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Fish Use and Water Quality Associated with a Levee Crossing the Tidally Influenced Portion of Browns Slough, Skagit River Estuary, Washington.

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August 1998

Report Prepared for:

Skagit County Diking District No. 22

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Fisheries and Environmental Services for the Swinomish Tribal Community, Upper Skagit and Sauk-Suiattle Indian Tribes

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ABSTRACT

Following the flood events of 1990, a levee with two top hinge gated culverts was constructed across the lower portion of Browns Slough in the Skagit River Delta, Washington. In this configuration the cross levee accommodated drainage of upstream lands, but not tidal inundation or fish passage from Skagit Bay to the habitat upstream of the cross levee. In 1994, another culvert was installed to restore fish access and tidal inundation to the upstream part of the slough. This new culvert has a manually operated gate that could be closed during flooding emergencies but remain open at other times of the year. This study investigated the impact of the cross levee's current configuration on fish use, water quality, and habitat conditions in the lower portion of Browns Slough.

This study found eleven fish species present in the Browns Slough Study Area with all eleven species captured upstream of the cross levee. We also show a close correlation in the timing curves of juvenile chinook upstream and downstream of the cross levee, over two seasons. Fish were able to find, occupy and outmigrate from habitat upstream of the cross levee in a similar pattern to those that did not navigate the culvert in the cross levee. Because anadromous salmonids and other estuarine fish can not access study sites upstream of the cross levee except by passing through the cross levee from the Skagit Bay side, we believe that these data support a conclusion that the culvert in the cross levee, with the manual gate operated in the full open position, is not a problem for fish passage.

The overall quality of the measured water parameters immediately above and below the cross levee appears to be similar. Where measured parameters exceeded state standards, the excursions did not appear to be caused or exacerbated by the cross levee. Flow through the cross levee culverts does act as mixing device that homogenizes the water column of the immediate receiving site. In general, no water quality transition at the cross levee appeared to be sufficient or sustained long enough to prevent fish passage through the cross levee.

Estuarine habitat loss and modification has occurred in lower Browns Slough since the pre-1990 conditions due to the footprint of the cross levee and only partially restoring tidal inundation. However, our results show that this type of project may be useful in restoring estuary habitat in other areas, while maintaining some drainage function and flood protection to adjacent land. The culvert, sized to allow partial tidal inundation, was also adequate to attract and allow passage of juvenile salmonid to habitat otherwise blocked from access within first rearing season following construction.

INTRODUCTION

During the emergency period of the 1990 floods, a levee was constructed across the lower portion of Browns Slough in the Skagit River Delta to provide protection from flooding (Figures 1 and 2). This cross levee was constructed with two four foot diameter culverts with metal gates hinged on the top side to accommodate the drainage of lands upstream, but not tidal inundation. The change denied juvenile salmonids and other estuarine fish unimpeded access to the habitat upstream of the cross levee. This change converted the area upstream of the cross levee from tidally influenced blind channel and saltmarsh habitat to palustrine openwater and freshwater marsh habitat respectively.

In 1994 a manually gated four foot diameter culvert was installed to restore fish access and tidal inundation to the upstream part of the slough. The design provided flood protection to adjacent land by constricting tidal flow. Moreover, the manual gate could be closed during large flood events. The effectiveness of this design, however, has never been tested in tidally influenced channels. It was unknown what the actual impacts to fish use would be at Browns Slough.

An evaluation simply documenting fish use upstream of the culvert would not determine whether the cross levee and culvert were adversely impacting the fish resources of this tidally influenced slough because there would be no context in which to interpret the results. However, because some pattern of fish use related to the tidal cycle is expected, the study was designed to identify these patterns throughout the study area which were used to provide a context for an analysis in the immediate area of the cross levee. The analysis approach required us to consider what the sampling results would be if the cross levee was not impacting fish distribution. Under this approach, adjacent sampling sites would be expected to be more similar than distant sites. Therefore, if the cross levee was not impacting fish distribution, we expected to find no difference (or less of a difference) between samples taken immediately above and below the cross levee than those that are more distant.

SAMPLING METHODS

SAMPLING SITES

This evaluation measured fish abundance, habitat type, and water quality in six different sites (3 upstream and 3 downstream of the cross levee) distributed throughout the study area (Figure 3). Site 1 was nearest to Skagit Bay at the junction between the slough and bay levees. Site 2 was near the midpoint between Site 1 and the cross levee. Sites 3 and 4 were adjacent to the cross levee (downstream and upstream sides respectively). Site 5 was near the midpoint between Site 6 and the cross levee. Site 6 was nearest to the tide gate at Fir Island Road. Data were collected by four tidal stages: high, ebb, low, and flood tides. Six sampling events were conducted in April and May of 1995 to coincide with peak juvenile salmon use. During this period the manually gated culvert was in the complete open position. Given logistical and budgetary constraints, more sampling was not possible.

FISH SAMPLING

A 21 x 3 meter beach seine with 0.3 centimeter mesh was used to capture fish at the six sites identified above. Two beaches (primary and alternate) were seined at Sites 3 and 4, because of the possibility of not being able to sample at the primary beach due to the presence of drift logs and other debris. Sampling at Site 5 was also divided into two sites (5A and 5B) to monitor the unique habitat occurring at this site. Site 5A was a deep scour hole in the slough created by a breach in the levee during the 1990 floods. Site 5B was similar to the habitats at the other sites. All beach seine locations are shown and labeled in Figure 3 as the combination of the site number (1-6) and beach location (A or B).

To capture fish, the net was deployed from a rowboat in the shape of a half circle. The boat started on the down-current end and moved up-current setting the net. The net was completely deployed when the boat reached the up-current shoreline and then gradually pulled ashore from both ends to retain the catch. Following each set, the catch was identified by species and enumerated. Stickleback and smelt were estimated on some occasions due to their abundance in some sets. Sub-samples of the chinook (age 0+) were measured for fork length (mm) data. Habitat conditions (dominant habitat type, area encircled by the net, and maximum water depth) were also recorded for each set.

Habitat types were defined as three types (channel, impounded, and marsh) based on morphology, substrate, and water depth characteristics. Because a shoreline is required to seine at each site, habitat type could vary at any site depending on water elevation. A schematic representation of the three habitat types and their relationship to water elevation related to tide is shown in Figure 4. Channel habitat was defined as a waterway that contains moving water at the flood and ebb tidal stages. Channel habitat has a definite bed and banks that confine water, and vary in water depth (0 to 3 meters) and width (4.5 to 45 meters) depending on tidal stage. Bed and bank substrate was dominated by mud. Impounded habitat was defined as a topographical depression within a channel that retained water greater than three meters deep at low tide. Impounded habitat also varied in depth and width depending on tidal stage and had bed and bank substrate of mud. Marsh habitat was defined as regularly flooded vegetated area. Marsh vegetation is dominated by rooted herbaceous hydrophytes, such as sedges (*Carex sp.*) and bulrush (*Scirpus sp.*).

Figure 1. Location of Browns Slough Study Area in the Skagit River Delta.

