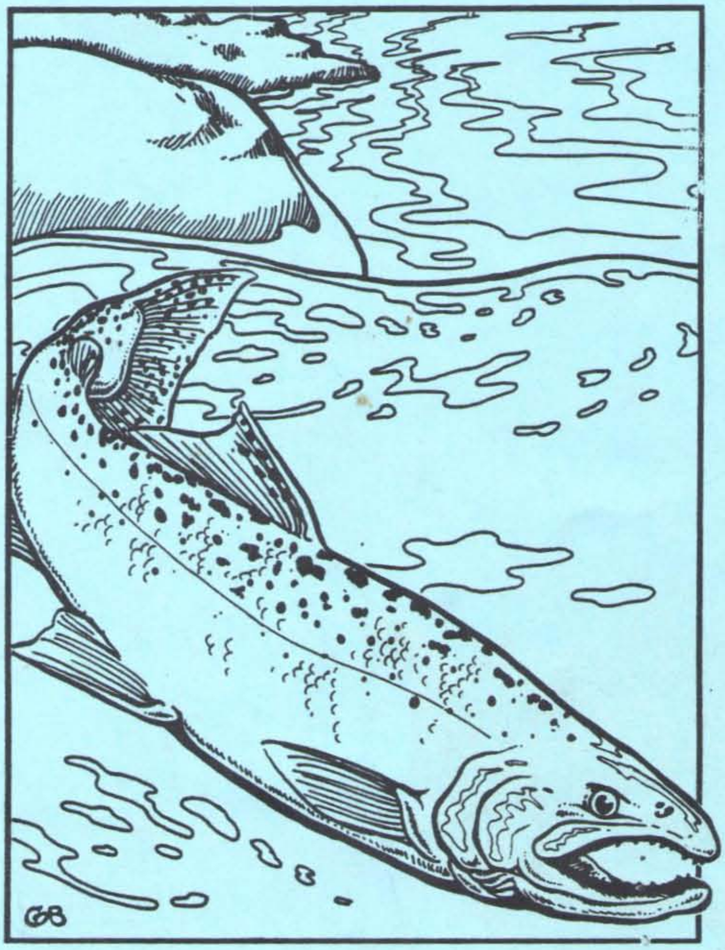
A PRELIMINARY ASSESSMENT OF THE SALMON HABITAT POTENTIAL OF BUTTE CREEK, A TRIBUTARY OF THE SACRAMENTO RIVER, BETWEEN THE BUTTE HEAD DAM AND CENTERVILLE DIVERSION DAM, BUTTE COUNTY, CALIFORNIA



Prepared for the Institute for Fisheries Resources
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For the

Institute for Fisheries Resources
San Francisco, California

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SUMMARY

The eleven-mile stretch of Butte Creek between Pacific Gas and Electric Company's (PG&E) Butte Head Dam and the company's Centerville Diversion Dam (photos 1 and 2, map 1) was surveyed during the summer of 1997 to determine the stream's potential for supporting self-sustaining populations of salmon, particularly spring-run chinook salmon, *Oncorhynchus tshawytscha.* Spring-run salmon numbers have declined dramatically in the Sacramento River watershed during the past three or four decades.

This Butte Creek survey was conducted for the non-profit Institute of Fisheries Resources (IFR) with funds provided by the National Fish and Wildlife Foundation (NFWF) and the William and Flora Hewlett Foundation. NFWF entered into a grant agreement with IFR (supplemented by Hewlett) in late 1996 for the purpose of exploring the practicality of modifying dams in the stream's canyon section to expand spring-run chinook habitat opportunities. The NFWF/Hewlett grant was modest, intending that if the stream appeared to have essential spring-run habitat potential then a subsequent, finer-grained habitat restoration plan should be undertaken in close consultation with PG&E and other Butte Creek watershed interests[1].

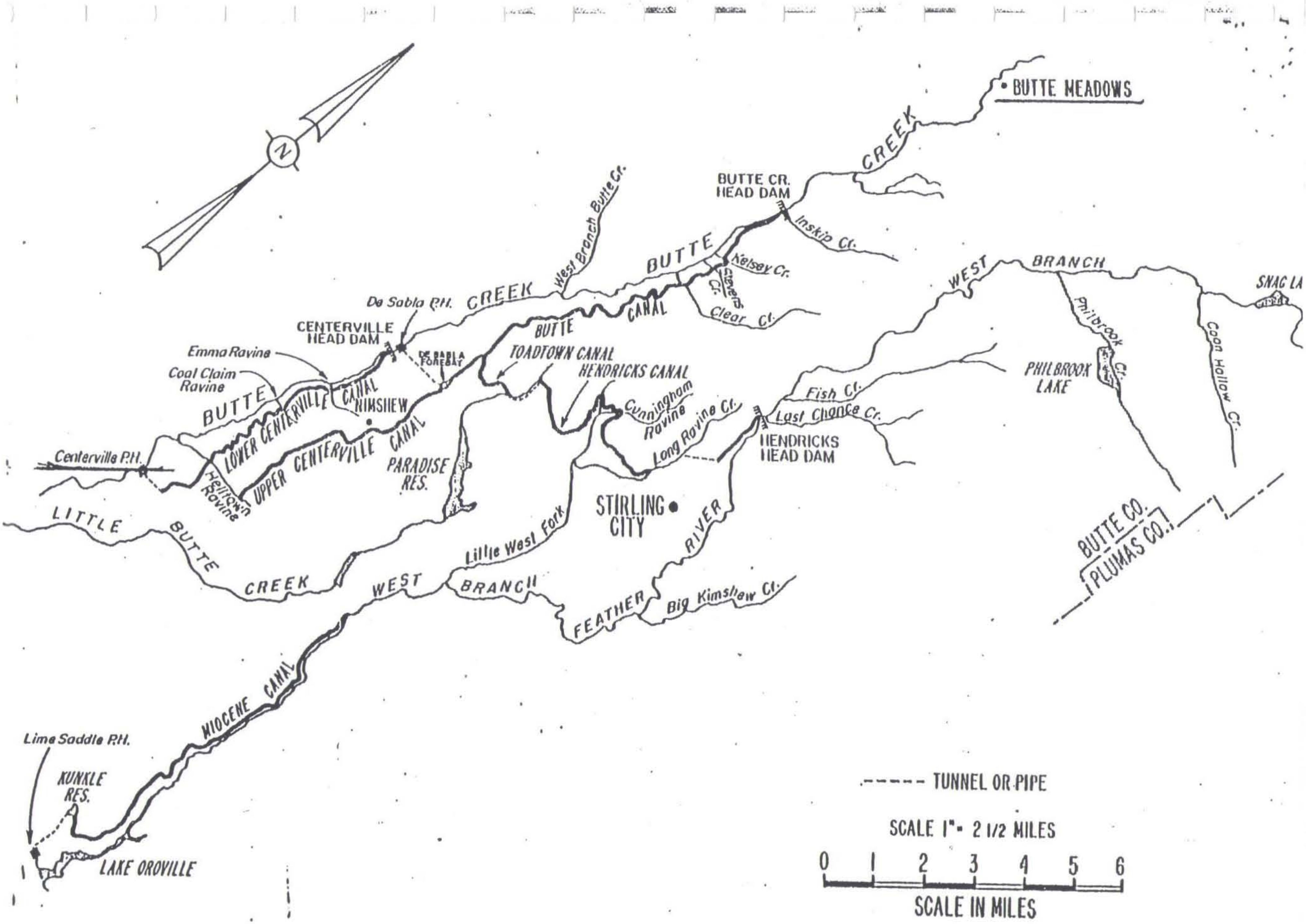
The Kier Associates team documented the location and qualities of the pools they thought would be suitable for holding spring-run salmon from the time of their migration into the canyon in spring until they were ready to spawn in early autumn; the quantity and quality of potential spawning gravel; the summer temperature regime of a sample of the pools; and the size and location of apparent barriers to upstream salmon migration.

A total of 77 natural barriers was encountered in the eleven-mile reach: 57 small waterfalls, eight chutes and eleven cascades. A hundred pools were measured, 27 of which had good structural characteristics for holding spring-run salmon. The team examined 54 graveled areas containing enough gravel to accommodate about 500 salmon redds. The gravel was generally of good quality for salmon spawning. Water temperatures in the potential holding pools ranged from less than 60 degrees to a high of 72 degrees F. during the hottest days of summer.

The eleven-mile canyon section of Butte Creek contains pools, shelter, spawning gravel and water quality sufficient to meet the summer holding and early fall spawning requirements of spring-run chinook salmon. The number of barriers observed during the summer survey is daunting, however most of the falls and chutes may be surmountable by adult salmon at the higher flows available during their springtime migration. If fish migration beyond the impassable Centerville Diversion Dam were made possible then the accessibility of the upper Butte Creek canyon would be determined largely - but not

[1] Evaluation of fish passage opportunities above PG&E's Centerville Diversion Dam is recommended as a high priority action in the U.S. Department of the Interior's 1997 ***Revised Draft Restoration Plan for the*** (Central Valley Project Improvement Act) ***Anadromous Fish Restoration Program.***

Photos 1 and 2. Looking up at the Butte Head Dam (upper photo) and down on the Centerville Diversion Dam. The dams, which are approximately 40 and 20 feet high, respectively, bracket the 11-mile canyon study reach



Map 1. Butte Creek canyon and environs, from Butte Meadows downstream to the Centerville Powerhouse

exclusively - by the amount of streamflow available. Fish could likely move through much of the section on higher spring flows, while several potential obstacles would require some degree of modification - gradient moderation, rock removal or small fish ladders - to enable fish passage in virtually all years.

Given the extreme scarcity of spring run chinook salmon habitat in the Sacramento River watershed, and the very great danger of extinction this species is facing, a closer examination of how to resolve the worst of the stream's migration barriers - in order to make the Butte Creek canyon available for spring-run chinook salmon production - definitely appears warranted.

METHODS

A hip-chain was used to establish the location of likely holding pools, potential spawning areas and apparent barriers to upstream migration. Hip-chain measurements were begun at the Butte Head Dam and all locations are referenced in feet downstream from that point, as well as to other fixed sites like the Ponderosa Way (Garland Rd.) Bridge, Forks of the Butte head dam, and the DeSabla Powerhouse. In this way the team established reasonably accurate locations of the pools, potential spawning sites and barriers to guide further study, mapping and site-specific restoration planning.

A 14-foot fiberglass stadia rod was used for height and depth measurements. Fiberglass tapes were used to measure width and length of stream units whenever hip chain measurements became impractical. All measurements were taken in feet, to the nearest one-tenth of a foot.

Pool measurements included the length of each pool unit, mean widths, mean and maximum depths, and the depth at the pool tail crest, so that residual pool volume could be calculated. Between four and ten width and depth measurements were taken over the length of each pool unit. An in-stream shelter rating and an in-stream shelter percent cover was determined for each pool unit, following the methods recommended by the California Department of Fish and Game (Flosi and Reynolds, 1994).

The mean length and width of each significant gravel deposit was measured to a tenth of a foot. The nature of the dominant and co-dominant substrates was determined by selecting twenty substrate samples at equidistant intervals along the velocity crossover site, or riffle crest. The substrate most frequently recorded is the dominant substrate, the next substrate most frequently recorded is the co-dominant substrate. An embeddedness rating was recorded at each site. Again, the methods used here are those recommended by Flosi and Reynolds (1994).

