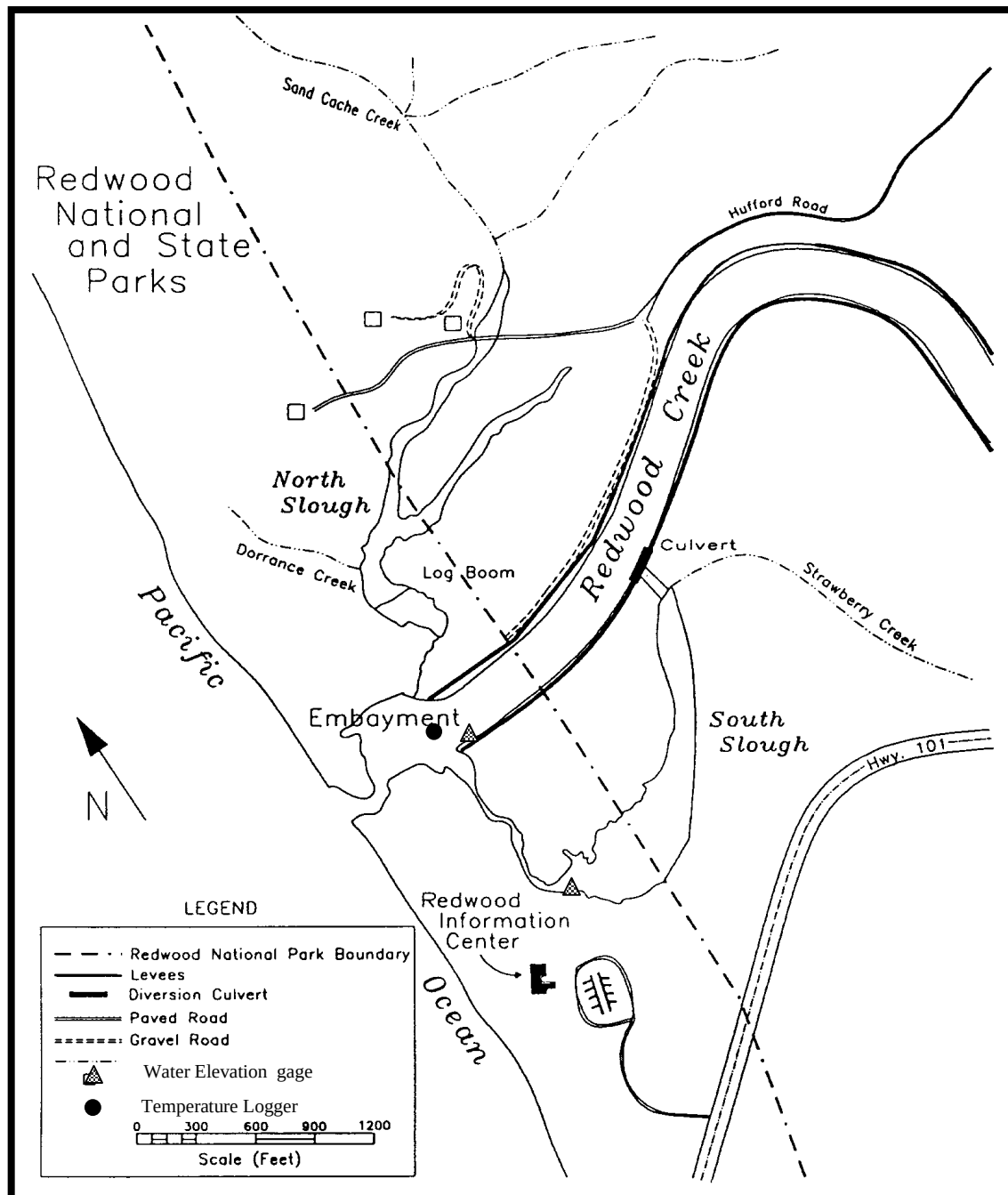


Figure 1. Map of the Redwood Creek Estuary, Humboldt County, California, including the embayment, north and south sloughs, and location of water elevation gages and temperature logger.

Condition Factor- Condition factor, a measure of fish ‘fatness’ was calculated for salmonid species measured and weighed. Because of the wide range of fish lengths, condition factor (K') was calculated as: $K' = (100 \times \text{Weight}_{(g)}) / \text{Fork Length}_{(cm)}^b$ (Begenal and Tesch 1978). Slope (b) was calculated as: $\log_{10} \text{Weight}_{(g)} = \log_{10} a + b \log_{10} \text{Fork Length}_{(cm)}$.

Water Quality Monitoring

Water Temperature - Water temperature (°C) was measured in the Redwood Creek embayment. An Onset TIDBIT™ temperature logger was located in the middle of the Redwood Creek channel between the ends of the north and south flood control levees at one foot from the bottom (Figure 1). It recorded water temperature once every hour. Temperature monitoring is special condition # 8 of the Corps permit.

Tide and Stream Flow Data

Tide Data: Calendar year 2002 tidal fluctuation at the mouth of Redwood Creek was compiled using Crescent City Harbor, California calculated data from tides software. It was corrected for the locality of the mouth of Redwood Creek [$\text{CC tide} \times 0.98$] and transformed to feet Mean Sea Level (MSL) [$\text{tide} - 3.65 = \text{ft MSL}$].

Stream Flow Data: Hourly Redwood Creek flow data at Orick for calendar year 2002 was downloaded from the California Department of Water Resources, Division of Flood Management website (<http://cdec.water.ca.gov>). Water Resources has not yet reviewed the preliminary flow data for accuracy and it is subject to change. The Orick gaging station (ORK) is located on Redwood Creek downstream of the confluence of Prairie Creek just north of Orick. Maintaining daily records of water flows in Redwood Creek is special condition # 3 of the Corps permit.

Estuary Water Levels

South slough water elevations (feet MSL) were recorded at 30-minute intervals by a continuous recording gage using a pressure transducer and ENMOS logger. The gage site is located at the end of the Redwood Information Center boardwalk trail (Figure 1). A seasonal gage site was installed at the end of the south levee to measure the water elevation in the estuary embayment. The south levee gage, a Global Water WL-14 Water Level Logger, measured embayment water levels every 12-minutes. Water elevation monitoring is special condition #3 of the Corps permit.

Estuary Cross Sections

As a special condition #6 of the Corps permit, five permanent cross-sections in the main embayment of the estuary perpendicular to the flow were surveyed. Established in 1998, the northside cross section endpoints are buried 8 ft t-bar fence posts, or bolts cemented into partially buried sea stacks located at the base of the hill. The permanent endpoints are surveyed and referenced to a BLM benchmark located at the park boundary fence separating the pasture from the parking area adjacent to the north levee. Each cross section was shot at a bearing of 170° using a Sokkisha Set 4 or Nikon Total Station. A wetsuited diver with rod and prism took points in the embayment at breaks in slope. Transects were measured to at least 11ft MSL in elevation.

Sand Berm Elevation Monitoring

Special condition #4 of the Corps permit specified a survey of sand berm elevations parallel to the shore, along the highest ridge of the sand dunes, once per month from May to September. The survey extended from a minimum of 100 feet north of the estuary to 100 feet south of the Redwood Information Center (RIC), approximately 3,000 ft in length. Surveys were conducted with a Sokkisha Set 4 or Nikon Total Station and rod with prism. Measurements were taken at breaks in slope along the sand berm. Survey elevations were referenced in the south to *Melch 3*, a permanent NOAA benchmark located west of RIC, to the end of the RIC west boardwalk, and in the north to the BLM benchmark, and the western most estuary cross-section endpoint, RM2 (of E-5), a double monumented sea stack.

Corophium Monitoring

Special condition #8 of the Corps permit specified *Corophium* abundance be documented prior to and one week after a planned breaching event. No diver transects were conducted in 2002 as the mouth breached naturally.

Other Activities

Adipose Clipped Pit-tagged Coho Salmon and Cutthroat Trout

Humboldt State University California Cooperative Fishery Research Unit graduate students have pit-tagged and adipose clipped coho salmon juveniles in Prairie Creek and coastal cutthroat trout in Boyes, Streelaw, and Prairie Creek. No adipose clipped pit-tagged fish were captured in the estuary by RNSP monitoring activities in 2002.

Student Science Fair Project

Kathy Kelsey, an Arcata High School student, measured water quality (temperature, salinity, and dissolved oxygen) over a 24-hr period in the south slough and embayment between July 2001 and February 2002 as part of a science fair project at different tidal cycles and mouth configurations. Her report is attached (Appendix VIII).

Results

Fish Monitoring

Presence – During the summer and fall of 2002, four salmonid species were seined in the Redwood Creek embayment; chinook and coho salmon, and steelhead and coastal cutthroat trout. Eight other fish species were captured. One amphibian, 39 bird, one mammal, and one invertebrate were observed. A complete list of all fish and other species captured or observed in and adjacent to the Redwood Creek estuary is presented in Table 1. No tidewater gobies (*Eucyclogobius newberryi*) were found in the estuary (Anderson 2002).

Population Estimates – Four population estimates were conducted in the embayment the summer of 2002 during the weeks of June 10, July 15, August 12, and September 9, 2002 (Table 2). The mouth closed after the June 10 estimate and remained closed during the last three estimates. The number of fish marked, marked recaptures, total individuals captured in the second sample, and fins marked are listed in Appendix II.

Table 1. List of salmonid and non-salmonid fish seined, birds, amphibians, mammals, and invertebrates observed at and adjacent to the Redwood Creek estuary, Redwood National and State Parks, Humboldt County, California during summer/fall 2002 fish sampling. (X denotes presence.)

Species	2002 Date (*Week of)						
	June 10*	June 27	July 15*	Aug 12*	Aug 29	Sept 9*	Oct 1
Salmonid Fish							
Coastal Cutthroat Trout	X	X	X	X	X	X	X
Steelhead Trout	X	X	X	X	X	X	X
Chinook Salmon	X	X	X	X	X	X	X
Coho Salmon	X	X	X	X	X		
Non-Salmonid Fish							
Three Spine Stickleback	X		X	X	X	X	X
Staghorn Sculpin	X	X	X	X	X	X	X
Prickly Sculpin	X						X
Coast Range Sculpin					X		
Sucker			X			X	X
Starry Flounder			X	X	X	X	X
Nightfish (smelt)		X					
Lingcod juvenile	X						
Amphibians							
Redlegged Frog			X			X	
Birds							
Brown Pelican	X		X	X	X	X	X
Great Blue Heron			X		X		
Great Egret					X	X	X
Double Crested Cormorant				X	X	X	
Turkey Vulture	X	X	X	X	X	X	X
Osprey	X	X	X	X	X	X	X
Kestrel						X	X
Northern Harrier					X		
Coopers Hawk				X			
Sharp Shinned Hawk						X	
Red Shouldered Hawk					X	X	
Peregrine Falcon						X	
Bald Eagle		X		X			
Least Sandpiper				X		X	
Western Sandpiper				X	X	X	
Killdeer			X	X		X	X
Sanderling				X	X	X	
Dowitcher						X	
Longbilled Curlew					X		
Gulls (Western, Heerman, California, Mew, and Ringbilled)	X		X	X	X	X	X
Caspian Tern	X	X	X	X	X	X	
Violet Green Swallow	X	X	X	X		X	
Barn Swallow	X	X	X	X	X	X	
Belted Kingfisher			X		X	X	X

Species (Con't.)	2002 Date (Week of *)						
	June 10*	June 27	July 15*	Aug 12*	Aug 29	Sept 9*	Oct 1
Piliated Woodpecker			X				
American Goldfinch	X		X				
Wrentit			X		X	X	
Bushtit				X			
Bandtailed Pigeon			X				
Corvids (Crows and Ravens)	X		X	X	X	X	
Canada Geese	X				X		
Oyster Catcher	X						
Merganser	X	X	X		X	X	X
Mallard				X		X	
Mammals							
River Otter			X	X			
Invertebrates							
Jelly Fish	X						

Chinook Salmon - The first juvenile chinook salmon estimate, the week of June 10, was 18,710 (95% Confidence Interval [CI] 12,500 to 24,900). On July 16, the population had increased to 27,460 (95% CI 22,080 to 32,850). On August 12, the population had decreased to 2,520 (95% CI 1,490 to 3,550). By the last chinook estimate, the week of September 9, the chinook population had further decreased to 1,370 (95% CI 550 to 2,200).

Coho Salmon – A total of 45 coho salmon juveniles were captured during the 2002 sample season. Only one population estimate, 180 fish (95% CI 30 – 520), was possible, the week of June 10. It corresponded to 30 coho caught that week. No other population estimates were possible as no marked fish were recaptured. Four coho were captured the week of July 15, seven the week of August 12, and none the week of September 9. Though not part of the population estimates, during the growth estimates, two coho was captured on June 27, and two on August 29. None were captured October 1.

Steelhead Trout - The initial juvenile steelhead trout estimate the week of June 10 was unsuccessful. No marked fish were recaptured and a total of 297 steelhead were captured. On July 15, the population was 13,420 (95% CI 9,720 to 17,110). On August 12, the estimated population decreased to 3,380 (95% CI 2,790 to 3,960). By the last steelhead estimate on September 10, the estimated population decreased again to 2,640 (95% CI 1,930 to 3,340).

Cutthroat Trout - No cutthroat trout population estimates were possible for the four population estimates as no marked fish were recaptured. The total count of fish captured in population estimates was 101; 3, 38, and 33, and 27 for the population estimate weeks of June 10, July 15, August 15, and September 9, respectively. An additional 53 cutthroat trout were caught during the three one day growth estimates.

Table 2. Population estimates and 95 percent confidence intervals for juvenile chinook and coho salmon, juvenile steelhead trout, and coastal cutthroat trout seined in the Redwood Creek estuary embayment, Humboldt County, California, summer 2002. Mouth of creek denotes if Redwood Creek mouth was open or closed to the Pacific Ocean during the estimate.

2002 DATE	Mouth of Creek (Open or Closed)	Chinook Salmon		Coho Salmon	
		Population Estimate	95% Confidence Interval	Population Estimate	95% Confidence Interval
06/10, 11, 13	OPEN	18,710	12,500 – 24,900	180	30 ^b - 520
07/15, 16, 18	CLOSED	27,460	22,080 – 32,850	4 ^a	---
08/12, 13, 15	CLOSED	2,520	1,490 – 3,550	7 ^a	---
09/ 09, 10, 12	CLOSED	1,370	550 – 2,200	0 ^a	---
		Steelhead Trout		Cutthroat Trout	
06/10, 11, 13	OPEN	297 ^a	---	3 ^a	---
07/15, 16, 18	CLOSED	13,420	9,720 – 17,110	38 ^a	---
08/12, 13, 15	CLOSED	3,380	2,790 – 3,960	33 ^a	---
09/ 09, 10, 12	CLOSED	2,640	1,930 – 3,340	27 ^a	---
a. Actual count of fish captured in seine net hauls. No marked fish were recaptured.					
b. Actual minimum count, calculated 95% lower confidence interval was below what was actually caught					

Growth Estimates – Seven growth estimates were conducted, four in conjunction with population estimates during the weeks of June 10, July 15, August 12, and September 9, and three one day growth estimates on June 27, August 29, and October 1 (Table 3). The last growth estimate on October 1 was 36 days before the estuary breached on November 6. A total of 2,723 salmonids were measured and 614 of those weighed.

Chinook – From a sample of 1,126 chinook, mean fork length increased from 64 to 91 mm, an increase of 27 mm, between the June and October sample dates (113 days) (Table 3 and Figure 2). Minimum and maximum fork lengths ranged from 46 to 85 mm on June 10 and increased to 73 to 148 mm by October 1, a summer/fall range of 46 to 148 mm. Mean weight increased from 2.7 to 9.5 grams (g), a 6.8g increase. Minimum and maximum weights ranged from 1.3 to 35.3g, respectively for the season, and ranged from 1.3 to 6.0g on June 10 and 4.1 to 35.3g on October 1.