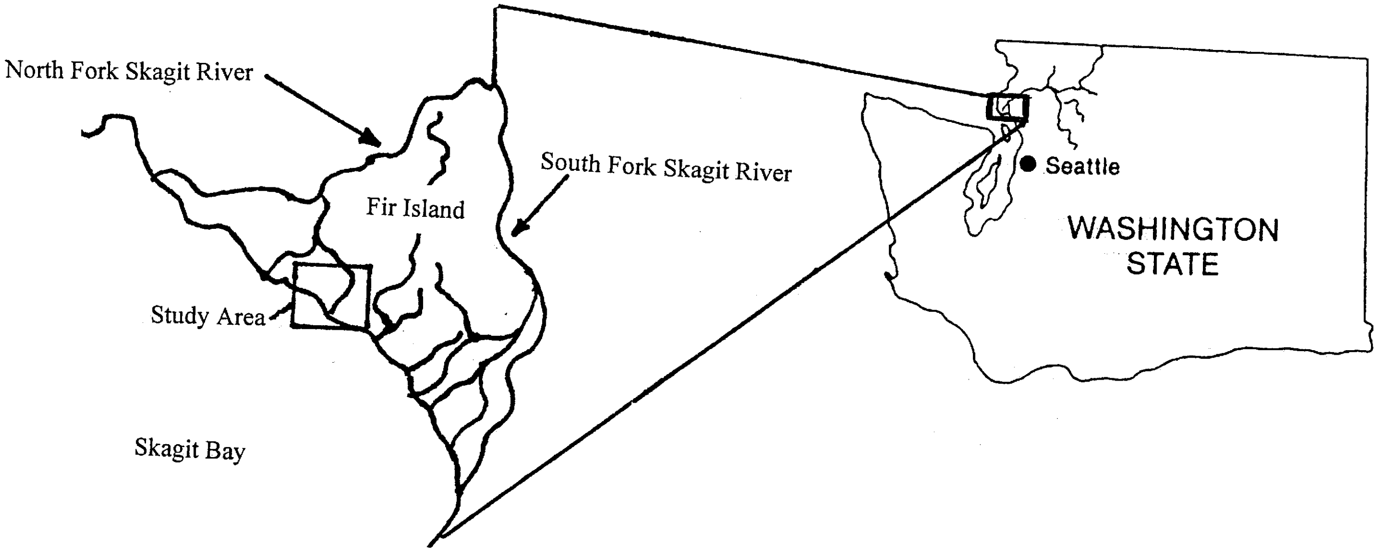
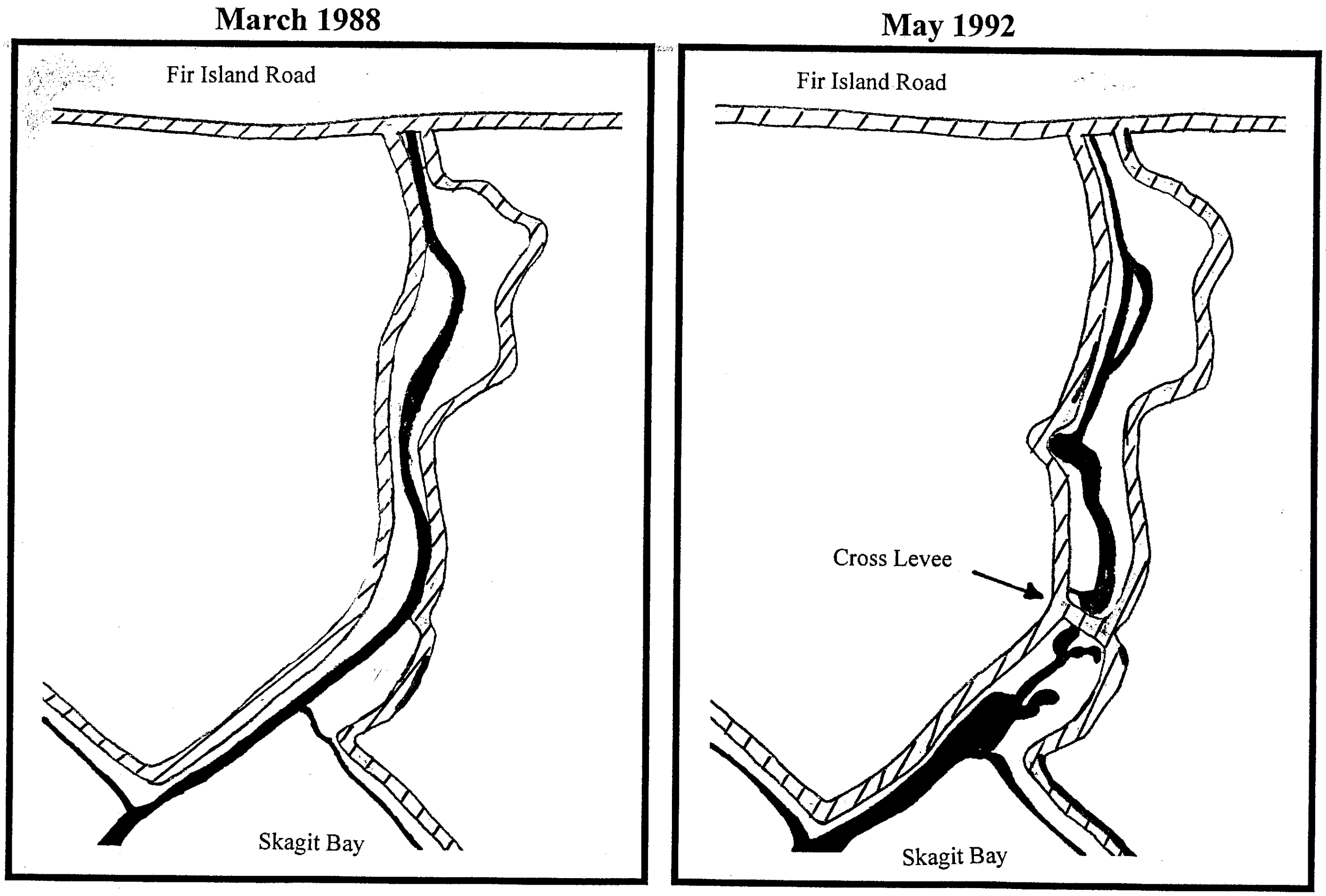
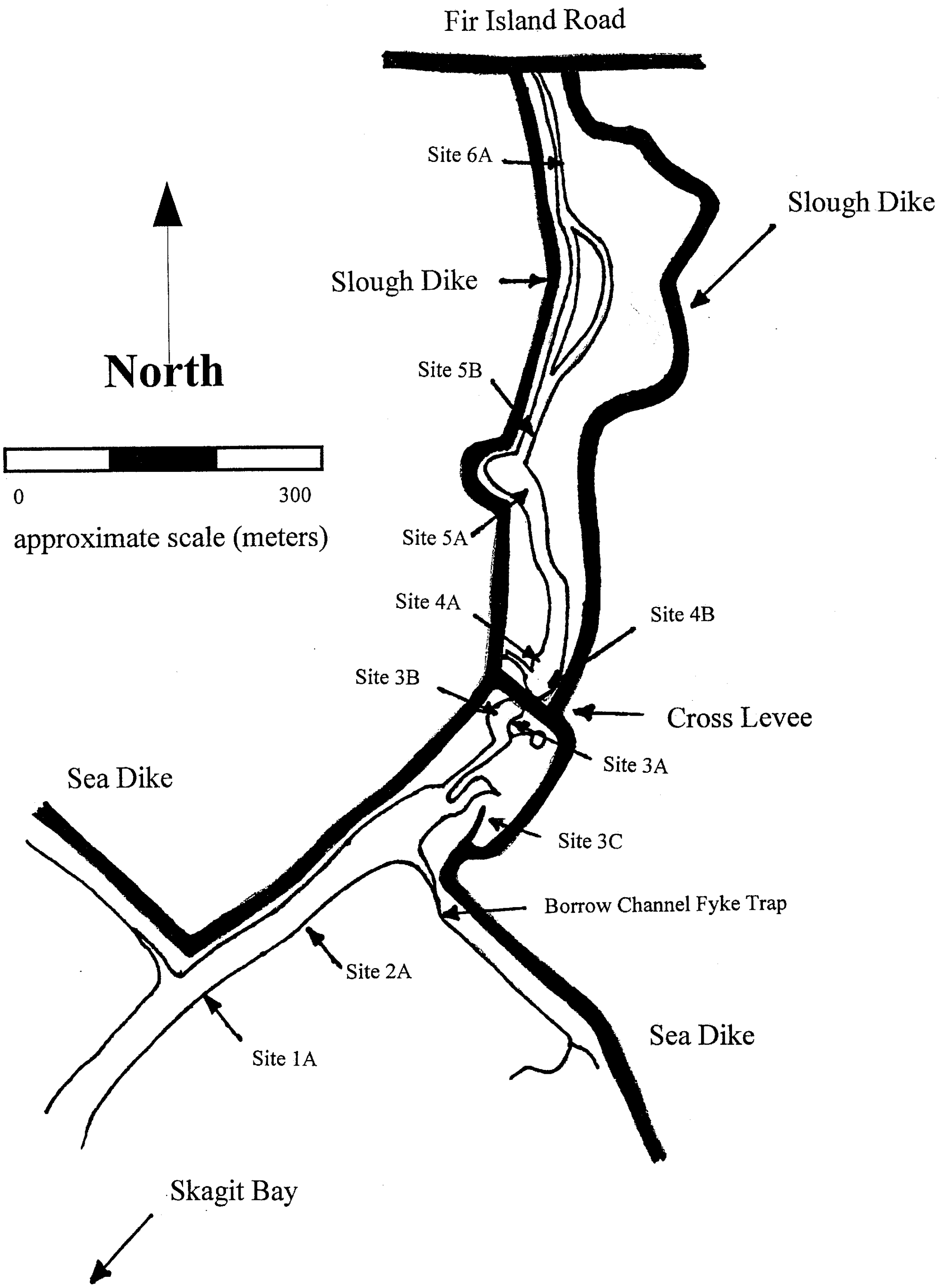


Figure 2. Change in the Browns Slough Study Area between March 1988 and May 1992. Levees and roads are hatched, water (at low tide) is shaded dark.