Temperatures were taken with a hand-held thermometer during the first trek through the canyon. Once the locations of suitable candidate holding pools had been determined six Stowaway™ temperature recorders were deployed in them. Full deployment was completed before the end of July. Each recorder was encased in an open-ended section of

PVC pipe, a 6-ounce weight was attached to the outside of the pipe, and the assembly was then anchored to the streambed with airplane cable. The recorders were placed reasonably close to canyon access points, in areas where they could be successfully anchored. They were set to log the temperature each hour, 24 data points a day. Data from five of the recorders was retrieved and the loggers re-deployed on October 9, 1997 in the hope of capturing winter and spring stream temperature data as well. One of the recorders, located not far above the Garland Road bridge, had disappeared by October.

Apparent barriers to the upstream migration of adult salmon were evaluated using criteria advanced by Stuart (1964), Hoar and Randall, (1978), Powers and Orsborn (1985), and Aaserude (1994), in particular, concerning plunge pool depth requirements; the ratio of waterfall height to plunge pool depth; the distances over which salmon can sustain high swimming speeds; and the condition one would expect salmon to be in by the time they had traveled from the ocean to the Butte Creek canyon.

Barrier measurements included the depth of each plunge pool, the height from the plunge pool surface to each waterfall crest; and the horizontal distance of the barrier from the point of the penetrating falls to the landing area just upstream of the waterfall crest. If the barrier contained multiple falls and pools, the fall with the greatest attraction flow was measured. Streamflow and water velocities were *not* measured, although there were attempts to estimate surface velocities. The lesser split channels were not characterized. Multiple falls were regarded as complex cascades.

RESULTS

Holding Pools

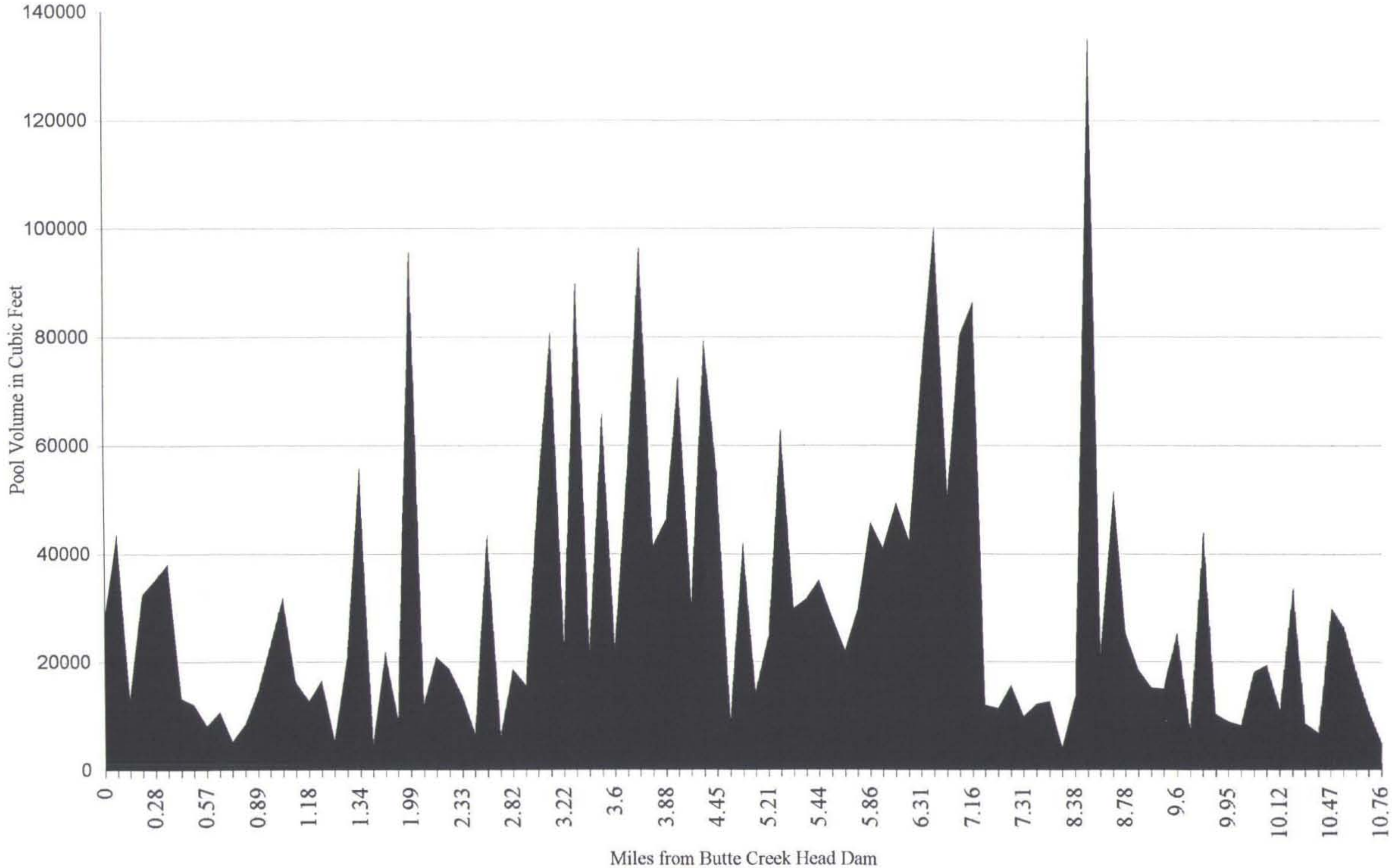
The team identified 100 pools in the 11-mile reach ranging in maximum depth from 15.5 feet down to 5.0 feet. The pools are well distributed along the length of the reach, as indicated in Figure 1. Twenty-two of the pools had maximum depths of 10 feet or more. The 100 pools had a combined volume of more than three million cubic feet and a combined surface area of more than a half-million square feet. Roughly a third of the total pool volume enjoyed an instream cover rating greater than 100. These higher instream cover ratings were typically the result of many large boulders in the pools, extensive bubble curtains, or both, as shown in photograph 3.

Data concerning all the pools measured in the canyon reach is found at Appendix 1.

Spawning Gravel Potential

Figure 2 shows the extent and location of significant gravel areas. Figure 3 shows where relatively silt-free gravel of the most suitable size for salmon spawning is located. Taken together, the two figures show that significant amounts of clean gravel of suitable size for

Figure 1. Volume and location of pools, Butte Creek canyon



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Photos 3 and 4. Eight-feet-deep pool (upper photo) with extensive bubble curtain, resulting in high cover rating. Pool tail-out (lower photo) below Garland Road bridge, showing gravel highly suitable for salmon spawning.