Coho - Of the 45 coho salmon measured, 30 (67%) were from the week of June 10. Mean fork length was 62 mm on that date, 61 mm for two fish on June 27, 83 mm for four fish on July 15 week, 72 mm for seven fish on August 12 week, and 81 mm for two fish on August 29. Minimum and maximum fork length ranged from 46 to 135 mm. Mean weight ranged between 3.1g and 8.6g.

Steelhead - Steelhead trout mean fork length increased from 68 to 116 mm between the week of June 10 and October 1, peaking at 120 mm on August 29. The large standard deviations represent several age classes present (Table 3 and Figure 3). Mean juvenile steelhead weight increased from 6.9 to 19.7g between the week of June 10 and October 1. Minimum and maximum weight ranged between 0.6g and 91.1g, respectively.

Cutthroat - Cutthroat trout mean fork length varied from 243mm on July 15 week to 312 mm on June 10 week. Seasonal minimum and maximum fork length was 173 mm and 410 mm, respectively. Mean weight varied from 195.4g on July 15 week to 340.7g on June 10 week. Seasonal cutthroat minimum and maximum weight was 50.1g and 838g, respectively.

Condition Factor (K') – Fish condition factors are presented in Table 4. Mean conditions factors for each species remained approximately the same throughout the season. Mean chinook K' ranged from 0.981 to 1.013, the average for all chinook was 1.002. Mean coho K' ranged from 0.743 to 0.889, the average for all coho was 0.791. Mean steelhead K' ranged from 0.893 to 0.997, and the average for all steelhead was 0.939. Mean cutthroat K' ranged from 0.490 to 0.552, the average for all cutthroat was 0.512.

Table 3. Mean fork length (mm), mean weight (g), standard deviation, range, and dates and numbers sampled of juvenile chinook and coho salmon, and steelhead and coastal cutthroat trout seined in the Redwood Creek estuary embayment, Humboldt County, California, during summer and fall of 2002 from June 10 to October 1, 2002. Mouth denotes if Redwood Creek mouth was open or closed to the ocean.

Growth - Redwood Creek Estuary – Summer/Fall 2002							
2002 DATE	MOUTH	FORK LENGTH (mm)			WEIGHT (g)		
		Mean (No. Measured)	Std. Dev	Range	Mean (No. Weighed)	Std. Dev.	Range
JUVENILE CHINOOK SALMON							
06/10	OPEN	64 (200)	7.7	46 – 85	2.7 (30)	1.1	1.3 – 6.0
06/27	CLOSED	73 (205)	7.0	56 – 89	4.2 (30)	1.2	2.4 – 6.7
07/15	CLOSED	77 (205)	5.9	58 – 94	5.1 (30)	1.2	2.5 – 8.6
08/12, 13	CLOSED	77 (205)	5.9	62 – 90	4.8 (30)	1.5	2.5 – 9.0
08/29	CLOSED	83 (42)	6.7	61 – 95	6.2 (30)	1.4	2.4 – 8.5
09/9, 10, 12	CLOSED	85 (205)	6.5	65 – 99	6.0 (30)	1.6	2.7 – 9.0
10/01	CLOSED	91 (64)	10.5	73 – 148	9.5 (31)	5.1	4.1 – 35.3
JUVENILE COHO SALMON							
6/10, 11, 13	OPEN	62 (30)	18.7	46 – 119	3.1 (30)	4.0	0.8 – 17.4
06/27	CLOSED	61 (2)	1.4	60 – 62	2.6 (2)	0.4	2.3 – 2.8
07/15, 18	CLOSED	83 (4)	34.5	64 – 135	8.6 (4)	10.7	3.0 – 24.6
08/12, 13, 15	CLOSED	72 (7)	11.4	54 – 93	4.9 (6)	1.8	3.8 – 8.6
08/29	CLOSED	81 (2)	2.1	79 – 82	5.1 (2)	0.1	5.0 – 5.1
09/9, 10, 12	CLOSED	(0)	---	---	---	---	---
10/01	CLOSED	(0)	---	---	---	---	---

Growth – Redwood Creek Estuary – Summer/Fall 2002 (con't.)							
2002 DATE	MOUTH	FORK LENGTH (mm)			WEIGHT (g)		
		Mean (No. Measured)	Std. Dev	Range	Mean (No. Weighed)	Std. Dev	Range
JUVENILE STEELHEAD TROUT							
06/10, 11	OPEN	68 (202)	22.2	42 - 140	4.6 (30)	6.9	0.6 - 31
06/27	CLOSED	70 (174)	21.4	48 – 127	3.1 (30)	4.1	0.9 – 19.6
07/15	CLOSED	85 (205)	30.5	53 – 197	10.6 (30)	12.5	1.5 – 40.7
08/12	CLOSED	76 (213)	18.0	52 – 182	8.1 (30)	11.3	1.8 – 52.4
08/29	CLOSED	120 (183)	41.6	60 – 222	19.2 (30)	15.9	2.5 – 68.5
09/9, 10	CLOSED	108 (284)	30.4	59 – 204	10.8 (30)	8.2	2.2 – 28.9
10/01	CLOSED	116 (133)	36.2	68 – 217	19.7 (30)	20.5	3.8 – 91.1
CUTTHROAT TROUT							
06/10, 11, 13	OPEN	312 (3)	5.9	305 – 316	340.7 (3)	21.4	316 - 354
06/27	CLOSED	296 (8)	54.3	205 – 355	352.5 (8)	179.8	86 - 556
07/15, 16, 18	CLOSED	243 (38)	55.6	177 – 402	195.4 (38)	182.0	51.5 - 772
08/12, 13, 15	CLOSED	252 (33)	44.2	173 – 384	200.7 (33)	144.9	50.1 - 768
08/29	CLOSED	267 (31)	51.3	199 – 410	246.3 (26)	192.4	80.7 - 838
09/9, 10, 12	CLOSED	275 (31)	46.3	215 - 384	284.0 (27)	179.2	102.0 - 730
10/01	CLOSED	271 (14)	48.8	205 – 382	252.3 (14)	170.4	94.0 - 698

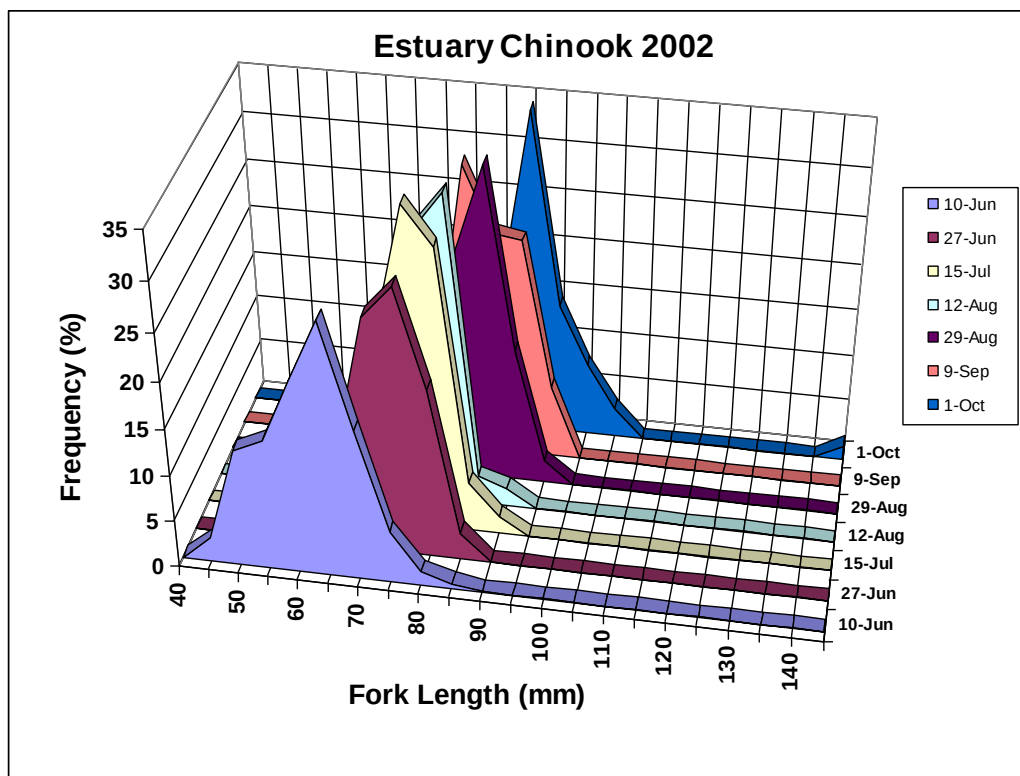


Figure 2. Fork length (mm) versus frequency (%) histogram of Redwood Creek Estuary juvenile chinook sampled between June 10 and October 1, 2002. The fork length classes are 5-mm increments.

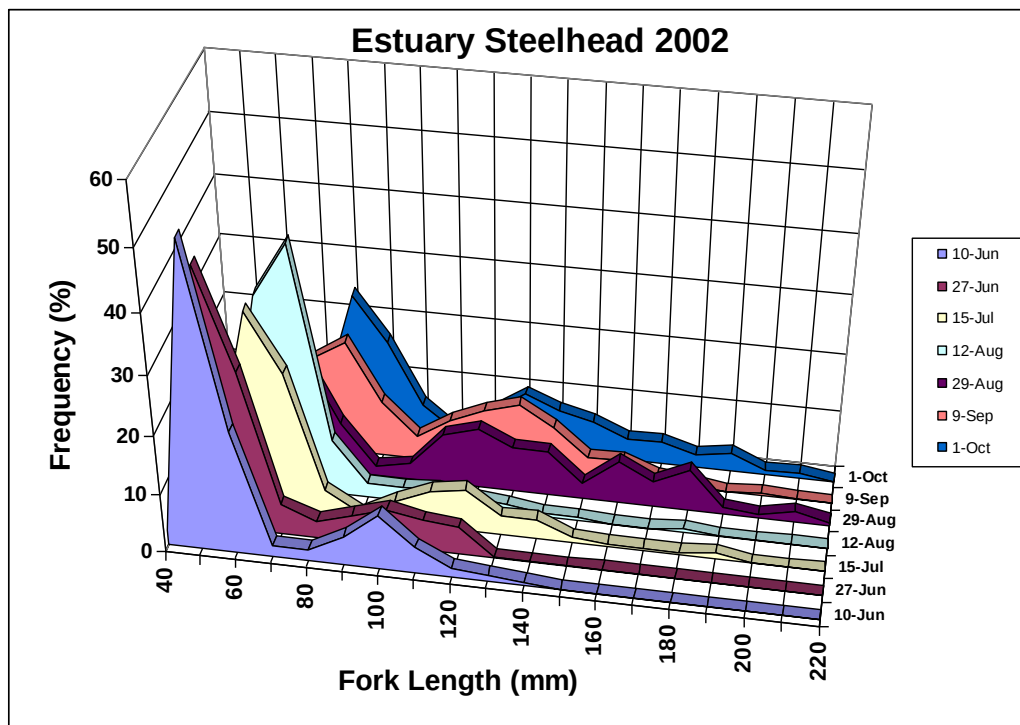


Figure 3. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile steelhead trout sampled between June 10 and October 1, 2002. The fork length classes are 10-mm increments.

Table 4. Mean condition factor (K') of captured salmonids measured (mm) and weighed (g) from the Redwood Creek embayment, Humboldt County, California, during the summer and fall of 2002. Condition factor is calculated as: $K' = 100W_{(g)}/FKL_{(cm)}^b$. Slope (b) was calculated as: $\log_{10} \text{Weight}_{(g)} = \log_{10} a + b \log_{10} \text{Fork Length}_{(cm)}$.

Condition Factor (K') - Redwood Creek Estuary 2002							
Date (week of)	6/10/2002	6/27/2002	7/15/2002	8/12/2002	8/29/2002	9/9/2002	10/1/2002
Chinook Salmon (b = 3.019)							
Mean	0.981	1.011	1.010	1.013	0.978	1.013	1.005
Count	30	30	30	30	30	30	31
Standard Deviation	0.094	0.074	0.088	0.174	0.078	0.069	0.095
Minimum	0.801	0.905	0.904	0.488	0.814	0.907	0.767
Maximum	1.214	1.257	1.338	1.500	1.165	1.160	1.185
Steelhead Trout (b = 3.062)							
Mean	0.893	0.893	0.997	0.949	0.946	0.941	0.951
Count	30	30	30	30	30	30	30
Standard Deviation	0.138	0.101	0.260	0.111	0.069	0.072	0.068
Minimum	0.666	0.680	0.680	0.698	0.841	0.748	0.822
Maximum	1.227	1.126	2.154	1.237	1.094	1.055	1.080
Cutthroat Trout (b = 3.241)							
Mean	0.490	0.540	0.518	0.510	0.506	0.552	0.508
Count	3	8	38	33	26	27	14
Standard Deviation	0.007	0.030	0.032	0.030	0.038	0.245	0.026
Minimum	0.485	0.482	0.452	0.447	0.437	0.420	0.465
Maximum	0.498	0.576	0.596	0.575	0.584	1.765	0.563
Coho Salmon (b = 3.127)							
Mean	0.765	0.889	0.837	0.875	0.743	--	--
Count	30	2	4	6	2	--	--
Standard Deviation	0.161	0.059	0.101	0.048	0.051	--	--
Minimum	0.503	0.847	0.718	0.805	0.707	--	--
Maximum	1.168	0.931	0.963	0.938	0.779	--	--

Water Quality Monitoring

Water Temperature - Water temperature (°C) was the only water quality parameter monitored in the Redwood Creek estuary in summer/fall 2002. The TidBit temperature logger recorded water temperature every 1-hour from June 13 through October 1, 2002 (Figure 4). The maximum and minimum water temperatures were 19.96°C (on July 10) and 13.5°C (on October 1), respectively. The average water temperature for the period of was 17.4 °C. Maximum weekly average temperature (MWAT) was 18.7°C, and the seven-day maximum average temperature (7-Day MAT) was 19.6°C. The maximum and minimum daily diurnal range were 3.0°C and 0.3°C, respectively. Percentile temperature exceedence is shown in Figure 4, the 50 percentile at 17.5°C.

Tide and Stream Flow

Tides at the Mouth of Redwood Creek - The maximum and minimum calculated tide at the mouth was 4.8ft MSL and – 5.6ft MSL, respectively, a range of 10.4 feet. Tidal data is included in Figure 5.

Stream Flow - Calendar year 2002 stream flow data, January 1 through December 31, is presented in Appendix III. The maximum flow was 23,100 cfs on December 28, 2002. Redwood Creek flow increased from about 1000 cfs to 23,000 cfs in a half day on December 27. This flow value has a return interval of 2 years, not very large in the long-term record (MaryAnn Madej, personal communication). The ORK gage measured a minimum flow of 53 cfs during the summer, but was unable to measure lower flows between June 25 to November 8 and November 14 through December 11, 2002 as discharge was below the rating table. The flow data is provisional and subject to revision.

Estuary Water Level

South Slough and South Levee/Embayment Water Level Gaging - Two gages, one in the south slough and another at the end of the south levee, recorded Redwood Creek estuary water levels. South slough water elevations (feet MSL) were recorded for the period January 1 to December 31, 2002, excluding February 12 through 25 (Figures 5 and 6). The temporary south levee gage, located at the end of the south levee, was installed on June 26 and removed on December 12 (Figure 6). Data recorded between October 7 and 14 was overwritten.

The embayment gage site could measure lower water elevations (to – 0.5 ft MSL) than the gage in the south slough. Lower water levels in the south slough are limited by the invert of the south slough culvert gates and/or sand deposited in the south slough outlet channel. The culvert openings (invert) are lower than the south slough channel thalweg.

