

Redwood Creek Estuary Monitoring 2001 Annual Progress Report

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Introduction

This annual report summarizes Redwood National and State Parks' Fish and Wildlife Branch monitoring activities in the Redwood Creek estuary for the calendar year 2001. 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 the parks' 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 of 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.

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. 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-long, 15-foot wide, ¼ inch mesh beach seine net deployed off the bow of a 16-foot motor boat. A blue 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 estimates were conducted during the summer/fall 2001.

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. Other salmonid species, coastal cutthroat trout (*O. clarki*) and coho salmon (*O. kisutch*), though not as numerous as chinook or steelhead, were also measured and weighed. Eight growth estimates were conducted, four in conjunction with the population estimates, and four other days between and after the population estimates.

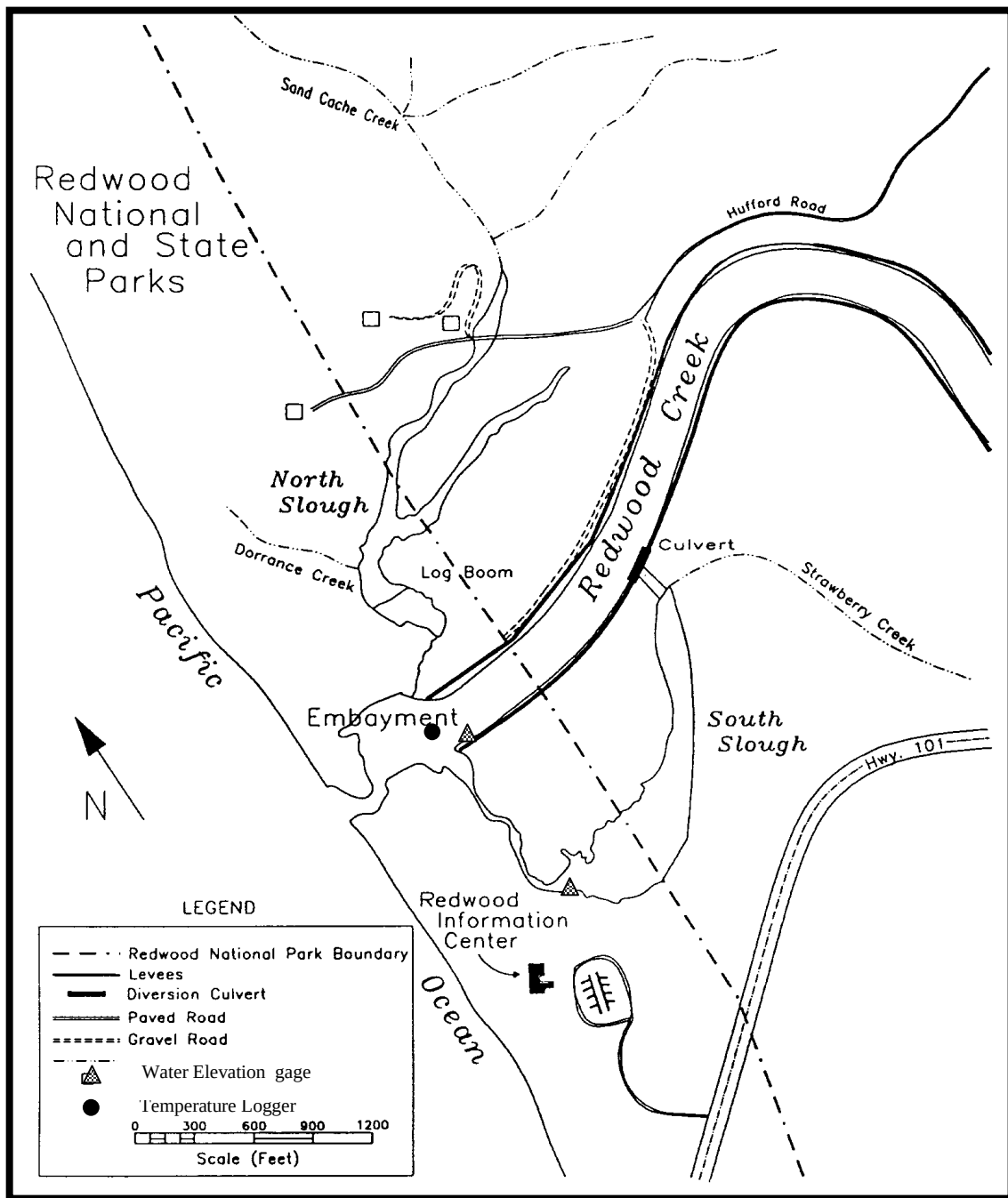


Figure 1. Map of the Redwood Creek Estuary, Humboldt County, California, including the embayment, north and south sloughs, and location of water elevation gages and temperature logger.

Water Quality Monitoring

Water Temperature - Water temperature (°C) was measured in the Redwood Creek embayment. A 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 or less 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 2001 tide data for the mouth of Redwood Creek was compiled using software for Crescent City Harbor, California. It was corrected for the locality of the mouth of Redwood Creek [CC tide x 0.98] and transformed to feet Mean Sea Level (MSL) [tide – 3.65 = ft MSL].

Stream Flow Data: Hourly Redwood Creek flow data at Orick for calendar year 2001 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 10-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 monumented partially buried sea stacks located along 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 Total Station. A diver with a 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 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 2001 as the mouth breached naturally.

Other Activities

North Slough Outlet Channel

The park surveyed a longitudinal and perpendicular cross section of the north slough outlet channel to provide information for an Army Corps application dated August 8 from Joe Hufford and Tom McNamara, adjacent landowners. Their application proposed to remove the driftwood and excavate a channel to alleviate seasonal flooding of their fields. The park moved some of the driftwood ‘dam’ that had accumulated in the north slough outlet channel with two backhoes on May 15 and 16. Due to a misunderstanding with the Eureka office of the Corps of Engineers, we thought heavy machinery could be used to move the driftwood (not classified as fill) out of the channel. However, because the backhoes were moving sand incidentally (which is classified as fill) along with the wood, the Corps called the second day and ordered us to shut down operations, before all the driftwood dam was removed from the existing channel.

Adipose Clipped Pit-tagged Coho Salmon and Cutthroat Trout

Humboldt State University California Cooperative Fishery Research Unit graduate students pit-tagged and adipose clipped coho salmon juveniles in Prairie Creek and coastal cutthroat trout in Boyes, Streelaw, and Prairie Creek the previous falls. With their assistance and equipment, we looked for tagged coho smolts and cutthroat in the estuary seine hauls.

Student Science Fair Project

Cathy Kelsey, an Arcata High School student, measured water quality (temperature, salinity, and dissolved oxygen) in the embayment as part of a science fair project at different tidal cycles and mouth configurations. We have not received her information.

2001 Results

Fish Monitoring

Presence – During the summer and fall of 2001, four salmonid species were seined in the Redwood Creek embayment; chinook and coho salmon, and steelhead and coastal cutthroat trout. Two adult-sized steelhead were captured. Five other fish species were captured. One reptile, 28 bird, one mammal, and two invertebrate species were observed. A complete list of all fish and other species captured or observed in and around the Redwood Creek estuary is presented in Table 1. No tidewater gobies (*Eucyclogobius newberryi*) were found in the estuary (Anderson 2002).

Table 1. List of salmonid and non-salmonid fish seined, birds, reptiles, mammals, and invertebrates observed at and around the Redwood Creek estuary, Redwood National and State Parks,

Humboldt County, California during summer/fall 2001 fish sampling.

	2001 Date (*Week of)							
	June 4*	June 25	July 16*	Aug 13*	Aug 30	Sept 10*	Oct 2	Oct 23
Salmonid Fish								
Coastal Cutthroat Trout	X	X	X	X	X	X	X	X
Steelhead Trout	X	X	X	X	X	X	X	X
Chinook Salmon	X	X	X	X	X	X	X	X
Coho Salmon	X	X	X	X				
Non-Salmonid Fish								
Three Spine Stickleback	X	X	X	X	X	X	X	X
Staghorn Sculpin	X	X	X	X	X	X		
Prickly Sculpin	X	X		X		X		X
Sucker			X					
Starry Flounder			X			X	X	
Reptiles								
Garter Snake				X				
Birds								
Brown Pelican	X	X	X	X	X	X	X	X
Great Blue Heron		X						
Snowy Egret			X					
Double Crested Cormorant	X			X		X	X	
Turkey Vulture	X	X	X	X		X	X	
Osprey	X	X	X	X	X	X		
Kestral			X				X	
Northern Harrier				X				
Peregrine Falcon						X		
Western Sandpiper				X		X	X	
Killdeer						X	X	X
Sanderlings								X
American Avocet					X			
Gulls (Western, Heerman, California, and Ringbilled)			X	X	X	X	X	X
Caspian Tern			X	X	X	X		
Black Phoebe						X		
Violet Green Swallow	X							
Barn Swallow	X		X	X				
Kingfisher				X				
Meadowlark								X
Corvids (Crows and Ravens)	X							X
Canada Goose	X	X		X				
White Fronted Goose							X	X
Merganser	X	X	X	X			X	
Mammals								
River Otter	X							
Invertebrates								
Isopod (<i>Gnorisphaerama</i>)			X					
Shrimp (<i>Crangon franciscorum?</i>)			X					

Population Estimates -Four population estimates were conducted in the embayment the summer of 2001 during the weeks of June 4, July 16, August 13, and September 10, 2001 (Table 2). The mouth closed, breached, and closed again between the June 4 and July estimates. The mouth was closed during the last three estimates. The number of fish marked, marked recaptures, total individuals captured in the second sample, and location of marks are presented in Appendix II.

The first juvenile chinook salmon estimate, the week of June 4, was 58,630 (95% Confidence Interval [CI] 39,100 to 78,160). On July 16, the population had decreased to 34,260 (95% CI 7,230 to 61,290). The CI was poor because only six marked fish were recaptured. On August 13, the population had decreased to 3,620 (95% CI 580 to 6,650). By the last chinook estimate on September 10, the population had decreased to 2,290 (95% CI 185 to 4,770).

The initial juvenile steelhead trout estimate the week of June 4 was 38,460 (95% CI 1,150 to 75,760). The CI was poor because only four marked fish were recaptured. The population decreased to 9,470 (95% CI 6,800 to 12,150) on July 16. On August 13, the estimated population was 4,610 (95% CI 3,780 to 5,450). By the last steelhead estimate on September 10, the estimated population increased to 9,350 (95% CI 6,420 to 12,280).

A largest number of coho salmon smolt captured, 53, were captured the first sample week of June 4. Two were captured the week of July 16, five the week of August 13, and none the week of September 10. No population estimates were possible as no marked fish were recaptured. Though not part of the population estimates, during the growth estimates, one coho was captured on June 25, and no coho were captured on August 30, October 2, and October 23.

No cutthroat trout population estimates were possible for the June, July, and August estimates as no marked fish were recaptured. The actual count of fish captured in seine hauls were 14, 25, and 14, for the weeks of June 4, July 16, and August 13, respectively. The estimate for the week of September 9th was 260 (95% CI 54 to 520).

Growth Estimates – Eight growth estimates were conducted, four in conjunction with population estimates during the weeks of June 4, July 16, August 13, and September 10, and four one day growth estimates on June 25, August 30, October 2, and October 23 (Table 3). The last growth estimate on October 23 was 24 days before the estuary breached on November 16 and does not represent the mean size at which they migrated into the ocean.

Chinook salmon mean fork length increased from 62 to 102 mm, an increase of 40 mm, between the June and October sample dates (142 days). Minimum and maximum chinook fork lengths ranged between 46 and 130 mm during summer and fall. Minimum and maximum fork lengths ranged from 46 to 88 mm on June 4 and increased to 77 to 114 mm by October 23 (Figure 2). Mean weight rose from 3.0 to 12.2 grams (g), and increase of 9.2 g. Minimum and maximum weights ranged from 1.1 to 17.7 g respectively for the season, and went from 1.1 to 7.2 g on June 4 to 7.2 to 17.7 g on October 23.

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 2001. Mouth of creek denotes if Redwood Creek mouth was open or closed to the Pacific Ocean during the estimate.

2001 DATE	Mouth of Creek (Open or Closed)	Chinook Salmon		Coho Salmon	
		Population Estimate	95% Confidence Interval	Population Estimate	95% Confidence Interval
06/04, 05, 07	OPEN	58,630	39,100 – 78,160	53 ^a	---
June 28 Estuary Breach					
07/16, 17, 19	CLOSED	34,260	7,230 – 61,290	2 ^a	---
08/13, 14, 16	CLOSED	3,620	580 - 6,650	5 ^a	---
09/10, 11, 13	CLOSED	2,290	185 ^b - 4,770	0	---
		Steelhead Trout		Cutthroat Trout	
06/04, 05, 07	OPEN	38,460	1,150 – 75,760	14 ^a	---
June 28 Estuary Breach					
07/16, 17, 19	CLOSED	9,470	6,800 – 12,150	25 ^a	---
08/13, 14, 16	CLOSED	4,610	3,780 - 5,450	14 ^a	
09/10, 11, 13	CLOSED	9,350	6,420 – 12,280	260	54 ^b - 520
a. Actual count of fish captured in seine net hauls. No marked fish were recaptured.					
b. Actual minimum count, calculated 95% lower interval was below what was actually caught					

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 2001. Mouth denotes if Redwood Creek mouth was open or closed to the ocean.

