Title

Fall-run chinook salmon habitat assessment : lower Marsh Creek, Contra Costa, CA

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Fall-Run Chinook Salmon Habitat Assessment: Lower Marsh Creek, Contra Costa County, CA

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ABSTRACT

Although lower Marsh Creek, in eastern Contra Costa County, CA, is heavily impacted by human activities on adjacent and upstream lands, scientists and residents have observed fall-run Chinook salmon in the channel. A grade control dam four miles from the mouth of the creek prevents Chinook from migrating to a more natural, unchannelized segment of lower Marsh Creek that may contain suitable spawning habitat. We assessed the quality of potential spawning habitat in a 1.2-mile reach of lower Marsh Creek. Through pebble counts and visual observations at six study sites between Concord Avenue and Marsh Creek Reservoir, we evaluated gravel quality to ascertain whether gravel sizes are within identified ranges for spawning, gravels are movable by spawning fish, fine sediment concentrations allow for egg incubation and fry emergence, and if gravel bars are large enough for spawning. Using a long profile, we investigated whether the gradient of the channel is acceptable for spawning. Using field measurements at our six study sites, along with USGS stream gauge records, we analyzed whether water velocities and depths during the fall months are suitable for salmon spawning.

Our results indicated that gravels in the study reach are at the smaller end of ranges reported in spawning studies and that gravels in the channel can be moved by spawning fish. Despite the presence of Marsh Creek Reservoir and Dam upstream of our study reach, gravels had a low level of embeddedness at half of six stations surveyed and moderate or high levels at the other half. Gravel bars are large enough for Chinook spawnin g. The average gradient of the channel bed is also acceptable for spawning. Water velocities and depths likely to support spawning are present about 2.5 percent of fall days (correlated to peak storm events). We concluded that the 1.2-mile stretch of lower Marsh Creek contains satisfactory habitat to support fall-run Chinook spawning. Based on these findings, we recommended removal of the grade control structure on lower Marsh Creek to allow salmon migration to the unchannelized section of lower Marsh Creek for spawning.

INTRODUCTION

Marsh Creek in Context

Flowing for about thirty river miles, Marsh Creek drains 128 square miles of agricultural, grazing, and urban land in eastern Contra Costa County as it travels north from its headwaters to the San Joaquin River in the western Sacramento-San Joaquin Delta (Figure 1). The lower stretch of the creek includes eleven river miles from the outfall of the Marsh Creek Reservoir into the western Delta (Cain et al. 2003). Although most of the lower zone was channelized between the 1930s and 1970s (Figure 2), the three-mile stretch from Creekside Park upstream to the Marsh Creek Reservoir was never channelized (Figure 3). This section of lower Marsh Creek retains a "relatively natural shape and mature riparian vegetation" (Cain et al. 2003).

The salmon in Marsh Creek are part of what is designated as the Central Valley Chinook Fall-run Evolutionarily Significant Unit (ESU) by the National Marine Fisheries Service (NMFS), which is a candidate for threatened or endangered species listing (West Coast Chinook Salmon Biological Review Team 1999). Human activities have led to the loss of over 80 percent of suitable spawning habitat for fall-run Chinook in the Sacramento and San Joaquin drainages (Yoshiyama et al. 1996). The activities that have caused such large-scale spawning habitat degradation include hydraulic mining for gold, gravel mining, construction of dams, and construction of flood control infrastructure. Increased water temperatures, changed sediment loads, and water pollution resulting from urbanization have also contributed to the isolation and loss of spawning habitat (Yoshiyama et al. 1996).

Cain et al. (2003) summarized many of the human impacts affecting lower Marsh Creek. In addition to the dam at Marsh Creek Reservoir, a grade control structure about four miles from the creek mouth has isolated potential spawning habitat in the upper reach of the lower creek. The channelization of the lower eight miles of the creek and urbanization alongside the creek has reduced shade for the channel, thus increasing water temperatures. The Marsh Creek Reservoir and presence of impervious surfaces in the lower watershed have reduced overall sediment delivery into the lower creek. New construction throughout the lower watershed is likely to increase sediment loading into the channel, albeit temporarily. Mining activities in the upper watershed have created mercury contamination problems in the upper and middle reaches of Marsh Creek, but it remains unclear how much mercury has been transported through the lower stretch of the creek. Nonetheless, water quality in the lower reach is undoubtedly affected by agriculture and urbanization. Student volunteers found low levels of dissolved oxygen, possibly the result of sewage discharge or agricultural runoff (Cain et al. 2003).

Despite human impacts on lower Marsh Creek, many sources – including observations by community members, surveys by scientists, and interviews of local fishermen – indicate that Chinook salmon regularly spawn in the lower channelized section (Cain et al. 2003). Between 1995 and 2002, Fish and Game biologists saw 60-80 mm juvenile Chinook salmon in the lower four miles of the creek. However, the six-foot high grade control structure four miles from the mouth of the creek, just upstream of the Brentwood Wastewater Treatment Plant (Figure 4), is a barrier to fish migration beyond this point. Scientists suspect that removal of this structure would allow salmon to migrate up the lower creek to utilize a three-mile reach of more natural habitat between Creekside Park and the Marsh Creek Reservoir for spawning (R. Walkling, Natural Heritage Institute, personal communication, March 2004). The Marsh Creek Dam prevents migration upstream beyond the Reservoir. Reconnaissance surveys indicate that this three-mile reach may contain suitable fall-run Chinook spawning habitat.

Research Questions

This study evaluates the suitability of lower Marsh Creek as spawning habitat for fall-run Chinook salmon. Specifically, we analyzed the suitability of 1.2-miles, between Concord Avenue and Marsh Creek Reservoir, of the 3 mile-long unchannelized reach of lower Marsh Creek.

To assess habitat suitability, we evaluated four physical characteristics that determine spawning habitat: substrate composition, gradient (slope) of the streambed, water velocity, and water depth (Riggers et al. 2003). Specifically, we determined:

- if framework gravel sizes are likely to be movable by spawning fish

- if fine sediment contents in gravels are low enough to permit successful incubation and emergence of fry
- if surface areas of potential spawning gravel bars are large enough for redd construction
- if the channel bed gradient is comparable to that observed for spawning elsewhere
- if water velocities during the fall are comparable to that observed for spawning elsewhere
- if water depths during the fall are comparable to that observed for spawning elsewhere

DATA SOURCES

Field Work

On March 13, 2004, we walked the 1.2 mile study reach between Concord Avenue and the Marsh Creek Reservoir (Figure 5) to develop a comprehensive understanding of the substrate composition of the creek bed, variations in water depth, channel morphology, and shadedness. Based on our observations of channel conditions, we selected six reaches for our field work with visible presence of gravels likely to be movable by spawning fish and a relatively low fine sediment content in gravels (Figure 6). On March 26, 2004, we returned to conduct pebble counts and record depth and channel width at six stations along our study reach.

Balance Hydrologics

The Natural Heritage Institute provided a long profile and several cross-sections for the reach of Marsh Creek between Concord Avenue and Marsh Creek Reservoir. This data had been prepared by Balance Hydrologics for the Cain et al. report (2003). We used the data to determine the streambed gradient, and in our analysis of water velocity and depth.

USGS Flow Records

We downloaded two sets of USGS streamflow records for mean daily discharge:

- Lower Marsh Creek: We used mean daily streamflow recorded on March 26, 2004 at the new Brentwood gauge on lower Marsh Creek. We used this discharge to estimate water velocity at our study stations on our field day.

- Upper Marsh Creek: USGS flow records for the Byron gauge, on the undeveloped stretch of Marsh Creek above Marsh Creek Reservoir, are available for water years 1953-1983. Although the Byron gauge has been discontinued, these flow records provide an approximation of discharge in the upper Marsh Creek watershed. Because Marsh Creek Reservoir does not actively regulate flow (M. Kondolf, University of California, Berkeley, personal communication, April 2004), we assumed that the amount of discharge flowing into the Reservoir from upper Marsh Creek was equal to the amount flowing over the spillway into lower Marsh Creek. We used the Byron gauge flow record in our analysis of historic fall flows.

Literature Review

We determined the criteria for suitable spawning habitat through a review of existing literature and data provided by local fish biologists.