Estuary Closure - The estuary water elevation began to rise in May, the mouth to the south, and the outlet channel lengthening and shortening. In May and June the mouth was observed being one-half and two-thirds the distance to RIC, and in front of RIC. Based on the graph (Figure 6), berm closure occurred on June 23 at 6.81ft MSL. Water flowed in the outlet channel, but not enough to reach the ocean, the water percolating into the sand. The estuary water level peaked at 8.47ft MSL on July 1. It slowly declined 4.8 feet because of water seepage through the berm (Figure 7) and evaporation to its lowest closed level of 3.65ft MSL on Oct 13, 104 days later.

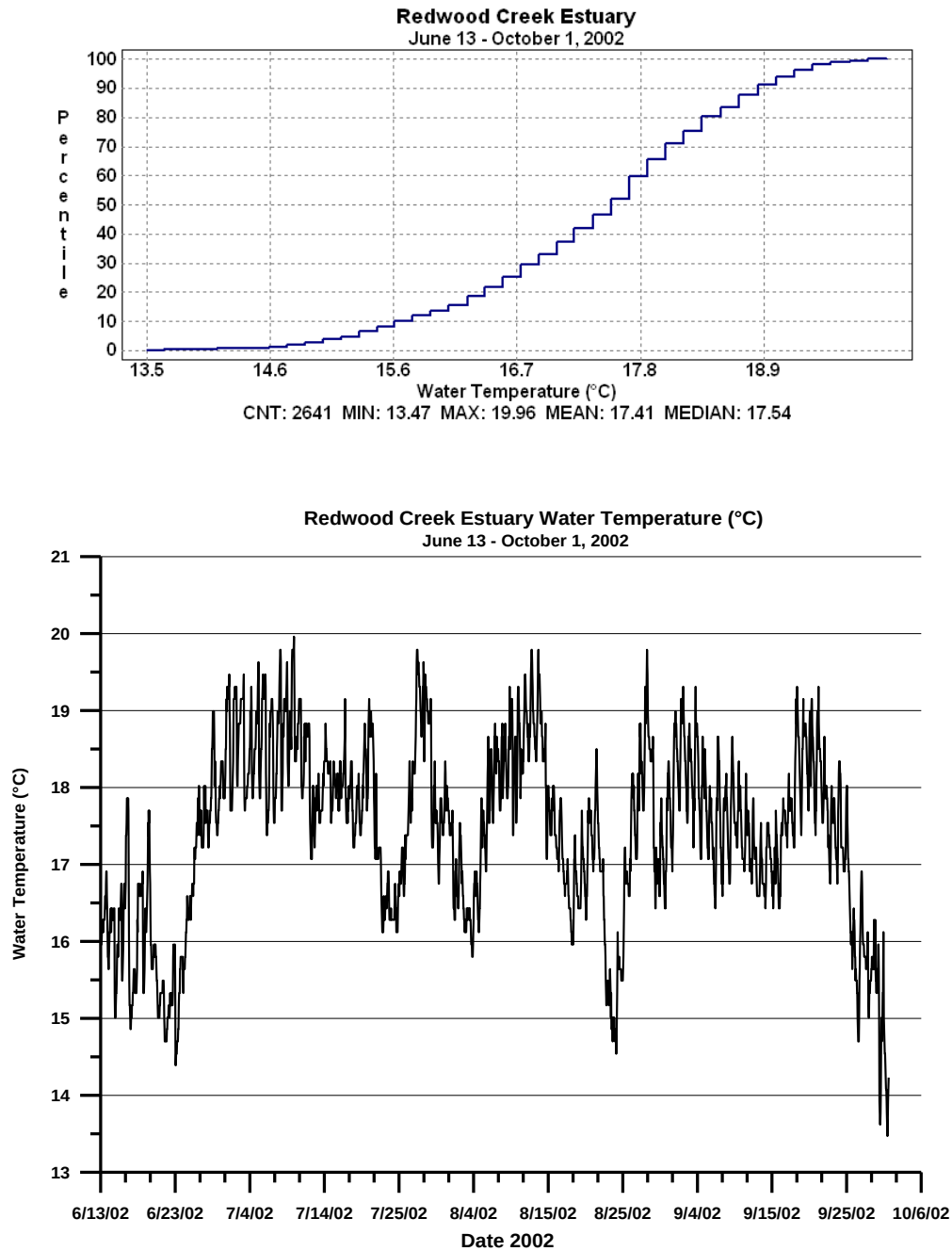


Figure 4. Percentile of water temperature exceeded or equaled temperature value in the Redwood Creek estuary embayment. Redwood Creek estuary water temperatures (°C) measured by an Onset Tidbit temperature logger located in the embayment between the ends of the north and south flood control levees. The temperature logger, located one foot from the bottom, recorded water temperature every 1-hour from June 13 through October 1, 2002.

2002 South Slough Water Level Record 01/01/02 - 12/31/02

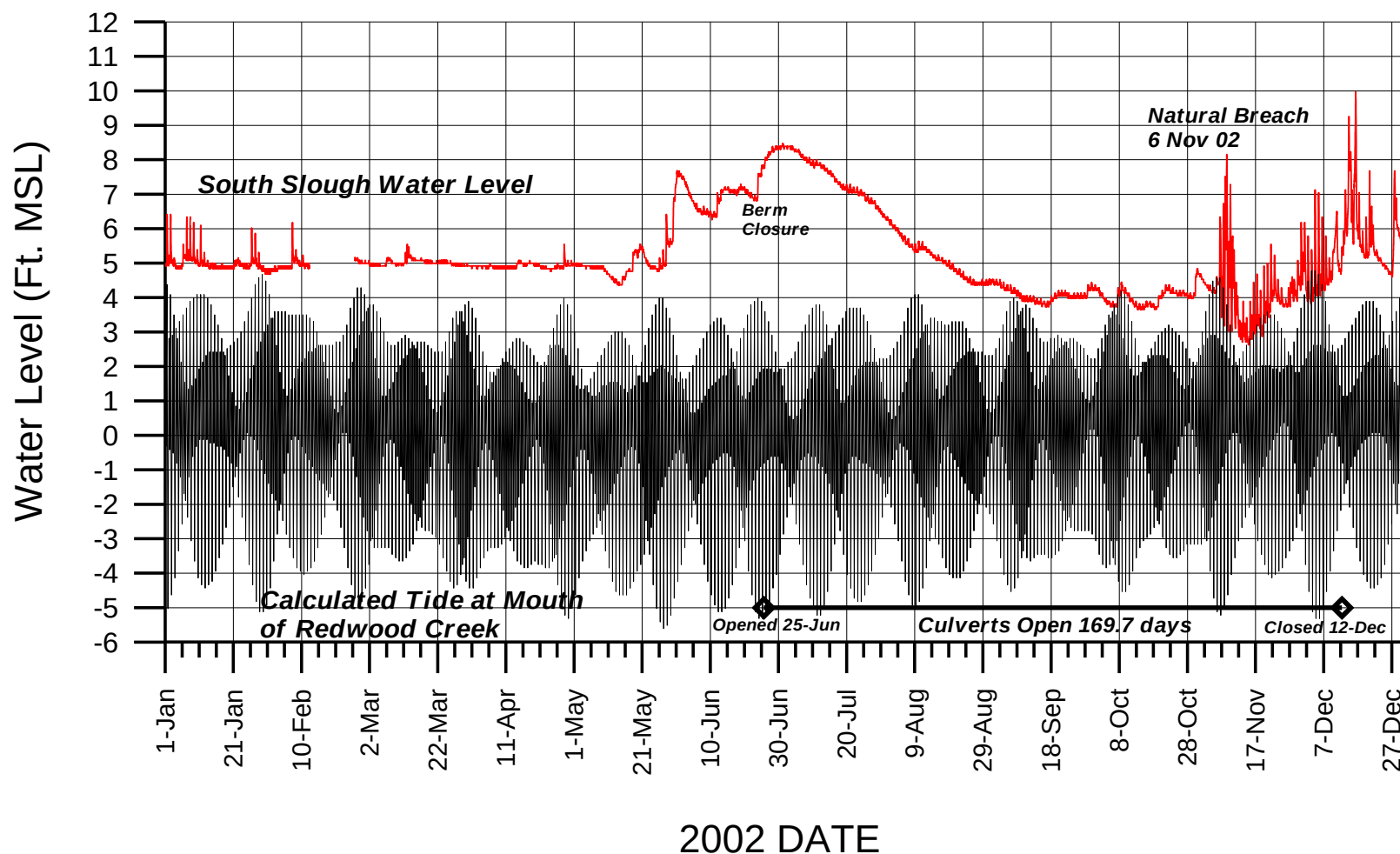


Figure 5. South Slough water elevations (feet Mean Sea Level [MSL]) of the Redwood Creek estuary, Humboldt County, for the period January 1 to December 3, 2002, excluding February 12 through 26. Estimated ocean tidal elevations are corrected for the coastal locality at the mouth of Redwood Creek and adjusted to feet MSL.

2002 South Slough/SouthLevee Water Level Record

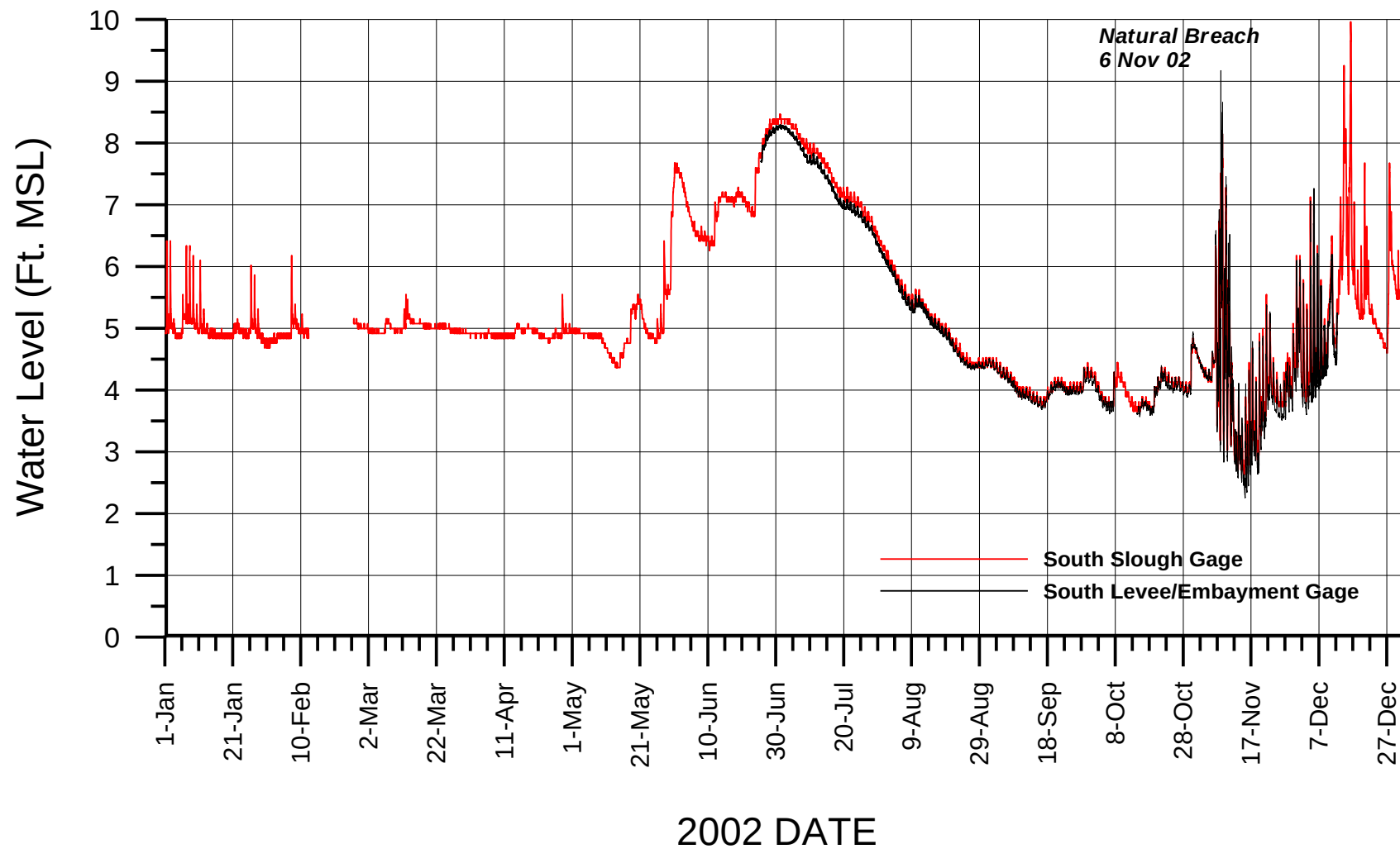


Figure 6. Water level elevations (ft. Mean Sea Level [MSL]) recorded in the south slough and end of the south levee of the embayment, Redwood Creek estuary, Humboldt County, California for calendar year 2002.



Figure 7. Water flow through the sand berm. Headcutting of the sand berm on the ocean side of the Redwood Creek berm at minus tide on June 27, 2002. Water flowed through the berm to erode sand where water emerged. (Photo by Frank Kemp-RNSP).

This was a decrease of 1,615,960 ft³ (59,850 yd³) in embayment water volume (area east of the berm to the ends of the levees), from 2,701,080 ft³ to 1,085,120 ft³. The estuary remained closed till November 6 providing 135.8 days of increased volume (compared to an open mouth) to salmonid fish rearing in the embayment and south slough.

Breaching and Estuary Response

November 6, 2002 Breach – The estuary breached naturally on November 6 as a result of wave overwash accentuated by a very high tide. It did not breach as a result of a rain event filling up the embayment. Waves washing over the berm at high tide raised the water level and overtopped the berm. Seas were reported at 20 feet high that day and the estuary water level rose from 4.45ft at 10:12 am to 6.52ft MSL at 2:24 p.m before breaching. The high high tide on November 6 was 4.6 ft MSL [8.2ft MLLW (Mean Lower Low Water)] at 11:48 am. Flow at the Orick gaging station was reported as reading below the rating table. The mouth of Redwood Creek was observed open on November 7, the channel about 10 ft wide and located north by the rocks. The Redwood Creek streambed above Prairie Creek was dry. Estuary water levels went through a series of tidally influenced swings between 3.0 and 6.9ft MSL on November 7, peaking at 8.15ft MSL on November 8 at 2:pm. That corresponded to the high high tide of 3.8ft MSL [7.4ft MLLW] at 1:17 p.m. (The south levee gage peaked at 9.17 ft MSL at 2:36pm, a possible reading influenced by large waves propagating into the embayment). After several tidal cycles the water level eventually bottomed out at 2.25 ft MSL on November 15 at 6:12 am (tide at 1.1ft MSL [4.8ft MLLW] at 6 am) before increasing the rest of the year.

The highest estuary water elevation recorded in 2002 was 9.96 ft MSL on December 16 at 9:40 am. The Redwood Creek flow gage at Orick was not recording the entire day, but flow was at least 11,100 cfs (at 3pm) that day. The high high tide was 3.4 ft MSL [7.1ft MLLW] at 8:51 am.

Illegal Breaching – On Monday morning, July 15, we found a shovel-dug trench through the berm, an attempted illegal breaching of the estuary, on the north end of the berm by the rocks. It appeared water had flowed through the trench but must have stopped when tidal waves partially filled the trench with sand. We filled in the trench by pushing the sidecast sand into it. We also found the remains of another trench that had been filled in with sand from wave overwash. Someone or multiple persons had spend considerable time and effort to attempt an illegal breach. RNSP law enforcement rangers and other park personnel were informed and asked to watch the area and stop anyone who tried to open the mouth. The Eureka Corps office was also informed.