March 1988

May 1992

Figure 3. Location of sampling sites within the Browns Slough Study Area.



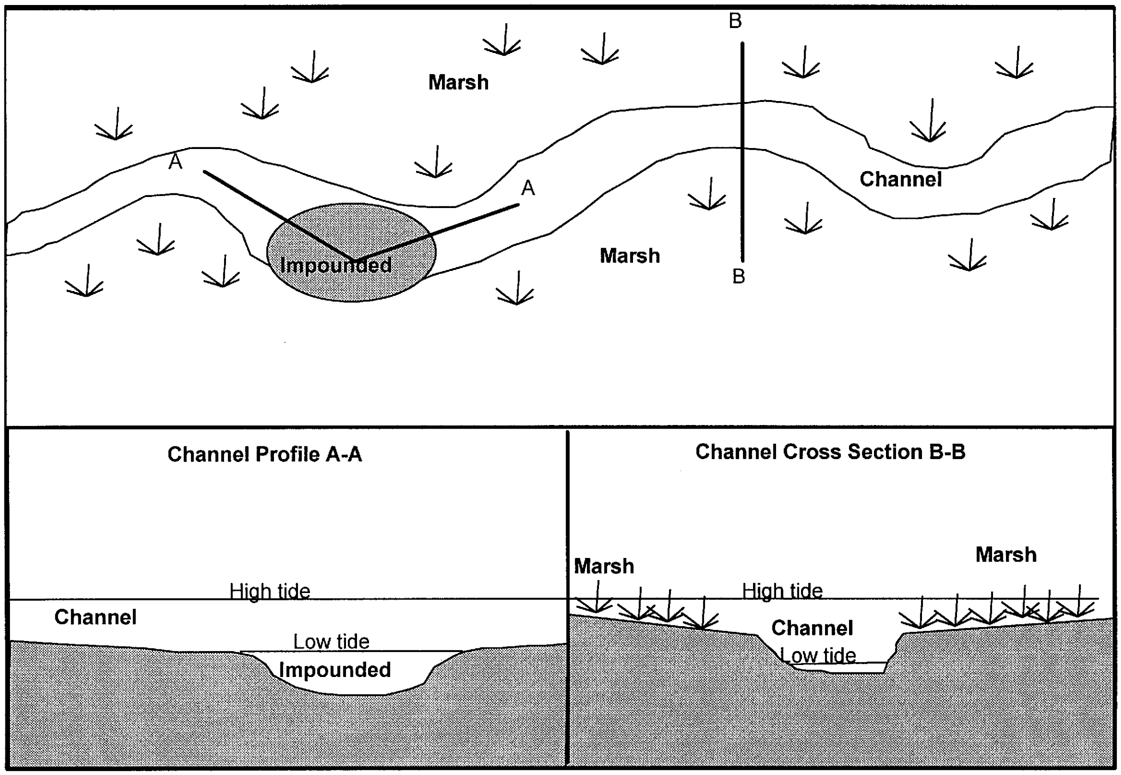


Figure 4. Schematic diagram of the three habitat types (channel, impounded, and marsh) sampled by beach seine.

WATER QUALITY

Measured water quality parameters were: temperature in degrees Celsius (°C), depth of the sample (feet), specific conductivity (umhos), hydrogen ion activity (pH), and dissolved oxygen (DO) in miligrams per liter (mg/l). Salinity was computed from the specific conductance. Water quality parameters were sampled using a Hydrolab with multiple probes and a digital data recorder. The probe was fitted with an attachable stirring device to keep water circulating over the dissolved oxygen probe in the relatively still water.

Two methods were used to physically place the Hydrolab probe for each measurement. On some days the probe was lowered from a boat in mid-channel where surface and bottom measurements were taken. On other days the probe was placed from the shoreline and allowed to sink to the bottom several feet out from the shore. Water Quality measurements were generally taken within one day of the fish sampling days.

ANALYSIS METHODS

Correspondence between agencies involved in the permitting process for the cross levee and Skagit County Diking District 22 identified the following fish use and water quality analyses.

FISH USE

Beach seine data for juvenile salmon were to be sorted by tidal stage and sampling week. The individual catches were to be converted to a percentage of the total weekly catch by tidal stage. Average values for each tidal stage at each site were to be plotted to generate a catch profile. The Diking District may be obligated to complete additional habitat work at the site based on the following results:

- Site 4 values are 75-100% of Site 3 values,
- Site 4 values fall below 75% but are greater than 25% of Site 3, and
- Site 4 values fall below 25% of Site 3.

WATER QUALITY

Measured parameters were compared to Class A standards for marine waters. These standard values are:

- Lowest concentration of DO: 6 milligrams per liter (mg/L).
- Maximum water temperature: 16 degrees Celsius.
- Range of pH factor: 7.0 to 8.5.

Excursions beyond standards were examined for physical patterns between stations and between surface and bottom measurements to determine if they appeared to be natural or affected by human activity or structures (i.e., the cross levee).

The data from all the sampling stations were studied to discern any patterns or trends between stations for each tidal phase and between sampling days as the spring season progressed. Of particular interest was the comparison of parameter values between the stations on each side of the cross levee in question, that is, site 3 on the bay side and site 4 on the slough side.

A rigorous statistical analysis is not presented due to the small number of samples for each tide cycle and some missing data that prevented complete pairing of data.

ANALYSIS STEPS FOR JUVENILE CHINOOK AND CHUM DATA

A goal of this study was to compare fish abundance between Sites 3 and 4 within the context of other sites up and downstream of the cross levee. Sampling over a range of dates, habitat types (including water quality), and tidal stages or using data from alternate beach seine locations within the same site, could potentially influence the relationship of fish abundance between sites. Therefore, the following analysis steps were used to screen and control for these potential effects before we compared fish abundance between Sites 3 and 4. The steps were applied only to chinook (age 0+) and chum (age 0+) data because other juvenile salmon were not as numerous during sampling.

Abundance over the study period

Juvenile salmonid presence in estuary habitat is ephemeral by nature. Even during the period when juvenile salmonids are present in estuarine habitats, other juveniles from riverine habitats are recruiting to the estuary, while still others are leaving the estuary to enter marine areas. These factors could change the Browns Slough Study Site salmonid population on a daily basis. Because of this possibility, the mitigation plan required examining data between sites as a trend (i.e., percentage of the total weekly catch) in an effort to minimize these differences over the study period.

Use of alternate beach seine locations at Sites 3 and 4

We seined at alternate beaches within the same site because beach debris was expected to prevent sampling at the same beach location on some days. The hypothesis, that fish density at the primary and alternate beach seine locations within a site are the same, was tested using paired data. If significant differences were observed, then this hypothesis was rejected and samples from the primary and alternate beach seine locations would be treated as different sites within the study area. If the hypothesis is not rejected with adequate statistical power (0.8 or greater), then samples collected from the primary and alternate beaches would be treated as samples from the same site. Under this scenario, samples collected at the alternate beach could be substituted for missing samples at the primary beach.

Habitat type

Habitat preference by juvenile chinook and chum could potentially influence their abundance within the study area. Because of this possibility, we tested whether juvenile chinook and chum abundance varied significantly by the three habitat types defined in this study: channel, marsh, and impounded.

Tidal stage

Mason (1974), Congleton (1978), Congleton *et al.* (1981), and Levy and Northcote (1981) found that tidal stage significantly influences fish abundance because of differences in water surface elevation, water velocity, direction of flow, and wetted area by tidal stage. Therefore our sampling was stratified by four tidal stages: ebb, flood, high, and low.