GRAVEL QUALITY: METHODS, RESULTS AND DISCUSSION

Methods

Gravel Size

At each of the six stations that we selected, we sampled the surface layer of gravel through pebble counts, following a procedure outlined by Kondolf (2000). At each station, we randomly selected – by hand – at least 125 stones from the creek bed and measured their diameter along the intermediate axis by passing them through a gravelometer.

We sorted the measurements for each location into rank order in order to plot a cumulative frequency line and calculate the median diameter (D50) of gravel at the station. To assess whether gravels are small enough to be movable by spawning fish, we considered the relation between the D50 and reported sizes of Chinook in the ESU. A potential shortcoming of this method is that is does not indicate whether gravels are too *small* for spawning. Because of this limitation, we also compared gravel sizes in Marsh Creek with those reported in fall-run Chinook spawning habitat literature.

Embeddedness

While the spawning habitat literature should address both whether fish can move the gravel and whether there is too much fine sediment, we performed an additional qualitative analysis of fine sediment. To estimate the amount of fine sediment present in the channel bed, we performed an embeddedness assessment at each station using the technique described by Bain (1999). We visually estimated the percentage of the gravel surface covered by fine sediment. Based on the percentage estimate, we assigned an embeddedness rating for each study site as follows:

Negligible: less than 5% of surface covered by fine sediment

Low: 5-25% of surface covered by fine sediment

Moderate: 25-50% of surface covered by fine sediment

High: 50-75% of surface covered by fine sediment

Very high: greater than 75% of surface covered by fine sediment

Gravel Bar Surface Area

We measured the length and width of the gravel bar at each station to calculate the surface area of each gravel bar.

Summary of Findings

In order to comprehensively assess gravels in the study reach, we developed four criteria related to gravel quality: gravel sizes that are adequate for spawning fish to move them, gravel sizes within the range indicated in the literature, a low level of embeddedness, and a sufficient gravel bar surface area. We created two criteria related to substrate size because this factor is the most frequently cited in terms of its importance in determining spawning habitat. We devised a scoring system where for each criteria, a score between 1 and 4 (1 = very unlikely, 4 = very likely) was assigned based on our assessment of how well the criteria was met at the station.

Results and Discussion

Gravel Size

Gravel size requirements for spawning are proportional to salmon size (Spence et al. 1996). By analyzing 135 size distributions of spawning gravels, Kondolf and Wolman (1993) found that fish can generally spawn in gravels with a D50 of up to 10 percent of their body length. Although data about Chinook fish lengths in Marsh Creek has not been collected, survey data collected on the lower Tuolumne River, another stream in the Central Valley Chinook Fall-run ESU, for a 21 year period (1981 to 2002), revealed an average length of 71.0 cm for female Chinook (S. Kirahara, Turlock Irrigation District, personal communication, April 2004). Although the Tuolumne is a much wider, higher flow tributary of the San Joaquin River than Marsh Creek, a California Department of Fish and Game biologist verified that the Tuolumne data adequately covers the range of Chinook sizes in this Central Valley ESU (T. Heyne, California Department of Fish and Game, personal communication, April 2004). Through a review of several stocks of Chinook in the Sacramento and San Joaquin River drainages, NMFS reported an average fish length of 84.2 cm. (Myers et al. 1998). This information indicates that Chinook in the region require spawning gravels with a median diameter of less than 70-84 mm.

Table 1 summarizes the results of the pebble counts. Figure 7 is the cumulative size distribution plots from our research. The D50 of gravels at the six stations surveyed ranged from 6-14 mm. These values are clearly much lower than the 70-80 mm maximum size calculated above. These results indicate that these gravels are not too large to be moved by spawning fish.

Through a literature review, Bjornn and Reiser (1991) found that Chinook typically spawn in gravels ranging from 3-150 mm, while Flosi et al. (1998) reported that California Chinook spawn in substrate from 13-254 mm, dominated by 25-127 mm cobble. Gravel size at all six stations is within the acceptable range for spawning as reported by Bjornn and Reiser, but at most stations it is smaller than the range reported by Flosi et al. The fact that the gravel from our samples is at the low end of the ranges reported in the literature indicates that these gravels may be most suitable for smaller, younger Chinook salmon.

Of the six stations surveyed, stations 3, 4, and 6 have the largest substrate. At these stations, over 50 percent of gravels are between 8-23 mm. If the spawning gravels at stations 1, 2, and 5 are actually too small for spawning because they are at the lower ends of the reported gravel sizes, it is likely that 3, 4, and 6 still provide suitable spawning habitat.

Embeddedness

For successful spawning and incubation, salmonids require gravels with low concentrations of fine sediment. By clogging substrate interstices, fine sediment may reduce the water flow necessary to maintain high dissolved oxygen levels around buried eggs and to remove metabolic wastes (Spence et al. 1996). Because we were unable to do bulk sampling, our visual estimates of embeddedness serve as qualitative assessments of the concentration of fine sediment.

Table 2 summarizes our visual estimates of embeddedness as well as the levels of embeddedness associated with each estimate. At three of our stations (Stations 1, 3, and 5), we found a low level of embeddedness. At two of our stations (Stations 2 and 4), there is a moderate level of embeddedness. At one of our six survey locations, Station 6, the embeddedness level is high.

The results of our visual estimates suggest that embeddedness may be a factor limiting spawning success at some locations along this stretch of Marsh Creek. To deal with this uncertainty, we recommend additional analysis through a more precise technique such as bulk sampling.

Surface Area

Sufficient surface area of substrate is important for redd construction. Riggers et al. (2003) found that for Oregon streams (as opposed to mainstem and large tributaries), a minimum surface area of 10 square meters qualified a "spawning habitat unit," while Bell (1986) recommended a surface area of 24 square meters for spawning. Table 3 indicates the surface area of each gravel bar that we studied. All of our stations met the former requirement, while five of six of our stations met the latter requirement. Thus the extent of spawning gravels in lower Marsh Creek seems sufficient for fall-run Chinook spawning.

Summary of Findings

Table 4 summarizes our findings about gravel quality in the study reach of lower Marsh Creek. Stations 3, 5, and 6 appear to have the best habitat for spawning Chinook, while stations 2 and 4 have the least suitable spawning habitat. At station 4, we found a high level of embeddedness, and at station 2, gravel sizes were lower than those indicated in the literature. In short, half of the stations surveyed appear to be promising spawning sites. Therefore, our gravel analysis indicates that suitable spawning gravels are very likely to exist in the unchannelized stretch of Marsh Creek.

CHANNEL BED GRADIENT: METHODS, RESULTS AND DISCUSSION

Methods

Using the long profile prepared by Balance Hydrologics (Figure 8), we calculated the average gradient of the thalweg for our 1.2 mile study reach. Because we observed that the actual gradient of the substrate between pools and riffles in Marsh Creek was variable, we also calculated the average slope between stations along the long profile.

Results and Discussion

Flosi and Reynolds (1991) reported that Chinook salmon generally spawn in channels with channel bed gradients of 0.2 to 1.0 percent. Riggers et al. (2003) reported that both the orientation and gradient of the channel substrate influence the likelihood that Chinook salmon will spawn. If gravel deposits are situated such that the streambed is bisected by the current, they tend to be more heavily used. However, a channel gradient greater than 5 percent is likely to jeopardize the stability of a gravel bar.

The average slope of the thalweg for our study reach of Marsh Creek is approximately 0.51 percent. However, the various pools and riffles within the channel resulted in gradients ranging from 0.0-24.6 percent between the long profile stations. Table 5 lists the thalweg elevation and average gradient between stations along the long profile. Along 42 percent of our study reach, streambed slope is within the range identified in the literature as appropriate for Chinook salmon spawning.