South Slough Culvert Gates

The culvert gates are opened to increase circulation between the south slough and the embayment after the last storms of spring. The three south slough culvert gates were opened on June 25, 2002 and closed on December 12, 2002 to prevent sedimentation in the south slough from large storm events. The gates were open for 169.5 days (Figure 5). However, the gates were not completely closed. No connection between the south slough channel and the embayment was observed on February 23, 2003. The culverts were checked, and water was flowing out through the gates into Redwood Creek. On February 25, the gates were “cinched down” another half-inch or so, the flow stopped, and water started to flow from the south slough via the channel to the embayment.

Estuary Cross Sections

Starting at the ends of the levees with E-1 and ending to the west with E-5 at the sea stack adjacent to the berm, the five permanent parallel cross-sections (perpendicular to flow) in the embayment were surveyed on June 17 (cross section E-1), September 24 (cross sections E-2, E-3, and E-4) and September 30, 2002 (cross section E-5). The surveys extended south through the embayment to the sand dunes. They are surveyed annually as specified by the Corps permit. Estuary cross sections, 1998 through 2002, are presented in Appendix IV. The lowest bottom elevation (i.e. deepest point MSL) at E-1 was -2.34ft MSL, at E-2 -3.39ft MSL, at E-3 -2.0ft MSL, at E-4 -2.47ft MSL, and at E-5 +7.00ft MSL. Cross section E-5 was the sand berm at the closed mouth. Based on the cross sectional data, at its greatest closed water elevation of 8.47ft MSL, at the deepest point surveyed, the water depth was 11.9ft. At its lowest closed water elevation of 3.65 ft MSL, at the deepest point surveyed, the water depth was 7ft.

The 2002 net change (scour or fill) compared to surveyed 2001 cross sections were as follows: E-1 -415.7 ft², E-2 -248.7 ft², E-3 -81.2 ft², E-4 -1,078.5 ft², and E-5 +6,429.8 ft². The change in each cross section thalweg location compared to 2001 was less than 1 ft, except for E-5, which was 7 ft.

Also calculated for the embayment (excluding the north and south sloughs and the area of the embayment/channel upstream of the ends of the levees) was embayment volume (ft³) and wetted width for the cross sections for varying water elevations (Appendix V and Table 6). The calculated embayment volume ranged from 1,939 ft³ at -3 ft MSL to 4,101,465 ft³ at 11 ft MSL.

Table 6. Calculated 1998, 1999, 2000, 2001, and 2002 water volume (ft³) of the Redwood Creek embayment at water elevations of 11 to -4 ft MSL. The embayment is the area west of the ends of the north and south levee to the berm and not including the north or south sloughs. (Compiled from Anderson 1998, 1999, 2000, and 2001)

Water Elevation (ft MSL)	1998 Volume (ft3)	1999 Volume (ft3)	2000 Volume (ft3)	2001 Volume (ft3)	2002 Volume (ft3)
11	10,441,569	3,872,874	4,177,581	3,993,996	4,101,465
10	4,976,663	3,809,759	3,496,947	3,227,290	3,478,444
9	4,216,846	3,059,301	2,917,624	2,586,978	2,945,105
8	3,491,578	2,450,967	2,580,270	2,091,913	2,484,680
7	2,843,996	1,981,568	2,139,865	1,713,288	2,116,909
6	2,320,103	1,617,018	1,754,518	1,388,538	1,784,138
5	1,886,777	1,296,799	1,408,439	1,094,115	1,471,633
4	1,495,882	1,014,197	1,097,161	827,395	1,179,381
3	1,134,128	760,089	819,706	592,615	910,060
2	798,888	527,405	572,810	394,905	658,224
1	464,790	332,726	362,282	231,135	426,413
0	226,903	171,681	182,379	98,823	234,313
-1	53,794	63,343	57,126	20,454	114,795
-2		22,052	13,012	7,012	32,459
-3		5,733	540	2,254	1,939
-4				90	

Sand Berm Elevation Monitoring

A longitudinal profile along the highest ridge of the sand berm parallel to the ocean shore separating the estuary from the ocean was surveyed during the summer and fall of 2002. The surveys were required once a month, May through September. Surveys were conducted on May 21 (Profile 1), June 17 (Profile 2), July 31 (Profile 3), August 28 (Profile 4), and September 30 (Profile 5). Due to an equipment malfunction on June 17, Profile 2 was not totally usable. The profiles are presented in Appendix VI. Both the winter storm berm, denoted as the high berm, and summer swell berm, denoted as the low berm, were surveyed when present. Because of the depth of the channel and flow, it was not always possible to wade into and survey the channel bottom. The mouth was completely closed to the ocean at the July 31, August 28, and September 30, 2002 surveys.

On May 21 (Profile 1), the mouth was open and a long 'low berm' was present. The outlet channel between the embayment and ocean was 1,376 feet long. The elevation difference between the embayment and mouth water surface was 6.4 ft. On June 17 (Profile 2), the channel was approximately 1,600 ft long and the elevation difference between the embayment and mouth water surface was 5.8 ft. On July 31 (Profile 3), the mouth was closed. The lowest elevation of the low berm was 9.36 ft MSL. The lowest berm depression represents the height at which the estuary would naturally breach on its own, meaning the estuary would have to rise 3.2 ft from 6.17 ft MSL before breaching. On August 28 (Profile 4), the mouth was closed and the lowest elevation of the low berm was 8.37 ft MSL. The water would have to rise 3.9 ft from 4.51 ft MSL to breach the berm. On the last survey, September 30 (Profile 5) the mouth was still closed, but most of the low berm had washed away. Its lowest elevation was 7.27 ft MSL, the embayment water surface elevation at 4.29 ft MSL, meaning the estuary would have to rise 3 ft to breach.

The survey points plotted on 1: 6000 aerial photos for the four useable surveys are presented in Appendix VII.

Other Activities/Events

North Slough Channel

A storm in October/November swept driftwood from the north shore of the embayment and deposited it into the north slough channel. It accumulated in one large dam like structure. Sand was deposited in the dry channel and the eastern bank of the north slough channel eroded back leaving the Hidden Beach gate and supports hanging in the air (Figure 8). Water flow (from Sand Cache Creek) was blocked by the elevated channel bottom and driftwood. Water backed up in the adjacent fields until someone opened the channel on December 19, 2002 (McKinleyville Press 2002).

The Army Corps of Engineers permit application from Thomas McNamara and Joseph Hufford, adjacent landowners for excavation of a channel in the north slough outlet channel was not pursued to completion. Instead a letter authorizing the removal of only woody debris which blocks the drainage of the north slough/Sand Cache Creek was issued by the Corps on May 1, 2002 (Figure 9).



Figure 8. North slough outlet channel on November 12, 2002 following estuary breaching and waves from high seas propagating into the estuary. Top: Bank erosion and Hidden Beach gate hanging in air. Bottom: Accumulation of woody debris swept by large waves from the beach and creek up into the north slough channel. Note there is no flow in the outlet channel.



DEPARTMENT OF THE ARMY
SAN FRANCISCO DISTRICT, CORPS OF ENGINEERS
333 MARKET STREET
SAN FRANCISCO, CALIFORNIA 94105-2197

MAY 1 2002

Regulatory Branch

SUBJECT: File Number 26172N

Mr. Thomas McNamara
P.O. Box 217
Orick, California 95555

Dear Mr. McNamara:

Thank you for your application of May 22, 2001 concerning a Department of the Army authorization for plans to excavate a channel approximately 16 feet top width, 4 feet bottom width, and 4 feet deep, to restore historic water levels in Sand Cache Creek Estuary. This channel work was proposed for a location in Sand Cache Creek near the Town of Orick, in Section 32, T11N-R1E, Humboldt County, California, as depicted on the attached map *Sand Cache Creek Project Location*, dated 4/11/02.

Based upon further discussions and our on-site visit on December 12, 2001 with you and staff from the National Park Service, we understand that the purpose of the project itself is to remove the woody debris which blocks drainage of Sand Cache Creek. We have determined that a Department of the Army authorization will not be required to simply remove the woody debris by dragging it with a chain or winch, or lifting it out with a boom-truck type equipment since the above activity will not involve the discharge of dredged or fill material into a water of the United States, including adjacent wetlands, pursuant to Section 404 of the Clean Water Act (33 U.S.C. 1344). Please note that this differs from the applied for channel excavation project, which would require a Department of the Army permit.

This determination will expire in five years from the date of this letter unless new information warrants revision of the determination before the expiration date. Also, a change to your project could also change this determination.

This determination does not obviate the need to obtain other Federal, State or local approvals required by law, including compliance with the Endangered Species Act (16 U.S.C. 1531 et seq.).

-2-

If you have any questions, please call Kelley Reid of our Regulatory Branch at telephone 707-443-0855. All correspondence should reference the file number at the head of this letter.

Sincerely,

Calvin C. Fong
Chief, Regulatory Branch

Enclosure

Copy Furnished:

CA CC, Eureka, CA
✓ Redwood National and State Parks, Orick, CA (Attn: T. Hofstra)
US EPA, San Francisco, CA

Figure 9. May 2, 2002 U.S. Army Corps letter to Thomas McNamara authorizing removal of woody debris from the North Slough/Sand Cache outlet channel.

Setback Levees Modeling

A contract to model setback levee alternatives was awarded to Moffatt and Nichol Engineers of Walnut Creek, California by Humboldt County Public Works. Funding for the study came from the California Coastal Conservancy.

2002 Summary/Conclusions

- Mean lengths and weights of chinook and steelhead residing in the estuary increased during the summer indicating the estuary provided rearing habitat. Those fish that resided in the estuary during through the summer and migrated to the ocean in the fall (early November) were larger than those that emigrated prior to the closure of the mouth in late June. Their larger size would confer an increased chance of survival in the ocean (Reimers 1973). However, there were much fewer surviving chinook and steelhead in the estuary in the fall.
 - The mean length of chinook increased from 64 to 91 mm, an increase of 27 mm, between the week of June 10 and October 1 sample dates (113 days). Steelhead trout mean fork length increased from 68 to 116 mm, peaking on August 29 at 120 mm.
 - The chinook population decreased 95%, from 27,460 in July to 1,370 in September. The steelhead population decreased 80%, from 13,420 to 2,640.
- Very few coho salmon reared in the estuary. Seining the week of June 10 captured 30 coho at the end of the spring coho out-migration. Only 14 coho were captured later in the summer, and none in September or October. Of salmonids handled, coho represented 0.45% of the total. This is similar to past years (Anderson 1995).
- Water temperatures in the estuary were warm. Between June 13 and October 31, the maximum and minimum water temperatures were 19.96°C (on July 10) and 13.5°C (on October 1), respectively. The average water temperature for the period of was 17.4 °C. Maximum weekly average temperature (MWAT) was 18.7°C. The 50 percentile water temperature was 17.5°C.
- The estuary was for closed for 135.8 days. The mouth appeared to close on June 23, and the water level peaked at 8.47ft MSL on July 1. It slowly declined 4.8 feet to its lowest closed level of 3.65ft MSL on Oct 13, 104 days later. The estuary breached naturally on November 6 at a water elevation of 6.52ft MSL. Waves washing over the berm at high tide raised the water level and overtopped the berm. The highest estuary water elevation recorded in 2002 was 9.96ft MSL on December 16.
- On Monday morning, July 15, two shovel-dug trenches through the berm on the north end of the berm by the rocks were found. We pushed the sidecast sand into the trenches to fill them. Someone or multiple persons had spend considerable time and effort to attempt an illegal breach.
- Based on the cross sectional data, at its greatest closed water elevation of 8.47ft MSL, at the deepest point surveyed, the water depth was 11.9 ft. At its lowest closed water elevation of 3.65 ft MSL, at the deepest point surveyed, the water depth was 7 ft.

- Berm profile surveys determined the high berm (winter berm) did not change. The lower berm profile changed as the location of the mouth migrated south, closed, and later when the beach receded and part of the low berm disappeared.
- Chinook mean fork length of estuary and upper Redwood Creek basin downstream migrants are presented in Figure 10. Chinook in the estuary were larger than fish at the trap during the same period but estuary growth slowed before increasing. It then appears to follow the slope of the upper basin fish.

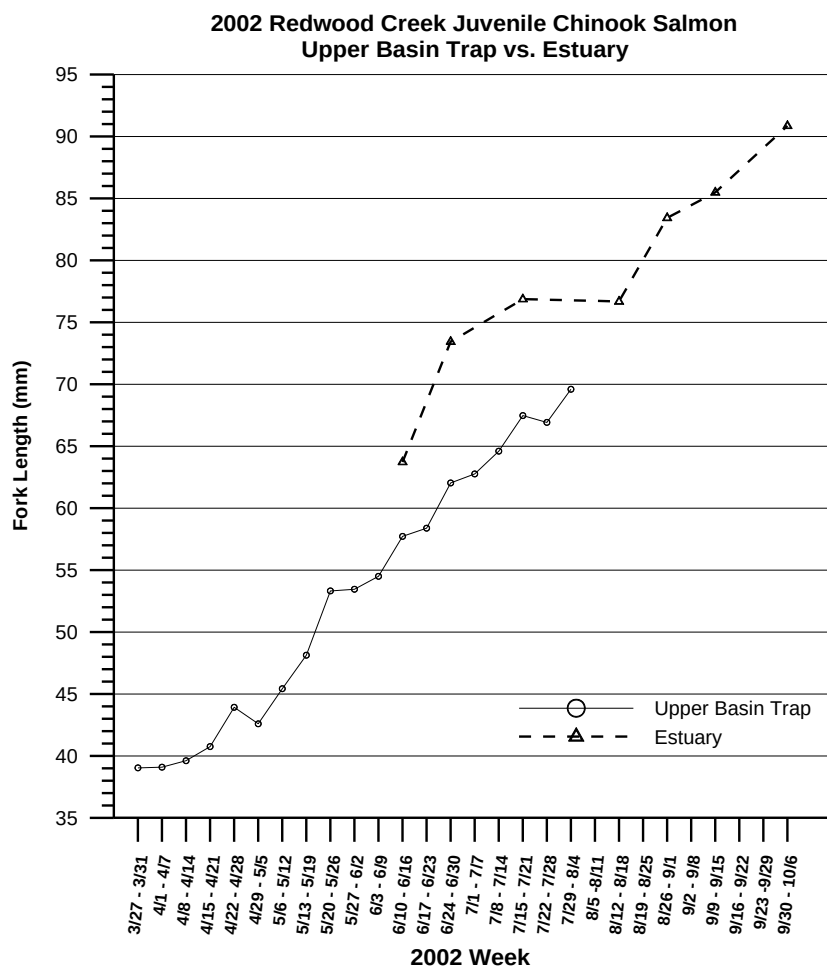


Figure 10. Mean fork length (mm) of chinook salmon sampled in spring/summer/fall 2002 in the Redwood Creek estuary and at the California Department of Fish and Game upper basin rotary screw trap in Redwood Valley. (Upper trap data from Mike Sparkman-CDFG-SRAMP).

References

- Anderson, D.G. 1995. Biological supplement to Redwood National and State Parks U.S. Army Corps of Engineers Application: Coho salmon utilization of the Redwood Creek estuary. Research and Resources Management Division, Redwood National and State Parks, Orick, California. 13 pp.
- Anderson, D.G. 1998. 1998 Redwood Creek Estuary annual monitoring report. Fish and Wildlife Branch, Redwood National and State Parks, Orick, California. 47pp.
- Anderson, D.G. 2000. 1999 Redwood Creek Estuary annual monitoring report. Fish and Wildlife Branch, Redwood National and State Parks, Orick, California. 44pp.
- Anderson, D.G. 2001. 2000 Redwood Creek Estuary annual monitoring report. Fish and Wildlife Branch, Redwood National and State Parks, Orick, California. 45pp.
- Anderson, D.G. 2002. 2001 Tidewater Goby annual report. Fish and Wildlife Branch, Redwood National and State Parks, Orick, California. 5pp.
- Bagenal, T.B. and F.W. Tesch. 1978. Age and Growth. Pp. 101-136. In: Methods of assessment of fish production in fresh waters. Third Edition. T. Bagenal (ed.) Blackwell Scientific Publications, London. 365 pp.
- Reimers, P.E. 1973. The length and residence of juvenile fall chinook salmon in Sixes River, Oregon. Research Reports of the Fish Commission of Oregon 4(2).
- McKinleyville Press. December 24, 2002. Page 9. Orick Log by Thelma Hufford.
- Youngs, W.D., and D.S. Robson. 1978. Estimation of population number and mortality rates. Pp. 137 - 164. In: Methods of assessment of fish production in fresh waters. Third Edition. T. Bagenal (ed.) Blackwell Scientific Publications, London. 365 pp.