Figure 2. Extent and location of significant spawning gravel

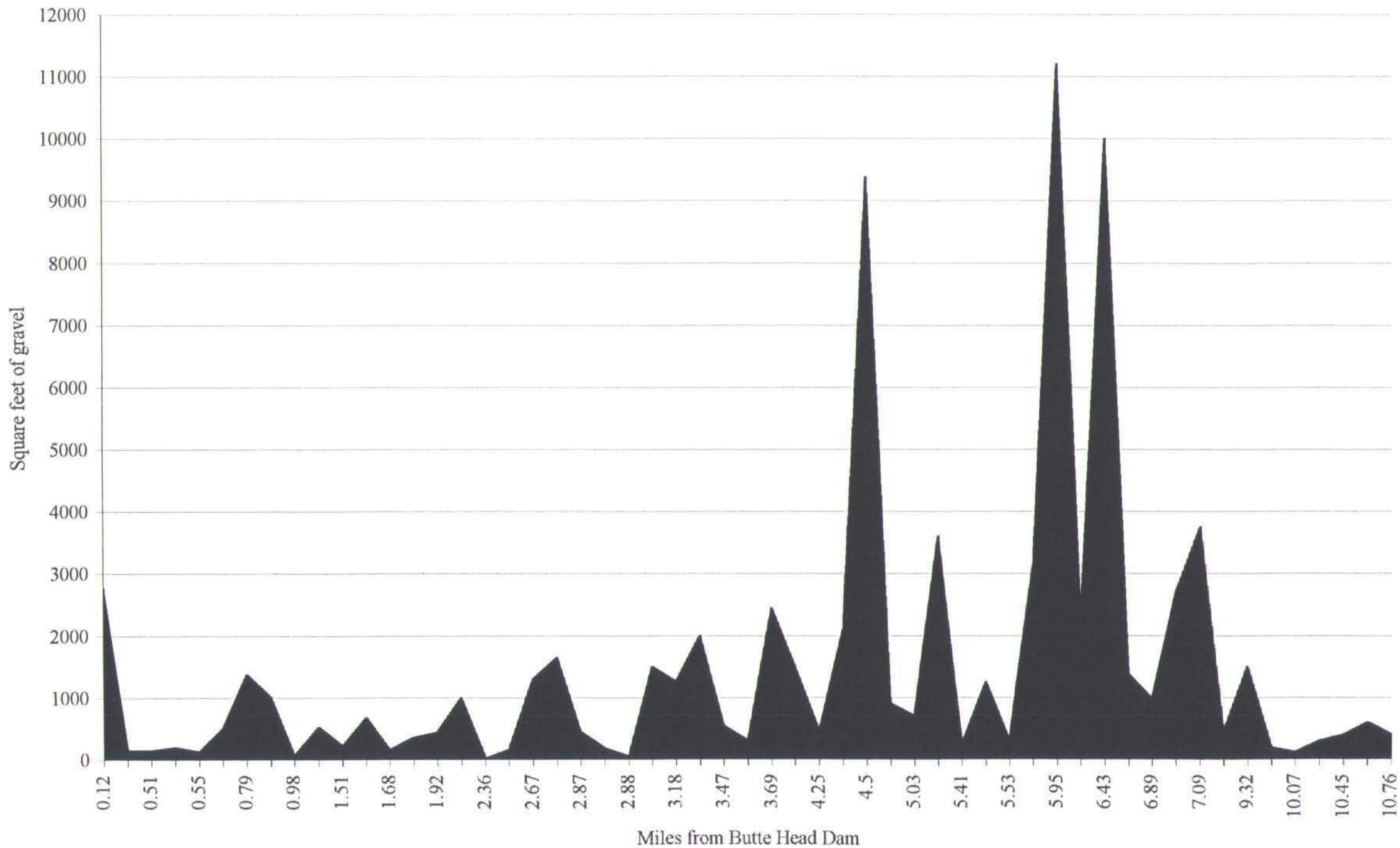

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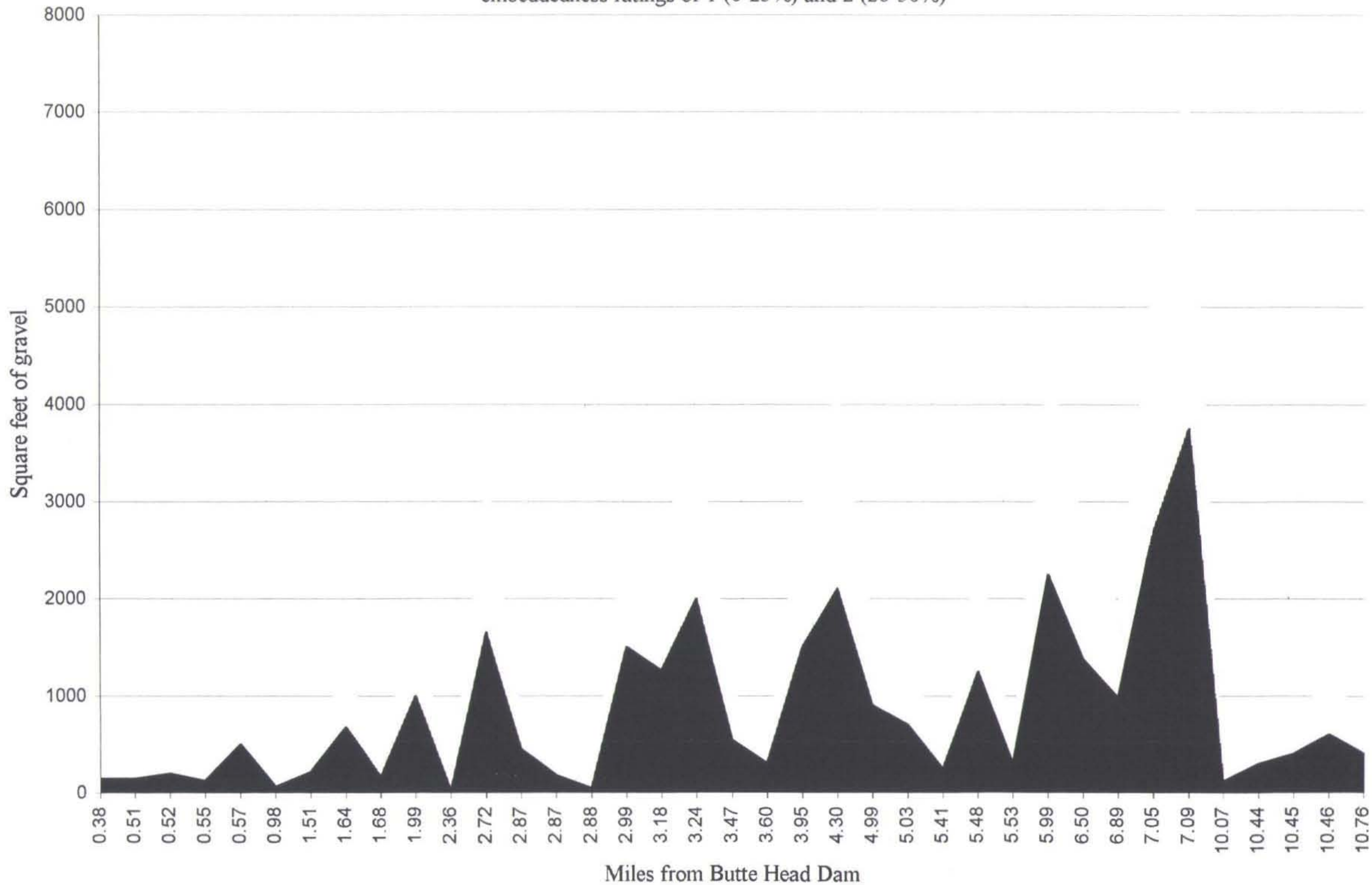
Figure 3. Butte Creek canyon areas with dominant gravel substrates (particle size .08-2.5") and small cobble (2.5-5") with embeddedness ratings of 1 (0-25%) and 2 (26-50%)



spawning, similar to that shown in photograph 4, are reached within four miles of the Centerville Diversion Dam.

The survey team noted 54 sites with sufficient gravel to support salmon spawning, a total of 81,344 square feet. Of the 100 pools noted above, two-thirds had gravel deposits usable by spawning salmon at their pool tail crests, while a third had bare bedrock tail-outs.

Data concerning all the gravel areas the team measured is found in Appendix 2.

Water temperatures

The measurements made with a thermometer held near the surface of the pools while the recorders were being deployed on July 23 and 24, 1997, ranged from 62 degrees F. to 72. The temperature recorders were deployed as far upstream as just below the U.S. Forest Service's Butte Meadows campground (i.e., above the canyon reach) to as far downstream as a half-mile above PG& E's De Sabla Powerhouse. The recorders were fixed at pool depths ranging from 6.5 feet down to 10.5 feet. The temperatures recorded at these pool depths ranged from 55 degrees F. up to (in one isolated case) 75 degrees.

Figure 4 shows the daily maximum, average and minimum temperatures recorded by the monitors in the four Butte Creek canyon pools. The location of and record for each of the pools is found in Appendix 3.

Barriers to salmon migration

The survey team encountered 77 apparent barriers to the upstream migration of adult salmon in the 11 mile reach - 80 counting the Centerville Diversion, Forks of the Butte Dam and Butte Head Dam (Figure 5). There were 57 single waterfalls, eight chutes and eleven cascades - and, at approximately seven miles below the Butte Head Dam, the unladdered, ten-foot-high Forks of the Butte hydroelectric diversion dam.

At the streamflow available on the survey dates, 74 of the apparent barriers had inadequate plunge pool depths. At those lower flows, 30 of the sites had vertical heights from their plunge pool surface to the crest of their falls that exceeded the leaping ability of chinook salmon. Fifty six of the barriers had horizontal distances and velocities that appeared to exceed the swimming abilities of salmon.

Half the barriers were relatively small, not more than 4.5 feet from plunge pool surface to waterfall height, and all of these lacked sufficient plunge pool depth *at the late summer study flows* to enable the upstream migration of salmon.

The complete record of apparent barriers to adult salmon migration created by the survey team may be found at Appendix 4.

Figure 4. Daily maximum, average, and minimum
Butte Creek pool temperatures

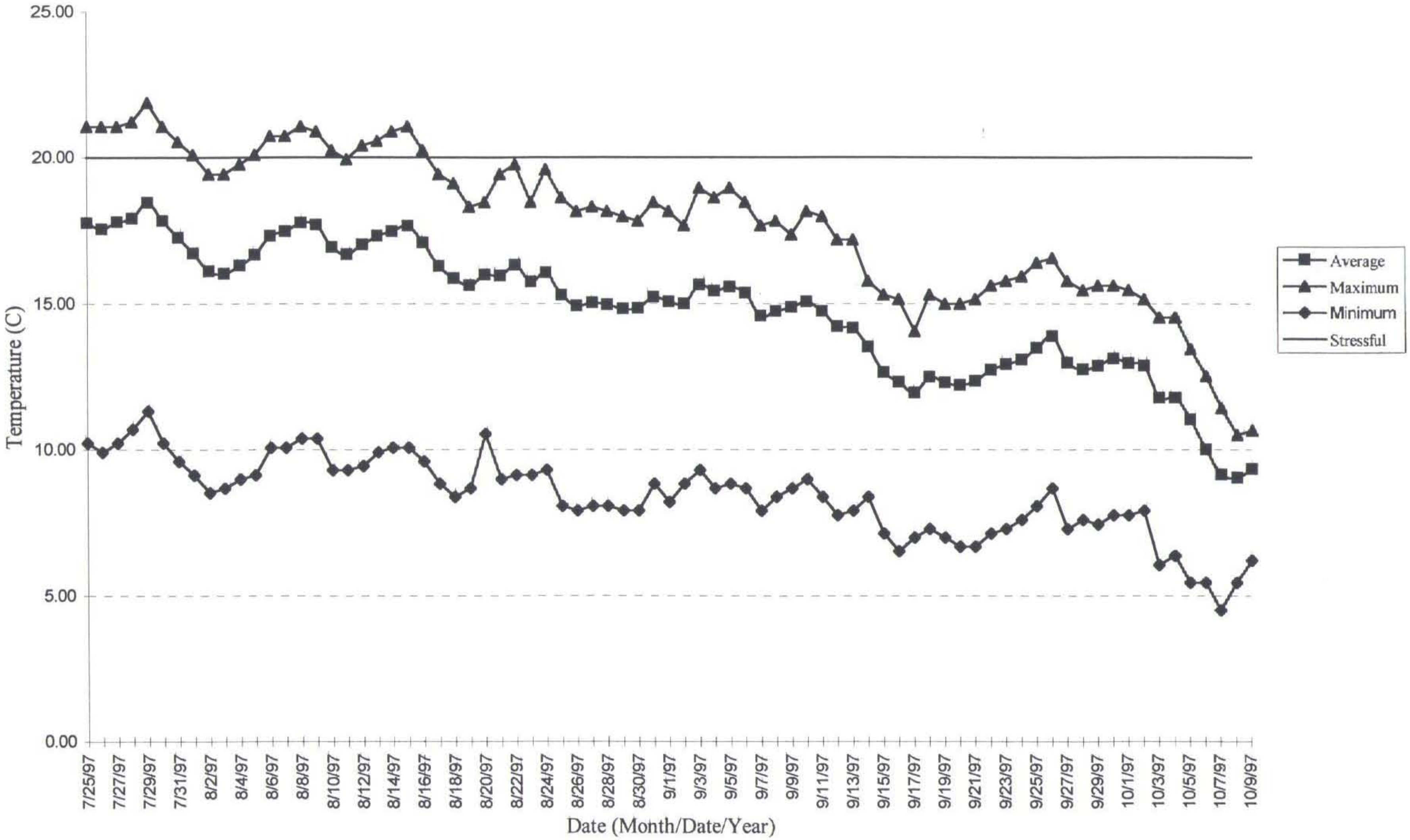
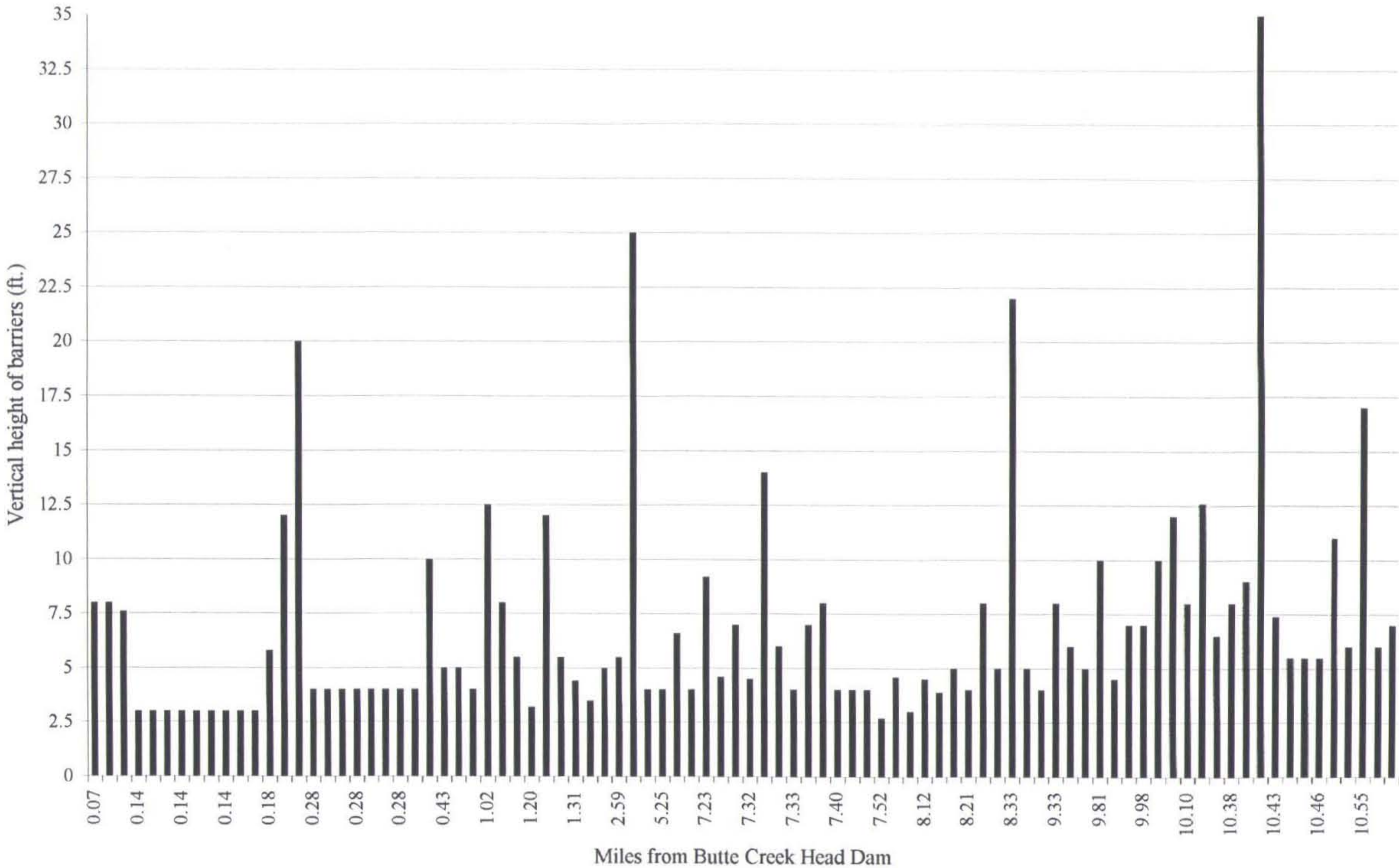