Redwood Creek Estuary – Summer/Fall 2001							
2001 DATE	MOUTH	FORK LENGTH (mm)			WEIGHT (g)		
		Mean (No. Measured)	Std. Dev	Range	Mean (No. Weighed)	Std. Dev.	Range
JUVENILE CHINOOK SALMON							
06/04	OPEN	62 (200)	9.8	46 - 88	3.0 (30)	1.8	1.1 - 7.2
06/25	CLOSED	67 (205)	7.2	50 - 86	3.3 (30)	1.1	1.3 - 6.1
07/16	CLOSED	71 (205)	5.8	54 - 85	3.9 (30)	0.7	2.2 - 5.1
08/13, 14	CLOSED	77 (200)	6.2	59 - 95	4.6 (30)	0.8	2.8 - 5.8
08/30	CLOSED	84 (89)	6.1	65 - 97	6.3 (30)	1.1	4.7 - 8.6
09/10, 11, 13	CLOSED	86 (185)	7.2	65 - 130	6.5 (30)	1.3	3.6 - 8.8
10/02	CLOSED	91 (159)	7.4	74 - 109	9.2 (30)	2.2	5.1 - 15.2
10/23	CLOSED	102 (37)	7.5	77 - 114	12.2 (30)	2.6	7.2 - 17.7
JUVENILE COHO SALMON							
06/04, 05, 07	OPEN	108 (52)	10.8	64 - 124	13.1 (52)	3.1	2.7 - 18.5
06/25	CLOSED	154 (1)	---	---	36.0 (1)	---	---
07/16	CLOSED	89 (2)	0.0	89 - 89	6.3 (2)	0.4	6.0 - 6.5
08/13, 16	CLOSED	75 (5)	7.7	68 - 86	4.4 (5)	1.3	2.8 - 5.8
08/30	CLOSED	--- (0)	---	---	--- (0)	---	---
09/10, 11, 13	CLOSED	--- (0)	---	---	--- (0)	---	---
10/02	CLOSED	--- (0)	---	---	--- (0)	---	---
10/23	CLOSED	--- (0)	---	---	--- (0)	---	---

Redwood Creek Estuary – Summer/Fall 2001							
2001 DATE	MOUTH	FORK LENGTH (mm)			WEIGHT (g)		
		Mean (No. Measured)	Std. Dev	Range	Mean (No. Weighed)	Std. Dev	Range
JUVENILE STEELHEAD TROUT							
06/04, 05	OPEN	113 (205)	23.2	49 - 184	19.7 (30)	10.7	1.4 - 38.0
06/25	CLOSED	98 (206)	35.2	48 - 191	16.9 (30)	16.2	1.0 - 69.0
07/16, 17	CLOSED	89 (205)	30.3	46 - 164	7.7 (30)	7.9	1.2 - 31.3
08/13	CLOSED	81 (205)	22.9	53 - 161	7.2 (30)	8.4	2.1 - 33.2
08/30	CLOSED	108 (323)	30.8	50 - 184	19.7 (30)	12.5	1.8 - 39.7
09/10, 11	CLOSED	126 (230)	34.5	54 - 230	9.2 (30)	9.2	3.4 - 47.4
10/02	CLOSED	118 (205)	36.4	70 - 217	22.1 (30)	19.7	3.9 - 62.8
10/23	CLOSED	147 (285)	36.0	76 - 221	40.6 (30)	25.2	5.1 - 88.6
CUTTHROAT TROUT							
06/04, 05, 07	OPEN	256 (14)	78.0	170 - 375	230.9 (14)	195.1	50.8 - 635
06/25	CLOSED	265 (6)	75.7	185 - 397	221.8 (6)	228.2	51.0 - 667
07/16, 17, 19	CLOSED	273 (25)	74.9	78 - 380	111.8 (12) ^a	25.9	65.0 - 148.7
08/13, 14, 16	CLOSED	309 (14)	51.2	195 - 366	94.6 (2) ^a	14.7	84.2 - 105.0
08/30	CLOSED	268 (10)	38.5	232 - 337	141.2 (4) ^a	7.2	130.8 - 146.4
09/10, 11, 13	CLOSED	307 (54)	52.4	214 - 401	328.0 (50)	166.5	103.0 - 748
10/02	CLOSED	302 (25)	48.2	234 - 404	322.3 (25)	172.4	114.0 - 746
10/23	CLOSED	302 (18)	56.0	228 - 405	326.5 (18)	196.4	156 - 716
ADULT STEELHEAD TROUT							
10/02	CLOSED	598 (1)	---	---	2092 (1)	---	---
10/23	CLOSED	609 (1)	---	---	2330 (1)	---	---
a. Larger fish exceeded the capacity of the available scale, 200g balance.							

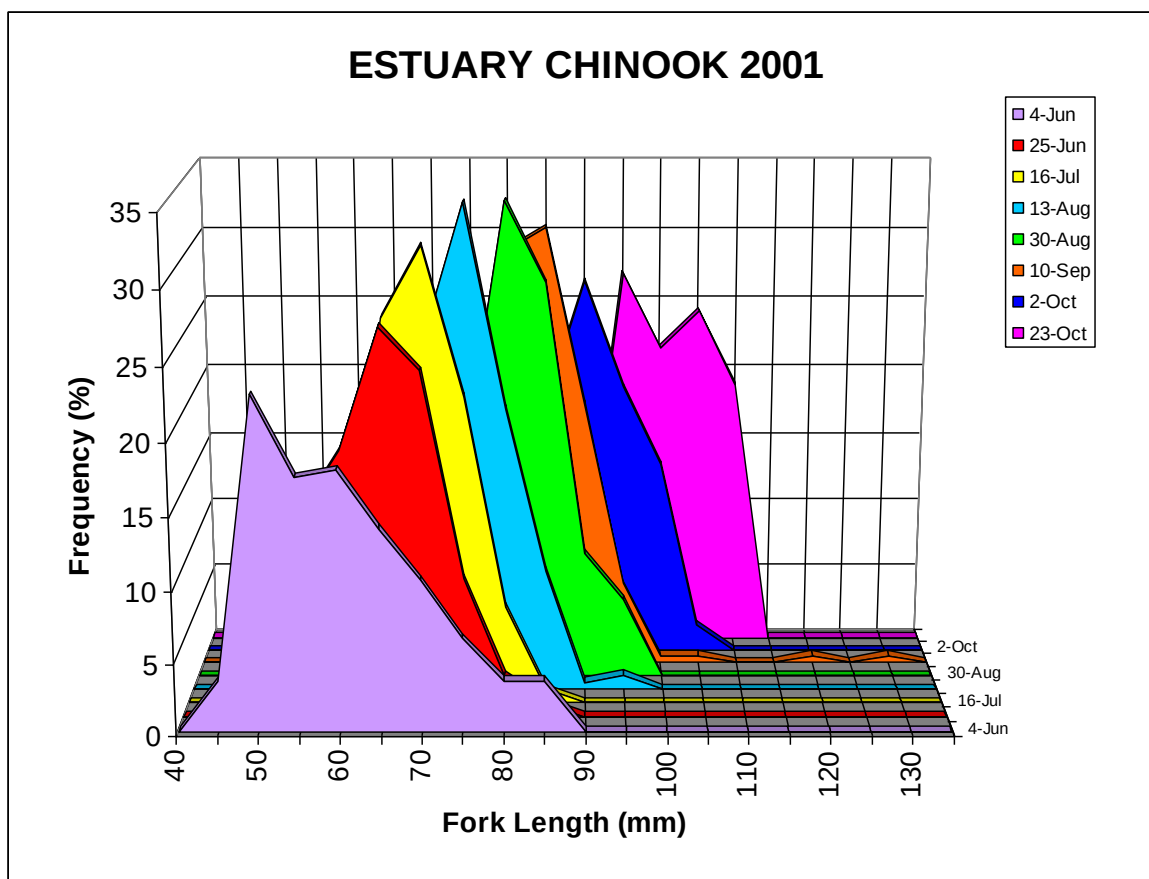


Figure 2. Fork length (mm) versus frequency (%) histogram of Redwood Creek Estuary juvenile chinook sampled between June 4 and October 23, 2001. The fork length classes were 5-mm increments.

Of the 60 coho salmon measured, 52 were from the week of June 4. Mean fork length was 108 mm on that date, 154 mm for one fish on June 25, 89 mm for two fish on July 16, and 75 mm for five fish on August 13 and 16. Minimum and maximum fork length ranged from 64 to 154 mm. Mean weight ranged between 4.4 g and 13.1 g, with 36 g for the one 154 mm fish.

Steelhead trout mean fork length increased from 113 to 147 mm between the week of June 4 and October 23. The fork length means of June 25, July 16, August 13 and 30, 98 mm, 89 mm, 81 mm, and 108 mm, respectively, were lower than that of June 4 and represent different proportions of several age classes present (Figure 3).

Mean juvenile steelhead weight increased from 10.7 to 25.2 g between the week of June 4 and October 23. Again the mean weights of June 25 (16.9 g), July 16 (7.7 g), August 13 (7.2 g), August 30 (19.7 g), and September 10 (9.2 g) were lower than or equal to the June 4 mean. Minimum and maximum weights ranged between 1.0 g and 5.1 g, and 31.3 and 88.6 g, respectively.

Two adult steelhead were caught, one each on October 2 and 23, when the mouth was closed. They ranged from 598 to 609 mm and 2,092 to 2,330 g.

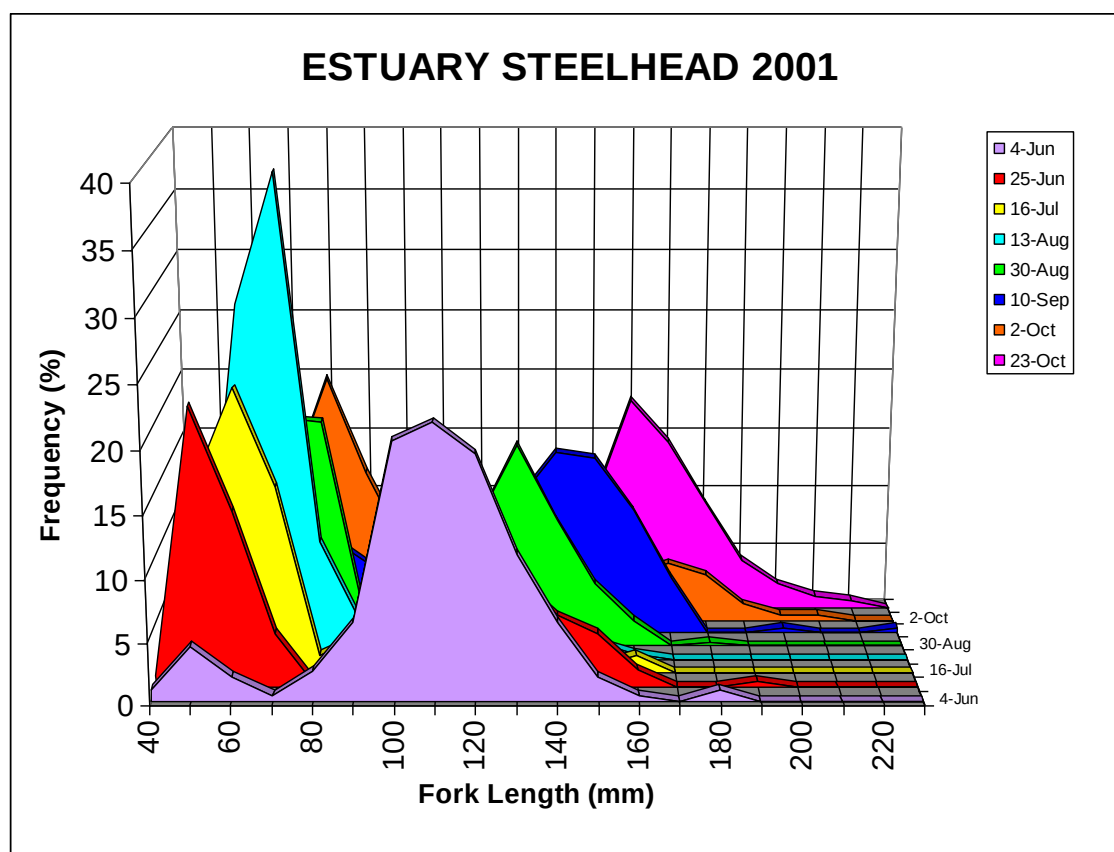


Figure 3. Fork length (mm) versus frequency (%) histogram of Redwood Creek estuary juvenile steelhead trout sampled between June 4 and October 23, 2001. The fork length classes were 10-mm increments.

Cutthroat trout mean fork length increased from 256 mm on June 4 to 302 mm on October 23, an increase of 46 mm. However, the highest mean fork length was measured the week of August 13 at 309 mm. Minimum and maximum fork lengths ranged between 170 mm and 228 mm, and 337 mm and 405 mm, respectively. During the period June through October, mean weight increased from 221.8 on June 25 to 326.5 g on October 23, and cutthroat weights ranged between 50.8 g and 748 g. The reported July 16, August 13 and 30 weights are biased as larger fish exceeded the 200 g capacity of the balance available.

Water Quality Monitoring

Water Temperature - In 2001, water temperature ($^{\circ}\text{C}$) was the only water quality parameter we monitored in the Redwood Creek estuary. The TidBit temperature logger recorded water temperature every 1-hour from June 1 through November 1, 2001 (Figure 4). The maximum and minimum water temperatures were 21.8°C (on June 29) and 11.5°C (on June 2), respectively. The average water temperature for the period of was 16.7°C . Percent temperature exceedence is shown in Table 4. Water temperature between June 1 and November 1 exceeded or equaled 17°C 50 percent of the time, and 74 percent of the time during the months of July and August. Exceedence percentages at higher temperatures decreased from August on.

Table 4. Percent of time water temperature (°C) exceeded or equaled temperature value in the Redwood Creek estuary embayment, Humboldt County, California, during June 1 through November 1, 2001. Temperatures measured by an Onset Tidbit temperature logger.