Personal Communication

Dr. MaryAnn Madej, Research Scientist, U.S.G.S.- BRD, Arcata, California.
Mike Sparkman, Fishery Biologist, CDFG-Steelhead Research and Monitoring Program, Arcata, California.

*Prepared by: David G. Anderson – REDW Fishery Biologist
Redwood National and State Parks, P.O. Box 7, Orick, California. 95555
(707) 464-6101 x 5271 david_g_anderson@nps.gov
[09/2003]*

Appendix I. U.S. Army Corps of Engineers permit No. 21881N, effective until December 31, 2002. The permit authorizes the Redwood National and State Parks to breach the mouth of Redwood Creek and includes eight special conditions.

DEPARTMENT OF THE ARMY PERMIT

Permittee: **Redwood National and State Parks**

Permit No.: **21881N**

Issuing Office: **San Francisco District**

NOTE: The term "you" and its derivatives, as used in this permit, means the permittee or any future transferee. The term "this office" refers to the appropriate district or division office of the Corps of Engineers having jurisdiction over the permitted activity or the appropriate official of that office acting under the authority of the commanding officer.

You are authorized to perform work in accordance with the terms and conditions specified below.

Project Description: **Excavation of approximately 1,250 cubic yards of sand, at the mouth of Redwood Creek, a water of the United States, as described in the attached drawings entitled "Purpose: Breaching of Mouth of Redwood Creek", Sheets 1 and 2 of 4**

Project Location: **Redwood Creek Estuary, west of the community of Orick, Humboldt County, California**

Permit Conditions:

General Conditions:

1. The time limit for completing the work authorized ends on **December 31, 2002**. If you find that you need more time to complete the authorized activity, submit your request for a time extension to this office for consideration at least one month before the above date is reached.
2. You must maintain the activity authorized by this permit in good condition and in conformance with the terms and conditions of this permit. You are not relieved of this requirement if you abandon the permitted activity, although you may make a good faith transfer to a third party in compliance with General Condition 4 below. Should you wish to cease to maintain the authorized activity or should you desire to abandon it without a good faith transfer, you must obtain a modification of this permit from this office, which may require restoration of the area.
3. If you discover any previously unknown historic or archeological remains while accomplishing the activity authorized by this permit, you must immediately notify this office of what you have found. We will initiate the Federal and state coordination required to determine if the remains warrant a recovery effort or if the site is eligible for listing in the National Register of Historic Places.
4. If you sell the property associated with this permit, you must obtain the signature of the new owner in the space provided and forward a copy of the permit to this office to validate the transfer of this authorization.
5. If a conditioned water quality certification has been issued for your project, you must comply with the conditions specified in the certification as special conditions to this permit. For your convenience, a copy of the certification is attached if it contains such conditions.
6. You must allow representatives from this office to inspect the authorized activity at any time deemed necessary to ensure that it is being or has been accomplished in accordance with the terms and conditions of your permit.

Special Conditions:

1. **Before work commences, the permittee shall complete Section 7 consultation with the National Marine Fisheries Service. All relevant special conditions of the Biological Opinion shall become part of this permit. The**

ENG FORM 1721, Nov 86

1

(33 CFR 325 (Appendix A))

permittee shall notify the Corps of any conflicts between the biological opinion and this permit, and shall apply to the Corps for an amendment to resolve the conflicts.

2. The permittee shall not breach the mouth of Redwood Creek until the estuary waterlevel elevation has reached 8.0 feet National Geodetic Vertical Datum (NGVD).
3. The permittee shall maintain daily records of water elevation in Redwood Creek estuary (main embayment) and water flows in Redwood Creek.
4. The permittee shall survey sand berm elevations parallel to the shore, once per month from May to September, along the highest ridge of the sand dunes, from a minimum of 100 feet north of the estuary to 100 feet south of the information center. Surveys shall note the lowest elevation of the sand berm where breaching may occur and any changes in elevations from previous survey. Surveys shall map ridge line locations on an aerial plan of the estuary.
5. In the event of any type of breach, the permittee shall submit to the Corps the following information: estuary water elevation at time of breach, water flow in Redwood Creek at time of breach, last survey of sand berm elevations, indications of type of breach (man induced or natural) and tide height at time of breach.
6. The permittee shall survey, on a yearly basis, permanent cross-sections of the estuary perpendicular to flow, with a minimum of three cross-sections through the main embayment. Cross-sections shall be monumented to ensure subsequent remeasurement in the following years. The permittee shall submit cross sections to the Corps each year by December 31, with the first set of cross-sections due in 1998.
7. The permittee shall submit to the Corps, on a yearly basis, all information gathered, an analysis of the information, and a summary of the estuary response to any action or no action taken by the National Park Service during the year. Reports shall be due December 31.
8. In the event of a planned breach by the permittee, the permittee shall document *Corophium* abundance, by utilizing transects, prior to the breach and one week after the breaching event. The permittee shall also maintain temperature recordings on a continuous reading hobotemp until September 1 of the year in which breaching occurred.

Further Information:

1. Congressional Authorities: You have been authorized to undertake the activity described above pursuant to:
 - (X) Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403).
 - (X) Section 404 of the Clean Water Act (33 U.S.C. 1344).
2. Limits of this authorization.
 - a. This permit does not obviate the need to obtain other Federal, state, or local authorizations required by law.
 - b. This permit does not grant any property rights or exclusive privileges.
 - c. This permit does not authorize any injury to the property or rights of others.
 - d. This permit does not authorize interference with any existing or proposed Federal project.
3. Limits of Federal Liability. In issuing this permit, the Federal Government does not assume any liability for the following:
 - a. Damages to the permitted project or uses thereof as a result of other permitted or unpermitted activities or from natural causes.

- b. Damages to the permitted project or uses thereof as a result of current or future activities undertaken by or on behalf of the United States in the public interest.
 - c. Damages to persons, property, or to other permitted or unpermitted activities or structures caused by the activity authorized by this permit.
 - d. Design or construction deficiencies associated with the permitted work.
 - e. Damage claims associated with any future modification, suspension, or revocation of this permit.
4. **Reliance on Applicant's Data:** The determination of this office that issuance of this permit is not contrary to the public interest was made in reliance on the information you provided.
5. **Reevaluation of Permit Decision.** This office may reevaluate its decision on this permit at any time the circumstances warrant. Circumstances that could require a reevaluation include, but are not limited to, the following:
- a. You fail to comply with the terms and conditions of this permit.
 - b. The information provided by you in support of your permit application proves to have been false, incomplete, or inaccurate (See 4 above).
 - c. Significant new information surfaces which this office did not consider in reaching the original public interest decision.

Such a reevaluation may result in a determination that it is appropriate to use the suspension, modification, and revocation procedures contained in 33 CFR 325.7 or enforcement procedures such as those contained in 33 CFR 326.4 and 326.5. The referenced enforcement procedures provide for the issuance of an administrative order requiring you to comply with the terms and conditions of your permit and for the initiation of legal action where appropriate. You will be required to pay for any corrective measures ordered by this office, and if you fail to comply with such directive, this office may in certain situations (such as those specified in 33 CFR 209.170) accomplish the corrective measures by contract or otherwise and bill you for the cost.

6. **Extensions.** General condition 1 establishes a time limit for the completion of the activity authorized by this permit. Unless there are circumstances requiring either a prompt completion of the authorized activity or a reevaluation of the public interest decision, the Corps will normally give favorable consideration to a request for an extension of this time limit.

Your signature below, as permittee, indicates that you accept and agree to comply with the terms and conditions of this permit.

Andrew T. R-sold 1/13/98
(PERMITTEE) (DATE)

This permit becomes effective when the Federal official, designated to act for the Secretary of the Army, has signed below.

Richard G. Thompson 1-27-98
(DISTRICT ENGINEER) RICHARD G. THOMPSON (DATE)
LTC, EN

When the structures or work authorized by this permit are still in existence at the time the property is transferred, the terms and conditions of this permit will continue to be binding on the new owner(s) of the property. To validate the transfer of this permit and the associated liabilities associated with compliance with its terms and conditions, have the transferee sign and date below.

(TRANSFEREE) (DATE)

Appendix II. Number of salmonid fish marked, marked recaptures, and total individuals captured in the second sample from the RNSP Redwood Creek estuary mark and recapture population estimates during the summer of 2002. Fish fins, top, middle, and bottom caudal, anal, dorsal, and pelvic fins were marked with a Panjet needleless injector using Alcian Blue dye. Mark appearance ranged from a blue dot to a pigment streak along the fin rays. Formulas used to calculate estimated population estimate and its 95% Confidence Interval.

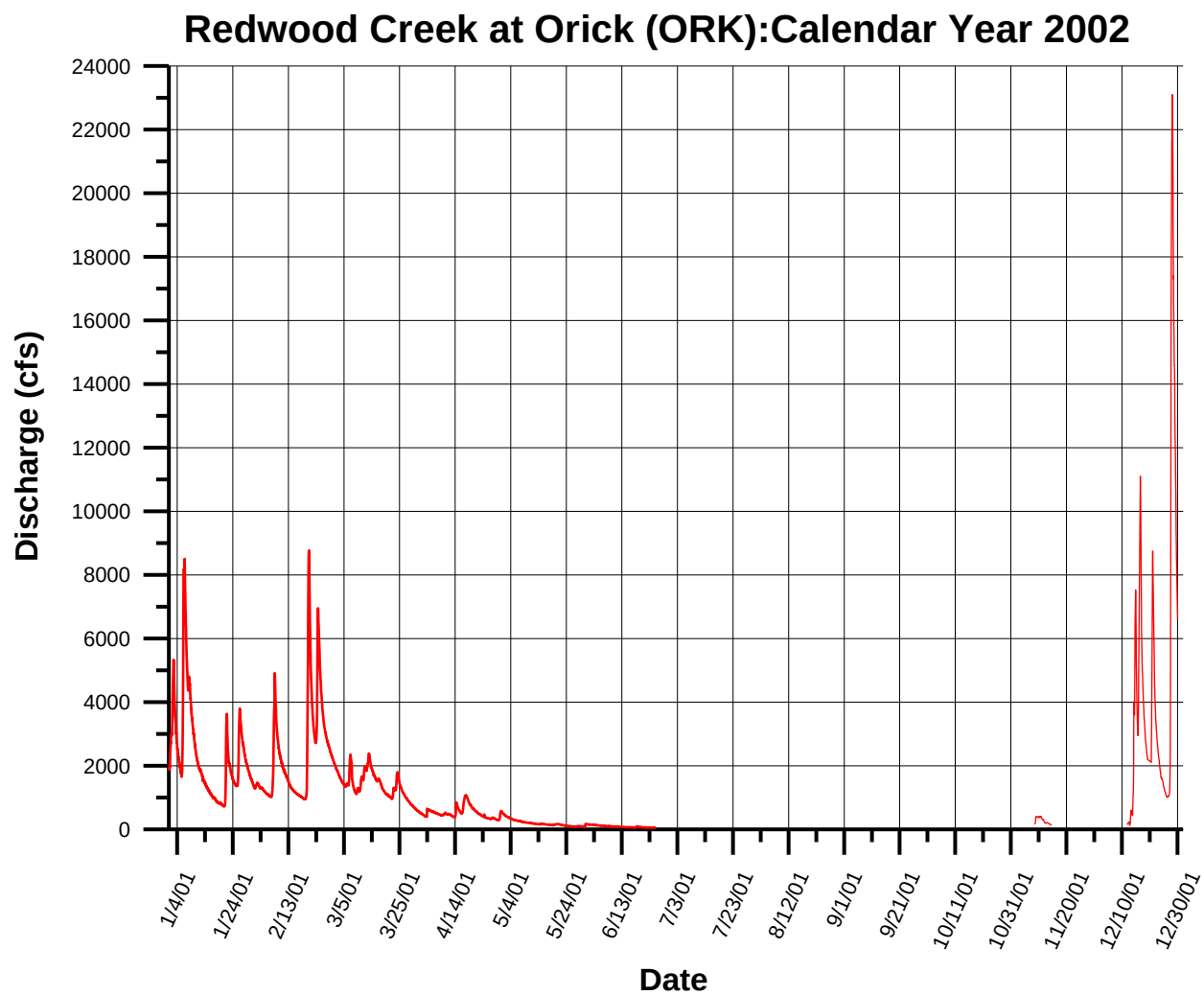
2002 Date	Number Marked Marks Recaptured Total Captured in Second Sample				Fin Marks
	Chinook	Coho	Steelhead	Cutthroat	
June 10 & 11	1,119	23	202	2	Top caudal – KS, SHD, Coho Left pelvic – CUT
June 13	32	1	0	0	
	535	8	93	1	
July 15 & 16	1,551	1	781	27	Bottom caudal –KS, SHD, Coho Dorsal – CUT
July 18	89	0	45	0	
	1,576	3	773	11	
Aug 12 & 13	275	6	581	18	Anal – All Fish
Aug 15	19	0	89	0	
	174	1	517	15	
Sept 9 & 10	133	0	343	9	Middle caudal – All Fish
Sept 12	9	0	41	0	
	93	0	315	18	

$$\text{Population Estimate (N)} = \frac{(\text{No. of fish marked}) \times (\text{total no. captured in second sample})}{(\text{No. of marked fish recaptured in second sample})}$$

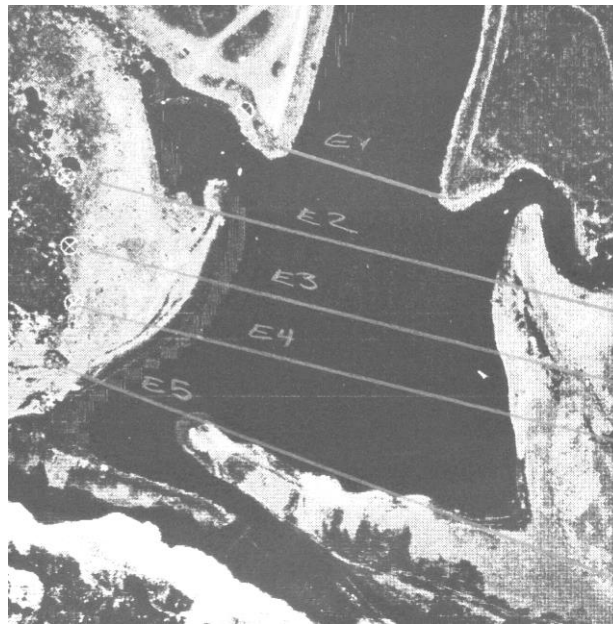
$$95\% \text{ CI} = \pm 1.96 \times \sqrt{\frac{(N^2) \times (N - \text{no. marked}) \times (N - \text{no. in second sample})}{(N - 1) (\text{no. marked}) \times (\text{no. in second sample})}}$$