Figure 5. Size and location of barriers, Butte Creek canyon



Other observations

The survey team was instructed to keep an eye out for aquatic species of concern. Team members observed six yellow legged frogs (*Rana boylii or R. muscosa?)* during the course of the survey.

The Butte Creek canyon supports very large populations of aquatic insects. Caddis, mayflies, and stoneflies were all observed in large numbers throughout the canyon reach, suggesting that the stream produces a great deal of food for salmonid fishes of all ages.

DISCUSSION

Pools

The authors compared their Butte Creek pool measurements to those made by Barnhart and Hillimeier on the South Fork Trinity River (1994). The Butte Creek pools tend to be a third smaller than South Fork Trinity pools, on average, reflecting the differences in the morphology of the two systems. Barnhart and Hillimeier determined through a linear regression analysis that total surface area appeared to be the strongest predictor of the presence of spring-run chinook salmon in South Fork Trinity River pools. Those investigators did not suggest, however, how many salmon might occupy a pool of a given size. LaFaunce (1967) estimated the adult spring-run chinook salmon population of the South Fork Trinity in 1964 to be 11,604. The highest South Fork Trinity spring-run count in recent years was 350 adults. In several years counts have fallen below 100, suggesting that the existence of natural spring-run chinook salmon populations in the Klamath-Trinity basin may be as precarious as that of the remnant populations of the Sacramento River system.

As indicated in the results section, above, the Butte Creek canyon reach surveyed contains enough pools of sufficient depth, quality and dispersal to hold a large number of spring-run chinook salmon, certainly 1,000 adults, successfully throughout the summer months.

Gravel

The amount of space that salmonids require for their spawning depends on the size and behavior of the spawners and the quality of the spawning area. Large fish make large redds, the tolerance for nearby fish varies by species, and poor-quality spawning areas may force females to construct more than one redd. Substrate size criteria for spring-run chinook salmon is 1.3 to 10.2 centimeters (0.5 to 4.0 inches) according to Bell (1986). Burner (1951) suggests that a conservative estimate of the number of salmon that a stream can accommodate may be obtained by dividing the area suitable for spawning by four times the average size of a redd. Hanson et al. (1940) measured salmon redds in the mainstem Sacramento river and in upper Sacramento tributaries and determined the average redd to be 39 square feet in size.

Using the 39 ft^2 Hanson figure and Bell's four-fold expansion, the 81,344 ft^2 of gravel measured by the Butte Creek team could support 521 salmon redds. If only the highest quality sites, those 31,044 ft^2 of gravel with embeddedness ratings of 1 and 2 were used, the number of potential redds would drop to 199.

It should be noted that a great deal of gravel appears to have been transported out of the canyon reach between the summers of 1995 and 1997. Holtgrieve and Holtgrieve (1995) measured 9,050 lineal feet of gravel between Butte Head Dam and Centerville Diversion Dam. The 1997 survey measured 2,905 lineal feet. Much of the difference in the 1995 and 1997 measurements is likely explained by the huge storm and flood event that began on January 1, 1997. According to California Fish and Game Warden Gayland Taylor, who flew over the creek during the height of the flood, there appeared to be 20 vertical feet of water raging over the crest of the Butte Head Dam. The huge boulders resting behind the crest of the Centerville Diversion Dam shown in photograph 2 were probably carried there on the New Year's Day flood.

As things now stand, there is good-to-fair gravel in the Butte Creek canyon sufficient to accommodate from 200 to 500 spawning pairs of spring-run chinook salmon.

Water temperatures

Figure 6 shows that average water temperatures in the four pools from which recorders were recovered rarely rose to levels regarded as stressful for adult chinook salmon. There are a couple of things about the pool temperatures worth noting, however. First, the average temperatures just below the Butte Head Dam and just above the Forks of the Butte diversion are virtually identical - the two graph lines are literally on top of one another in Figure 6 - while the temperature just above De Sabla Powerhouse is significantly cooler. The surveyors believe this is the effect of the hydroelectric diversions. Several small, cool tributary streams enter Butte Creek between Forks of Butte Dam and the De Sabla Powerhouse, allowing Butte Creek to gain some flow and lose some heat. This gaining section of Butte Creek, it should be noted, is even cooler than Butte Creek at a much higher elevation just below Butte Meadows.

The water temperatures recorded in the four selected canyon reach pools are suitable for holding spring-run salmon through the summer.

Barriers to upstream migration

As indicated above, the principal reasons for designating Butte Creek canyon stream structures as barriers were the inadequate depth of the plunge pools below them, the excessive height from their plunge pool surface to waterfall crest, or the combination of the two. When the team returned to Butte Creek in October to recover the pool temperature data they could see the difference that a slight increase in streamflow makes to these barrier conditions. The depth of the plunge pool below the Forks of the Butte

Dam had increased by more than two feet, erasing the plunge pool's depth as a barrier consideration. The distance between the plunge pool surface and the waterfall crest had shortened accordingly.

Photographs 5 and 6 show how the relatively modest flow increase that resulted from the first fall, 1997 rainstorm appears to have opened up a riffle area to adult salmon migration - were the canyon reach open to salmon migration at all. Photographs 7 and 8 show how significantly the modest fall flow increase modified a 12-foot waterfall above the De Sabla Powerhouse.

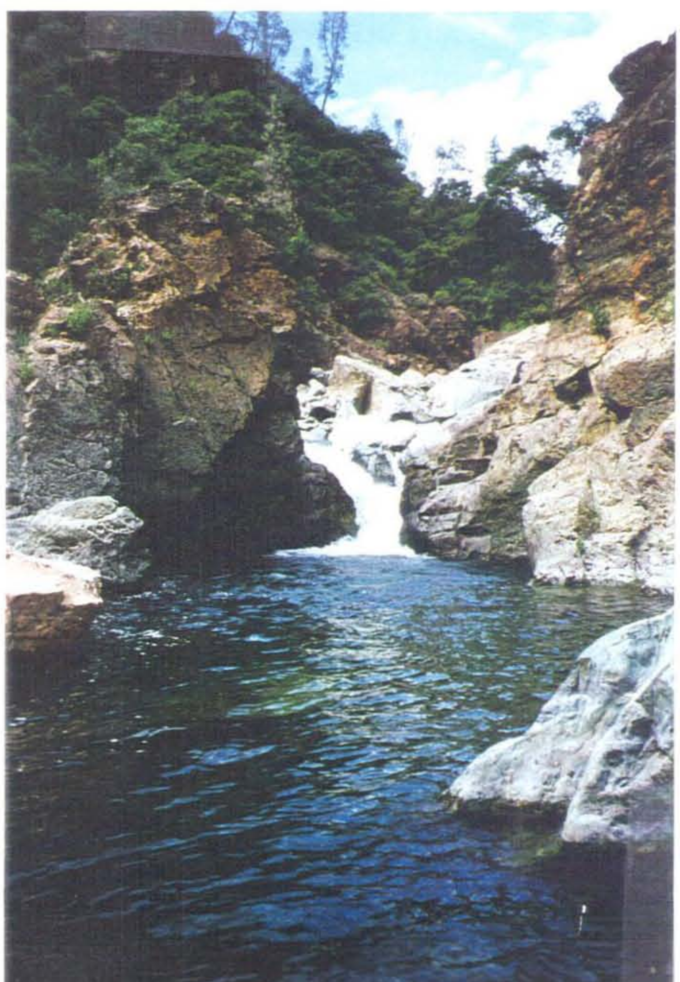
These increased flow effects suggest that salmon passage problems at the more modest barriers could be expected to resolve at the higher flows that occur when spring-run chinook salmon would migrate into the canyon. If increased streamflow were in this way to resolve salmon passage problems at the more modest barriers, say those with vertical heights up to 4.5 feet, then 35 of the barriers in the 11 mile reach would be resolved, 16 of them in the lower four miles of the reach alone.