Month YR 2001	Redwood Creek Estuary											
	Percent of Time Water Temperature (°C) Exceeds or Equals Temperature Value											
	≥11	≥12	≥13	≥14	≥15	≥16	≥17	≥18	≥19	≥20	≥21	≥22
June 1-30	100	99.4	98.6	96.4	91.4	68.8	45.1	14.2	2.6	1.9	0.7	0.0
July 1-31	100	100	100	100	97.3	93.8	74.7	48.4	12.9	2.4	0.9	0.0
August 1-31	100	100	100	99.7	98.9	93.4	74.2	49.3	21.2	2.8	0.0	0.0
September 1-30	100	100	96.5	89.6	84.0	63.9	44.2	15.4	2.9	0.0	0.0	0.0
October 1-31	100	98.9	84.9	59.7	45.3	25.7	12.1	5.1	0.0	0.0	0.0	0.0
Nov 1	100	100	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun 1 to Nov1	100	99.7	96.0	88.7	83.0	68.9	49.9	26.5	8.0	1.4	0.3	0.0

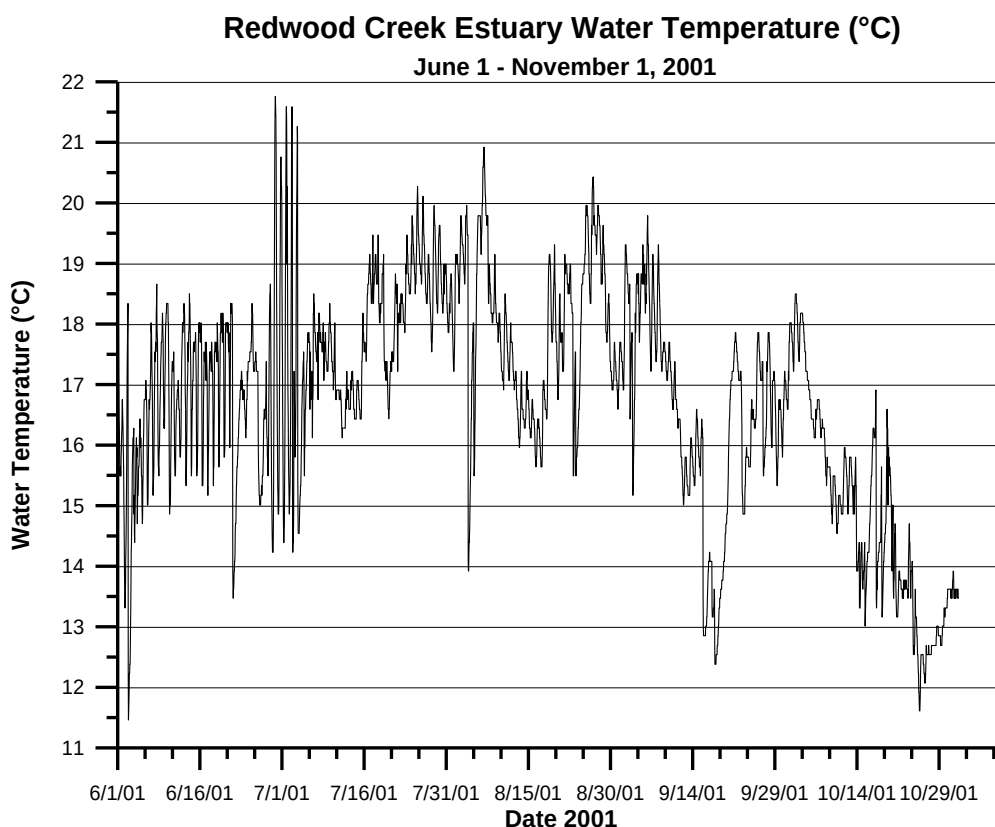


Figure 4. Redwood Creek estuary water temperatures (°C) measured by an Onset Tidbit temperature logger located in the embayment between the ends of the north and south flood control levees. The temperature logger, located one foot from the bottom, recorded water temperature every 1-hour from June 1 through November 1, 2001.

Tide and Stream Flow

Tides at the Mouth of Redwood Creek - The maximum and minimum calculated tide at the mouth was 4.97 ft MSL and -5.71 ft MSL, respectively, a range of 10.68 feet. Tidal data is included in Figure 5).

Stream Flow - Calendar year 2001 stream flow data, January 1 through December 31, is presented in Appendix III. The maximum flow was 16,430 cfs on December 6, 2001. The gage measured a minimum flow of 7 cfs during the summer, but was unable to measure lower flows. No streamflow events occurred between late June and late October.

Estuary Water Level

South Slough and South Levee/Embayment Water Level Gaging

South slough water elevations (feet MSL) were recorded for the period January 1 to December 31, 2001, excluding April 10 through 26, and some data points between April 4 and 10 (Figure 5). The temporary south levee gage was installed on July 2 and removed on December 11. The temporary gage malfunctioned and only select data was used to analyze the November 16 breach.

The embayment site could measure lower water elevations (to -2.14 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. Based on south slough water elevation gaging data, with the south slough culverts open, the lowest slough water elevation was limited to 2.6 ft MSL. With the culverts closed, the lowest south slough elevation was 4.2 ft MSL prior to the opening of the culverts and 4.7 ft MSL after closing of the culverts in late November. The culvert openings (invert) are lower than the south slough channel thalweg. Evidently in 2001, additional sand was deposited in the south slough channel during the time the culverts were open. The lowest embayment water elevation measured, 0.31 ft MSL, was lower than that measured in the south slough (2.63 ft MSL).

Breaching and Estuary Response

The estuary breached naturally twice, on June 28 and November 16, 2001. This was the first time in many years that the estuary had breached naturally in the summer after closing in June. Initially in January, the mouth flowed north between the two sea stacks at the base of the hill. During the spring, the mouth migrated to the south. As a result of a 16,430 cfs flow event on December 6, the mouth flowed straight out from levees.

June 28, 2001 Breach – The estuary breached on June 28 at 12:55 am at a height of 8.23 ft MSL (Figure 5). The tide was -1.69 ft MSL (2.0 ft) at 1 am and rising. A late season rain event of 0.92 inches over 18 hours was the cause. Redwood Creek flow rose from 47 cfs on June 25 to a peak of 165 cfs on June 27 at 11 am. River flow was 128 cfs when the breach occurred (Figure 6). A total of 0.96 inches of rain in 42 hours was recorded at the ORK gage prior to the breach. A berm reconnaissance on June 27 indicated that the remaining dry outlet channel was partially filled with sand, though it appeared that any water coming out of the estuary would just flow down the existing channel. However, it did not. A new outlet shortened the existing channel causing the water level to drop.

South Slough Water Level and Tide 01/01/01 - 12/31/01

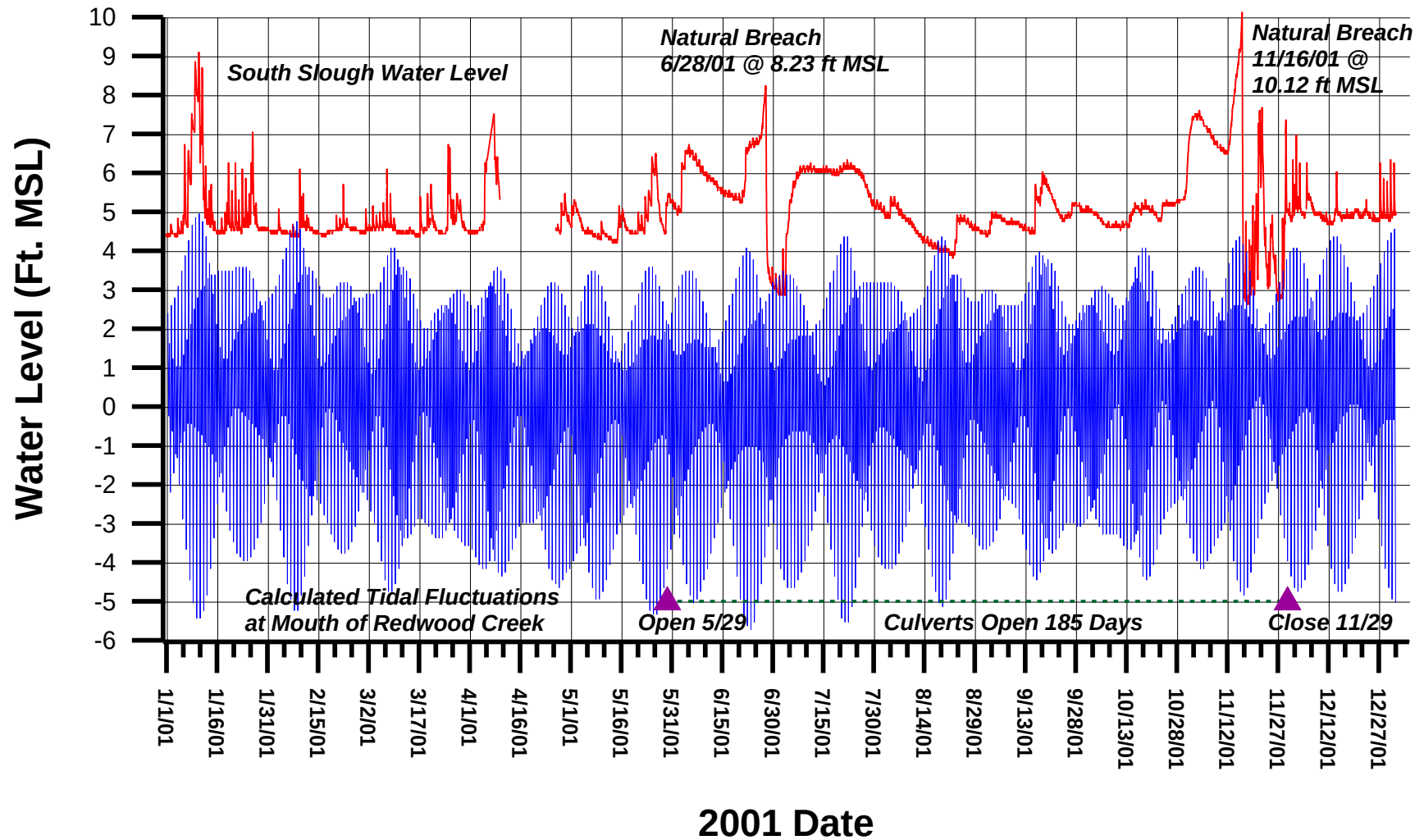


Figure 5. South slough water elevations (feet Mean Sea Level [MSL]) of the Redwood Creek estuary, Humboldt County for the period January 1 to December 31, 2001, excluding April 10 through 26, and some data points between April 4 and 10. Estimated ocean tidal elevations are corrected for the coastal locality at the mouth of Redwood Creek and adjusted to feet MSL

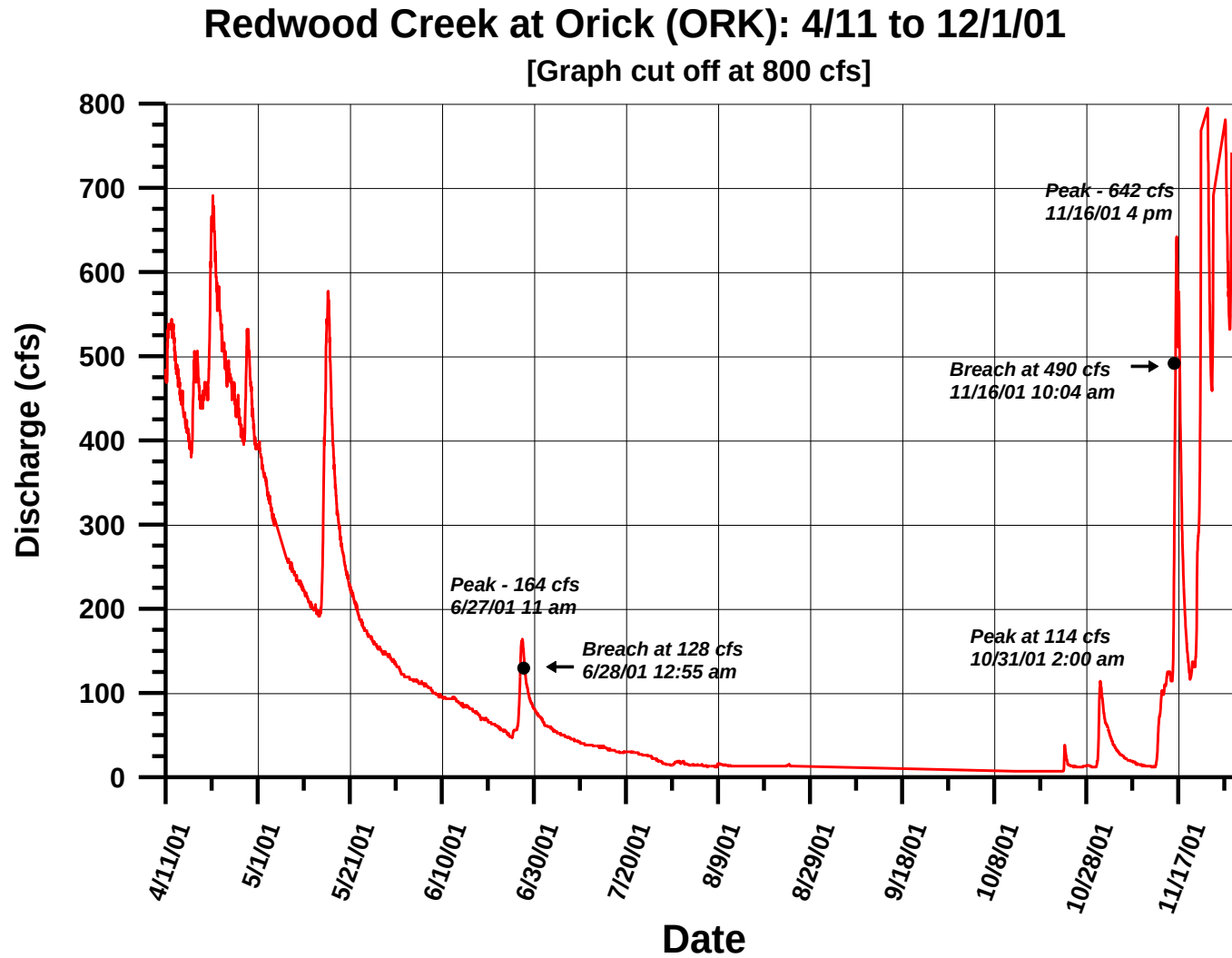


Figure 6. Redwood Creek discharge (cfs) measured at ORK station for April 11 to December 1, 2001. Natural breaches of the estuary occurred on June 28, 2001 at 128 cfs and on November 16, 2001 at 490 cfs.

The water level dropped to 3.10 ft MSL, a decrease of 5.13 ft in 31 hours before the incoming tide stopped the decline. The breach represented a volume loss of at least 1,590,000 ft³ (58,900 yd³) of water from the embayment (east of the berm to the ends of the levees), not including the volume upstream between the levees and the north and south sloughs. After several tidal cycles, the water elevation declined below the south slough gage lower range (2.87 ft MSL) on July 2. On July 3 at 8:39 p.m., the estuary began to rise and close off, filled to 6 ft MSL by July 7, and leveled off. The mouth was open during the berm survey on May 22 preceding the breach so no record is available to determine the height of the berm prior to breaching. The berm survey on July 2 measured the estuary embayment water elevation at 3.01 ft MSL and the thalweg at the mouth of Redwood Creek at -0.32 ft MSL.