VELOCITY AND DEPTH: METHODS, RESULTS AND DISCUSSION

Methods

We used Microsoft Excel to run calculations to project velocity and depth during the fall spawning season. Although we recognize a margin of error in calculations based on human assumption, we are confident that our results are reasonable. An overview of our methods is presented below:

Steps	*Data Used*
Step 1: Calculation of Average Velocity	Cross-sectional area of gravel stations; USGS Brentwood gauge 2004, mean daily flow
Step 2: Calculation of Roughness Coefficient	Average gradient from long profile; Average water depth at gravel stations; Velocity from Step 1
Step 3: Projected Increases in Velocity	Average gradient from long profile; Average water depth at gravel stations; N value from Step 2
Step 4: Projected Increases in Discharge	Velocity from Step 3; Cross-sectional area of plotted cross-sections
Step 5: Estimation of Velocity During Spawning Season	USGS Byron gauge 1953-1982, mean daily flow; Discharge from Step 4
Step 6: Estimation of Depth During Spawning Season	USGS Byron gauge 1953-1982, mean daily flow; Discharge from Step 4

Step 1: Calculation of Average Velocity

We calculated velocity of the water flowing in Marsh Creek on our field day using the equation,

V=A/Q,

where:

V = velocity
A= cross-sectional area
Q = flow

We used the average cross-sectional area of water in the channel among our six study stations for A. We used mean daily flow recorded at the USGS Brentwood gauge for Q.

Step 2: Calculation of Roughness Coefficient

We calculated a roughness coefficient for our study reach using the Manning equation,

$$\mathbf{n = 1.49(s^{0.5}R^{0.67})/V},$$

where:

n = roughness coefficient
s = gradient
R = hydraulic radius
V = velocity

We used the average gradient calculated from the long profile prepared by Balance Hydrologics for s. We used the average water depth recorded at our stations as a proxy for R. We used the velocity determined in Step 1 for V.

Step 3: Projected Increases in Velocity

Using the Manning equation,

$$\mathbf{V = 1.49(s^{0.5}R^{0.67})/n},$$

we estimated increases in velocity that would result from increases in water depth within the channel. As above, we used the average s from the long profile prepared by Balance Hydrologics and water depth as a proxy for R. We used the n value calculated in Step 2. Because overgrown vegetation and large woody debris continue to slow water velocities even as water in the channel increases in depth, we assumed a constant n value across all velocity and discharge calculations.

Step 4: Projected Increases in Discharge

Using the equation,

$$\mathbf{Q=VA},$$

we projected discharge at different water depths. We used the projected increases in velocity from Step 3 for V. Using the cross sections prepared by Balance Hydrologics (Figure 9), we estimated cross-sectional area of water in the channel based on increased water depths for A. After calculating Q, we plotted a rating curve to graphically illustrate the relation between water depth and discharge.

Step 5: Estimation of Velocity During Spawning Season

We used historic USGS Byron gauge records of daily mean streamflow for water years 1953-1982 to determine approximate velocities during the spawning season. Central Valley fall-run Chinook salmon spawn from October to December (Moyle 2002). We rank-ordered mean daily streamflow for all fall days in the record period and grouped them into 19 flow intervals. We then determined the percentage of total fall days within each interval. For each interval, we identified the velocity associated with that discharge based on Step 4. We compared fall velocities in Marsh Creek with literature reports of adequate velocity for Chinook spawning.

Step 6: Estimation of Depth During Spawning Season

We used historic USGS Byron gauge records of daily mean streamflow for water years 1953-1982 to determine approximate water depths during the spawning season (October to December). We used the same 19 flow cohorts from Step 5. For each cohort, we identified the depth associated with that discharge based on the rating curve. We compared fall water depths in Marsh Creek with literature reports of adequate depths for Chinook spawning.

Results and Discussion

An overview of our results is presented below:

Steps	*Results*
Step 1: Calculation of Average Velocity	Average velocity = 0.82 ft/s
Step 2: Calculation of Roughness Coefficient	N value = 0.09
Step 3: Projected Increases in Velocity	Velocities range from 0.82 ft/s at 0.6 ft depth to 3.99 ft/s at 6.6 ft depth
Step 4: Projected Increases in Discharge	Discharge ranges from 6.5 cfs at 0.6 ft depth to over 195 cfs at 6.6 ft depth
Step 5: Estimation of Velocity During Spawning Season	3.5 percent of fall days comparable to velocities observed for spawning
Step 6: Estimation of Depth During Spawning Season	4.2 percent of fall days comparable to depths observed for spawning

Step 1: Calculation of Average Velocity

Water depth at our study stations ranged from 0.25 ft (8 cm) along riffles above gravel bars to 1.0 ft (30 cm) in deep-flowing channels; the average depth was 0.63 ft (19.2 cm). We found that A, the average cross-sectional area of water at our stations, was 7.9 sq ft. Table 6 shows cross-sectional area at each of our study stations. Q, the mean daily flow for lower Marsh Creek on that day, was 6.5 cfs. Therefore, the average velocity of water at our stations was 0.82 ft/s (0.25 m/s). Table 7 shows estimated velocity at each station.

Step 2: Calculation of Roughness Coefficient

We determined that our study reach had a roughness coefficient of approximately 0.09. Table 8 lists the values used in the Manning's equation. This relatively high roughness coefficient is likely due to the pools, shoals, weeds, stones, and vegetation within the channel.

Step 3: Projected Increases in Velocity

Table 9 displays projected velocity as a function of increased depths. We found that velocities increase from 0.82 ft/s at depths of 0.6 ft to 3.99 ft/s at depths of 6.6 ft. In short, incremental increases in depth result in proportional increases in velocity.

Step 4: Projected Increases in Discharge

We projected that flows will increase from 6.5 cfs at depths of 0.6 feet to over 195 cfs at depths of 6.6 feet. Table 10 shows expected flows at different water depths. The rating curve (Figure 10) illustrates the relation between water depth and discharge.

Step 5: Estimation of Velocity During Spawning Season

Table 11 lists the number and percentage of fall days within each of the 19 flow/velocity cohorts. Table 12 analyzes our fall velocity estimates based on the range of acceptable spawning velocities reported in the literature. Riggers et al. (2003) found that Chinook salmon are able to spawn in water with velocities of 1.1-2.5 ft/s (0.33-0.76 m/s) and 1.2-6.2 ft/s (0.37-1.89 m/s). Flosi and Reynolds (1991) reported that Chinook salmon generally spawn in velocities ranging from 1.0-3.0 ft/s (0.3-0.9 m/s). Similarly, Reiser and Bjornn (1979) found that fall-run Chinook prefer velocities between 1.0-3.0 ft/s (0.3-0.9 m/s).

On 85.2 percent of fall days on record, Marsh Creek had no flows and therefore no Chinook habitat. Average velocity on Marsh Creek is likely too slow for Chinook spawning in the 10.6 percent of storm events that produce flows ranging from 1-15 cfs. However, the larger fall storms ranging from 16-235 cfs are within the range of appropriate velocities reported in the literature for fall-run Chinook salmon spawning. Approximately 3.5 percent of fall days have adequate velocities to support Chinook salmon spawning.

Step 6: Estimation of Depth During Spawning Season

Table 13 lists the number and percentage of fall days within each of the 19 flow/depth cohorts. Table 14 analyzes our fall depth estimates based on the range of acceptable spawning depths reported in the literature. Flosi and Reynolds (1991) noted that although Chinook salmon generally spawn in water 1.0-3.0 ft (30-91 cm) deep, scientists have observed spawning in depths ranging from 0.5-20 ft (15-610 cm). In a literature review, Riggers et al. (2003) reported that Chinook have been observed spawning in water depths ranging from 1.0-15 ft (30-460 cm), 0.9-1.3 ft (28-41 cm), and 0.3-3.9 ft (10-120 cm). Reiser and Bjornn (1979) found that 0.8 ft (24 cm) is a minimum depth for fall run Chinook spawning.

On the 85.2 percent of fall days with no flows, Chinook spawning is impossible. Average depth on the 10.6 percent of storm events that comprise low velocities (1-15 cfs) may provide marginal habitat for the smaller, younger Chinook. Approximately 4.2 percent of fall days have higher storm flows (greater than 16 cfs) with depths within the range identified by the literature as appropriate for fall-run Chinook spawning.

The combination of adequate velocities and depths to support Chinook spawning on Marsh Creek total approximately 3.5 percent of fall storms that generate flows between 16-235 cfs.