Figure 7 classifies the barriers in the canyon reach on the basis of their height from plunge pool surface to waterfall crest *at the low, late-summer flow available at the time of the survey.*

Conclusions

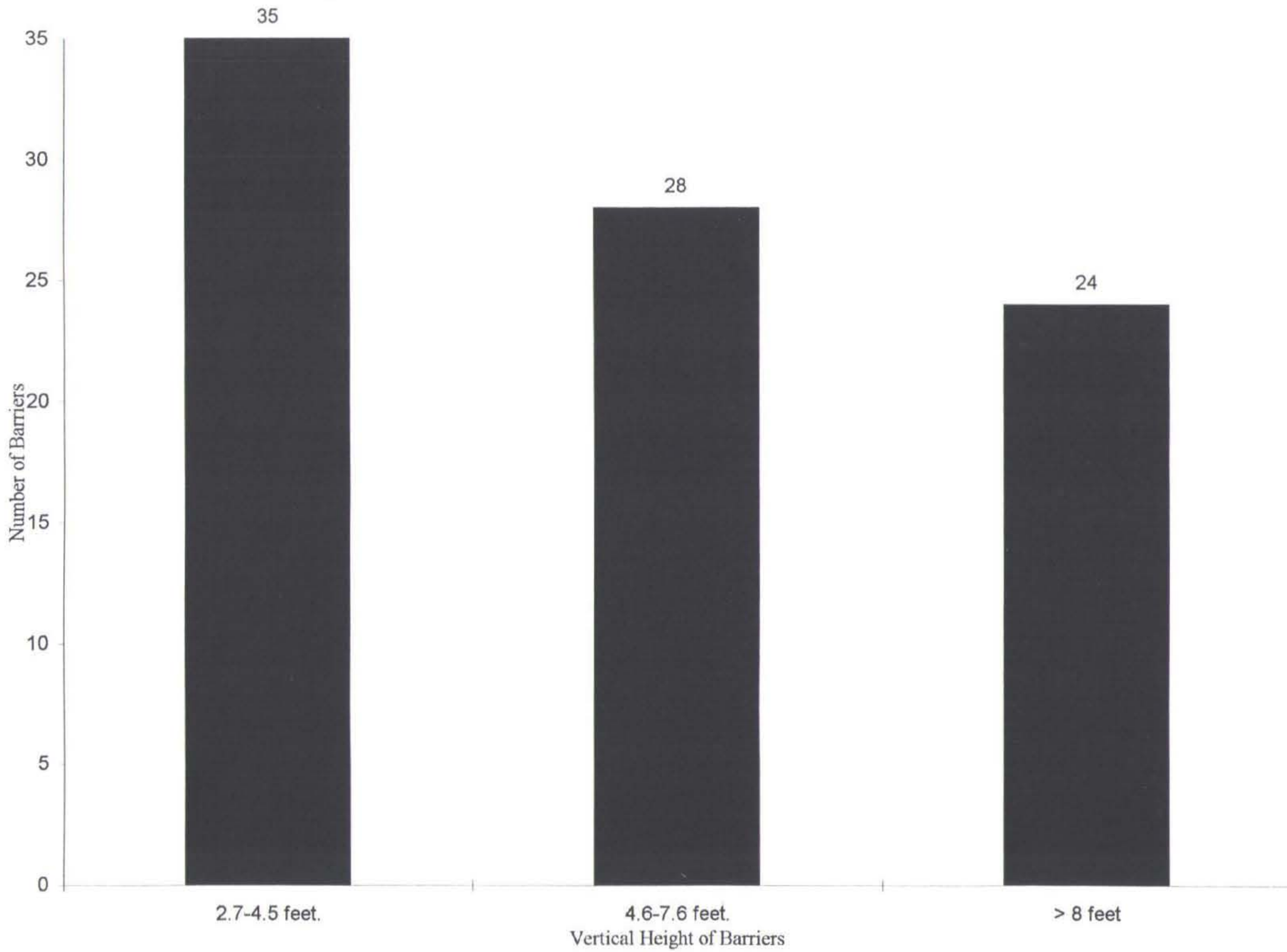
Butte Creek's spring run chinook salmon spawning runs decreased severely through the 1970s and '80s. The 1967 to 1991 returns to those reaches of the stream now accessible to salmon plummeted to 900 fish. The Central Valley Project Improvement Act's 1997 *Revised Restoration Plan for the Anadromous Fish Restoration Program* proposes that Butte Creek's spring-run chinook salmon numbers be boosted to 2,000. The Institute for Fisheries Resources-sponsored 1997 preliminary assessment of the Butte Creek canyon's salmon habitat potential suggests that up to 500 spawning pairs of chinook salmon could easily be accommodated in the 11-mile study reach.

Given the extreme scarcity of spring- run chinook salmon habitat in the Sacramento River watershed, and the very great danger of extinction this species is facing, a closer examination of the channel morphology and hydraulics, together with ways of easing constraints to the upstream passage of adult salmon into the canyon definitely appears warranted. Were the migration barriers eased through improvement of streamflow, modification of slope or construction of fishway facilities, there is no doubt in the authors' minds that the Butte Creek canyon would prove an excellent opportunity for rebuilding the watershed's natural spring-run chinook salmon numbers, as envisioned in the CVPIA Anadromous Fish Restoration Program plan.



Photos 7 and 8. Twelve-foot waterfall salmon barrier above PG&E's De Sabla Powerhouse, at flows of approximately 25 c.f.s (left) and 50 c.f.s. (above), showing increase in plunge pool depth and decrease in vertical waterfall height at the higher flow.

Figure 7. Size classes of barriers between Butte Creek Head Dam and Centerville Head Dam



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ACKNOWLEDGEMENTS

This assessment of the Butte Creek canyon's fish habitat was a component of a broader effort to explore opportunities in the watershed to restore spring-run salmon undertaken by Marc Reisner on behalf of the Institute for Fisheries Resources. Funding for the work was provided by the National Fish and Wildlife Foundation (Grant Agreement 1425-96-FG-81-07011), supplemented by funding from the William and Flora Hewlett Foundation. The habitat survey enjoyed strong support and encouragement from Alan Harthorn of the Butte Creek Watershed Conservancy, California Fish and Game Warden Gayland Taylor, and Don Holtgrieve of the Department of Geography and Planning, California State University, Chico.

Paul Ward of the California Department of Fish and Game and John Icanberry of the U. S. Fish and Wildlife Service helped design the fieldwork. The strong backs in the canyon included those of Carl Page, Byran Taylor, and AmeriCorps watershed intern Toni Ouradnik.

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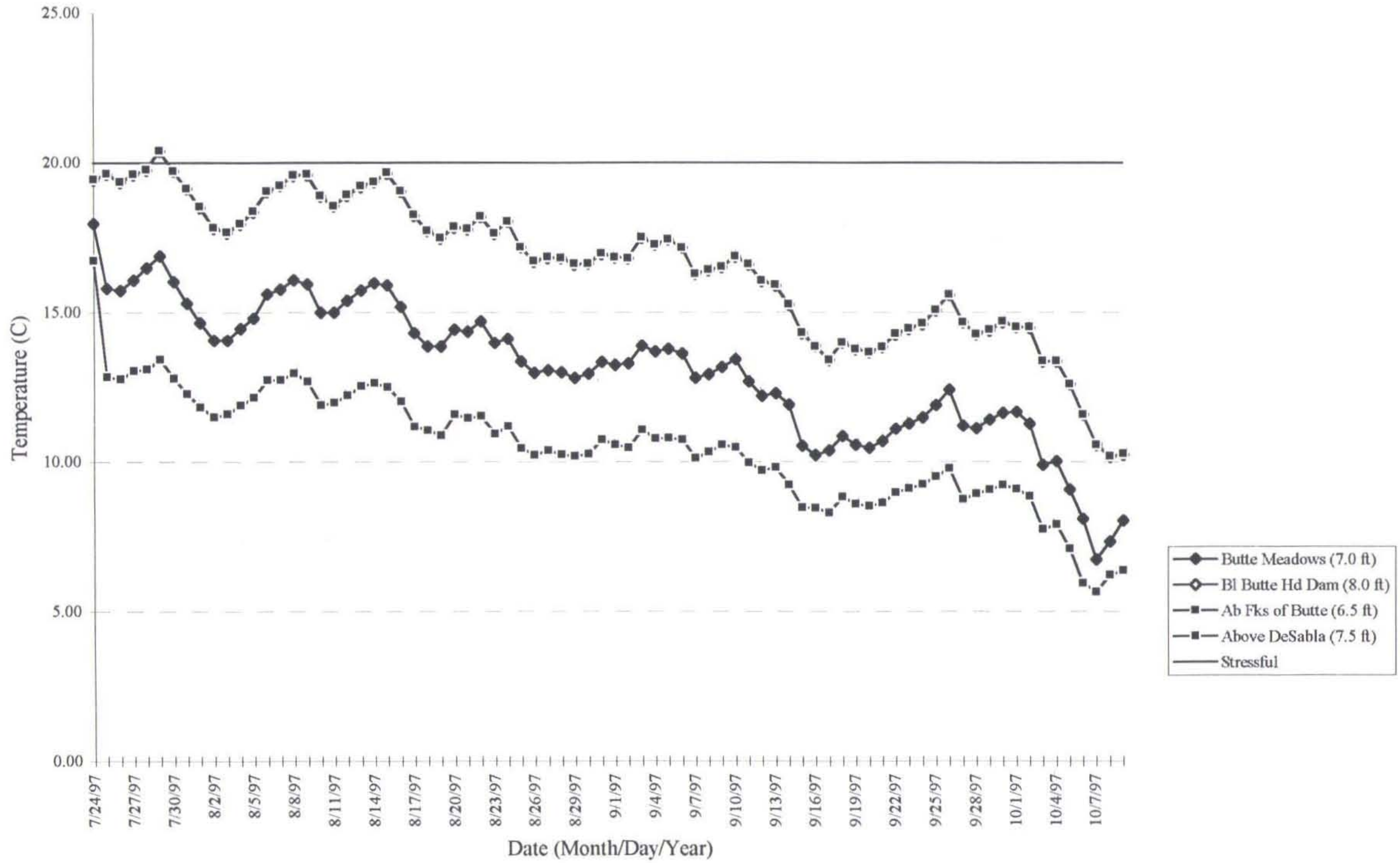
Figure 6. Average Butte Creek pool temperatures at four locations