The estuary remained closed until November 16, 2001 providing 132 days of increased rearing volume to salmonid fish utilizing the embayment and south slough. It declined to a low of 3.8 ft MSL on August 24, probably a result of evaporation and seepage through the berm. The water elevation 'stepped up' several times, most likely a response to wave overwash over the berm. Waves washing over the berm at high tides would raise the water level. Water would seep out through the berm, and the pattern would repeat again at the next series of higher high tides.

November 16, 2001 Breach – The estuary breach naturally on November 16 at 10:04 a.m. at 10.12 ft MSL (Figure 5). The tide was 3.41 ft MSL (7.2 ft) at 10 a.m. and rising. The breach was a result of rain and wave overwash events. Between November 12 12 midnight and November 14 8 a.m. (56 hours) 1.32 inches of rain fell, and between November 15 11 p.m. and November 16 12 midnight (13 hours) an additional 1.04 inches of rain fell. The resulting flow event, the third of the season, peaked at 642 cfs at 4 p.m. on November 16 (Figure 6). Flow at the time of the breach at 10 a.m. was 490 cfs. The day prior to the breach, we observed large waves from high sea conditions washing across the berm into the estuary. The last berm survey of the year on October 1 had the lowest elevation on the low (summer) berm at 9.78 ft MSL. Additional sand must have been deposited by waves on the berm after the last survey. The water elevation bottomed out to 2.79 ft by 11:34 p.m. that night, a drop of 7.33 ft in 13.5 hrs and a volume loss of 2,768,000 ft³ (102,530 yd³) in the embayment. Immediately thereafter the estuary water elevations followed the tidal cycle. A lower water elevation of 0.31 ft MSL was recorded on November 18, at total decrease of 9.81 ft, before the water elevations increased.

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 May 29, 2001. The embayment and south slough were at the same water level as no water flowed through the culverts when the gates were opened. The gates were closed on November 29, 2001 to prevent sedimentation in the south slough from large storm events. The gates were open for 185 days (Figure 5).

Estuary Cross Sections

Five permanent parallel cross-sections (perpendicular to flow) in the embayment were surveyed on June 20 (cross sections E-1 through E-3) and July 24, 2001 (cross sections E-4 and E-5). 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 surveys extended south through the embayment to the sand dunes. They are surveyed annually as specified by the Corps permit. Estuary cross sections are presented in Appendix IV. The lowest bottom elevation (i.e. deepest point MSL) at E-1 was -0.75 ft MSL, at E-2 -1.06 ft MSL, at E-3 -1.71 ft MSL, at E-4 -4.25 ft MSL, and at E-5 +0.01 ft MSL. Based on the cross sectional data, at its greatest water elevation of 10.12 ft MSL, the deepest point surveyed in the embayment was 14.37 ft deep.

The net change (scour or fill) compared to surveyed 2000 cross sections were as follows: E-1 +433.0 ft², E-2 +195.5 ft², E-3 -215.8 ft², E-4 +2,854.2 ft², and E-5 -5,220.5 ft².

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 5). The calculated embayment volume ranged from 90 ft³ at -4 ft MSL to 3,993,996 ft³ at 11 ft MSL. Embayment volume (based on one foot intervals) has decreased an average of 47 % since surveying began in 1998, and 27% since 2000 surveys.

Table 5. Calculated 1998, 1999, 2000, 2001 water volume (ft³) of the Redwood Creek embayment at water elevations 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)

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

Sand Berm Elevation Monitoring

A longitudinal profile of the sand berm parallel to the ocean shore separating the estuary from the ocean was surveyed the required five times during the summer and fall of 2001, on May 22, July 2, July 10, September 5, and October 1. The surveys were required once a month, May through September. However, this summer our attempts to survey the berm according to the schedule were repeatedly hindered by low fog along the 3,200 to 5,400 ft long profile. This was the first time we had encountered fog problems since berm surveying began in 1998. The longitudinal berm surveys, profiles 1 through 5, 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.

Only on the May 22 and July 2 surveys was the mouth open to the ocean. On May 22, the low berm was very well developed. The channel was 2,010 feet long and the elevation difference between the embayment and mouth water level was 3.5 ft (See Profile 1). After the breach of June 28, the channel shortened. The channel on the July 2 berm survey was only 1,010 ft long. The elevation difference between the embayment and mouth water level was 2.13 ft (See Profile 2). The thalweg at the mouth was -0.32 ft MSL.

By the July 10 berm survey, the mouth had closed and the remaining channel had water in it, the same level as the embayment. The channel was 850 ft long (See Profile 3). On September 5, only an isolated pool existed where the channel had been, most of the original channel having been filled in with sand from wave overwash. The lowest elevation of the low berm was 6.94 ft MSL. The lowest berm depression represents the height at which the estuary would naturally breach on its own. The embayment water elevation was 4.84 ft MSL, meaning the estuary would have to rise another 2.1 ft before breaching. On the last berm survey of the season, October 1, the mouth was still closed. Wave overwash had transported sand into the embayment filling in some of the embayment and covering the lower benchmark pin at RM2, the sea stack. Most of the low summer berm had washed away except near the estuary, the beach appearing narrower. The low berm was about 1,500 ft long compared to 4,000 ft on July 2. Its lowest elevation was 9.78 ft MSL, the water surface of the embayment at 6.34 ft MSL, meaning the estuary would have to rise 3.44 ft to breach (See Profile 5).

The survey points plotted on 1: 6000 aerial photos for each survey are presented in Appendix VII.

Other Activities

North Slough Channel Survey

A longitudinal and cross section channel profile of the north slough outlet channel was surveyed on May 30, 2001 (Figures 7, 8, 9) to support a Corps application of letter permission (No. 26172N dated August 8, 2001). The applicants, Tom McNamara and Joe Hufford, landowners on the north side of the estuary want to remove approximately 2000 cubic yards of driftwood debris and sand from Sand Cache Creek/North Slough and transport the excavated material to an upland disposal site located on Redwood National Park property just north of the Redwood Creek Federal Levee. As of March 2002, the Corps had not permitted the work.



Figure 7. Survey points from May 30, 2001 longitudinal and cross-section survey of the North Slough Channel. The longitudinal survey started at the end of the north levee (point #1) and extended into the North Slough (point #8). Points 1W – 3W and #9 were on top of the accumulated driftwood in the remnant channel. The cross section (X/S Line) went west from benchmark RM1. The High Tide Line (HTL) at 3.25-ft Mean Sea Level elevation was located in the embayment of the Redwood Creek Estuary. The aerial photo is an older one and at the time of the survey, the area was dry except for the small outlet channel.

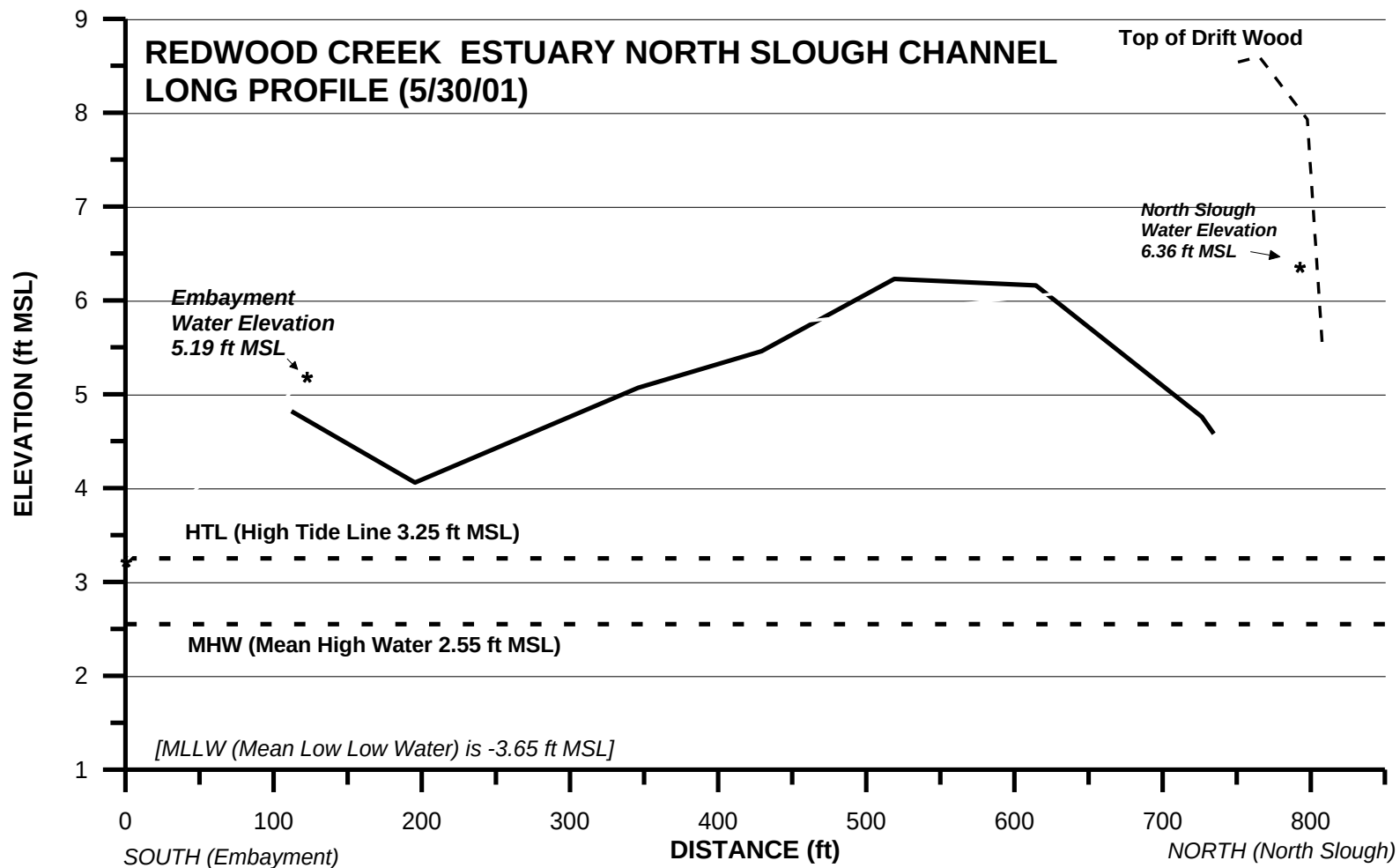


Figure 8. Longitudinal channel profile of the North Slough Channel of the Redwood Creek Estuary, Humboldt County, California surveyed on May 30, 2001. The profile started at the confluence of the channel with the embayment at the end of the north levee and extended into the North Slough. The High Tide Line (HTL) at 3.25-ft Mean Sea Level (MSL) elevation was about 100 feet into the embayment of the estuary.

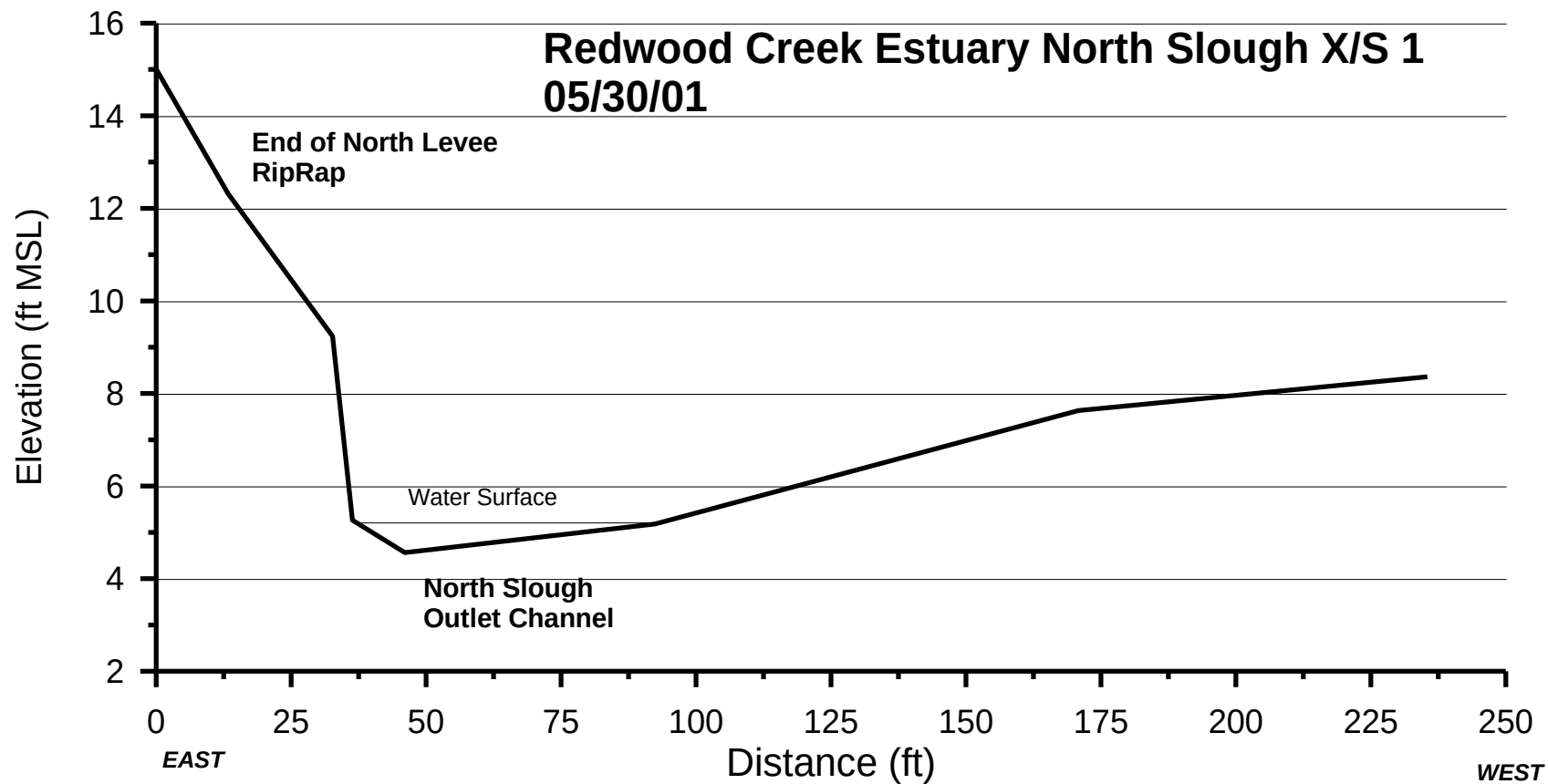


Figure 9. Cross-sectional profile (east to west) of the North Slough outlet channel, Redwood Creek Estuary, Humboldt County, California, surveyed on May 30, 2001.