ADDITIONAL FACTORS FOR CONSIDERATION

Two additional factors important to successful spawning are water quality and water temperature. Although beyond the scope of this analysis, these factors warrant additional consideration. Water quality is of concern because of mercury mining activities in upper Marsh Creek for nearly a century (Cain et al. 2003). The Marsh Creek Reservoir, just upstream of our study reach, has been closed to fishing for over twenty-five years due to "dangerously high concentrations of mercury found in fish both in and upstream of the Reservoir" (Cain et al. 2003). It is possible that this mercury source may impede successful spawning. Temperature is also an important physical characteristic that determines spawning habitat. The preferred water temperature range for fall-run Chinook spawning is 5.6 - 13.9 C, although spawning migration temperatures range from 10.6 - 19.4 C (Spence et al. 1996, modified after Bjornn and Reiser 1991). Although we selected stations that have shade, we were not able to determine fall water temperatures at our study stations because our field work took place in the spring. However, because salmon have been observed in lower, less shaded reaches of the creek, it is unlikely that temperature is a limiting factor in this reach's capacity to support fall-run Chinook.

CONCLUSIONS

Our results indicate that our 1.2-mile study reach of lower Marsh Creek contains adequate physical habitat to support fall-run Chinook salmon spawning. Half of the gravel bars we analyzed contain suitable gravels and fine sediment concentrations for spawning. We expect that gravels and fine sediment concentrations in multiple locations along the unchannelized stretch of the channel will support spawning. The channel gradient is likely to be sufficient for salmon migration and spawning. During large fall storms when Chinook are likely to navigate the channel, water velocities and depths are satisfactory for redd construction. Our estimates suggest that velocity and depth are satisfactory for migration and spawning on 3.5 percent of fall days.

It is critical to remember that physical habitat is not the only factor that may limit Chinook salmon spawning. Disease, predation, competition, food availability, water quality, and weather may all affect spawning success (Flosi et al. 1998). Nonetheless, our findings indicate that the physical characteristics of our study reach should support spawning. In light of the decline in spawning habitat for Central Valley fall-run Chinook, we support removal of the grade control structure on lower Marsh Creek to make possible salmon spawning in the unchannelized section of lower Marsh Creek.

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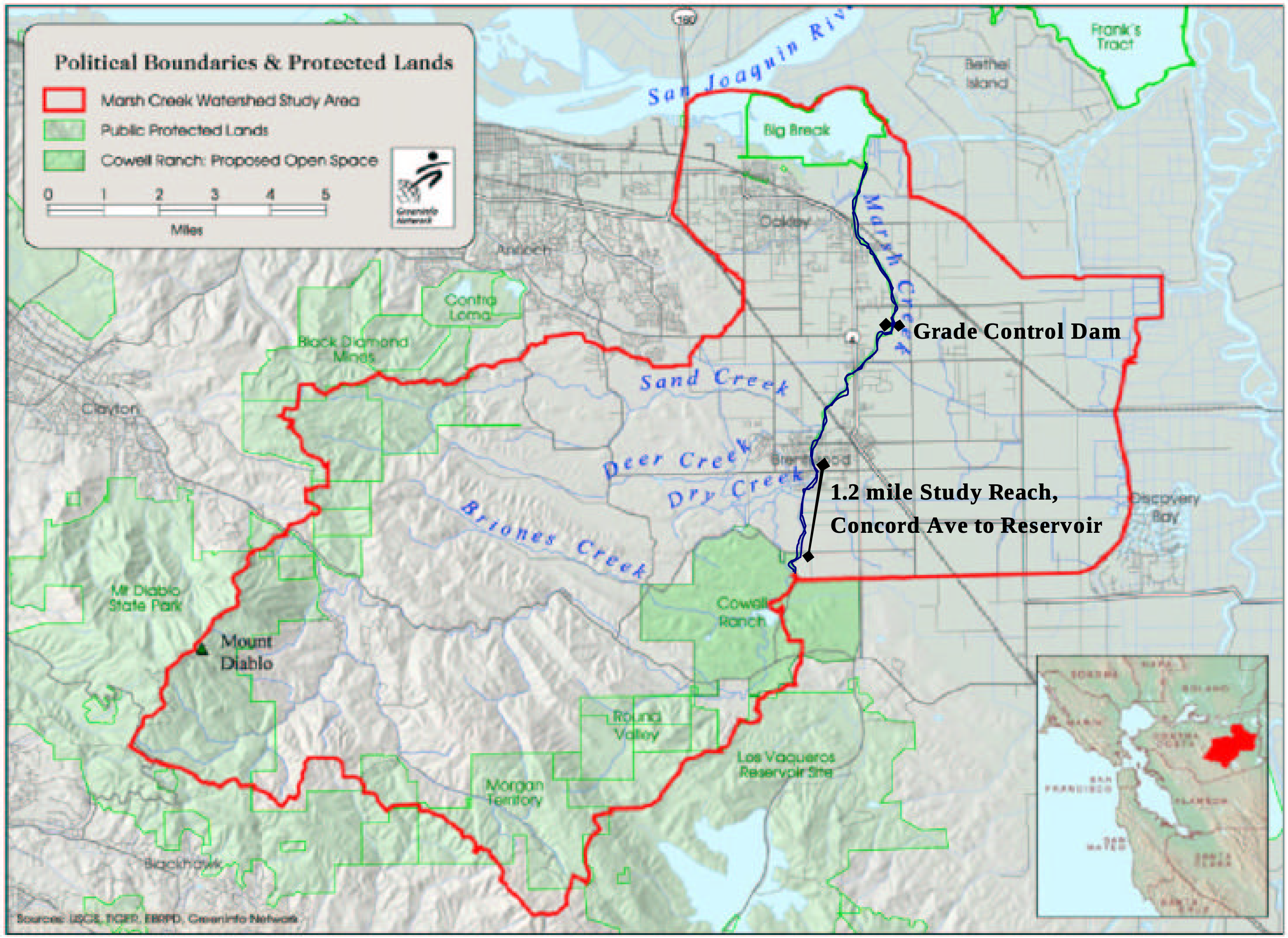
Figures and Tables

Figure 1: Marsh Creek Location Map and Watershed Boundaries



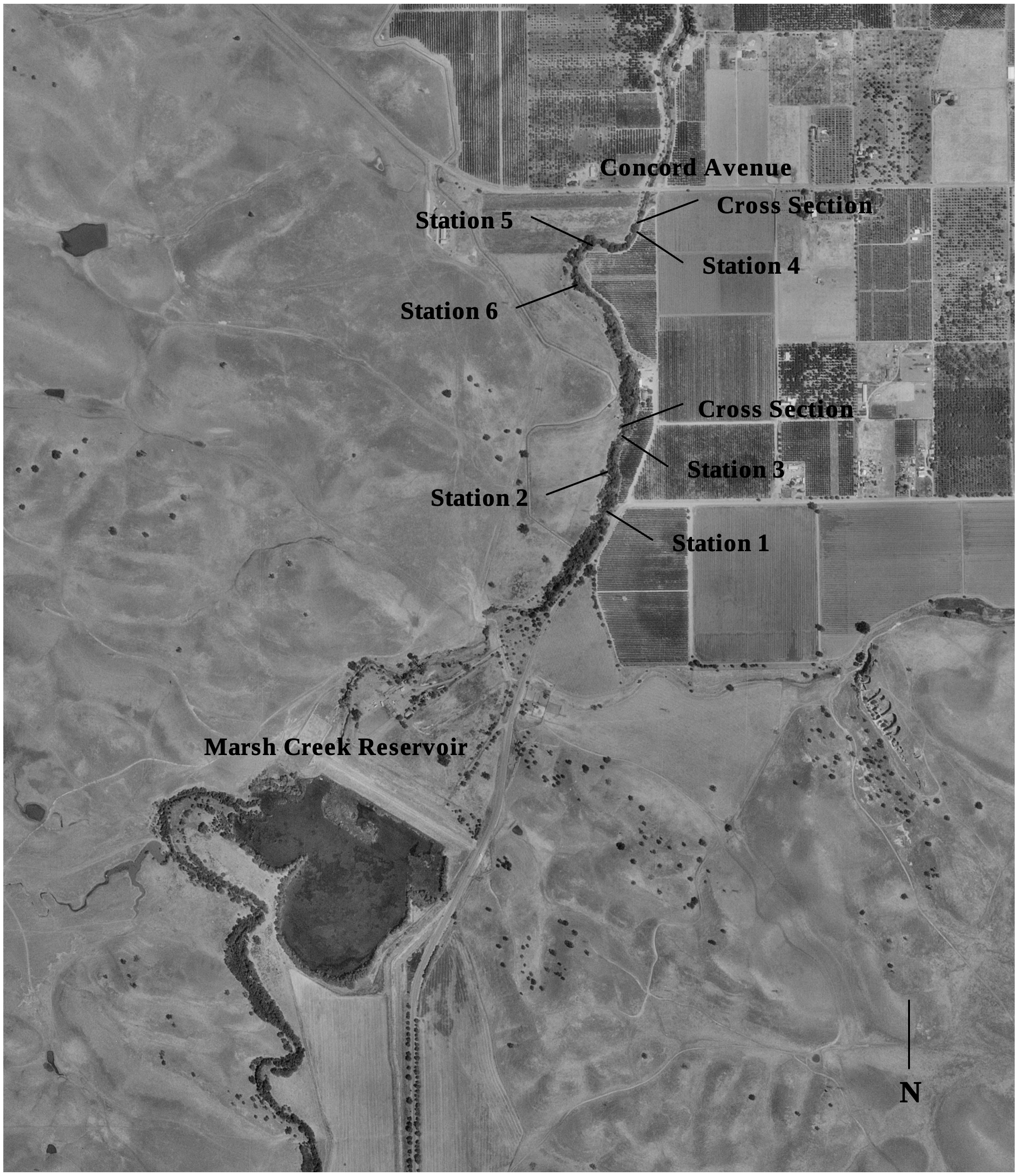
Source: Cain, J.R., J.D. Robins, and S.S. Beamish. 2003. The Past and Present Condition of the Marsh Creek Watershed. Natural Heritage Institute, Berkeley, CA.