RESULTS

PHYSICAL HABITAT CHARACTERISTICS OF THE STUDY AREA

Wetted area of study area

Using an enlarged aerial photograph, the wetted area of the Browns Slough Study Area at high tide (mhhw) is estimated at 6.4 ha (2.8 ha upstream of the cross levee and 3.6 ha downstream of the cross levee). At low tide, the wetted area is estimated at 2.5 ha (1.1 ha upstream of the cross levee and 1.4 ha downstream of the cross levee). At low tide, a mud and sand sill located bayward of Site 1 maintains the water surface elevation by impounding water above the true low tide elevation in Skagit Bay. The footprint of the cross levee is approximately 0.08 ha.

Differences in high tide magnitude and timing on either side of the cross levee

Although not explicitly listed as a study objective, water surface elevation was tracked in order to conduct our beach seine sampling at the four tidal stages. As a result, we noted that the time and elevation of high tide was significantly different on either side of the cross levee. Water surface elevation on the slough side of the cross levee (upstream) was 0.2 to 1.9 feet lower than the bay side (downstream), depending on the size of the high tide (Figure 5). Also, the time of high tide was ½ to 1¼ hours later on the slough side when compared to the bay side (Figure 5).

Habitat conditions at beach seine sampling sites

Habitat conditions (i.e., type, and maximum depth) were measured at each beach seine site during the sampling period. Channel habitat was beach seined at all tidal stages and sites, except for Site 5A. Site 5A was impounded habitat at all tidal stages, except for one occasion. Marsh habitat was beach seined only at high tide, and was sampled most frequently downstream of the cross levee at Sites 1A, 2A, and 3C. However, on April 13th, Sites 4A and 5A were sampled as marsh habitat at the high tide phase. Mean maximum depth varied significantly by habitat type (Independent Group t -test, $p < 0.05$). Impounded habitat was the deepest with a mean depth of 4.05 meters. The mean depths for channel and marsh habitats were 1.52 and 0.37 meters respectively.

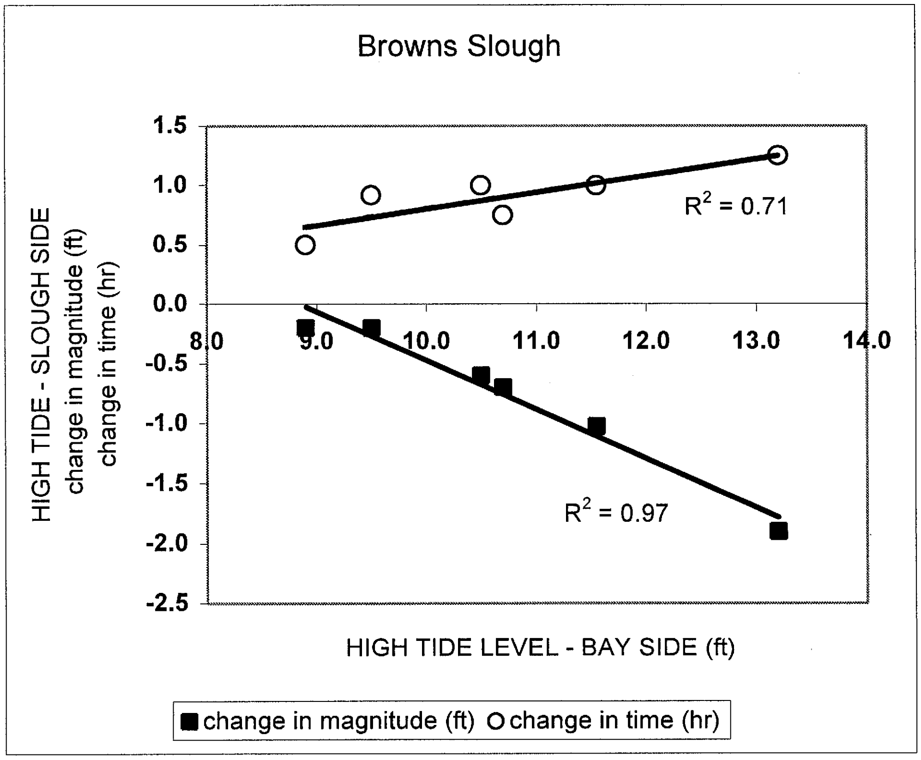


Figure 5. Change in the magnitude and time of high tide on the slough side of the cross levee as compared to the bay side of Browns Slough. Filled boxes show how much high tide magnitude is lowered, while open circles show how later high tide occurs on the slough side of the cross levee.

FISH USE

Frequency and abundance of fish species present in the study area

All sampling was completed between April 7, 1995 and May 10,1995, during the first estuarine rearing season available to juvenile salmon following the installation of the manually gated culvert in the cross levee.

Nearly 24,000 fish of eleven different species were captured in 144 beach seine sets over the one day per week, six week sampling period (Table 1). Three-spined Stickleback (*Gasterosteus aculeatus*) were most abundant, accounting for 11,079 fish, and were present in 85% of the 144 sets. Smelt (*Hypomesus pretiosus pretiosus*) were second most common with 7,881 fish, and were present in 50% of the sets. Only 12 smelt were large (> 200 mm fork length), while most were between 60 and 90 mm fork length. Juvenile chum (*Oncorhychus keta*) and chinook (*Oncorhychus tshawytscha*) were the most abundant salmon species with 1,947 and 1,173 fish captured respectively. Chum were present in 86% of the sets, while chinook were present in 84%. Chinook, chum, coho, smelt, stickleback, Staghorn sculpin, and Starry flounder were were captured throughout the entire six week sampling period. Shiner perch and Peamouth Chub were not common in beach seine catches until the last sampling event, May 10th.

Table 1 also shows a summary of each species captured both upstream and downstream of the cross levee. All eleven species were captured upstream of the cross levee and only one species, cutthroat trout, was not captured downstream of the cross levee. Mean catch (fish per beach seine set) was significantly higher (Independent Group t -test, $p < 0.05$) upstream of the cross levee for stickleback, and higher downstream of the cross levee for staghorn sculpin and starry flounder. No significant difference was detected in the means of chinook (age 0+), chum (age 0+), smelt, shiner perch, or peamouth chub. Chinook (age 1+), coho (age 1+), cutthroat (age 2+ or >), and prickly sculpin were not tested due to the low number caught.

Table 1. Total catch, average catch per beach seine set, and the percentage of sets where a species or age class of a species was present in the 144 beach seine sets over the Browns Slough Study Area. Table A is for all sites combined (Sites 1-6). Table B combines sites on the Skagit Bay side (Sites 1-3) and slough side (Sites 4-6) of the cross levee.

TABLE A

Common Name	Scientific Name	Total Catch	Average Catch	% Present
Chinook (age 0+)	Oncorhynchus tshawytscha	1,163	8.1	84%
Chinook (age 1+)	Oncorhynchus tshawytscha	10	0.1	6%
Chum (age 0+)	Oncorhynchus keta	1,947	13.5	86%
Coho (age 1+)	Oncorhynchus kisutch	11	0.1	7%
Cutthroat	Oncorhynchus clarki clarki	4	0.0	3%
Smelt	Hypomesus pretiosus pretiosus	7,881	54.7	50%
Three-spine Stickleback	Gasterosteus aculeatus	11,079	76.9	85%
Staghorn Sculpin	Leptocottus armatus	810	5.6	72%
Prickly Sculpin	Cottus asper	5	0.0	3%
Starry Flounder	Platichthys stellatus	266	1.8	52%
Shiner Perch	Cymatogaster aggregata	636	4.4	17%
Peamouth Chub	Mylocheilus caurinus	100	0.7	9%

TABLE B

		Bay Side		Slough Side	
Common Name	Scientific Name	Total Catch	Average Catch	Total Catch	Average Catch
Chinook (age 0+)	Oncorhynchus tshawytscha	422	6.6	741	9.3
Chinook (age 1+)	Oncorhynchus tshawytscha	4	0.1	6	0.1
Chum (age 0+)	Oncorhynchus keta	1,159	18.1	788	9.9
Coho (age 1+)	Oncorhynchus kisutch	4	0.1	7	0.1
Cutthroat	Oncorhynchus clarki clarki	0	0.0	4	0.1
Smelt	Hypomesus pretiosus pretiosus	4,334	67.7	3,547	44.3
Three-spine Stickleback	Gasterosteus aculeatus	1,768	27.6	9,311	116.4
Staghorn Sculpin	Leptocottus armatus	481	7.5	329	4.1
Prickly Sculpin	Cottus asper	2	0.0	3	0.0
Starry Flounder	Platichthys stellatus	162	2.5	104	1.3
Shiner Perch	Cymatogaster aggregata	613	9.6	23	0.3
Peamouth Chub	Mylocheilus caurinus	61	1.0	39	0.5

Crab (*Hemigrapsus sp., Cancer magister, and C. productus*) and shrimp (*Crago sp. and small shrimp from the Order Mysidacea*) were also present in the beach seine catch, although none were enumerated. Crago shrimp and Mysids were often abundant (hundreds per set) at each of the six sites. Amphipods were common, but generally not contained by the beach seine net.