The longitudinal survey showed sand had deposited in the channel to a high point of 6.23 ft MSL, and driftwood debris had rafted and accumulated to an elevation of 8.60 ft MSL (Figure 8). The sand at its highest was 5.35 ft above the high tide line of 3.25 ft MSL. The difference between the water elevation in the north slough and its confluence with the estuary embayment was 1.17 ft. The total channel gradient (ft/ft) was 0.0024. The thalweg of the one cross-section profile was 4.56 ft MSL.

Adipose Clipped Pit-tagged Coho Salmon and Cutthroat Trout – During the week of June 4th, 3 adipose clipped pit-tagged coho smolts were captured (fork lengths 101, 115, and 122 mm).

One adipose clipped pit-tagged (#4137203E30) cutthroat trout, 366 mm fork length, was captured in the embayment on August 16. It was the first recovery of a pit tagged cutthroat from the Prairie Creek study. It was initially tagged at 124 mm in a lower Prairie Creek study reach on October 8, 1999 (Steve Tussing, personal communication).

2001 Summary/Conclusions

- Mean lengths and weights of chinook, steelhead, and cutthroat residing in the estuary increased during the summer indicating fish reared in the estuary and the estuary provided rearing habitat. Those fish that resided in the estuary during the summer and migrated to the ocean in the fall were larger than those that emigrated prior to the closure of the mouth. Their larger size would confer an increased chance of survival in the ocean (Reimers 1973).
- The June breach likely contributed to a loss of fish between June 4 and July 16 population estimates. However, fish populations continued to decrease during the summer, mortality likely occurring as with the mouth closed, fish loss could not be attributed to migration into the ocean.
- Coho salmon did not rear in the estuary. Our seining sampled the end of the coho smolt out migration in June as only eight coho were captured later in the summer. This was similar to past years (Anderson 1995).
- The estuary provided 132 days of increased rearing volume to salmonid fish before a natural breach occurred on November 16, 2001 at water elevation of 10.12 ft MSL. Increased stream flow and wave overwash caused the breach. The breach decreased the water level 7.3 ft in 13.5 hrs, and eventually bottomed out at 0.3 ft MSL two days later.
- The estuary naturally breached on June 28, 2001 at a water elevation of 8.23 ft MSL. Increased stream flow caused the breach. The breach decreased the water level 5.13 ft in 31 hours.
- Water temperatures in the estuary were warm. Water temperature between June 1 and November 1 exceeded or equaled 17°C 50 percent of the time, and 74 percent of the time during the months of July and August.

- The berm profile surveys determined the high berm (winter berm) did not change between May and October unlike the lower berm profiles (Appendix VI high and low berm profiles 1-5). Location of the mouth changed as the channel migrated south and lengthened, and then shortened when the estuary breached in June. The low berm increased in height after closure of the mouth, but later when the beach receded, portions of the low berm disappeared.
- Embayment volume has decreased since cross section surveying began in 1998. Most channel change occurs at the cross sections closer to the ocean. Embayment volume (at one foot intervals) has decreased an average of 47% since surveying began in 1998, and 27% since 2000 surveys.

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- 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).
- 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

Steve Tussing, Humboldt State University, Fisheries Graduate Student, email dated 10/29/01.

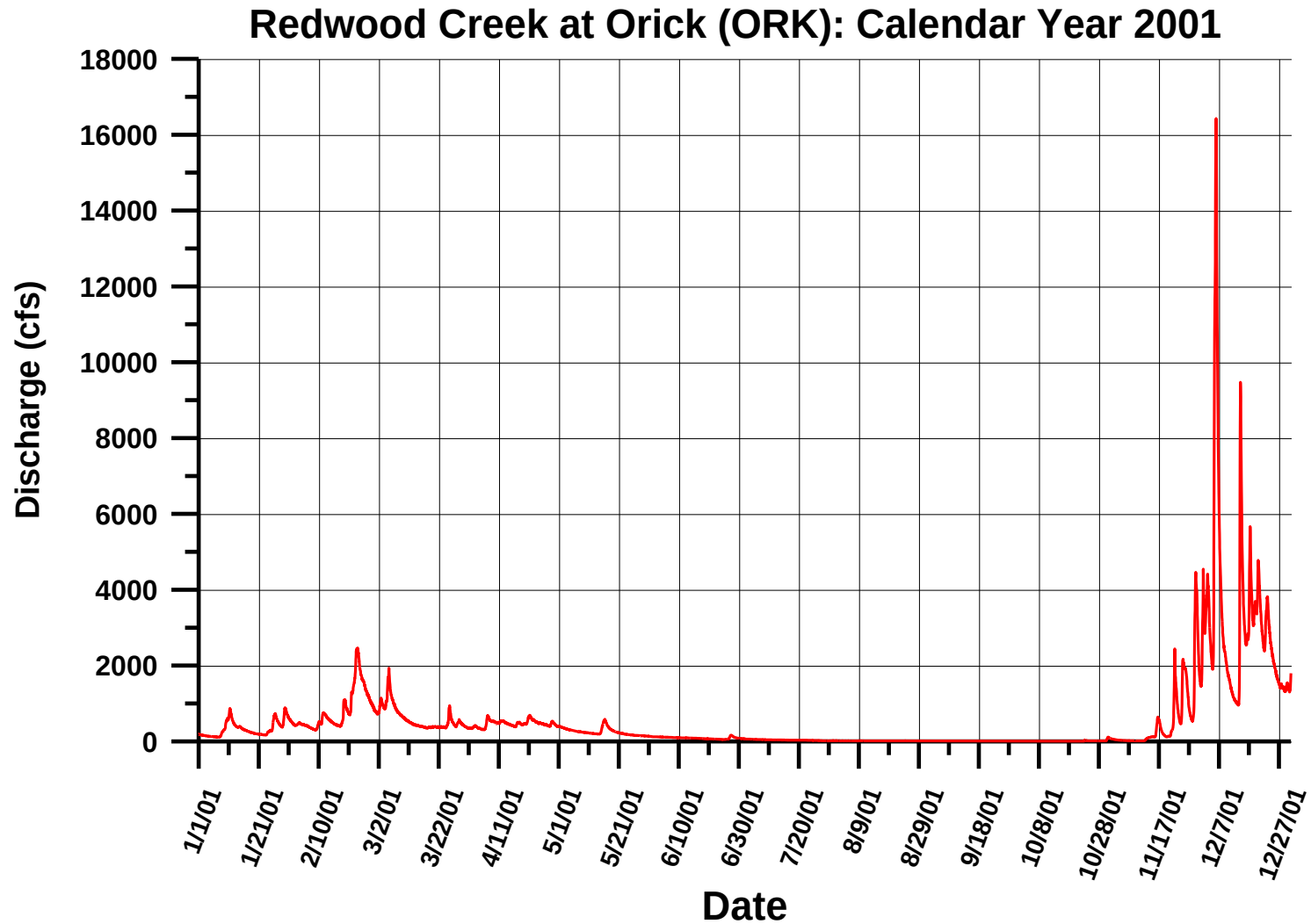
Prepared by: David G. Anderson – REDW Fishery Biologist
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 (707) 464-6101 x 5271
 [04/2002]

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. It includes eight special conditions.

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 2001. Fish fins, top, middle, and bottom caudal, anal, and pectoral 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.

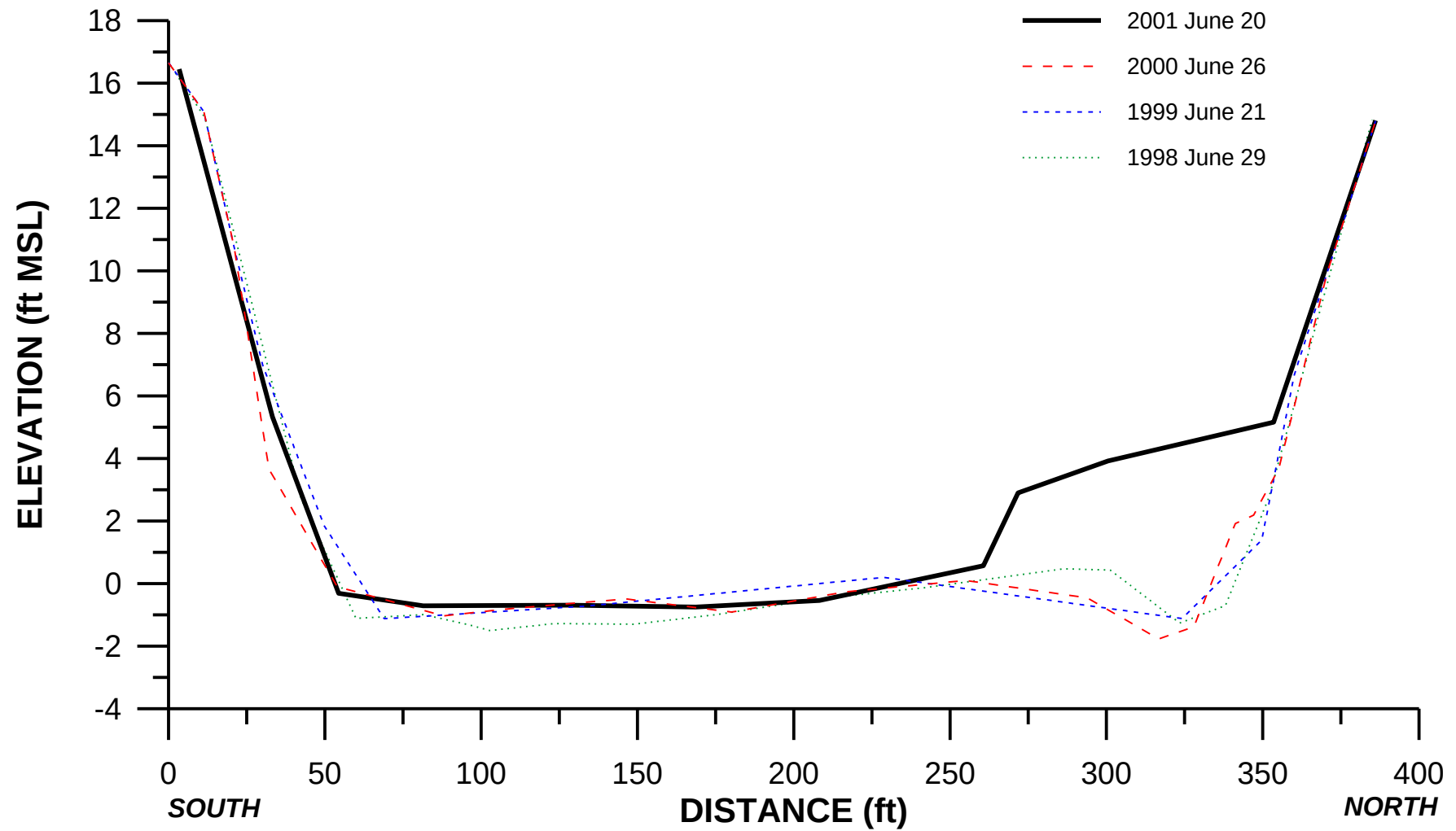
2001 Date	Fin Mark	Number Marked/Marks Recaptured/ Total Captured in Second Sample			
		Chinook	Coho	Steelhead	Cutthroat
June 4 & 5	Bottom caudal	1,392	37	437	6
June 7		33	0	4	0
		1,390	16	352	8
July 16 & 17	Top caudal - KS,SHD,Coho Top caudal/Right Pectoral – CUT	621	2	648	21
July 19		6	0	42	0
		331	0	614	4
Aug 13 & 14	Anal – all fish	226	1	760	7
Aug 16		5	0	87	0
		80	4	528	7
Sept 10 & 11	Middle caudal – KS & SHD Middle caudal/Left Pectoral - CUT	132	0	878	34
Sept 13		3	0	34	3
		52	0	362	23

Appendix III. Hourly Redwood Creek flow data for calendar year 2001, January 1 through December 31, 2001. Data is from the California Department of Water Resources Orick (ORK) gaging station located on Redwood Creek downstream of the confluence of Prairie Creek and north of Orick, California.

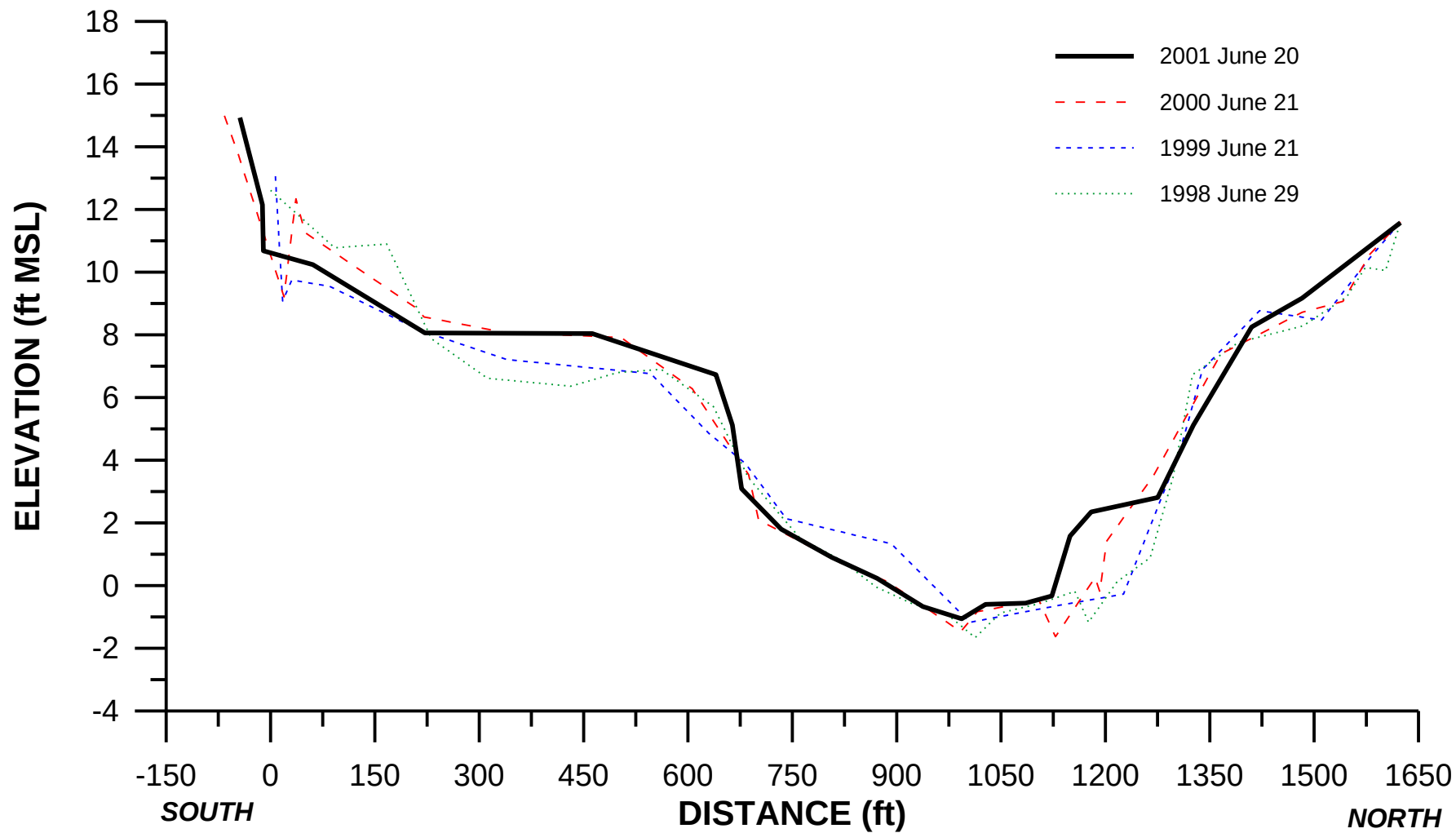


Appendix IV. The five permanent cross-sections surveyed on June 20 (cross sections E-1 through E-3) and July 24, 2001 (cross sections E-4 and E-5) in the Redwood Creek estuary embayment perpendicular to the flow. Established in June of 1998, each cross section was shot at a bearing of 170° from the north 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.