Figure 2: Channelized Reach of Lower Marsh Creek Below Grade Control Dam

Figure 3: Unchannelized Reach of Lower Marsh Creek Above Concord Avenue

Figure 4: Grade Control Dam on Lower Marsh Creek

Figure 5: Location Map of Stations Surveyed on March 26, 2004



Source: Victoria Seidman, Associate Research Ecologist, California State Parks Department, March 2004.

Figure 6: Study Stations

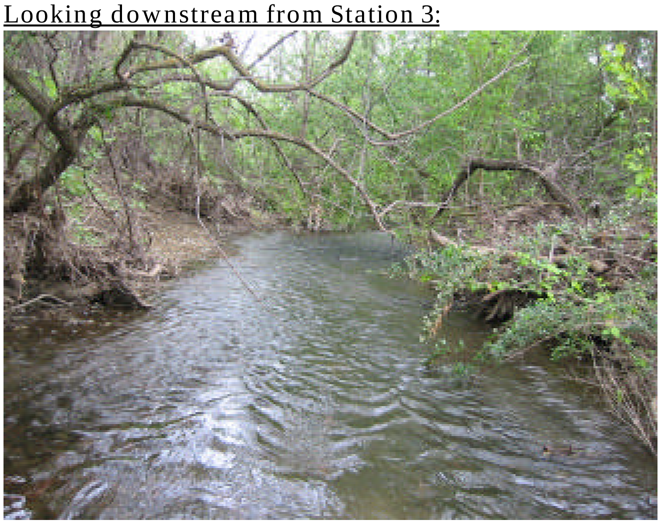
Looking downstream from Station 1:

Looking downstream from Station 4:

Looking downstream from Station 2:

Looking downstream from Station 5:

Looking downstream from Station 3:



Looking downstream from Station 6:

Figure 7: Cumulative Size Distribution Plots

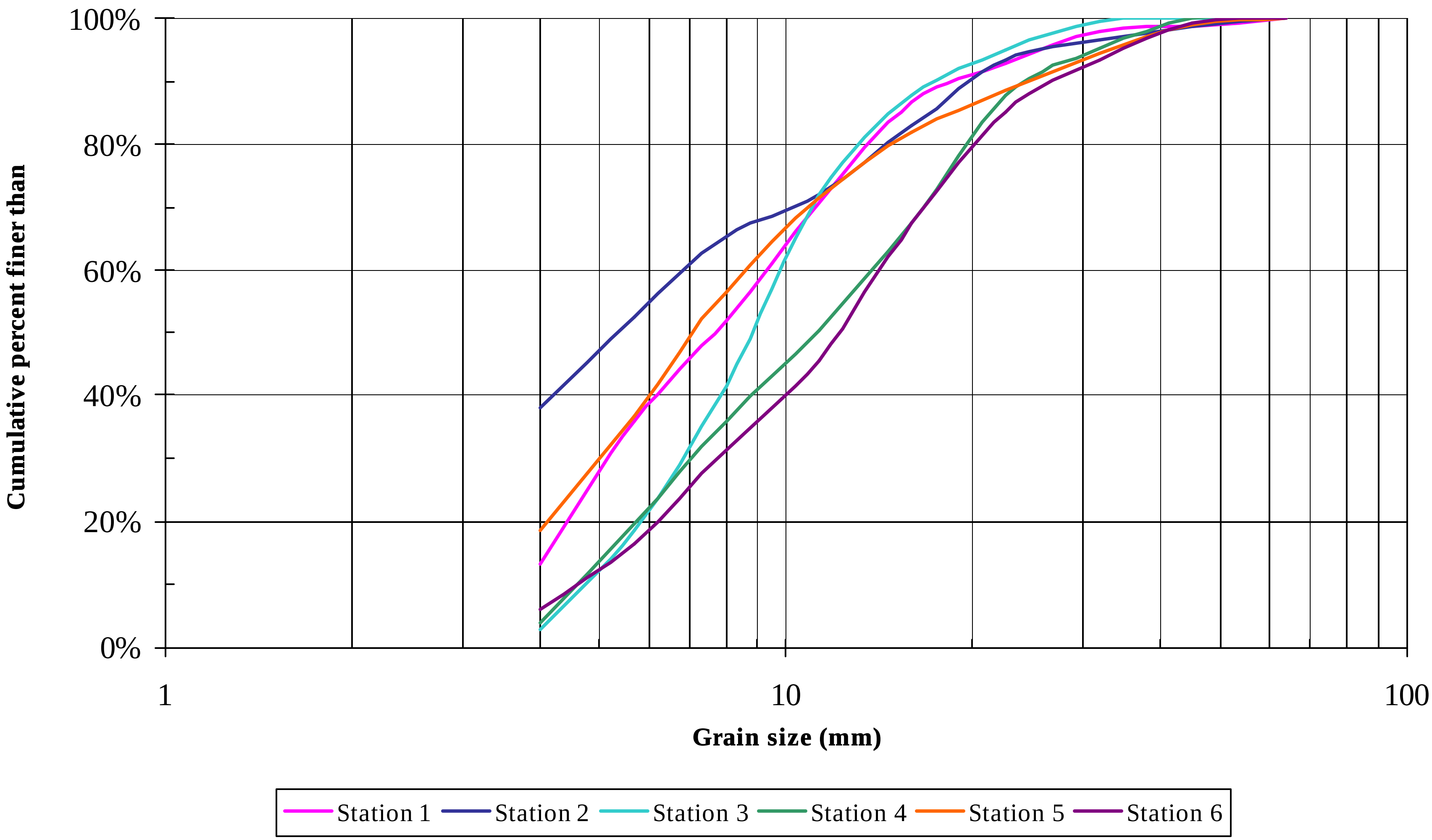
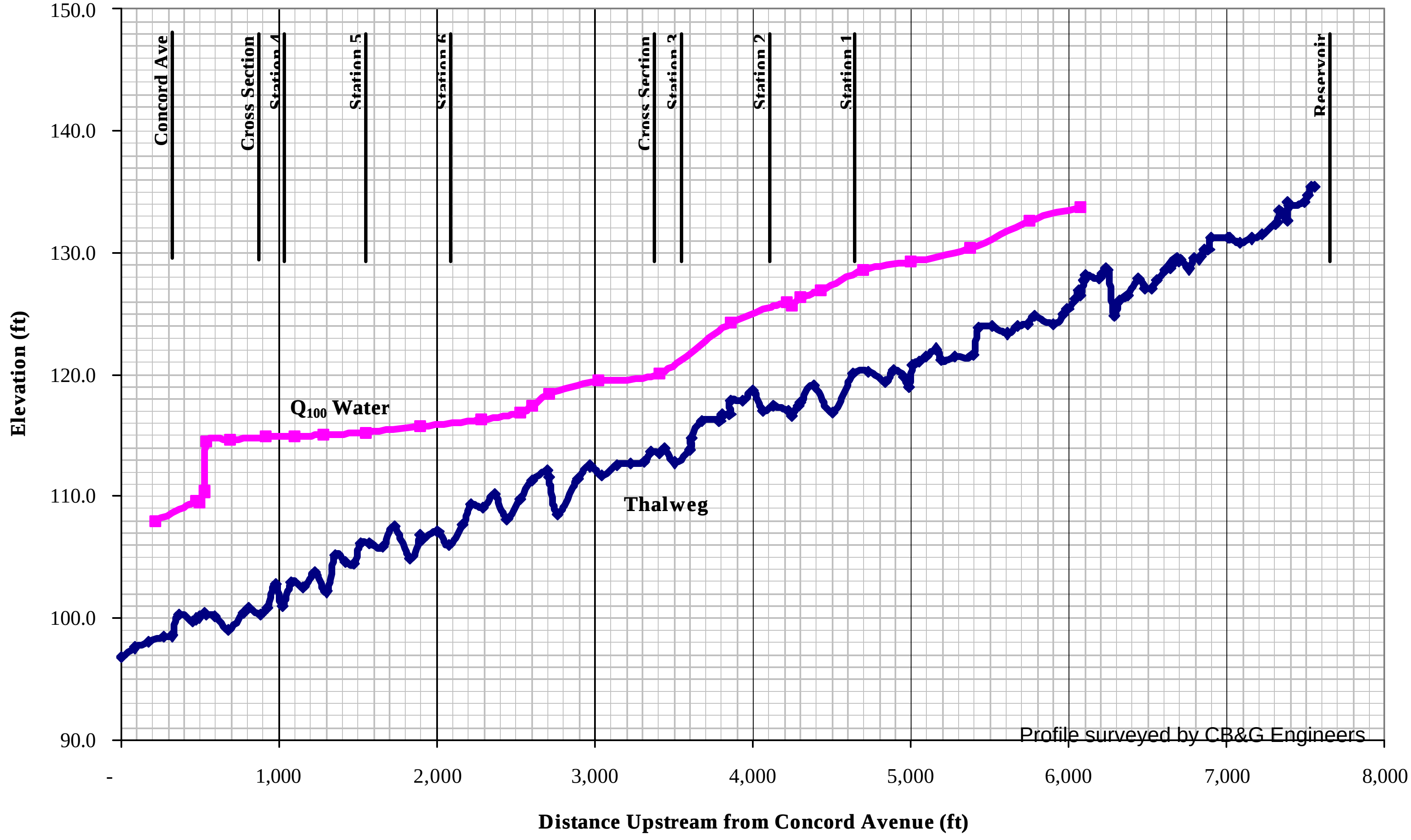
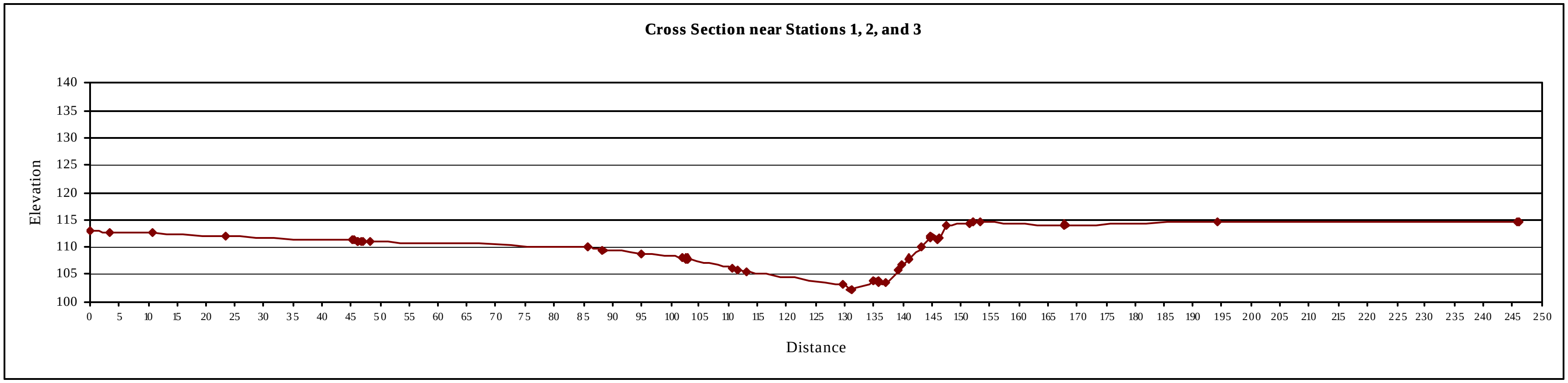


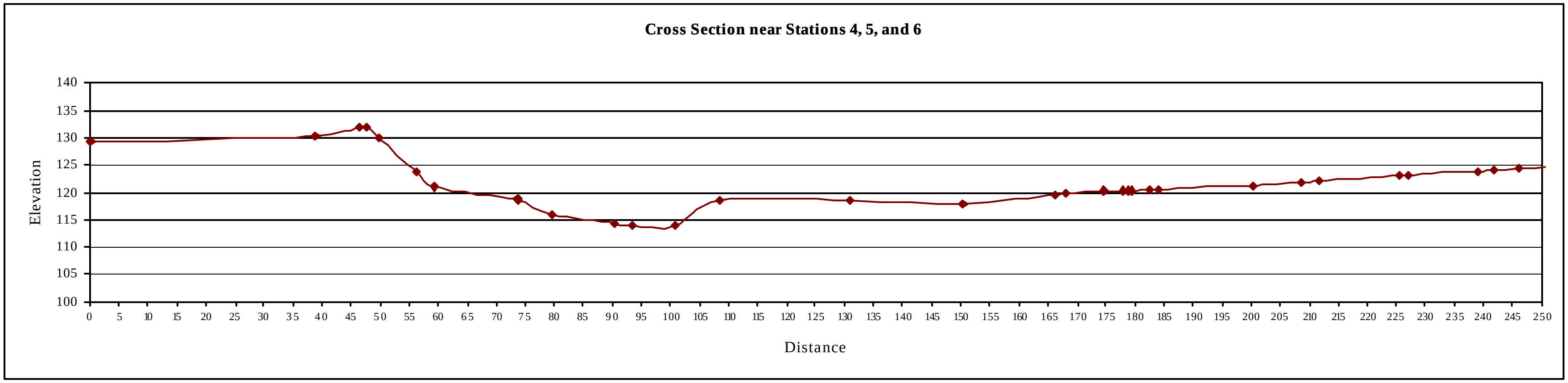
Figure 8: Long Profile of Study Reach



Source: Balance Hydrologics, Inc, March 2004.