Gut samples

Although not a study objective, several gut samples were recovered during beach seine sampling. Staghorn Sculpin were observed with crago shrimp, amphipods, and smelt in their stomach contents. Two cutthroat trout (170 mm and 240 mm fork length) regurgitated several smelt (80 mm range) and several chinook (65 mm range). No other gut samples were collected or inadvertently observed.

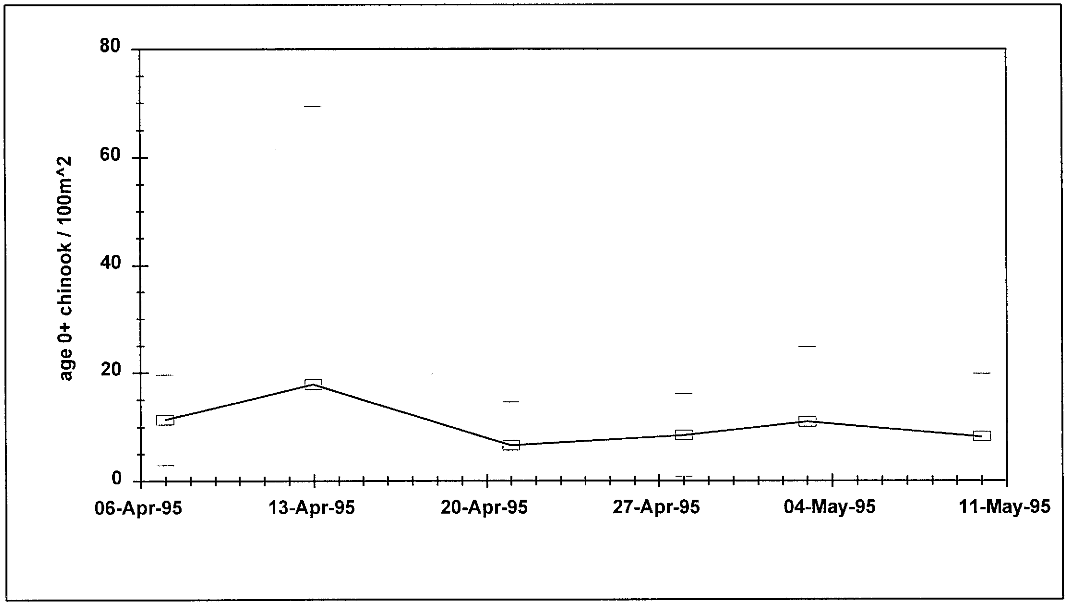
JUVENILE CHINOOK AND CHUM

Abundance over the study period

Average juvenile chinook abundance from beach seine sampling within the study area varied from 6.6 to 17.9 fish per 100 m^2 over the study period (Figure 6 - Top). Average juvenile chum abundance from beach seine sampling within the study area varied from 7.6 to 33.2 fish per 100 m^2 over the study period (Figure 6 - Bottom). While average chinook abundance varied by almost a factor of three, and chum abundance varied by over a factor of four, no significant difference between sampling dates was detected (Newman-Keuls multiple comparisons test, $\alpha = 0.05$). However, the statistical power of these tests is very low so we can not conclude that chinook or chum abundance within the study area was the same during the study period. Therefore, to compare chinook or chum abundance between sites within the study area, data were paired by sampling dates or standardized as percentage of the total weekly catch to account for any temporal difference in abundance during the sampling period.

Use of beach seine data from alternate beaches within Sites 3 and 4

We seined at alternate beaches because debris on the beach was expected to prevent sampling at the same beach location on some days. This proved to be true at Site 3, but not Site 4. The hypothesis, fish density at the primary and alternate beach seine locations within a site are the same, was tested using paired data. This hypothesis could not be rejected, but there was inadequate statistical power (0.8 or greater) in our test, therefore samples collected at the alternate beaches were not substituted for missing samples at the primary beaches. This reduced our sample size to 15 (out of a possible 18) at Site 3, but had no impact on sample size for Site 4.



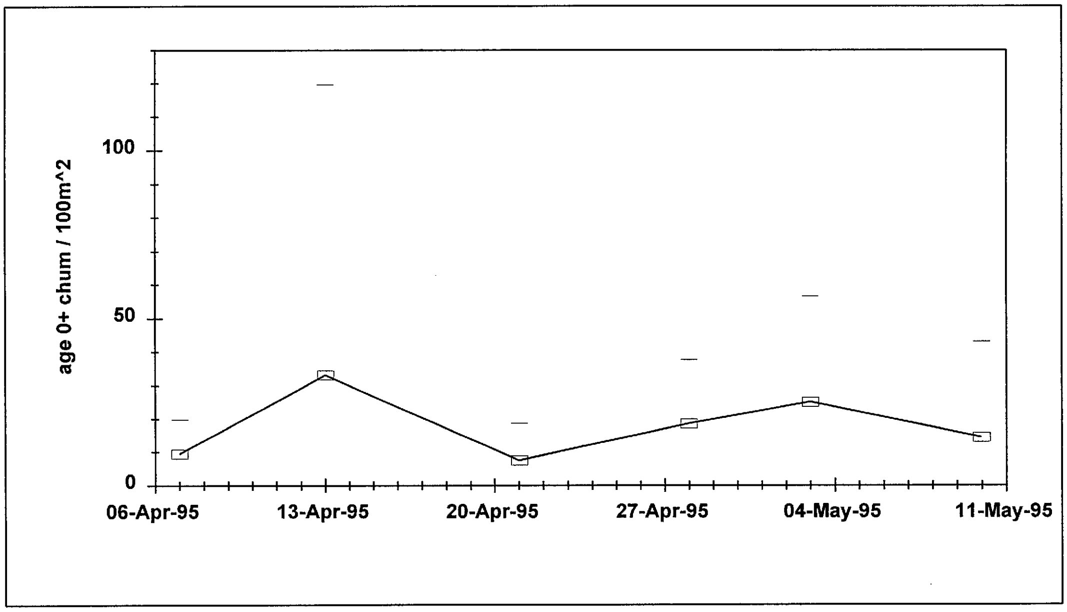


Figure 6. Average juvenile chinook (top figure) and chum (bottom figure) density (fish per 100 m^2) in Browns Slough Study Area. Error bars are ± 1 standard deviation.

Abundance by habitat type

We examined whether the three different habitat types (impounded, channel, marsh) influenced juvenile chinook and chum abundance within the study area. A two-stepped analysis was used to control for the potential differences caused by tidal stage and the location of different habitats. First, we compared results from sampling impounded habitat to channel habitat. Because impounded habitat was sampled only at Site 5A, we compared it to Site 5B, not the entire study area. Site 5B is located 30 meters upstream of Site 5A, and was channel habitat. A paired t-test for means was used to control for any potential difference caused by tidal stage or sampling date. Mean juvenile chinook density in impounded habitat was significantly lower than channel habitat (Table 2). However, mean juvenile chum density was not significantly different but the statistical power of the test is very low. Consequently, we can not conclude that chum abundance in impounded and channel habitat is the same.

Table 2. Comparison of juvenile chinook and chum density (fish/100m^2) between habitat types. An asterisk denotes means of the two groups are significantly different based on paired t-test, $\alpha = 0.05$. Complete results are shown in Appendix 1. Tables 3-6.