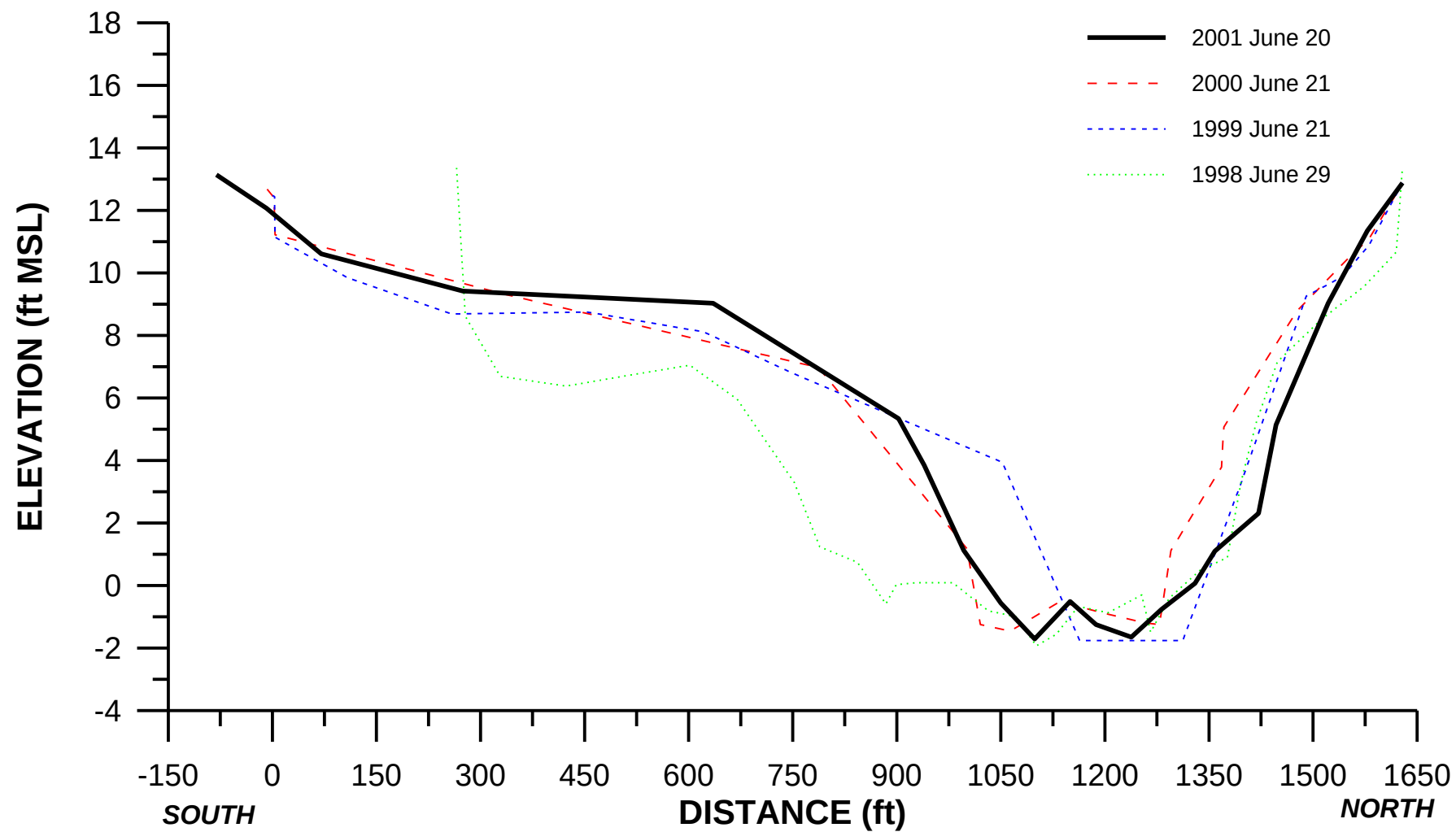
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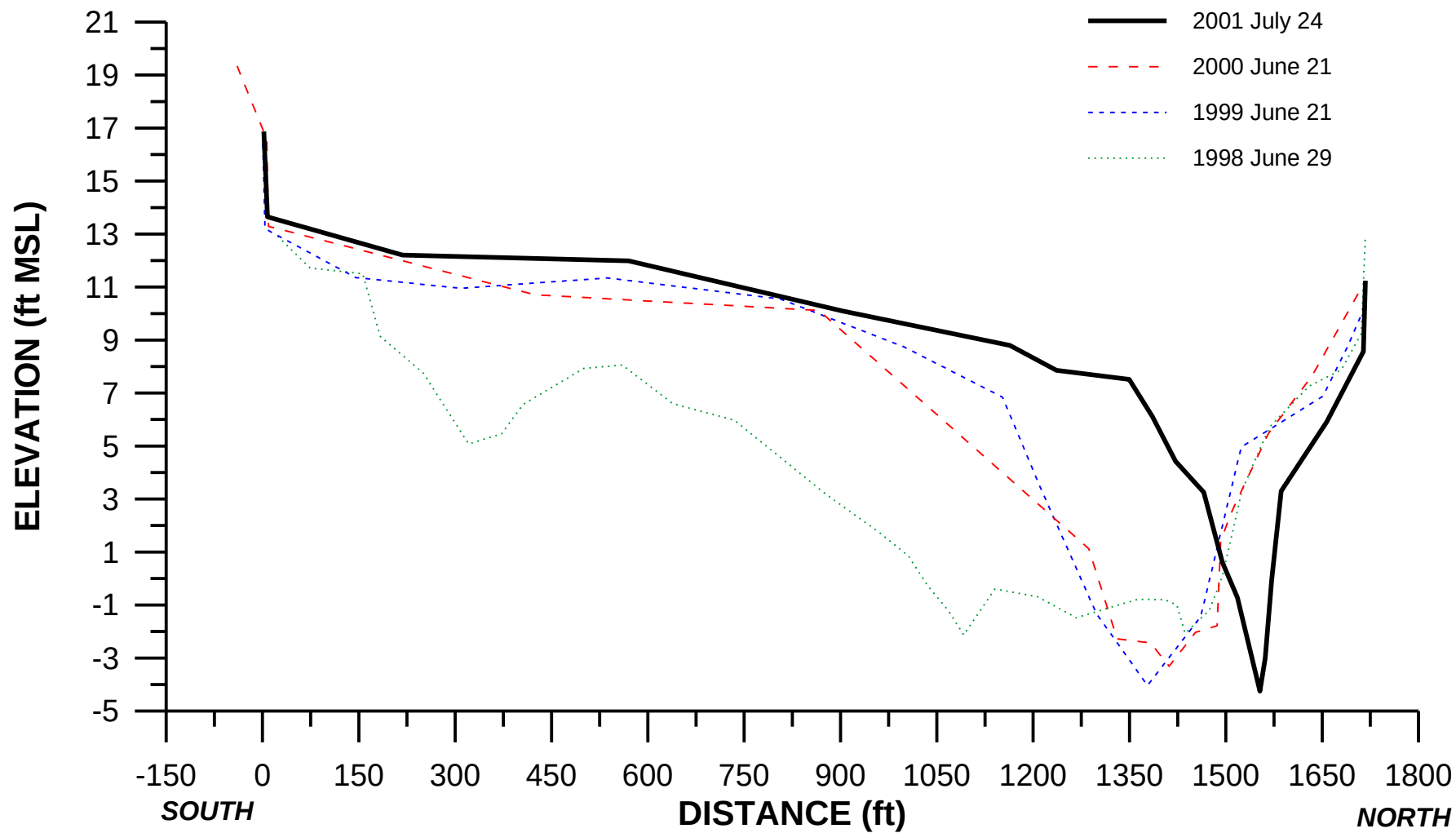
ESTUARY CROSS SECTION E-2



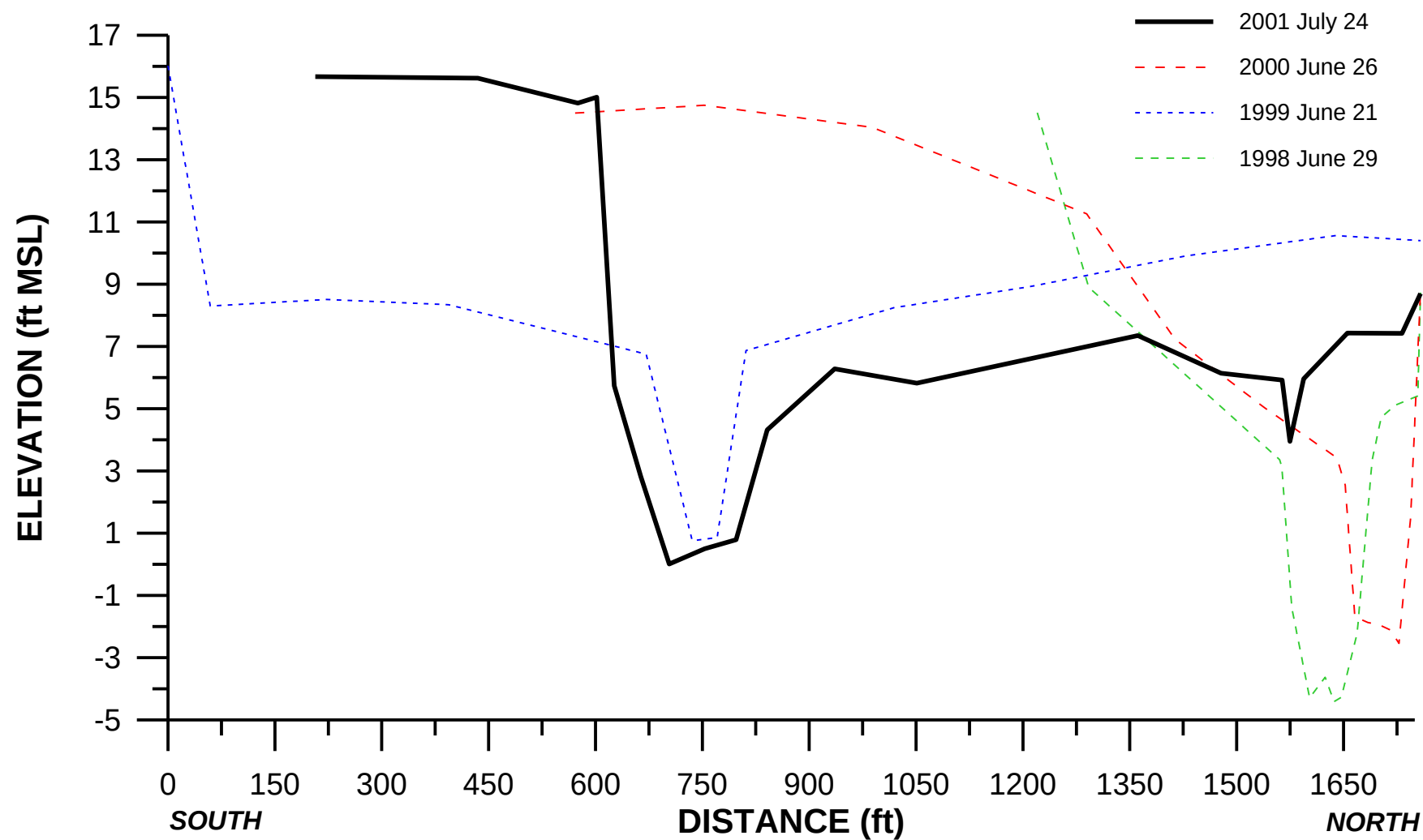
ESTUARY CROSS SECTION E-3



ESTUARY CROSS SECTION E-4



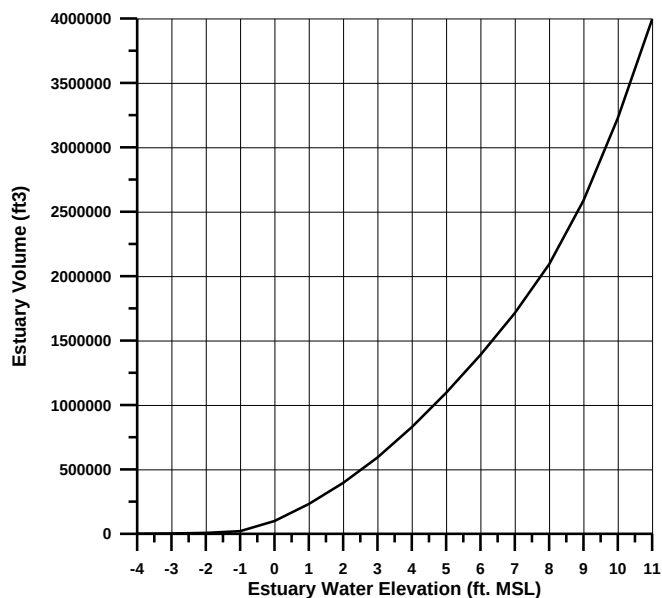
ESTUARY CROSS SECTION E-5



Appendix V. Calculated wet width (ft) and volume (ft³ and yd³) of the Redwood Creek embayment at water elevations of -4 to 11 ft MSL based of the five cross sections E-1 through E-5 surveyed on June 20 (E-1 through E-3) and July 24, 2001 (E-4 through 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.