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Station # (ft)	Dist. in Miles	Mean Length (ft)	Mean Width (ft)	Avg. Pool Area (sq. ft)	Mean Depth (ft)	Total Pool Vol. (cub ft)	Residual PV (cub ft)	Max Depth (ft)	TC Pool Vol.	Pool TC Depth (ft)	Embeddedness	Shelter Complexity	% Cover	Shelter Rating
0	0	77	48	3696	7.6	28089.6	18480.0	9.2	9609.6	2.6	Bedrock	2	45	90
516	0.10	158	46	7268	6.0	43608.0	29072.0	9.8	14536.0	2.0	Bedrock	1	40	40
969	0.18	113	25	2825	4.7	13277.5	7627.5	6.0	5650.0	2.0	Bedrock	1	60	60
1277	0.24	219	28	6132	5.3	32499.6	21462.0	6.6	11037.6	1.8	Bedrock	2	80	160
1496	0.28	134	35	4690	7.5	35175.0	22981.0	10.5	12194.0	2.6	2	2	60	120
1840	0.35	170	32	5440	7.0	38080.0	34816.0	9.0	3264.0	0.6	Bedrock	3	75	225
2272	0.43	118	32	3776	3.5	13216.0	6419.2	4.6	6796.8	1.8	1	2	45	90
2841	0.54	80	29	2320	5.2	12064.0	9744.0	6.2	2320.0	1.0	2	1	20	20
2992	0.57	47	35	1645	5.0	8225.0	5757.5	7.0	2467.5	1.5	1	1	15	15
3117	0.59	77	35	2695	4.0	10780.0	6468.0	5.4	4312.0	1.6	Bedrock	2	35	70
3339	0.63	44	30	1320	4.0	5280.0	3432.0	7.0	1848.0	1.4	1	1	20	20
4024	0.76	60	25	1500	5.7	8550.0	7800.0	7.0	750.0	0.5	3	3	60	180
4675	0.89	122	30	3660	4.0	14640.0	11346.0	5.3	3294.0	0.9	Bedrock	2	40	80
5104	0.97	109	35	3815	6.0	22890.0	18312.0	8.2	4578.0	1.2	3	2	25	50
5766	1.09	200	29	5800	5.5	31900.0	15660.0	9.5	16240.0	2.8	2	2	30	60
6020	1.14	104	34	3536	4.6	16265.6	8486.4	6.8	7779.2	2.2	1	3	50	150
6246	1.18	68	34	2312	5.5	12716.0	9941.6	6.8	2774.4	1.2	Bedrock	2	20	40
6319	1.20	73	35	2555	6.5	16607.5	12264.0	9.0	4343.5	1.7	1	3	60	180
6431	1.22	55	25	1375	4.0	5500.0	2475.0	5.2	3025.0	2.2	1	1	35	70
6576	1.25	114	35	3990	5.2	20748.0	13566.0	9.0	7182.0	1.8	2	2	40	80
7062	1.34	162	53	8586	6.5	55809.0	42930.0	10.0	12879.0	1.5	2	3	70	210
8147	1.54	45	27	1215	4.0	4860.0	607.5	5.0	4252.5	3.5	Bedrock	3	55	165
9078	1.72	116	45	5220	4.2	21924.0	17226.0	6.6	4698.0	0.9	2	3	65	195
10151	1.92	82	26	2132	4.4	9380.8	6609.2	6.6	2771.6	1.3	3	2	80	160
10485	1.99	174	55	9570	10.0	95700.0	83259.0	13.6	12441.0	1.3	2	3	55	165
11044	2.09	100	35	3500	3.5	12250.0	5250.0	5.5	7000.0	2.0	3	1	10	10
11326	2.15	150	40	6000	3.5	21000.0	15000.0	5.5	6000.0	1.0	1	1	15	15
11521	2.18	130	30	3900	4.8	18720.0	12870.0	7.0	5850.0	1.5	2	1	35	35
12309	2.33	78	32	2496	5.5	13728.0	10982.4	10.0	2745.6	1.1	1	2	30	60
12787	2.42	42	32	1344	5.0	6720.0	4704.0	5.5	2016.0	1.5	2	2	35	70
13782	*2.61*	*155*	*35*	*6425*	*8.0*	*43400.0*	*35262.5*	*10.6*	*8137.5*	*1.5*	*2*	*2*	*45*	*90*
14815	2.81	46	32	1472	4.4	6476.8	4857.6	5.3	1619.2	1.1	Bedrock	3	70	210
14909	2.82	141	33	4653	4.0	18612.0	8840.7	6.2	9771.3	2.1	1	2	35	70
15085	2.86	83	42	3486	4.5	15687.0	7669.2	6.8	8017.8	2.3	2	2	35	70
16011	3.03	191	59	11269	4.5	50710.5	34933.9	7.4	15776.6	1.4	2	2	30	60
16646	3.15	196	55	10780	7.5	80850.0	65758	10.4	15092	1.4	2	2	40	80
17002	3.22	124	35	4340	5.5	23870.0	19964	7.0	3906	0.9	1	2	45	90
17439	3.30	288	52	14976	6.0	89856.0	64396.8	8.6	25459.2	1.7	2	3	50	150
18025	3.41	85	40	3400	6.5	22100.0	19380	8.2	2720	0.8	3	2	30	60
18611	3.52	194	40	7760	8.5	65960.0	55096	11.6	10864	1.4	Bedrock	3	35	105
18983	3.60	123	40	4920	4.6	22632.0	11808	6.0	10824	2.2	2	3	35	105
19302	3.66	240	39	9360	6.0	56160.0	43056	9.8	13104	1.4	1	3	20	60
19673	3.73	127	80	10160	9.5	96520.0	80264	12.9	16256	1.6	Bedrock	3	45	135
20082	3.80	132	45	5940	7.0	41580.0	36234	8.9	5346	0.9	2	3	40	120
20481	3.88	178	40	7120	6.5	46280.0	35600	8.9	10680	1.5	1	2	35	70
21952	4.16	319	35	11165	6.5	72572.5	56941.5	9.0	15631	1.4	3	2	15	30
22318	4.23	173	40	6920	4.5	31140.0	22836	7.2	8304	1.2	3	1	10	10
22633	4.29	171	58	9918	8.0	79344.0	67442.4	12.8	11901.6	1.2	1	2	40	80
23518	4.45	170	50	8500	6.5	55250.0	44200	8.6	11050	1.3	2	2	40	80
25003	4.74	70	25	1750	5.5	9625.0	7875	7.0	1750	1.0	2	1	50	50
25117	4.76	224	25	5600	7.5	42000.0	33600	13.0	8400	1.5	1	2	30	60
27287	5.17	105	23	2415	6.0	14490.0	11833.5	8.0	2656.5	1.1	1	3	40	120
27483	5.21	153	36	5508	4.5	24786.0	19278	6.6	5508	1.0	1	2	45	90
27778	5.26	366	26	9516	6.6	62805.6	53289.6	11.6	9516	1.0	1	3	80	240
28146	5.33	156	35	5460	5.5	30030.0	21840	7.0	8190	1.5	2	1	35	35
28399	5.38	165	35	5775	5.5	31762.5	24832.5	8.0	6930	1.2	1	1	15	15
28732	5.44	201	25	5025	7.0	35175.0	32662.5	10.5	2512.5	0.5	2	1	25	25
30220	5.72	140	45	6300	4.5	28350.0	20790	6.5	7560	1.2	1	1	20	20
30335	5.75	115	35	4025	5.5	22137.5	17710	8.2	4427.5	1.1	1	1	25	25
30417	5.76	155	40	6200	4.8	29760.0	22320	7.8	7440	1.2	1	2	25	50
30953	5.86	191	40	7640	6.0	45840.0	37436	8.8	8404	1.1	1	2	35	70
31262	5.92	152	45	6840	6.0	41040.0	30780	10.0	10260	1.5	2	2	15	30
32413	6.14	200	45	9000	5.5	49500.0	40500	9.7	9000	1.0	2	1	5	5
33060	6.26	158	49	7742	5.5	42581.0	35613.2	6.2	6967.8	0.9	3	1	30	30
33328	6.31	217	45	9765	7.5	73237.5	59566.5	10.2	13671	1.4	1	2	30	60
34770	6.59	167	80	13360	7.5	100200.0	90848	11.7	9352	0.7	1	1	15	15