	Impounded Habitat mean, sd, n	Channel Habitat mean, sd, n	Marsh Habitat mean, sd, n
Chum (age 0+):			
	7.9, 13.6, 15	10.9, 11.3, 15	
		38.7, 49.6, 7	19.3, 11.8, 7
Chinook (age 0+):			
*	7.6, 6.1, 15	19.7, 17.3, 15	
*		10.7, 9.9, 7	0.1, 0.3, 7

Based on the previous test, we next compared samples collected in marsh habitat to those collected in channel habitat. We paired samples collected in marsh habitat to adjacent sites if the habitat type was channel. Because marsh habitat was sampled only at high tide and the adjacent site must be channel habitat, we only had seven pairings to compare. However, even with so few of samples, mean chinook density in marsh habitat was significantly lower than channel habitat (Table 2). Mean juvenile chum density was not significantly different but the statistical power of the test is very low. Consequently, we can not conclude that chum abundance in channel and marsh habitat is the same. Therefore, our analysis for chinook and chum abundance between sites within the study area was done using only samples collected in channel habitat.

Abundance profile of Sites 1 through 6

Based on the previous steps, chinook (age 0+) and chum (age 0+) data collected in channel habitat were standardized as the percentage of the study area total (D_i / D_T*100), where D_i is the density at an individual site and D_T is the sum of all sites for a specific tidal stage on a sampling date. Results are shown in Appendix 1, Tables 7 and 8. Average, maximum and minimum values are plotted for each site by tidal stage to provide a profile of juvenile chinook and chum use in the study area (Figures 7 and 8). These data provide the context for analysis between Sites 3 and 4.

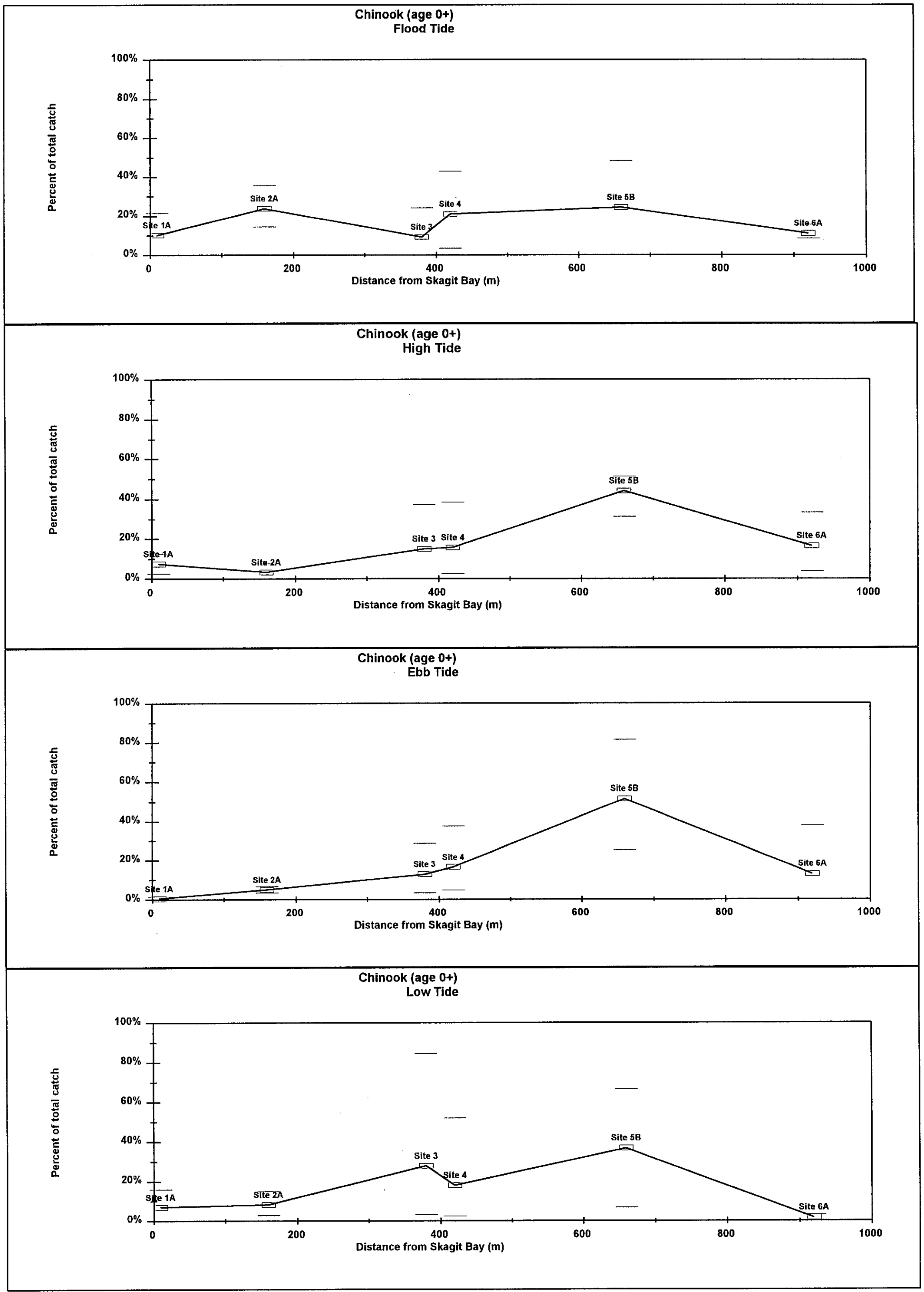


Figure 7. Average trend in chinook (age 0+) abundance within the Browns Slough Study Area by tidal stage. Bars represent the observed daily maximum and minimum. The culvert is between Sites 3 and 4; Fir Island Road is just upstream of Site 6A.

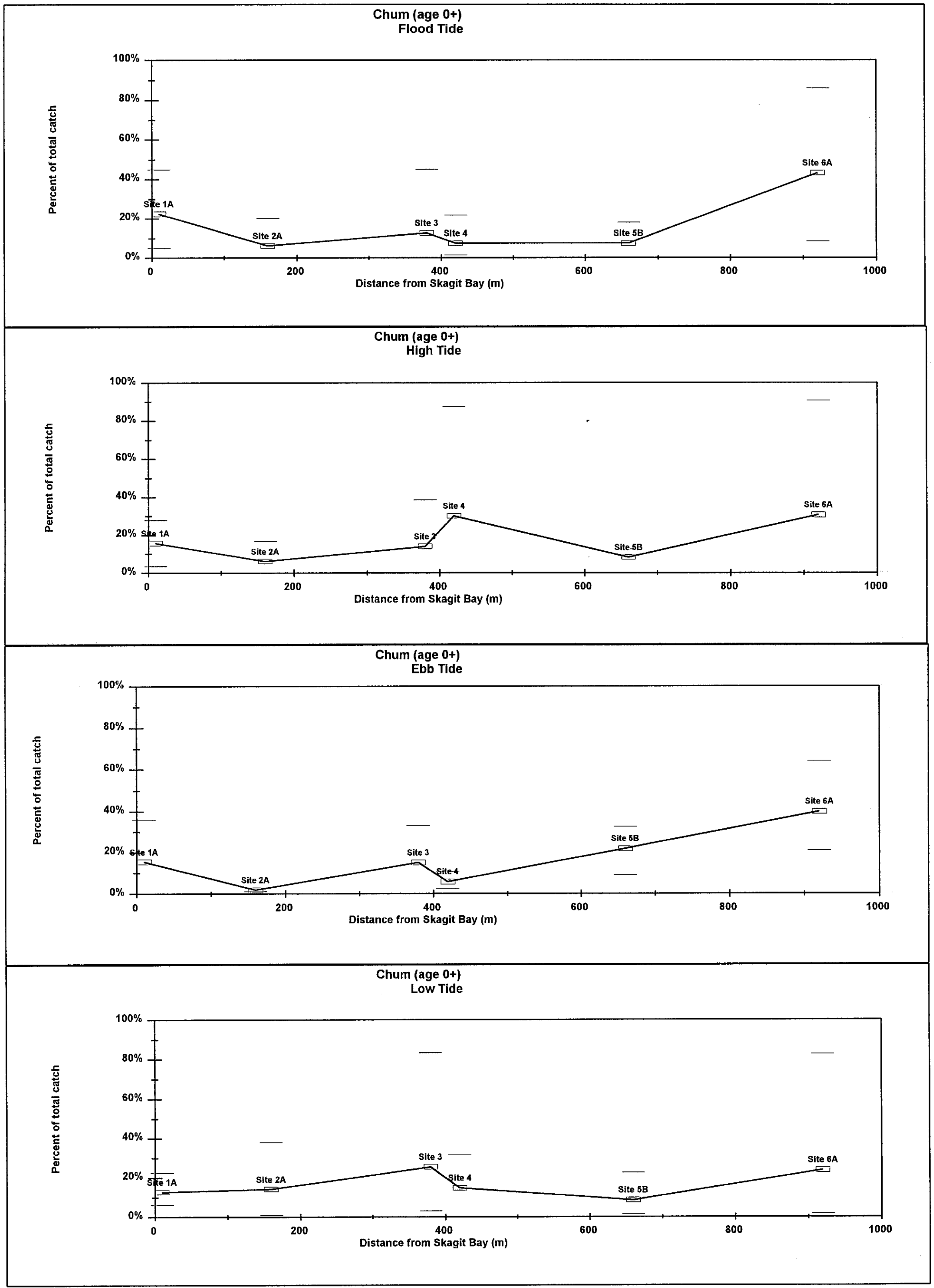


Figure 8. Average trend in chum (age 0+) abundance within the Browns Slough Study Area by tidal stage. Bars represent the observed daily maximum and minimum. The culvert is between Sites 3 and 4; Fir Island Road is just upstream of Site 6A