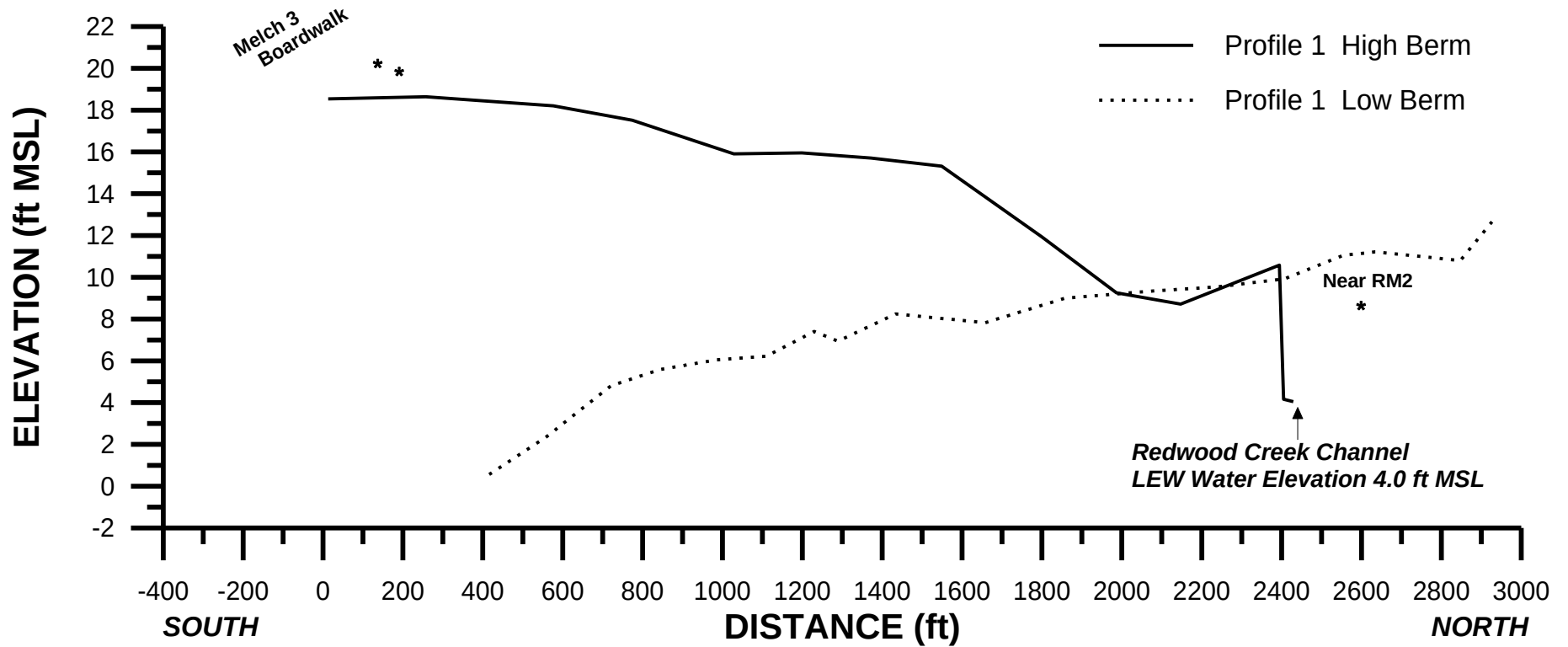
Width and Volume for Varying Water Elevations – Redwood Creek Estuary 2001							
Water Elev. (ft MSL)	X/S E1 Wet Width (ft)	X/S E2 Wet Width (ft)	X/S E3 Wet Width (ft)	X/S E4 Wet Width (ft)	X/S E5 Wet Width (ft)	Estuary Volume (ft ³)	Estuary Volume (yd ³)
11	355.22	1600.83	1520.60	972.81		3,993,996	147,926
10	349.16	1452.96	1370.52	792.96		3,227,290	119,529
9	343.11	1316.95	883.86	590.93		2,586,978	95,814
8	337.05	935.76	792.08	476.46	1123.85	2,091,913	77,478
7	330.99	773.32	700.30	317.76	910.07	1,713,288	63,455
6	324.93	699.12	608.52	271.15	441.57	1,388,538	51,427
5	312.23	659.10	534.41	223.13	254.35	1,094,115	40,523
4	265.74	630.37	500.74	167.84	189.67	827,395	30,644
3	232.62	598.25	470.28	116.66	163.75	592,615	21,949
2	221.76	440.51	427.02	101.25	137.44	394,905	14,626
1	213.25	342.54	355.11	85.84	110.89	231,135	8,561
0	180.53	238.69	293.56	66.41		98,823	3,660
-1		13.10	155.78	47.51		20,454	758
-2				34.18		7,012	260
-3				20.84		2,254	83
-4				4.17		90	3

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



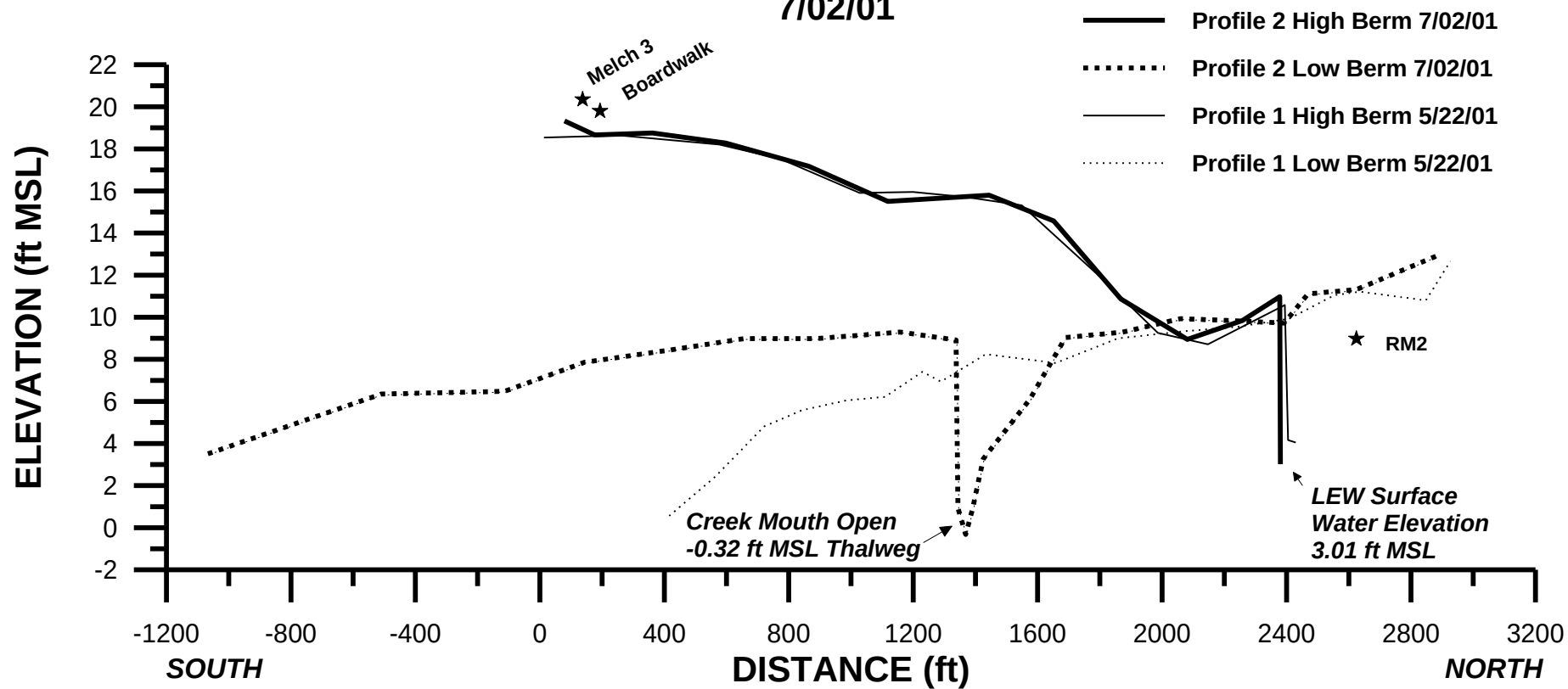
Appendix VI. Longitudinal profiles of the sand berms along the highest ridge parallel to the shore separating the estuary from the ocean for May 22, June 2, July 10, September 5, and October 1, 2001 (Profiles 1 through 5 respectively). The profiles extended from a minimum of 100 feet north of the estuary 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 referred to as Melch 3 located west of RIC and to the end of the RIC boardwalk. In the north, they were 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 10, September 5, and October 1, 2001 surveys.