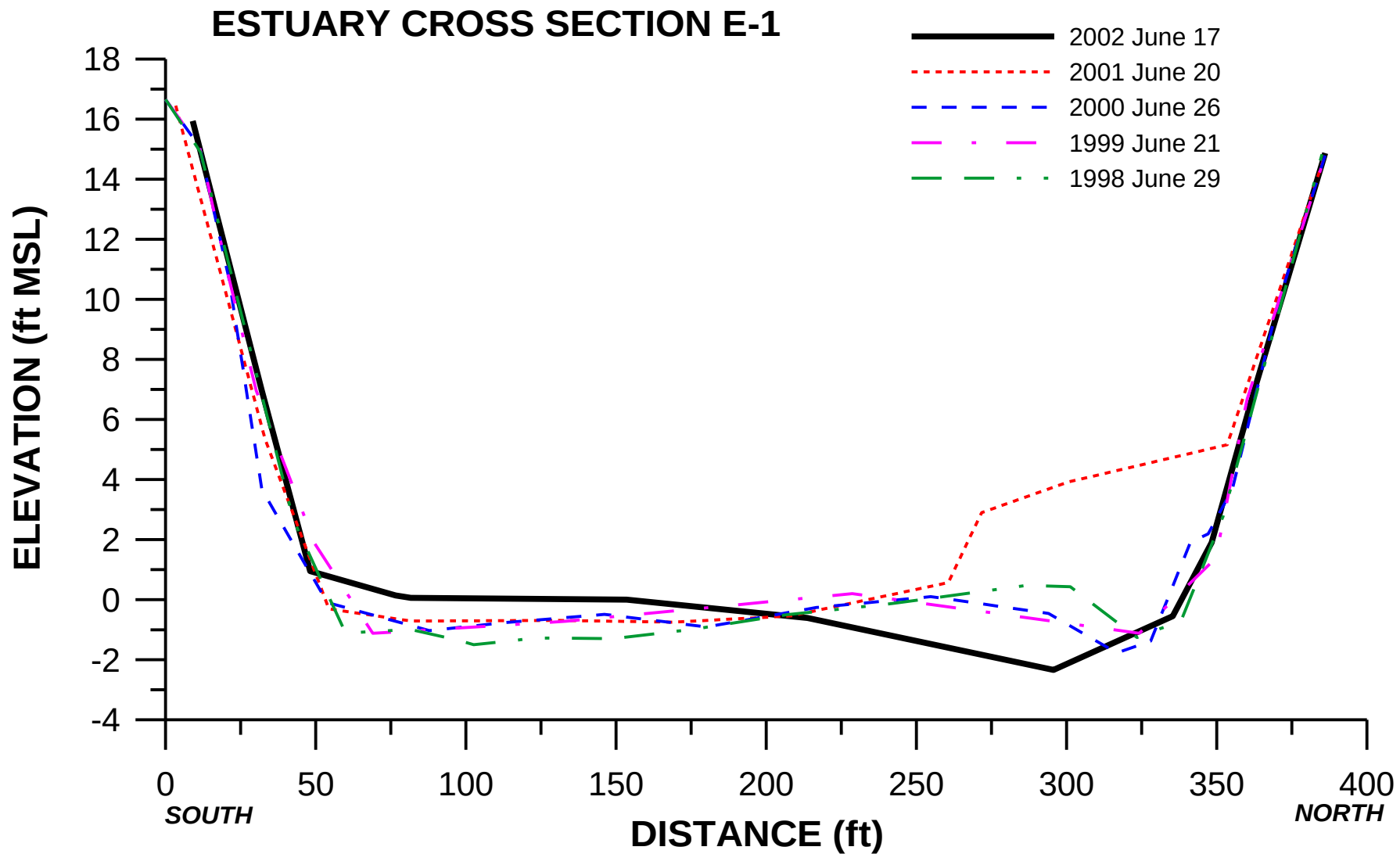
-

Appendix III. Hourly Redwood Creek flow (cfs) for calendar year 2002, January 1 through December 31, 2002. Data is from the California Department of Water Resources Orick (ORK) gaging station located on Redwood Creek downstream of the confluence of Prairie Creek north of Orick, California.

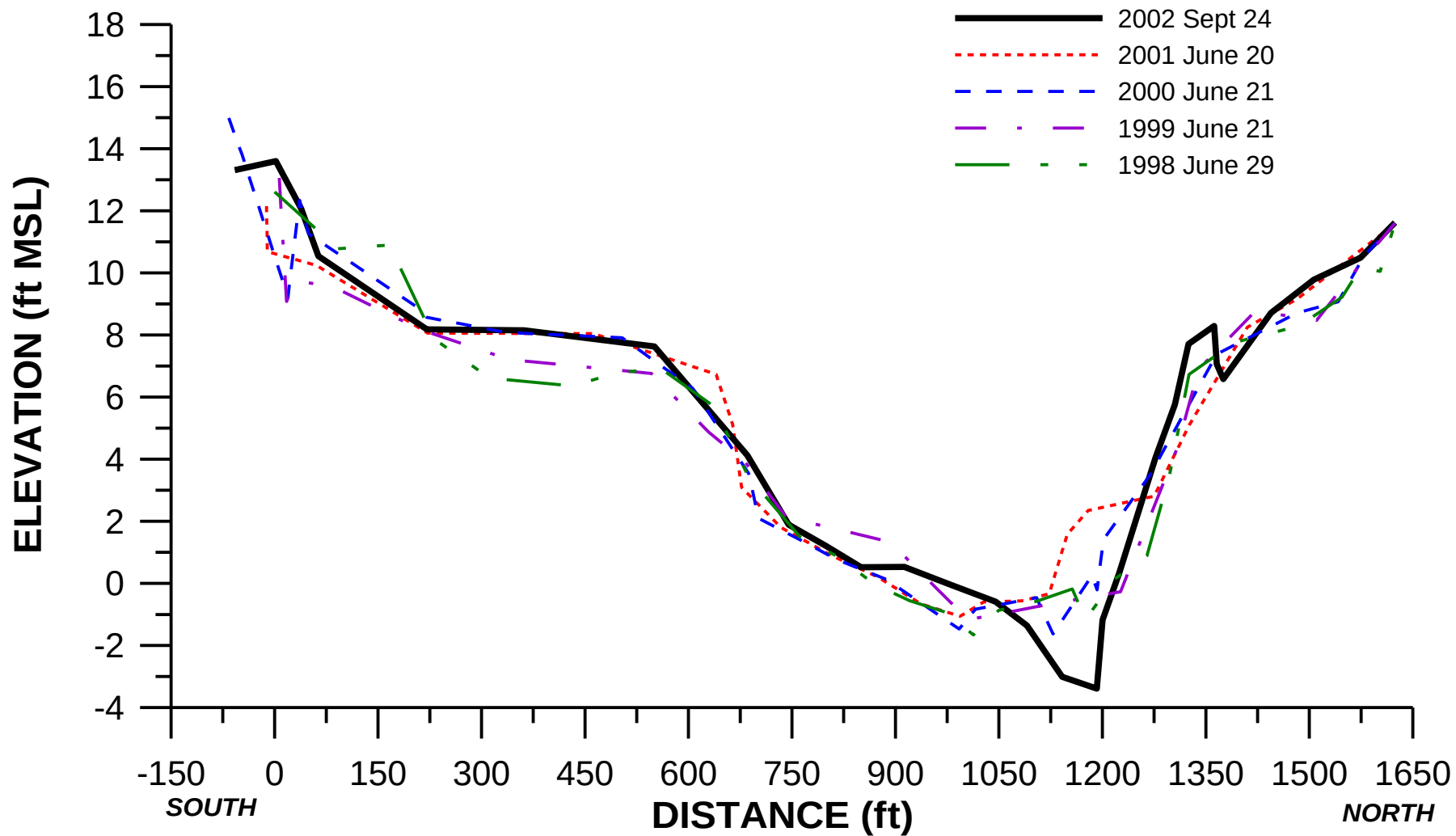


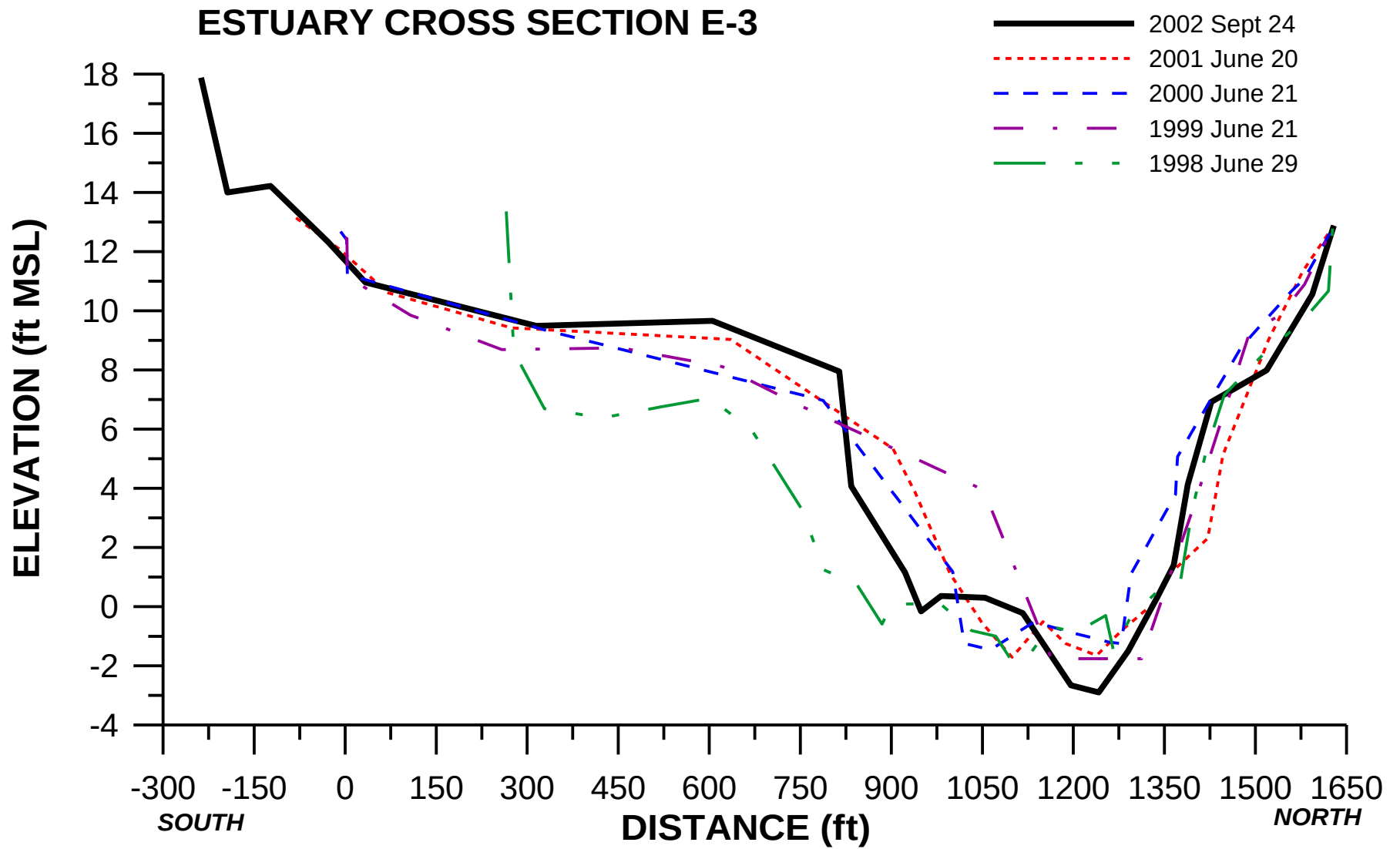
Appendix IV. The five permanent cross-sections surveyed on June 17 (cross section E-1), September 24 (cross sections E-2, E-3, and E-4) and September 30, 2002 (cross section E-5) in the Redwood Creek estuary embayment perpendicular to the flow. Established in June of 1998, each cross section was shot at a bearing of 170° from the north endpoints through the embayment to the sand dunes on the south. The parallel cross sections start between the ends of the levees with E-1 and end to the west with E-5 at the sea stack adjacent to the beach.