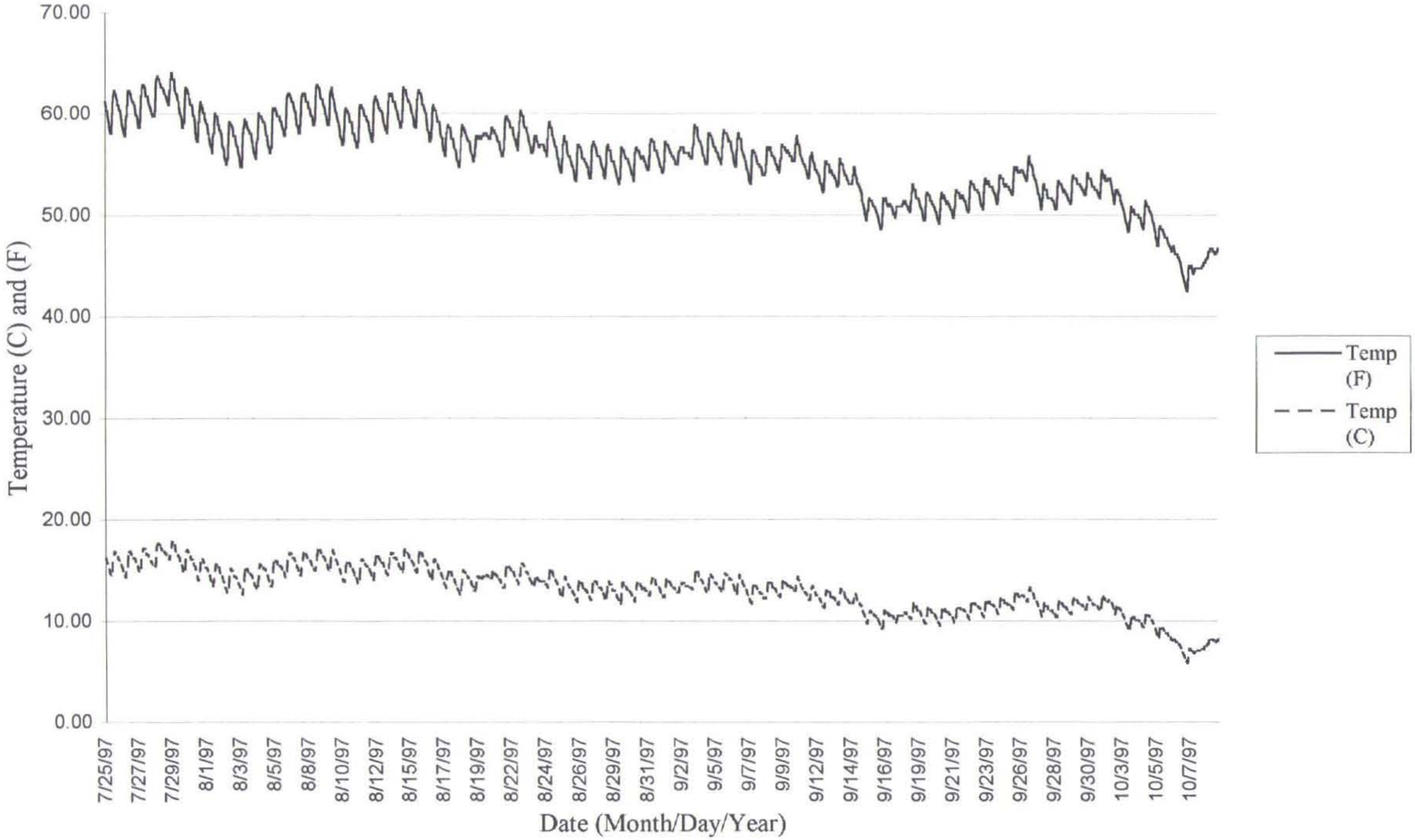
Appendix 1- Pools

35663	6.75	197	43	8471	6.0	50826.0	44896.3	10.7	5929.7	0.7	2	1	15	15
36340	6.88	423	38	16074	5.0	80370.0	67510.8	7.4	12859.2	0.8	2	1	30	30
37811	7.16	376	50	18800	4.6	86480.0	54520	7.3	31960	1.7	Bedrock	1	35	35
38187	7.23	208	16	3328	3.6	11980.8	5324.8	8.3	6656	2.0	Bedrock	1	5	5
38471	7.29	50	50	2500	4.6	11500.0	6000	5.4	5500	2.2	Bedrock	1	15	15
38508	7.29	75	30	2250	7.0	15750.0	9000	11.0	6750	3.0	Bedrock	2	30	60
38606	7.31	40	50	2000	5.0	10000.0	8400	8.0	1600	0.8	Bedrock	1	10	10
42710	8.09	70	35	2450	5.0	12250.0	10290	7.0	1960	0.8	3	1	10	10
43210	8.18	68	28	1904	6.7	12756.8	10091.2	10.4	2665.6	1.4	3	1	10	10
44210	8.37	35	24	840	5.0	4200.0	3108	8.4	1092	1.3	Bedrock	2	15	30
44260	8.38	60	35	2100	6.5	13650.0	11340	9.9	2310	1.1	Bedrock	2	15	30
44710	8.47	300	45	13500	10.0	135000.0	114750	15.0	20250	1.5	Bedrock	3	25	75
45060	8.53	80	45	3600	6.0	21600.0	17640	8.0	3960	1.1	2	1	30	30
45460	8.61	280	40	11200	4.6	51520.0	19040	6.6	32480	2.9	3	2	40	80
46360	8.78	125	45	5625	4.5	25312.5	16312.5	8.2	9000	1.6	2	2	65	130
49210	9.32	75	45	3375	5.5	18562.5	13162.5	7.8	5400	1.6	3	2	35	70
49710	9.41	95	35	3325	4.6	15295.0	4322.5	6.6	10972.5	3.3	Bedrock	2	70	140
50260	9.52	70	40	2800	5.4	15120.0	2800	7.7	12320	4.4	Bedrock	1	35	35
50710	9.60	120	46	5520	4.6	25392.0	16560	6.2	8832	1.6	2	1	15	15
51210	9.70	55	30	1650	4.6	7590.0	4620	7.6	2970	1.8	Bedrock	3	45	135
51510	9.76	260	26	6760	6.5	43940.0	39884	10.2	4056	0.6	3	2	30	60
52210	9.89	50	45	2250	4.6	10350.0	3150	6.6	7200	3.2	Bedrock	1	15	15
52510	9.95	55	30	1650	5.5	9075.0	6270	7.5	2805	1.7	3	2	25	50
52565	9.96	60	25	1500	5.5	8250.0	3300	7.1	4950	3.3	Bedrock	2	55	110
52860	10.01	90	44	3960	4.6	18216.0	3168	8.0	15048	3.8	Bedrock	2	15	30
53110	10.06	65	50	3250	6.0	19500.0	9750	9.0	9750	3.0	Bedrock	2	30	60
53410	10.12	75	26	1950	5.8	11310.0	8190	9.0	3120	1.6	Bedrock	1	35	35
53710	10.17	90	50	4500	7.5	33750.0	22950	15.5	10800	2.4	1	3	65	195
54710	10.36	45	35	1575	5.5	8662.5	4567.5	7.5	4095	2.6	Bedrock	3	45	135
55010	10.42	50	25	1250	5.5	6875.0	1250	8.0	5625	4.5	Bedrock	2	30	60
55260	10.47	80	50	4000	7.5	30000.0	20400	9.9	9600	2.4	2	3	45	135
55340	10.48	65	45	2925	9.0	26325.0	22522.5	13.0	3802.5	1.3	2	3	40	120
55710	10.55	70	30	2100	8.5	17850.0	10920	12.9	6930	3.3	Bedrock	3	60	180
56710	10.74	55	30	1650	6.5	10725.0	7425	7.9	3300	2.0	2	2	30	60
56810	10.76	45	22	990	5.0	4950.0	3366	7.0	1584	1.6	Bedrock	2	35	70

Station # (ft)	Dist. in Miles	Mean Length (ft)	Mean Width (ft)	Area of Gravel (sq. ft)	Dominant Sub	Co-Dom Sub	Embeddedness
628	0.12	60.0	46.0	**2760**	7	4	3
2010	0.38	25.0	6.0	**150**	5	4	2
2667	0.51	15.0	10.0	**150**	5	4	1
2763	0.52	20.0	10.0	**200**	4	5	1
2921	0.55	25.0	5.0	**125**	5	6	2
2992	0.57	25.0	20.0	**500**	5	4	2
4187	0.79	55.0	25.0	**1375**	6	4	3
5104	0.97	50.0	20.0	**1000**	6	4	3
5152	0.98	12.0	5.0	**60**	5	4	1
5558	1.05	35.0	15.0	**525**	5	6	3
7963	1.51	18.0	12.0	**216**	5	4	1
8645	1.64	45.0	15.0	**675**	4	3	1
8887	1.68	20.0	8.0	**160**	5	4	1
9367	1.77	45.0	8.0	**360**	4	6	3
10151	1.92	44.5	10.0	**445**	4	6	3
10485	1.99	50.0	20.0	**1000**	5	4	2
12487	2.36	6.0	3.0	**18**	4	5	1
12840	2.43	20.0	8.0	**160**	3	4	1
14097	2.67	65	20	**1300**	3	4	2
14357	2.72	55	30	**1650**	5	4	2
15160	2.87	18	25	**450**	4	3	2
15167	2.87	12	15	**180**	5	4	2
15220	2.88	12	4	**48**	5	4	1
15782	2.99	50	30	**1500**	5	6	2
16779	3.18	63	20	**1260**	4	5	2
17126	3.24	50	40	**2000**	4	5	1
18328	3.47	45	12	**540**	4	5	2
19002	3.60	20	15	**300**	5	6	2
19457	3.69	70	35	**2450**	5	4	3
20882	3.95	60	25	**1500**	5	4	2
22418	4.25	45	10	**450**	4	6	3
22697	4.30	70	30	**2100**	5	4	1
23752	4.50	268	35	**9380**	4	6	3
26341	4.99	45	20	**900**	4	5	1
26542	5.03	70	10	**700**	4	5	2
27558	5.22	90	40	**3600**	3	5	1
28564	5.41	30	8	**240**	5	4	1
28933	5.48	50	25	**1250**	5	4	2
29209	5.53	20	15	**300**	4	6	2
31144	5.90	90	35	**3150**	3	4	1
31414	5.95	200	56	**11200**	4	6	3
31649	5.99	50	45	**2250**	5	6	2
33946	6.43	200	50	**10000**	6	5	3
34326	6.50	55	25	**1375**	5	6	1
36397	6.89	65	15	**975**	5	4	2
37198	7.05	135	20	**2700**	5	6	2
37441	7.09	134	28	**3752**	4	5	2
45710	8.66	15	30	**450**	5	4	3
49210	9.32	30	50	**1500**	5	4	3
52860	10.01	13	15	**195**	5	4	3
53160	10.07	10	12	**120**	4	5	1
55110	10.44	30	10	**300**	5	4	1
55160	10.45	40	10	**400**	5	4	1
55210	10.46	20	30	**600**	5	4	1
56810	10.76	40	10	**400**	4	5	2

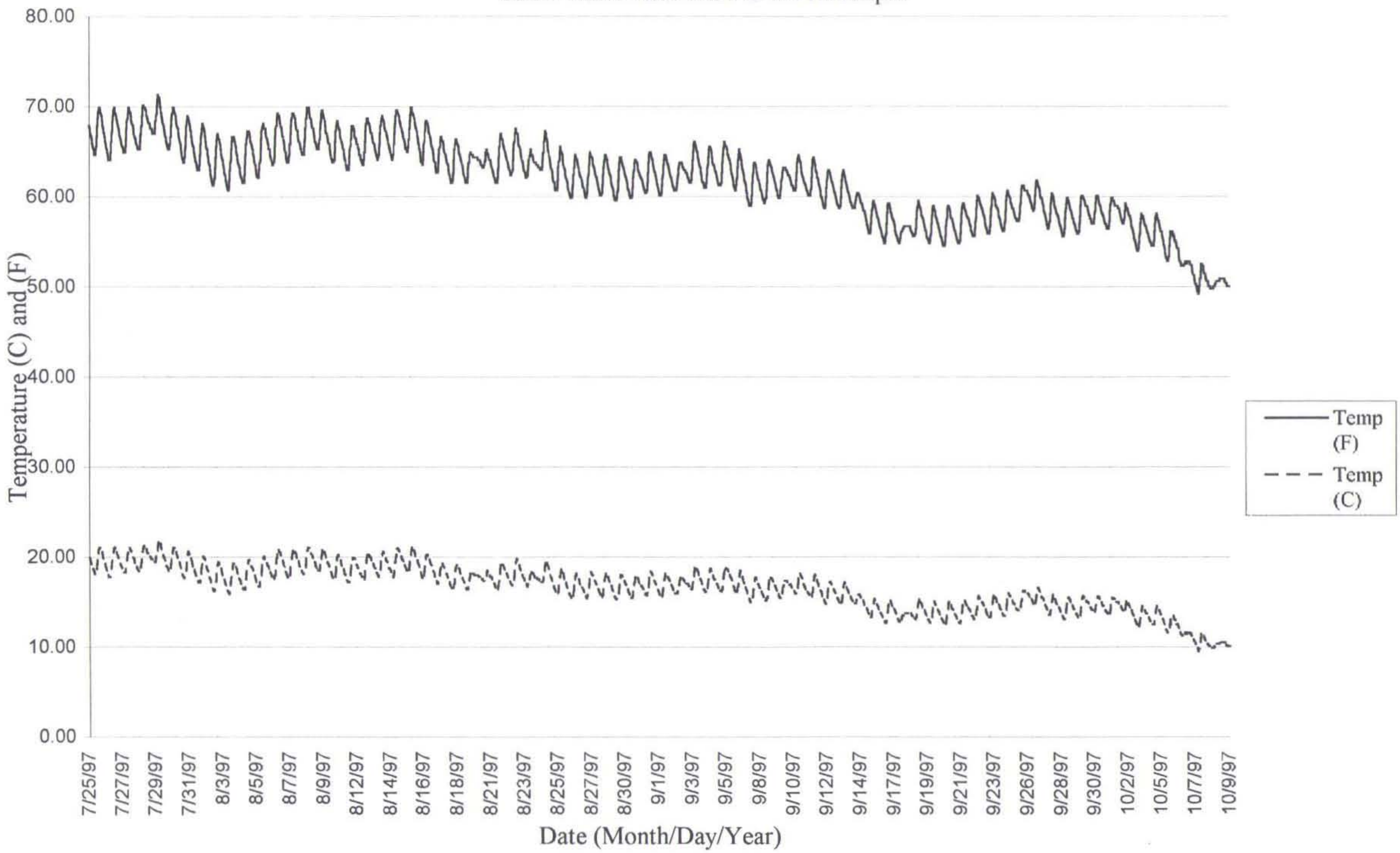
Appendix 3

Hourly temperatures, Butte Creek downstream of the Butte Meadows Campground at 7.0 feet depth