2001 RWC ESTUARY DUNE PROFILE 1 **5/22/01**

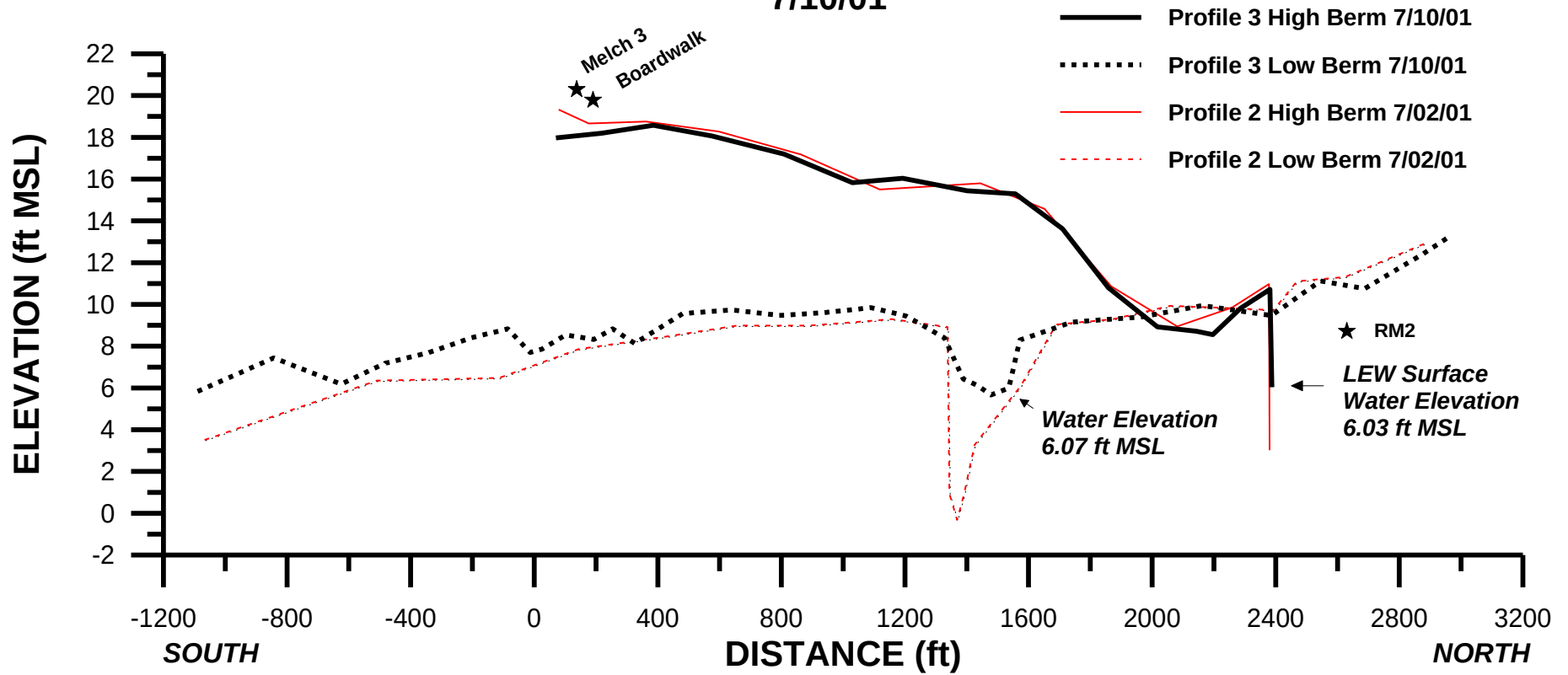


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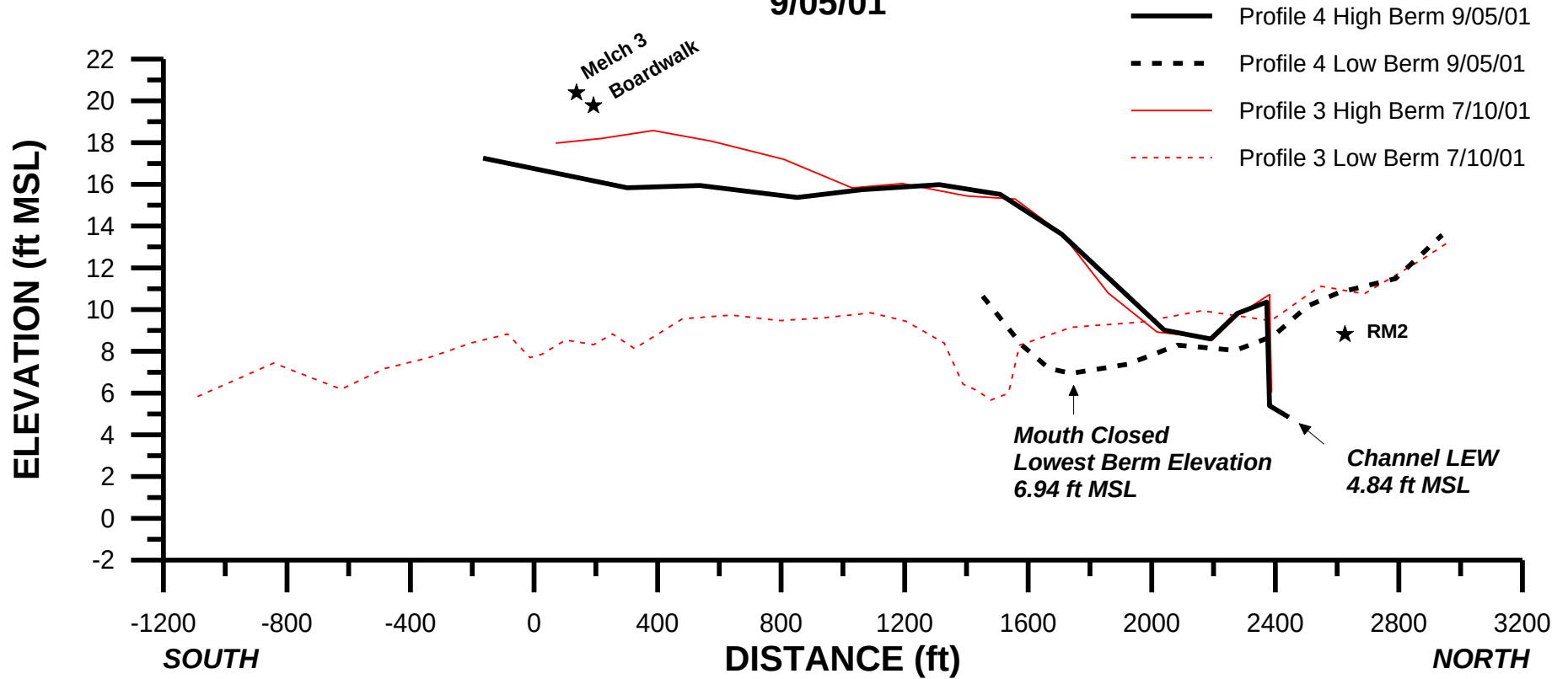
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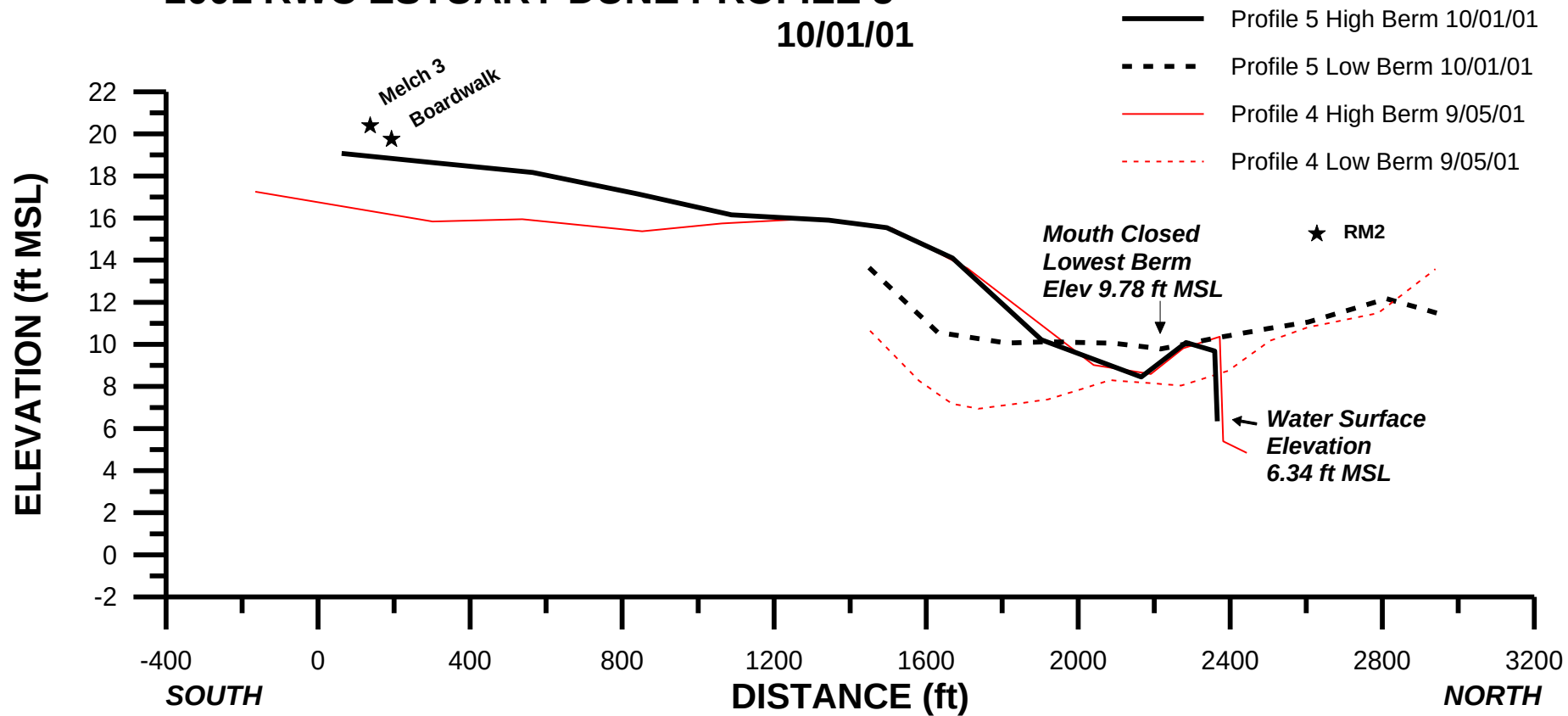
2001 RWC ESTUARY DUNE PROFILE 3 7/10/01



2001 RWC ESTUARY DUNE PROFILE 4 9/05/01

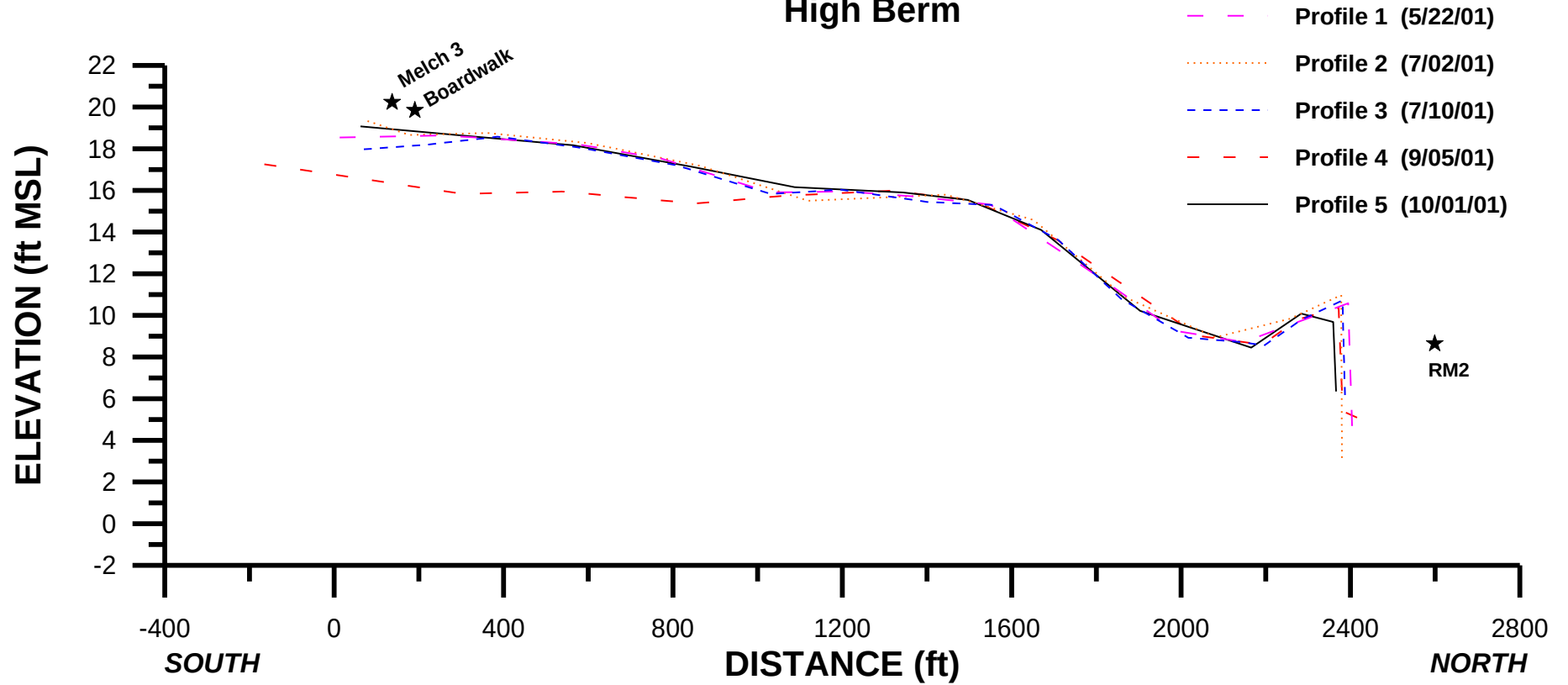


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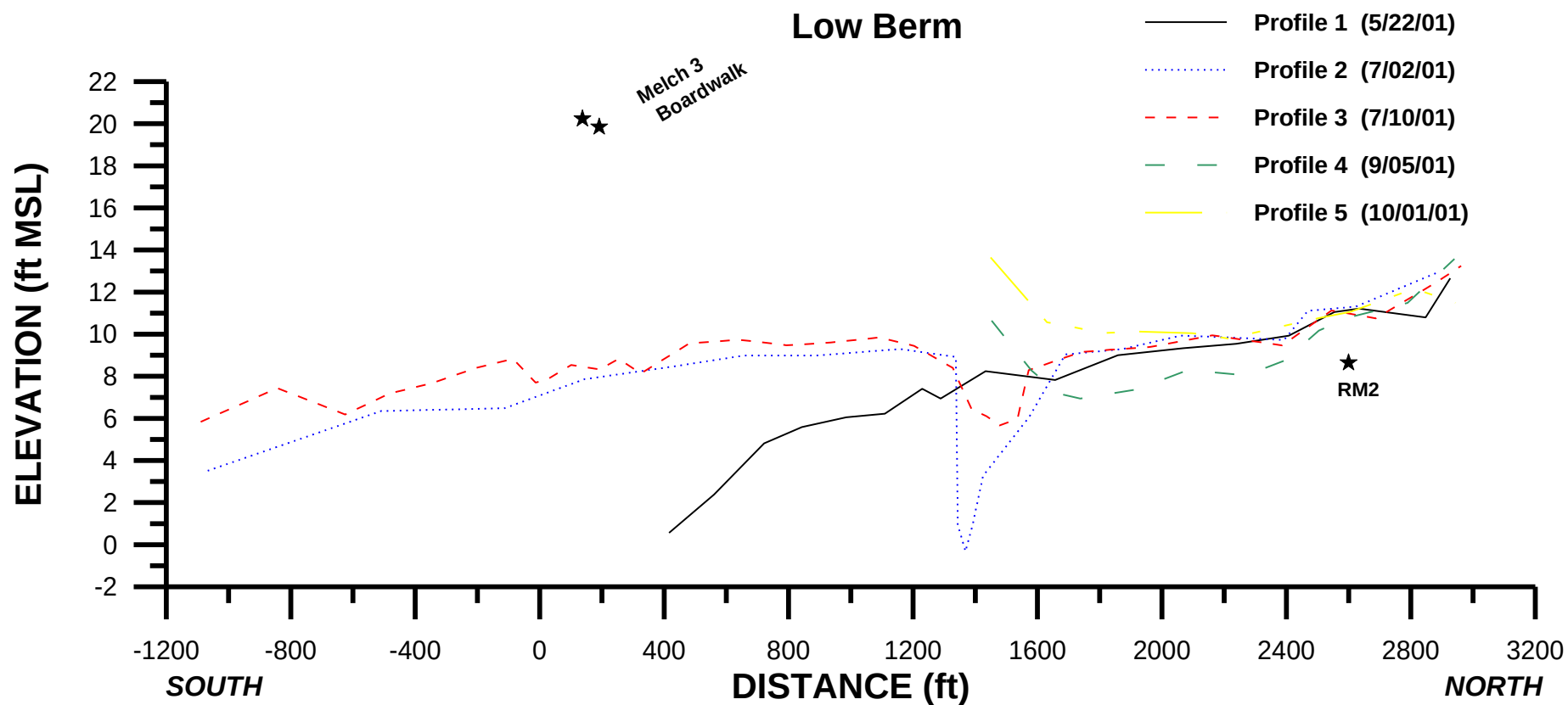
2001 RWC ESTUARY DUNE PROFILES 1- 5

High Berm



2001 RWC ESTUARY DUNE PROFILES 1- 5

Low Berm



Appendix VII. Survey points of the five 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).

2001 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 components.

Estuary Biological Monitoring (seining)

Fish and Wildlife Branch: David Anderson, Baker Holden III, Terry Hines, Keith Bensen, Kyle Max, Jeanne Mayer, Ben Littlefield, and Jesse Conklin.

Resource Management Labor Support Crew: Glen Fickbohm, Rick Campos, Tim Tanno, and Keith Richey.

Roads and Trails: Jason Santmyer, Heinz Gueldenpfenning, Karen Connolly, Shasta Williams, Josh Jimenez, Mike Ialongo, and Chuck Williams.

Interpretation: Jennifer Mall and Brian Olson

Volunteer In the Park: Johannes Breidenbach, Elke Wald, and Ute Sagasser

Agency: Don Baldwin and Bethany Reisberger (HSU- Fisheries Coop Unit), and Terry Roelofs (HSU-Fisheries Department)

Fish Descriptive Statistics

Fish and Wildlife Branch: Terry Hines

Estuary Water Level Monitoring

Geological Services: Carrie Jones (South Slough Data Collection and synthesis)

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

Installation and Removal of South Levee Water Elevation Recording Gage

Geological Services: Carrie Jones

Fish and Wildlife Branch: David Anderson, Keith Bensen, and Baker Holden III

Estuary Surveying of Berm and Embayment Cross Sections

Geological Services: Vicki Ozaki and Carrie Jones

Fish and Wildlife Branch: David Anderson and Baker Holden III

Culverts Opening and Closing

Fish and Wildlife Branch: David Anderson, Baker Holden III, and Terry Hines