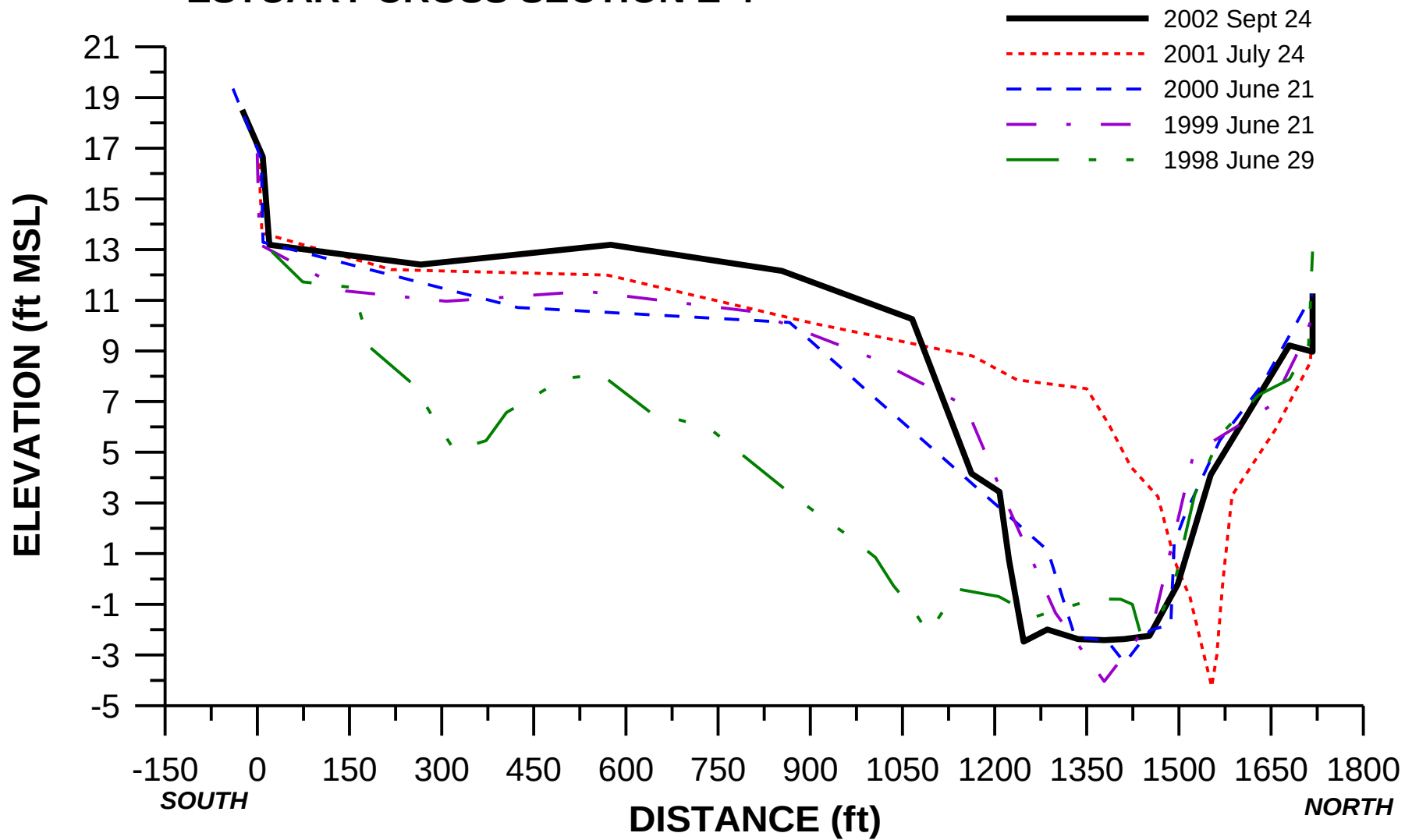


ESTUARY CROSS SECTION E-2

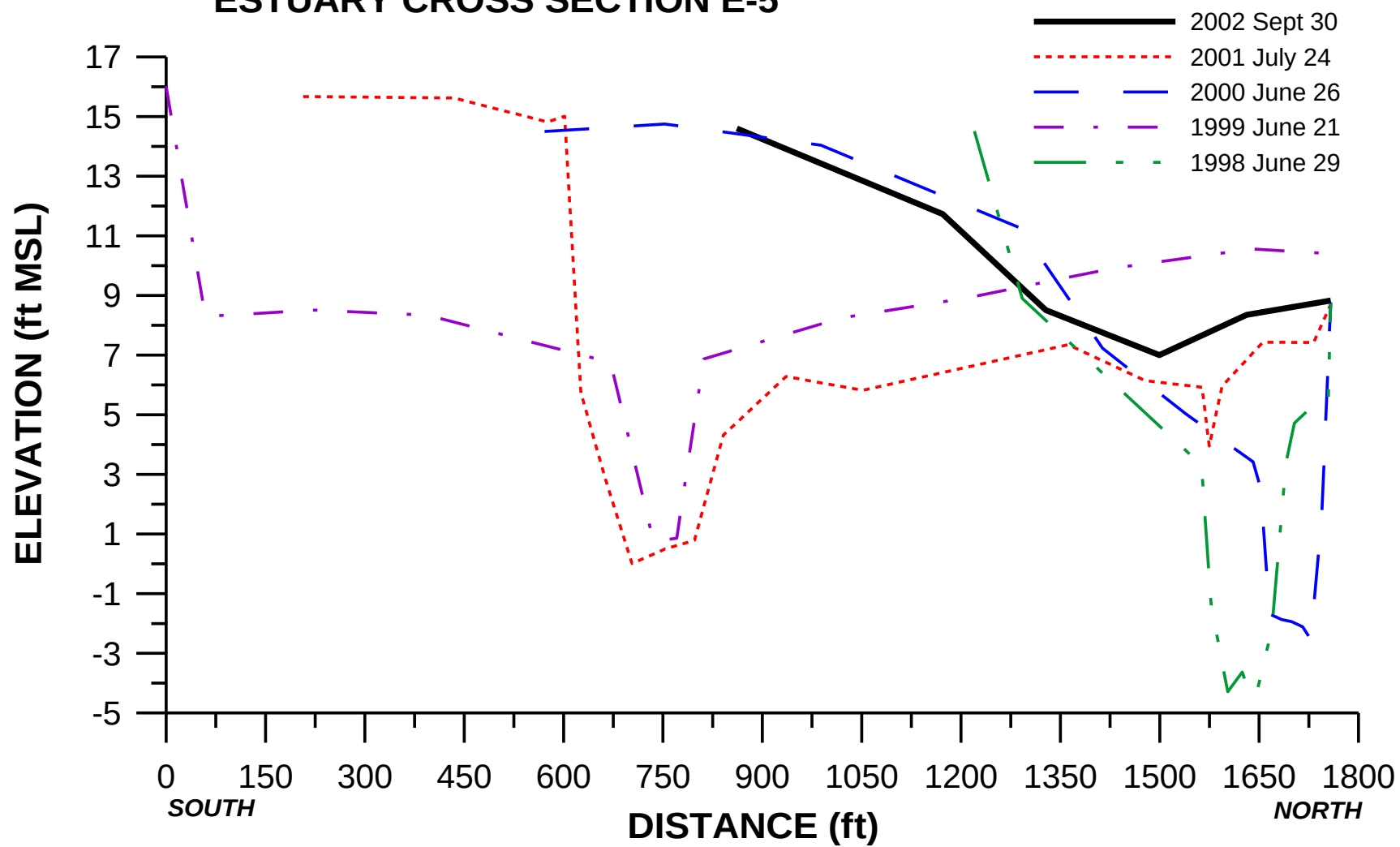




ESTUARY CROSS SECTION E-4



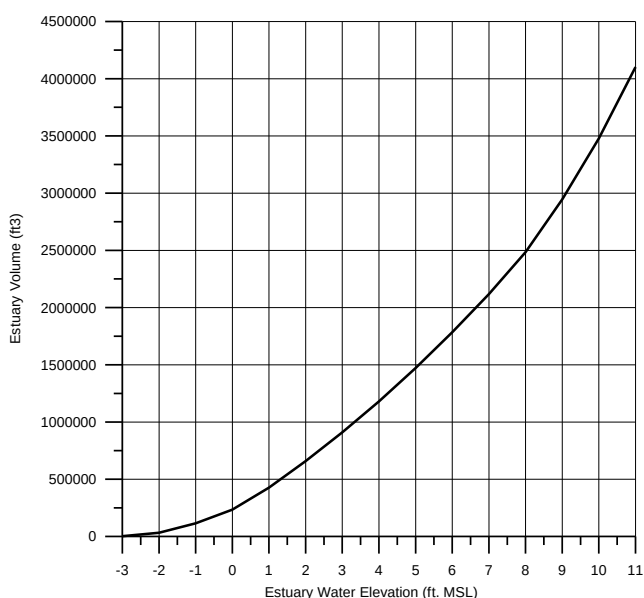
ESTUARY CROSS SECTION E-5



Appendix V. Calculated wet width (ft) and volume (ft³ and yd³) of the Redwood Creek embayment at water elevations of -3 to 11ft MSL based of the five cross sections E-1 through E-5 surveyed on June 17 (E-1), September 24 (E-2 through E-4) and July 24 (E-5). Volume of embayment is defined as the area west of the ends of the north and south levee and not including the north or south outlet channels or sloughs.

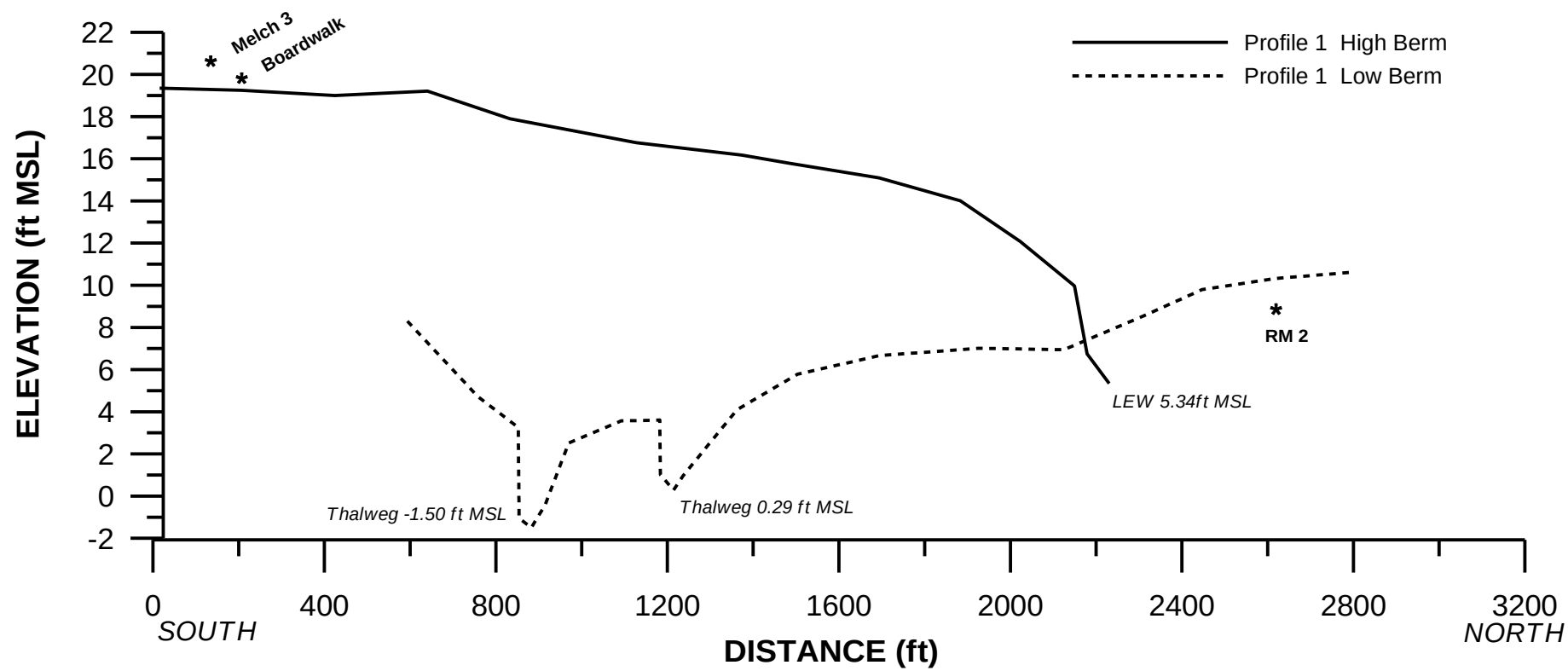
Redwood Creek Estuary 2002 - Width and Volume for Varying Water Elevations							
Water Elev. (ft MSL)	X/S E1 Wet Width (ft)	X/S E2 Wet Width (ft)	X/S E3 Wet Width (ft)	X/S E4 Wet Width (ft)	X/S E5 Wet Width (ft)	Estuary Volume (ft ³)	Estuary Volume (yd ³)
11	352.83	1540.70	1568.67	734.39		4,101,465	151,906
10	347.29	1427.90	1360.12	647.55		3,478,444	128,831
9	341.74	1295.04	862.00	593.01		2,945,105	109,078
8	336.20	985.73	710.66	547.59	211.03	2,484,680	92,025
7	330.65	764.61	614.97	506.70		2,116,909	78,404
6	325.17	694.28	590.24	465.81		1,784,138	66,079
5	319.70	641.03	571.24	424.92		1,471,633	54,505
4	314.22	587.80	551.17	377.80		1,179,381	43,681
3	308.75	546.79	512.37	327.33		910,060	33,706
2	303.27	505.79	473.56	309.24		658,224	24,379
1	295.54	419.47	429.76	291.15		426,413	15,793
0	184.91	244.43	252.98	271.73		234,313	8,678
-1	93.15	133.87	161.46	243.79		114,795	4,252
-2	23.65	86.85	98.43	211.62		32,459	1,202
-3		52.12				1,939	72

For Reference:
X/S E1 at end of Redwood Creek levees
X/S E5 near large sea stack on beach, X/S closest to ocean

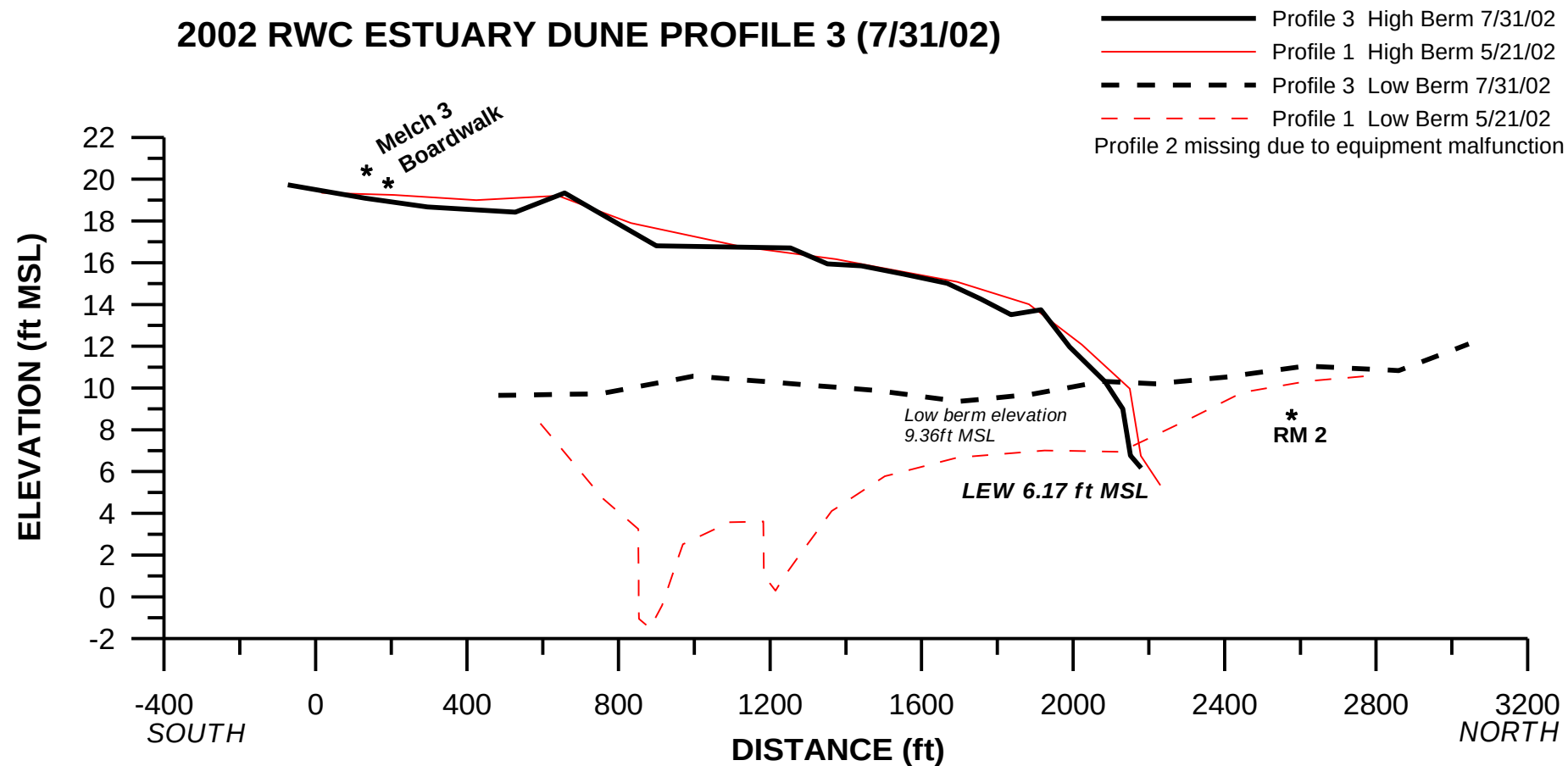


Appendix VI. Longitudinal profiles of the sand berm along the highest ridge parallel to the shore separating the estuary from the ocean for May 21 (Profile 1), July 31 (Profile 3), August 28 (Profile 4), and September 30 (Profile 5). Due to an equipment malfunction on June 17, Profile 2 survey was not usable. The profiles extended from a minimum of 100 feet north of the estuary to 100 feet south of the Redwood Information Center (RIC). Measurements were taken at breaks in slope along the sand berm. The elevations in feet MSL were referenced in the south to a permanent NOAA benchmark, Melch 3, located west of RIC, and to the end of the RIC boardwalk. In the north, they were initially referenced to a BLM benchmark, and the western most estuary cross section endpoint of E-5, RM2, a monumented rock sea stack. The winter storm berm, denoted as the high berm, and the summer swell berm, denoted as the low berm, were surveyed. The mouth was completely closed to the ocean on the July 31, August 28, and September 30, 2002 surveys.