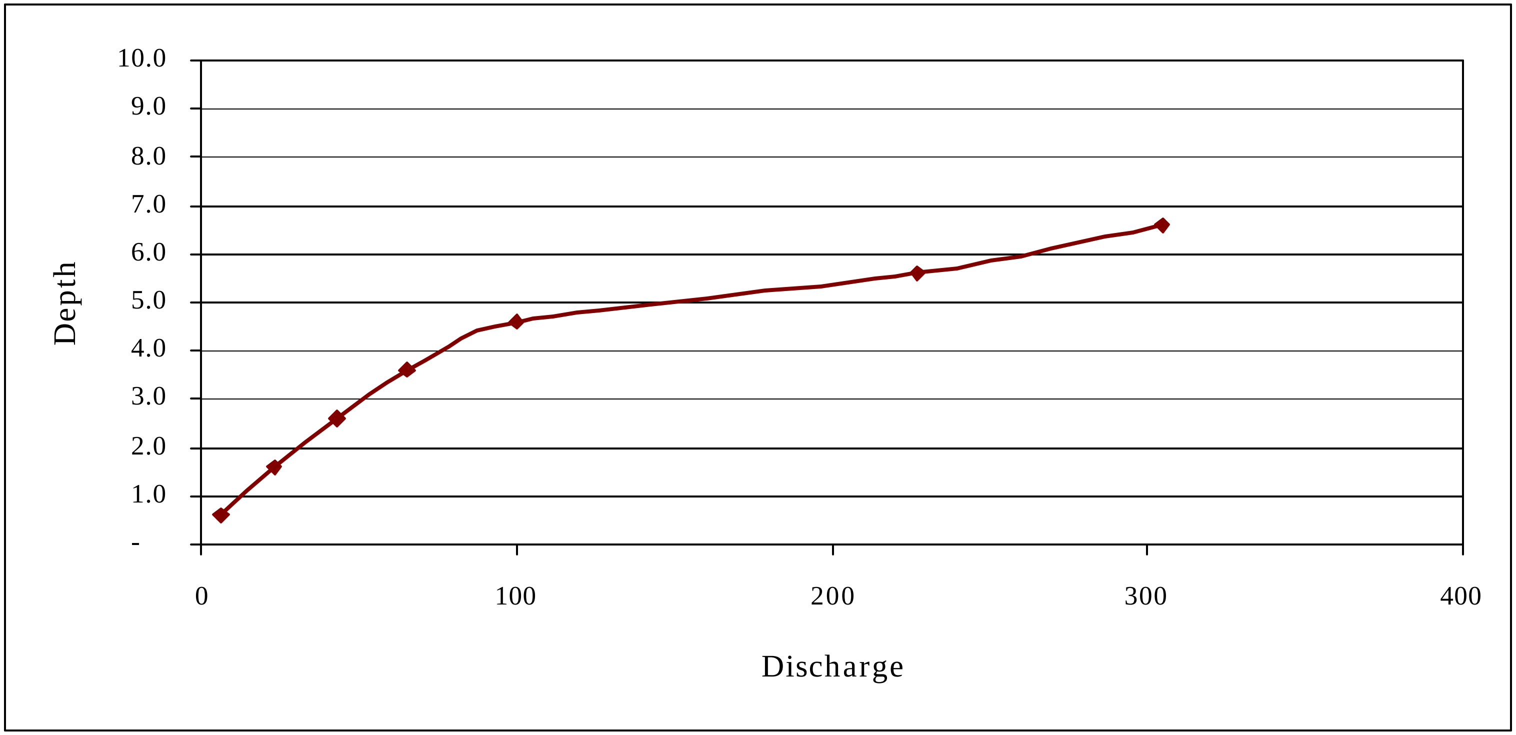
Figure 9: Surveyed Cross Sections of Study Reach





Source: Balance Hydrologics, Inc, March 2004.

Figure 10: Rating Curve for Lower Marsh Creek



Note: This rating curve illustrates the *__average__* *depth/discharge relation among the two cross-sections analyzed.*

Table 1: Pebble Count Results

Marsh Creek between Concord Ave and Marsh Creek Reservoir (3/26/04)

	Number of rocks in size class					
Size class	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
< 4 mm	20	57	4	6	28	9
4 - 5.7 mm	34	33	29	23	39	17
5.7 - 8 mm	24	22	41	24	36	23
8 - 11.3 mm	28	11	54	21	27	22
11.3 - 16 mm	24	19	28	25	19	34
16 - 22.6 mm	9	18	13	30	12	28
22.6 - 32 mm	8	5	8	11	11	13
32 - 45 mm	1	4	1	7	8	9
45 - 64 mm	2	2	0	0	2	1
Total	150	171	178	147	182	156

	Percent of rocks in size class					
Size class	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
< 4 mm	13%	33%	2%	4%	15%	6%
4 - 5.7 mm	23%	19%	16%	16%	21%	11%
5.7 - 8 mm	16%	13%	23%	16%	20%	15%
8 - 11.3 mm	19%	6%	30%	14%	15%	14%
11.3 - 16 mm	16%	11%	16%	17%	10%	22%
16 - 22.6 mm	6%	11%	7%	20%	7%	18%
22.6 - 32 mm	5%	3%	4%	7%	6%	8%
32 - 45 mm	1%	2%	1%	5%	4%	6%
45 - 64 mm	1%	1%	0%	0%	1%	1%

Cumulative % < 4 mm	13%	38%	3%	4%	19%	6%
Cumulative % < 5.7 mm	36%	53%	19%	20%	37%	17%
Cumulative % < 8 mm	52%	65%	42%	36%	57%	31%
Cumulative % < 11.3 mm	71%	72%	72%	50%	71%	46%
Cumulative % < 16 mm	87%	83%	88%	67%	82%	67%
Cumulative % < 22.6 mm	93%	94%	95%	88%	88%	85%
Cumulative % < 32 mm	98%	96%	99%	95%	95%	94%
Cumulative % < 45 mm	99%	99%	100%	100%	99%	99%
Cumulative % < 64 mm	100%	100%	100%	100%	100%	100%

D50 (mm)	7.5	5.5	8	11	7	14

Table 2: Embeddedness Estimates

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Embeddedness (%)	10-20	30-40	10-25	50-60	5-10	30-50
Level of embeddedness	Low	Moderate	Low	High	Low	Moderate

Table 3: Surface Area of Gravel Bars Surveyed

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Surface Area (sq. ft)	20	72	180	120	100	35

Table 4: Summary of Gravel Quality Analysis

Ranking system:

4 = very likely
3 = likely
2 = unlikely
1 = very unlikely

Criteria	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Gravels within size ranges reported in studies	3	2	3	4	3	4
Gravel size small enough for spawning fish to move	4	4	4	4	4	4
Level of embeddedness not excessive	4	3	4	1	4	3
Gravel bar surface area large enough for redd construction	3	4	4	4	4	4
Score (highest = 16)	**14**	**13**	**15**	**13**	**15**	**15**

Table 5: Gradient of Thalweg, Long Profile

Station*	Elevation (ft)	Gradient
-	96.8	
89	97.6	0.9%
173	98.0	0.6%
277	98.4	0.4%
324	98.5	0.2%
365	100.3	4.3%
454	99.7	-0.7%
478	99.9	0.8%
494	100.1	0.9%
528	100.4	1.0%
541	100.2	-1.5%
594	100.2	-0.1%
678	99.0	-1.4%
776	100.4	1.4%
806	100.9	1.4%
882	100.3	-0.7%
926	100.8	1.2%
980	102.8	3.7%
1,022	101.0	-4.5%
1,083	103.0	3.3%
1,156	102.5	-0.6%
1,231	103.7	1.6%
1,301	102.2	-2.2%
1,359	105.2	5.2%
1,423	104.6	-1.0%
1,477	104.5	-0.2%
1,516	106.1	4.3%
1,576	106.1	0.0%
1,655	105.8	-0.4%
1,732	107.5	2.2%
1,834	104.9	-2.6%
1,898	106.8	3.0%
1,901	106.5	-10.2%
2,007	107.1	0.6%
2,072	105.9	-1.8%
2,164	107.6	1.9%
2,216	109.3	3.3%
2,293	109.0	-0.4%
2,367	110.2	1.5%
2,441	108.1	-2.8%
2,525	109.8	2.0%
2,606	111.3	1.9%
2,700	112.1	0.9%
2,707	111.5	-8.1%
2,765	108.6	-5.2%
2,889	111.4	2.3%
2,967	112.5	1.4%
3,047	111.7	-0.9%
3,145	112.6	0.9%
3,230	112.7	0.1%
3,312	112.8	0.2%
3,358	113.6	1.8%
3,408	113.6	-0.1%
3,441	113.9	1.0%
3,507	112.8	-1.7%
3,603	113.9	1.1%
3,611	114.8	11.6%
3,679	116.2	2.1%
3,780	116.2	0.0%
3,790	116.2	0.0%
3,795	116.4	3.8%
3,805	116.8	3.7%
3,855	116.7	0.0%
3,860	117.9	24.6%
3,940	117.8	-0.1%
4,001	118.7	1.3%
4,062	117.1	-2.7%
4,132	117.4	0.5%
4,222	117.0	-0.4%
4,243	116.6	-2.1%
4,289	117.5	1.9%
4,305	117.7	1.4%
4,382	119.2	1.9%
4,505	116.9	-1.9%
4,634	120.1	2.4%
4,732	120.2	0.2%
4,841	119.4	-0.8%
4,891	120.4	2.0%
4,955	119.8	-0.8%
4,985	118.9	-3.1%
5,014	120.8	6.5%
5,056	121.1	0.6%