Abundance comparison between Sites 3 and 4

Table 3 compares the proportion of juvenile chinook and chum abundance between Sites 3 and 4. For chinook, the average proportion at Site 4 represented 16 to 21% of the study area's total and was higher than the average proportion at Site 3 for some tidal stages. The average value at Site 4 was more than double that of Site 3 at flood tide, 31% higher at ebb tide, 36% lower at low tide, and similar at high tide (Table 3). For chum, the average proportion at Site 4 represented 6 to 30% of the study area's total depending on tidal stage. This was generally lower than the proportion for Site 3, except at high tide. Site 4 was double the proportion of Site 3 at high tide, However, the average proportion at Site 4 was approximately one half that of Site 3 for the remaining tidal stages (ebb, low, and high).

Table 3. Comparison of juvenile chinook and chum abundance for Sites 3 and 4. Beach seine data were standardized as a percentage of the study area total by tidal stage; average and extreme values for the study period are shown.

Chinook (age 0+)

Tidal Stage	Site 3 average	Site 4 average	Deviation: Site 4 from Site 3	Site 3 range	Site 4 range
Flood	9%	21%	133%	0-24%	3-43%
High	15%	16%	7%	0-37%	3-38%
Ebb	13%	17%	31%	3-29%	5-38%
Low	28%	18%	-36%	3-84%	2-52%

Chum (age 0+)

Tidal Stage	Site 3 average	Site 4 average	Deviation: Site 4 from Site 3	Site 3 range	Site 4 range
Flood	13%	8%	-38%	0-45%	2-22%
High	14%	30%	114%	0-39%	0-88%
Ebb	15%	6%	-60%	0-33%	2-11%
Low	26%	15%	-42%	3-83%	0-32%

Chinook (age 0+) fork length

Sufficient sample sizes were not available at all six sites to analyze fork length data at the site level, so data collected during beach seining were pooled into two groups. Because the cross levee is located between Sites 3 and 4, length samples from Sites 1A, 2A, 3A, and 3B were combined into a Bay Side group, while samples from Sites 4A, 4B, 5A, 5B, and 6A were combined into a Slough Side group. Results are shown in Table 4 and Figure 9. Mean fork length increased significantly in the Bay Side and Slough Side groups over the six week sampling period (Newman-Keuls multiple comparisons test, $\alpha = 0.05$). Mean fork length was similar between both groups for the first five weeks of sampling. However by May 10th, chinook (age 0+) from the Bay Side samples were significantly larger than those collected from the Slough Side (Newman-Keuls multiple comparisons test, $\alpha = 0.05$).

Table 4. Mean, standard deviation, and sample size of chinook (age 0+) fork length samples (mm) from the Bay Side and Slough Side groups

Date	Bay Side			Slough Side		
	mean	**SD**	***n***	**mean**	**SD**	***n***
04/07/95	50.6	5.8	17	47.8	5.5	28
04/13/95	59.7	7.5	20	60.1	11.5	20
04/21/95	64.0	9.5	27	61.6	10.8	87
04/28/95	72.4	11.5	25	76.9	10.3	41
05/03/95	80.2	11.4	28	74.7	12.3	54
05/10/95	84.6	14.0	16	74.0	9.4	27

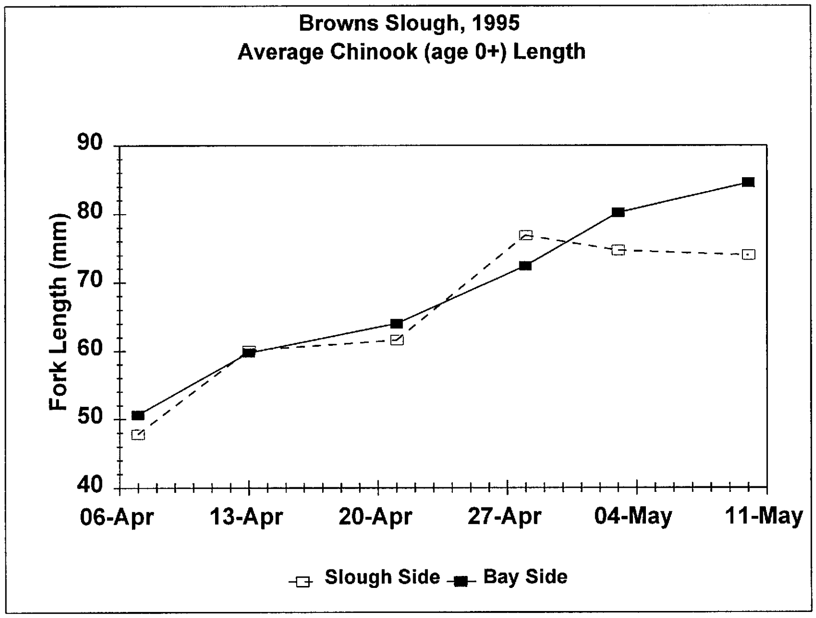


Figure 9. Trend in fork length of chinook (age 0+) upstream and downstream of the cross levee.

Observations on movement

Juvenile chinook were observed in schools, generally moving in the same direction as the tidal current. Those fish we could observe were jumping and feeding near or on the surface. They appeared to delay their movement with the current in locations such as lateral eddies, lower velocity areas, and channel depressions, where potential feed sources may accumulate.

Juvenile chum were also observed in schools moving with the current near the shoreline. School size ranged between 10 and 50 fish. These fish appeared to be feeding on or near the surface as they traveled. We did not observe the apparent delay in movement as was noted for juvenile chinook.

WATER QUALITY

Table 2-1 in the Appendix 2 displays all the water quality data for each monitoring site by parameter, tidal stage and location in the water column.

Tables 2-2 and 2-3 show the means and standard deviations for each parameter by site and tide phase. Figures 2-1 through 2-24 are plots of the means of each parameter by tidal phase across the profile of monitoring stations. The dash marks or error bars indicate plus and minus one standard deviation from the mean.

Table 2-4 displays the maximum and minimum measurement for each parameter at each site and on which tidal cycle it occurred. Figures 2-25 through 2-28 are plots of the maximum and minimum readings that occurred at each site for each parameter.

Perhaps the most important comparison between monitoring stations for the purposes of this study is between Site 4 just above the cross levee and Site 3 just below or on the Bayside of the cross levee. Table 2-5 presents the parameter values taken sequentially for each monitoring day and tide phase. The absolute value for the mathematical difference between each pair of values is shown.

Tables 2-6 and 2-7 in Appendix 2 show the mean, standard deviation and maximum difference between parameter measurements derived from Table 2-5 for each parameter and tide phase. Table 2-6 includes both top and bottom readings and Table 2-7 includes only the top or near surface readings. The shaded values in each table are the largest statistics for each parameter and show on which tide phase they occurred. The statistics are consistent in that the largest standard deviation and largest maximum difference accompanied the largest mean. All the largest statistics occurred on the flood phase except for the specific conductance when both top and bottom readings were included. In this case, the largest statistics occurred on the low tide phase. This deviation from the pattern was due to a single difference in bottom readings of 5375 µmhos (and the largest difference for specific conductance between 3 & 4) measured on 4-12-95.