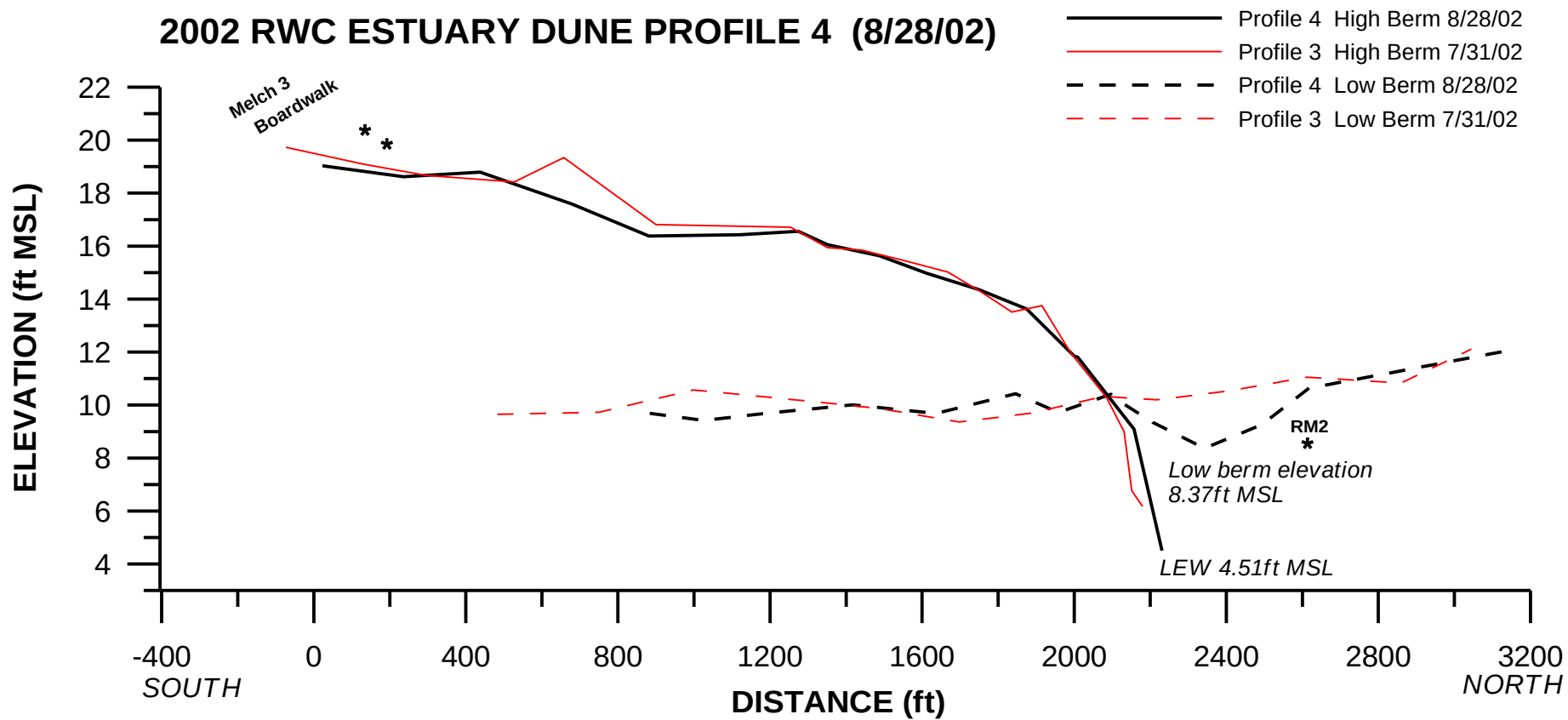
2002 RWC ESTUARY DUNE PROFILE 1 (5/21/02)



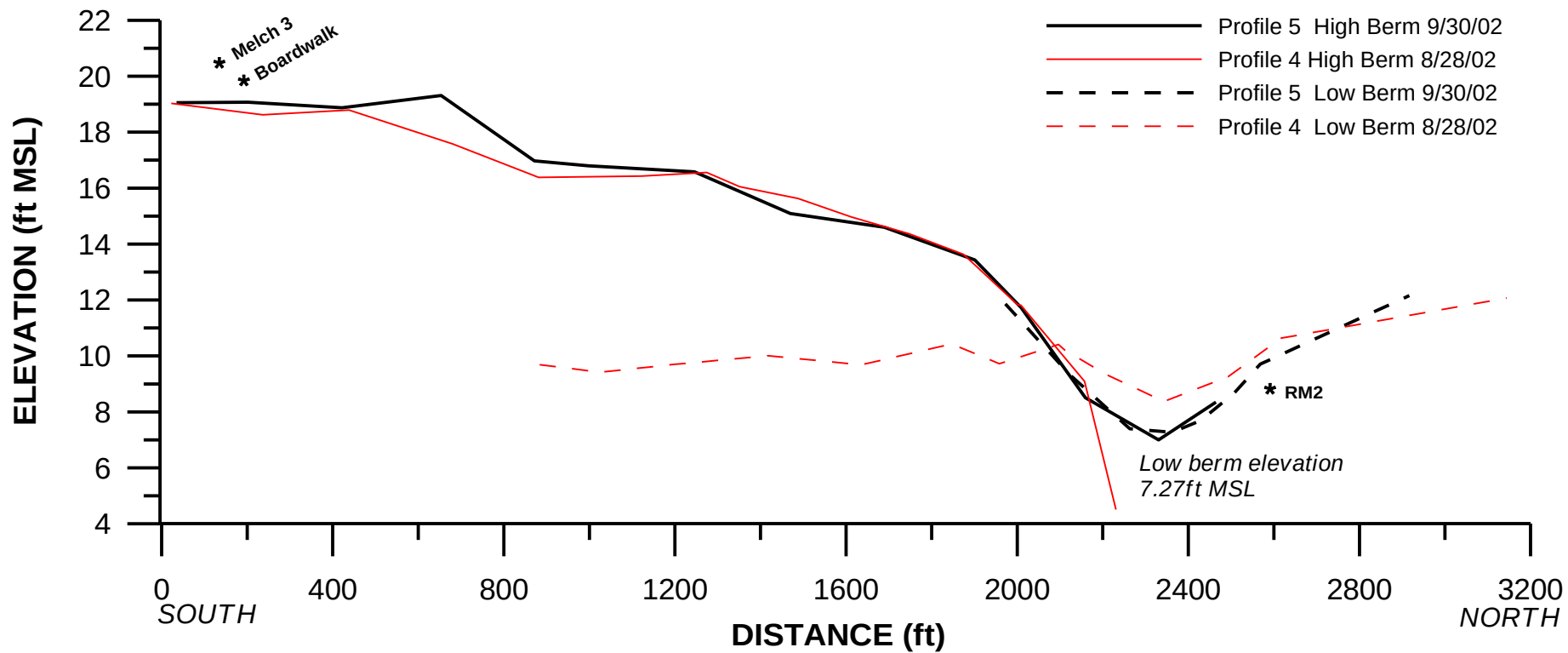
2002 RWC ESTUARY DUNE PROFILE 3 (7/31/02)

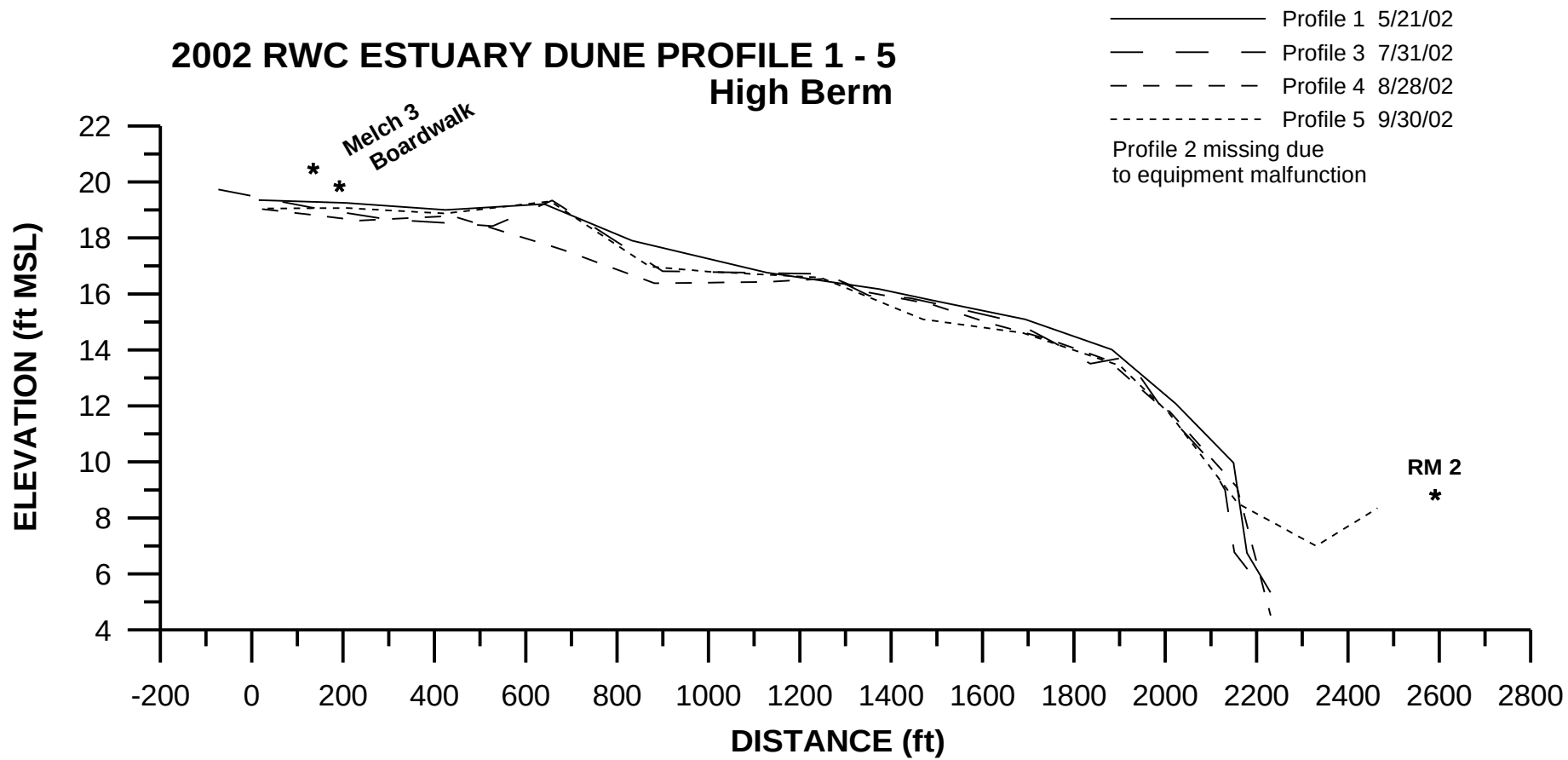


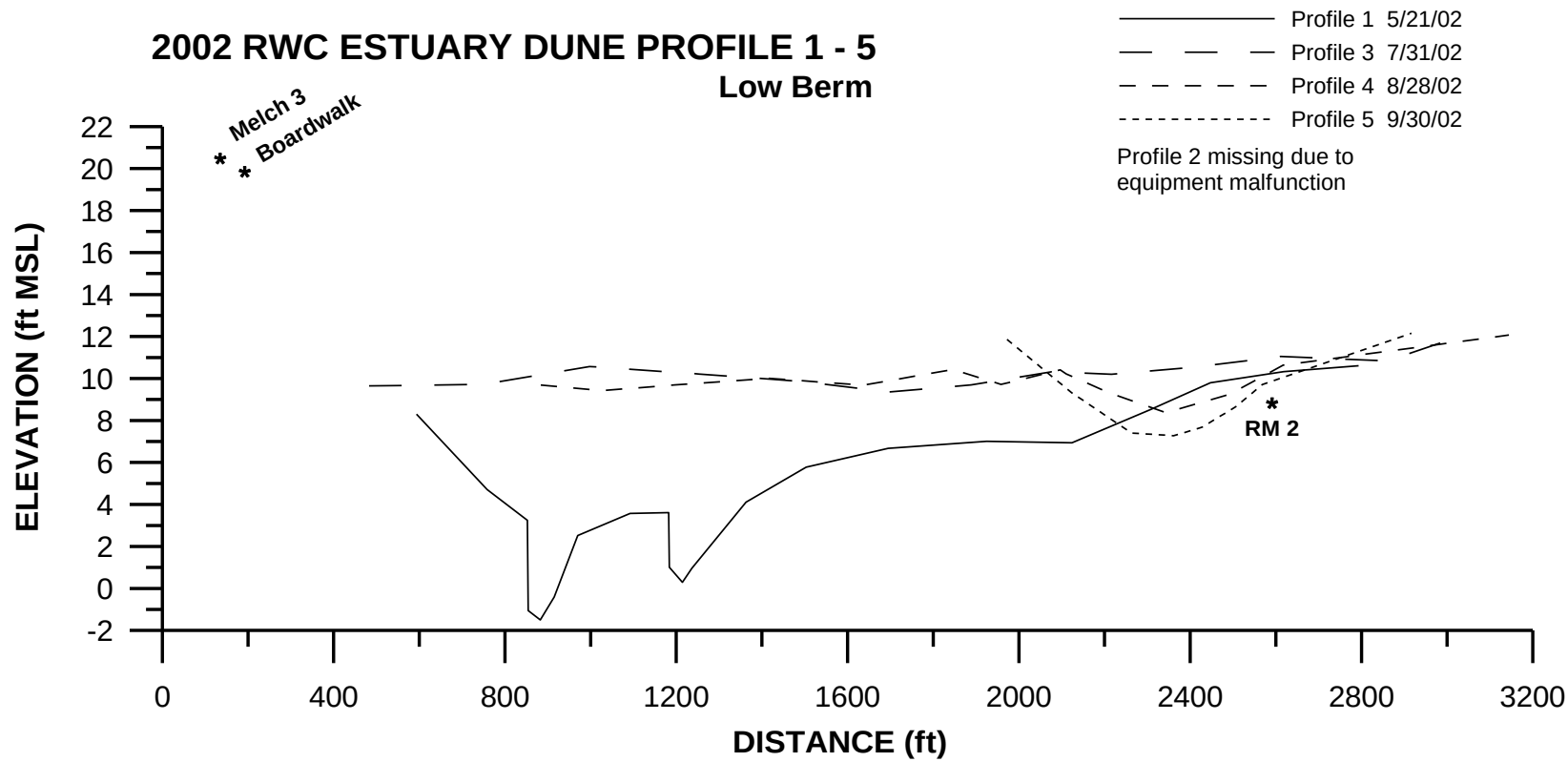
2002 RWC ESTUARY DUNE PROFILE 4 (8/28/02)



2002 RWC ESTUARY DUNE PROFILE 5 (9/30/02)







Appendix VII. Survey points of the four longitudinal sand berm profiles plotted on 1:6000 aerial photo for each of the five profiles (2 cm = 407 ft). (Redwood National and State Parks photo no. 15-12, Redwood Creek 97, dated 6/19/97, the latest estuary aerial may not reflect the exact beach and spit configuration each year and throughout the summer/fall season).

Appendix VIII. Kathy Kelsey's Humboldt County Science Fair Project Report, *Dissolved Oxygen in Redwood Creek Estuary and the Effect of Levee Construction*. (Arcata High School, June 2002).

2002 Acknowledgements

David Anderson, RNSP fishery biologist, led estuary monitoring in the field, analyzed data, and wrote the annual report. Others assisted, and/or contributed to the various estuary monitoring activities (e.g., seining, helping install or remove monitoring equipment, or surveying).

Estuary Biological Monitoring (seining)

Fish and Wildlife Branch: David Anderson, Baker Holden III, Terry Hines, Frank Kemp, Jeanne Mayer, Ben Littlefield, Kristin Schmidt, Keith Bensen, Kyle Max

Resource Management Labor Support Crew: Glen Fickbohm, Keith Richey, Tim Tanno, Roads and Trails: Dale Webster, Candy Gibson, Lee Wilson, Chuck Williams, Chuck Webster

Volunteer In the Park: Elke Wald

USGS-BRD: Nik Erickson and Scott Carroll

Fish Descriptive Statistics

Fish and Wildlife Branch: David Anderson

Estuary Water Level Monitoring

Geological Services: Carrie Jones (South Slough Data Collection and synthesis, gage maintenance).

Fish and Wildlife Branch: David Anderson (South Levee Data Collection and synthesis)

Installation or Removal of South Levee Water Elevation Recording Gage

Geological Services Branch: Carrie Jones

Fish and Wildlife Branch: David Anderson, Terry Hines, Kyle Max, and Jeanne Mayer.

Estuary Survey of Berm and Embayment Cross Sections

Geological Services Branch: Vicki Ozaki and Carrie Jones

Fish and Wildlife Branch: David Anderson

USGS-BRD: Chris Currens

Culverts Opening or Closing

Fish and Wildlife Branch: David Anderson, Terry Hines, Jeanne Mayer, and Kyle Max

Equipment Repair/Trailer Improvement

SOC Shop: Rodney Poole