Table 5: Gradient of Thalweg, Long Profile (continued)

Station*	Elevation (ft)	Gradient
5,098	121.4	0.8%
5,164	122.1	1.0%
5,196	121.2	-3.0%
5,278	121.4	0.3%
5,391	121.6	0.1%
5,426	123.8	6.3%
5,512	123.9	0.2%
5,613	123.4	-0.6%
5,673	124.0	1.0%
5,743	124.2	0.3%
5,782	124.8	1.7%
5,903	124.1	-0.6%
5,964	124.9	1.4%
5,991	125.4	1.6%
6,044	126.2	1.5%
6,061	126.9	4.1%
6,074	126.5	-2.7%
6,093	127.7	6.0%
6,108	128.2	3.3%
6,192	127.8	-0.4%
6,216	128.3	2.1%
6,231	128.7	2.6%
6,248	128.6	-1.1%
6,284	124.8	-10.5%
6,320	126.0	3.4%
6,368	126.5	0.8%
6,440	127.9	1.9%
6,485	127.1	-1.7%
6,522	127.1	-0.1%
6,556	127.7	1.9%
6,608	128.6	1.7%
6,628	128.9	1.4%
6,638	128.7	-1.8%
6,644	129.1	6.4%
6,667	129.2	0.5%
6,679	129.5	2.7%
6,696	129.2	-1.5%
6,707	129.5	2.1%
6,759	128.7	-1.6%
6,790	129.5	2.8%
6,828	129.5	-0.1%

Station*	Elevation (ft)	Gradient
6,839	129.7	1.6%
6,854	130.2	3.4%
6,882	130.3	0.3%
6,899	131.2	5.4%
7,004	131.2	0.0%
7,019	131.2	0.1%
7,082	130.8	-0.6%
7,157	131.2	0.4%
7,223	131.5	0.5%
7,305	132.4	1.0%
7,319	132.5	0.7%
7,334	133.5	6.8%
7,378	132.6	-1.9%
7,380	134.2	81.8%
7,397	133.8	-2.0%
7,490	134.2	0.4%
7,513	134.7	2.2%
7,534	135.5	3.6%
7,553	135.4	-0.2%
Average Gradient		0.51%

** Stations determined by Balance Hydrologics, Inc based on distance (ft) upstream from Concord Ave.*

Table 6: Cross-Sectional Area of Water at Stations

Station	Avg. Water Depth (ft)	Channel Width (ft)	Cross-Sectional Area of Water (sq ft)
Station 1	0.4	12.0	4.5
Station 2	0.7	16.0	10.7
Station 3	0.5	16.0	7.3
Station 4	0.6	15.0	8.8
Station 5	0.8	10.0	7.9
Station 6	0.9	7.0	6.1
Average	**0.63**	**12.67**	**7.9**

Table 7: Estimated Velocity of Water at Stations

Station	Cross-Sectional Area of Water (sq ft)	Velocity (ft/s)
Station 1	4.5	1.44
Station 2	10.7	0.61
Station 3	7.3	0.89
Station 4	8.8	0.74
Station 5	7.9	0.82
Station 6	6.1	1.06
Average	**7.9**	**0.82**

Table 8: Roughness Coefficient Calculation

V = velocity	0.82
c = 1.49	1.49
s = slope	0.0051
R = hydraulic radius	0.63
n = roughness coefficient	**0.09**

Table 9: Estimated Velocity with Increased Water Depth

	Depth (ft)	Velocity (ft/s)
Average Depth at Stations	0.63	**0.82**
Station Depth +1ft	1.63	**1.56**
Station Depth +2ft	2.63	**2.15**
Station Depth +3ft	3.63	**2.67**
Station Depth +4ft	4.63	**3.14**
Station Depth +5ft	5.63	**3.58**
Station Depth +6ft	6.63	**3.99**

Note: These calculations assume constant c (c = 1.49), slope (s = 0.51%), and roughness value (n = 0.09).

Table 10: Projected Flows with Increased Water Depth

Cross Section near Stations 1, 2, and 3					
	Depth (ft)	Width (ft)	Area (sq ft)	Velocity (ft/s)	Q cfs
Average Depth at Stations	0.63	12.67	7.92	0.82	**6.50**
Station Depth +1ft	1.63	20.67	15.92	1.56	**24.79**
Station Depth +2ft	2.63	26.67	21.92	2.15	**47.07**
Station Depth +3ft	3.63	31.67	26.92	2.67	**71.76**
Station Depth +4ft	4.63	36.67	31.92	3.14	**100.18**
Station Depth +5ft	5.63	45.67	40.92	3.58	**146.42**
Station Depth +6ft	6.63	53.67	48.92	3.99	**195.34**

Cross Section near Stations 4, 5, and 6					
	Depth (ft)	Width (ft)	Area (sq ft)	Velocity (ft/s)	Q cfs
Average Depth at Stations	0.63	12.67	7.92	0.82	**6.50**
Station Depth +1ft	1.63	18.67	13.92	1.56	**21.67**
Station Depth +2ft	2.63	22.67	17.92	2.15	**38.48**
Station Depth +3ft	3.63	26.67	21.92	2.67	**58.43**
Station Depth +4ft	4.63	36.67	31.92	3.14	**100.18**
Station Depth +5ft	5.63	90.67	85.92	3.58	**307.46**
Station Depth +6ft	6.63	108.67	103.92	3.99	**414.96**

Table 11: Ranking of Fall Days by Discharge/Velocity

Discharge (cfs)	# Days Oct-Dec 1953-1982	% Total Days	Calculated Velocity (ft/s)
0	2,361	85.2%	-
1-5	201	7.3%	0.82
6-10	66	2.4%	0.82
11-15	28	1.0%	0.82
16-25	24	0.9%	1.56
26-40	24	0.9%	1.56
41-55	14	0.5%	2.15
56-70	8	0.3%	2.15
71-85	3	0.1%	2.67
86-110	7	0.3%	2.67
111-135	5	0.2%	3.14
136-160	1	0.0%	3.14
161-185	6	0.2%	3.14
186-235	5	0.2%	3.14
236-285	1	0.0%	3.58
286-335	14	0.5%	3.58
336-435	1	0.0%	3.99
436-935	2	0.1%	3.99+
936+	1	0.0%	3.99+

Table 12: Summary of Discharge/Velocity Analysis

Total Days with No Flow	85.2%
Total Days with Velocity <0.82 – Unlikely Spawning	10.6%
Total Days with Velocity 1.56-3.14 – Likely Spawning	**3.5%**
Total Days with Velocity >3.58 – Unlikely Spawning	0.7%

Table 13: Ranking of Fall Days by Discharge/Depth

Discharge (cfs)	# Days Oct-Dec 1953-1982	% Total Days	Calculated Depth (ft)
0	2,361	85.2%	-
1-5	201	7.3%	0.63
6-10	66	2.4%	0.63
11-15	28	1.0%	0.63
16-25	24	0.9%	1.63
26-40	24	0.9%	1.63
41-55	14	0.5%	2.63
56-70	8	0.3%	2.63
71-85	3	0.1%	3.63
86-110	7	0.3%	3.63
111-135	5	0.2%	4.63
136-160	1	0.0%	4.63
161-185	6	0.2%	4.63
186-235	5	0.2%	4.63
236-285	1	0.0%	5.63
286-335	14	0.5%	5.63
336-435	1	0.0%	6.63
436-935	2	0.1%	6.63+
936+	1	0.0%	6.63+

Table 14: Summary of Discharge/Depth Analysis

Total Days with No Flow	85.2%
Total Days with Depth <0.63 – Possible Spawning	10.6%
Total Days with Depth >1.63 – Likely Spawning	**4.2%**