Appendix 3

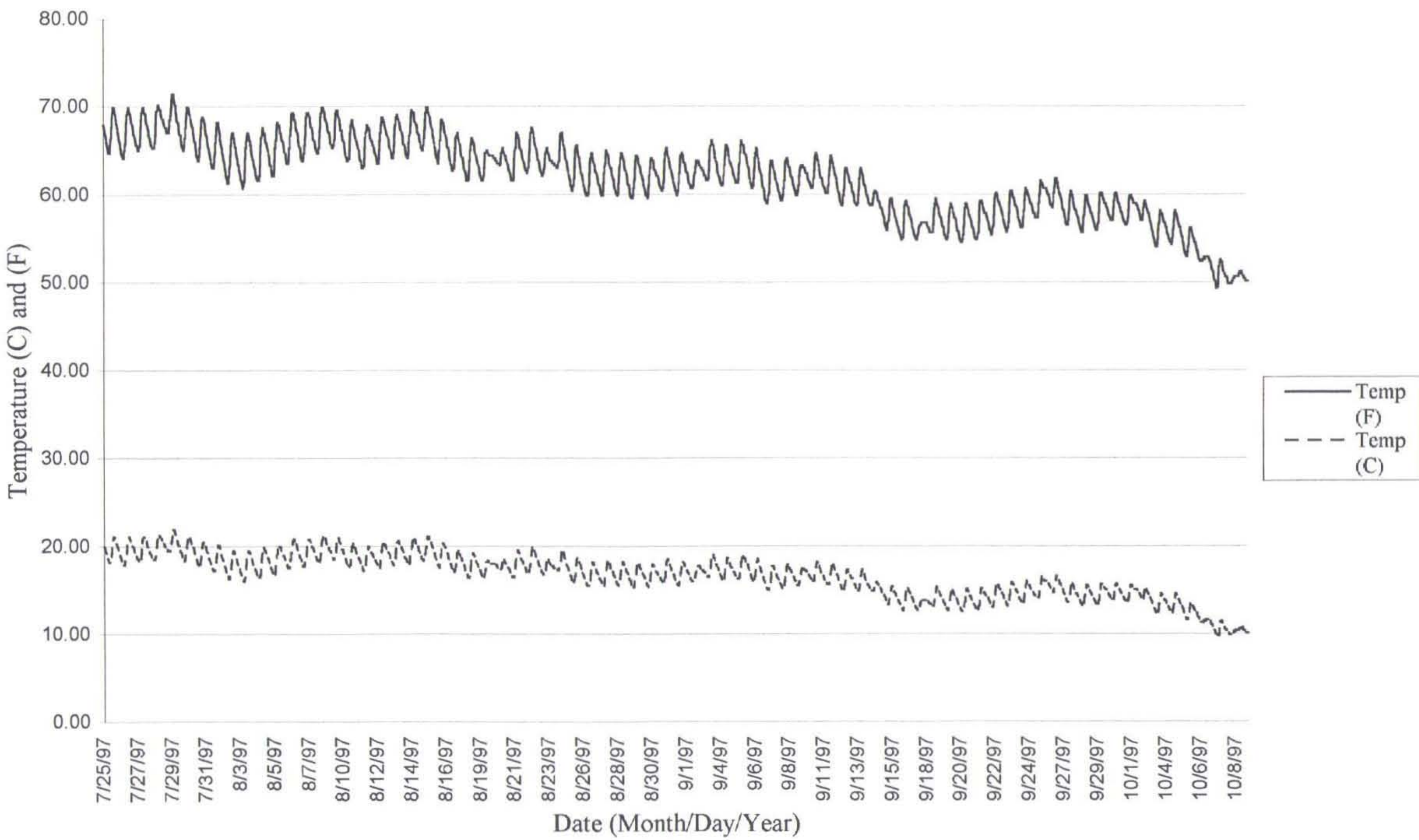
Hourly temperatures, Butte Creek approximately 0.25 miles below Butte Head Dam at 8.0 feet depth



Kier Associates

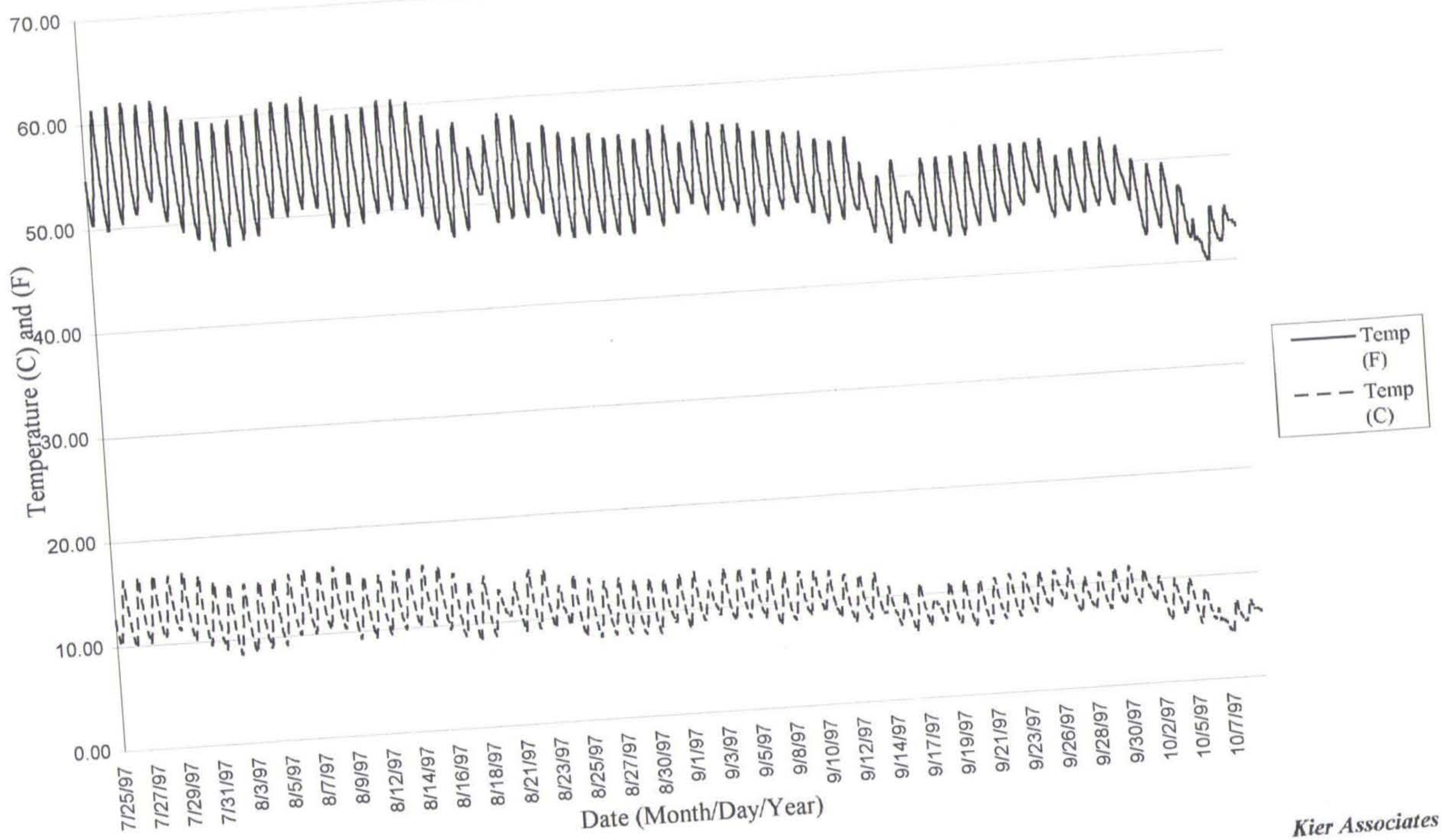
Appendix 3

Hourly temperatures, Butte Creek approximately 0.25 miles above Forks of Butte Diversion Dam at 6.5 feet depth



Appendix 3

Hourly temperatures, Butte Creek approximately 0.5 miles above De Sabla Powerhouse at 7.5 feet depth



Kier Associates

Barrier Type	*Station # (ft)*	*Dist. in Miles*	*Vertical Ht. (ft)*	*Horizt Dist. (ft)*	*Plunge Pool (ft)*
Cascade	377	0.07	2 x 8'	70	4.5
Single WFall	477	0.09	7.6	15	2.7
Cascade	764	0.14	9 x 3'	189	1.5
Single WFall	943	0.18	5.8	10	2.5
Cascade	1204	0.23	12	20	2.4
Chute	1272	0.24	20	68	3
Cascade	1496	0.28	8 x 4'	140	5.3
Single WFall	1769	0.34	10	20	2
Single WFall	2269	0.43	5	10	3
Single WFall	4024	0.76	5.0	15.0	2.6
Single WFall	4675	0.89	4.0	7.0	2.0
Chute	4861	0.92	30 over HD>>>	243.0	1.5 to 2
Chute	5360	1.02	12.5	65.0	1 to 3
Chute	5693	1.08	15 over HD>>>	93.0	3.5
Single WFall	5766	1.09	8.0	20.0	1.8
Cascade	6180	1.17	12 over HD>>>	56.0	2.4
Single WFall	6297	1.19	5.5	20.0	3.4
Cascade	6312	1.20	3.2	5.0	3.0
Chute	6754	1.28	12	53.0	3.5
Single WFall	6850	1.30	5.5	20.0	3.1
Single WFall	6894	1.31	4.4	15.0	2.6
Single WFall	7225	1.37	3.5	15.0	2.0
Cascade	7520	1.42	10+ x 3'-6'	130.0	6.0
Chute	10976	2.08	6+ x 3'-6'	58.0	1.4
Single WFall	12753	2.42	5.0	34.0	3.0
Single WFall	***13652***	***2.59***	***5.5***	***45***	***0.5***
Cascade	14815	2.81	25	55	0
Chute	27481	5.20	4.0	25	1.6
Single WFall	27703	5.25	4.0	8	4.0
Single WFall	27777	5.26	6.6	25	4.3
Single WFall	28074	5.32	4.0	20	2.6
Fks of Butte Dam	***38187***	***7.23***	***9.2***	***15' x 208' L***	***3.5***
Single WFall	38451	7.28	4.6	25.0	4.8
Single WFall	38638	7.32	7.0	15.0	3.0
Single WFall	38653	7.32	4.5	15.0	3.7
Single WFall	38688	7.33	14.0	25.0	3.5
Single WFall	38690	7.33	6.0	15.0	4.0
Single WFall	38710	7.33	4.0	15.0	3.0
Single WFall	38760	7.34	7.0	15.0	5.0
Single WFall	38810	7.35	8.0	45.0	2.0
Single WFall	39060	7.40	4.0	7.0	2.0
Single WFall	39710	7.52	4.0	10.0	2.0
Single WFall	39720	7.52	4.0	10.0	4.0
Single WFall	39730	7.52	2.7	5.0	1.0
Single WFall	39735	7.53	4.6	5.0	4.3
Single WFall	41710	7.90	3.0	7.0	2.0
Single WFall	42876	8.12	4.5	12.0	3.0
Single WFall	43092	8.16	3.9	7.0	2.0
Single WFall	43288	8.20	5.0	10.0	4.0
Single WFall	43360	8.21	4.0	10.0	3.0

Appendix 4 - Barriers

Single WFall	43440	8.23	8.0	30.0	3.0
Single WFall	43576	8.25	5.0	15.0	2.5
Single WFall	43960	8.33	22.0	45.0	1.5
Single WFall	46310	8.77	5.0	20.0	2.0
Single WFall	46760	8.86	4.0	10.0	3.0
Single WFall	49260	9.33	8.0	15.0	3.5
Single WFall	49710	9.41	6.0	20.0	5.0
Single WFall	51265	9.71	5.0	6.0	10.0
Cascade	51810	9.81	10.0	30.0	3.7
Cascade	51860	9.82	4.5	15.0	4.0
Single WFall	51910	9.83	7.0	25.0	2.5
Chute	52260	9.90	25 over HD>>>	150.0	3.3
Single WFall	52710	9.98	7.0	20.0	1.0
Single WFall	52950	10.03	10.0	25.0	3.5
Single WFall	53000	10.04	12.0	30.0	3.0
Single WFall	53310	10.10	8.0	10.0	5.0
Single WFall	53710	10.17	12.6	25.0	13.5
Single WFall	54710	10.36	6.5	2.0	4.0
Single WFall	54810	10.38	8.0	25.0	4.0
Single WFall	54910	10.40	9.0	35.0	0.0
Single WFall	55010	10.42	35.0	60.0	8.0
Single WFall	55060	10.43	7.4	10.0	2.0
Cascade	55210	10.46	3 X 5.5	10.0	0.0
Single WFall	55240	10.46	11.0	15.0	0.0
Single WFall	55360	10.48	6.0	8.0	4.0
Single WFall	55710	10.55	17.0	25.0	8.0
Single WFall	56710	10.74	6.0	15.0	3.0
Single WFall	56810	10.76	7.0	20.0	2.0