Dissolved Oxygen

The dissolved oxygen remained within standards for all measurements by not going below 9.1 at Site 3 nor below 7.7 at Site 4. Both minimums occurred on the same sampling profile during flood phase on 5-4-95 and are shown in Figure 10 contrasted with the water temperature taken at the same time. The measurements were taken at a time before the incoming flood front had a chance to mix thoroughly and dominate water quality characteristics at site 4. This was the greatest DO difference measured between the two stations, which were usually nearly the same. Appendix 2 Table 2-5 shows that the largest difference for DO occurred during flood stage on 4-27-95 and was 2.7 mg/L. The next largest was 1.6 mg/l on ebb flow stage. The largest mean difference (1.2 mg/L) occurred during flood phase and the second largest mean difference (0.61 mg/L) occurred on ebb phase (Table 2-6).

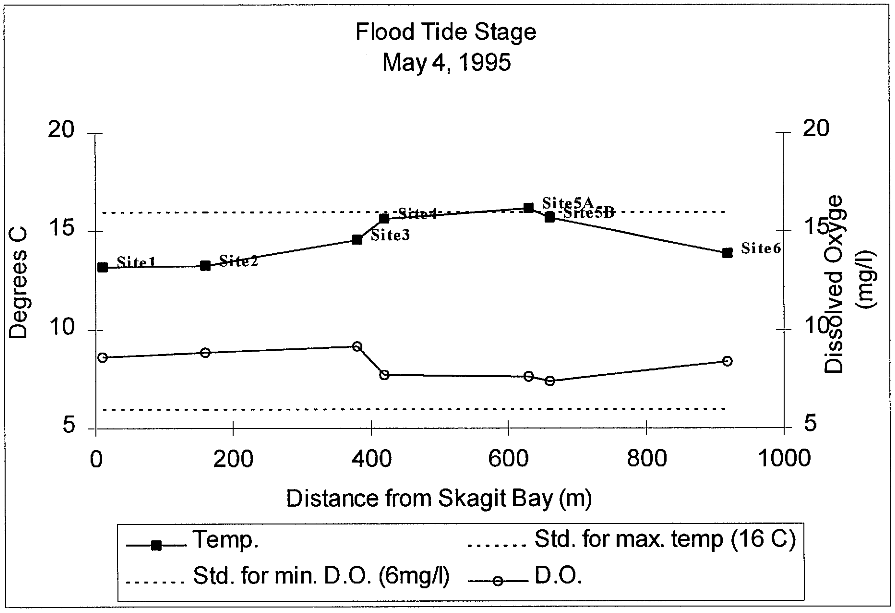


Figure 10. Dissolved oxygen and water temperature on May 4. 1995, flood tide stage in Browns Slough Study Area. The cross levee is between Sites 3 and 4; Fir Island Road is just upstream of Site 6A.

The most homogeneous tidal stage was high tide when the largest difference between stations was only 0.4 mg/ L because pipe flow was minimal and both sides of the cross levee had time to equilibrate. Also, high tide closes the tide gates at Fir Island Road from the land drainage ditches thus allowing bay water to nearly completely dominate quality characteristics at all stations. The largest DO difference at low tide was 1.3 mg/l. Low tide is not as homogeneous because the slough side stations may be dominated by ditch water flow since the tide gates are free to swing open in proportional response to antecedent precipitation and ditch drainage.

When all monitoring stations are included, the lowest DO readings for each tide phase occurred at site 5A at the bottom in the scour hole. The 3.7 mg/L on 4-21-95 flood phase and 3.8 mg/L on 4-20-95 low tide phase were the only DO readings to not meet the state DO minimum standard of 6 mg/L.

Water Temperature

Water temperature exceeded the maximum standard on several sampling profiles at all stations in the profile. At times temperature was higher in the bay and at other times higher in the slough. The maximum measured at Site 3 was 19.5 C at high tide and at Site 4 was 19.6 C at ebb tide both on 5-9-95.

Temperature differences between stations 3 and 4 were greatest during flood flow stage reaching 1.0 C. Differences at high tide did not exceed 0.5 C and low and ebb tide differences did not exceed 0.4 C.

pH

Flood flow stage on April 12th produced the largest difference for pH between stations 3 and 4. However it was only 0.3 pH. The other three tidal stages all had maximum differences of 0.2 pH. The pH exceeded the standard of 8.5 several times at all stations. Site 3 reached a maximum of 9.2 and Site 4 went to 9.4. No site exceeded 9.4. Figure 11 illustrates the ebb flow and high tide pH profiles for 5-9-95 showing higher readings occurring toward the bay, indicating that the high readings were characteristic of the bay water more than the ditch outflow water.

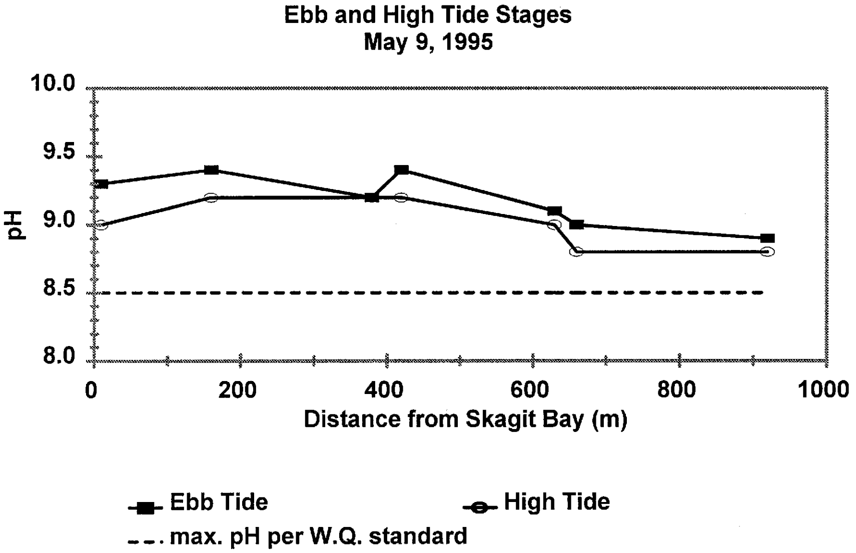


Figure 11. Profile of pH on May 9, 1995, ebb and high tide stages in Browns Slough Study Area. The cross levee is between Sites 3 and 4; Fir Island Road is just upstream of Site 6A.

Specific Conductivity

The greatest difference in specific conductivity and therefore salinity occurred at low tide since that is when the low salinity ditch water can dominate the slough side of the cross levee and salinity should increase outward on the bay side. That is what happened for most of the near surface or top measurements. The bottom measurements on 4/12/95 showed the greatest difference between stations 3 and 4 of 5375 micro mhos (µmhos) and the readings were inverted in that the more saline reading was above the cross levee at site 4. This may be indicating that the less dense fresh water is flowing out over the more saline water, an observation based on comparing the top and bottom readings at stations 4, 5a, 5b and 6 on 4/12/98 and 4/20/98 (Table 2-1, Figures 12 and 13).

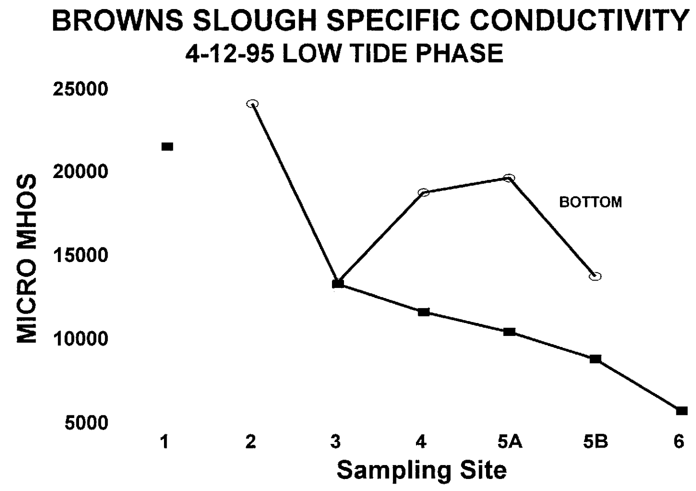


Figure 12. Specific conductivity of water in the Browns Slough Study Area taken on April 12, 1995 during low tide. Samples collected at the bottom of the water column are shown as open ellipses while samples collected near the surface are shown as filled boxes. The cross levee is between Site 3 and 4.

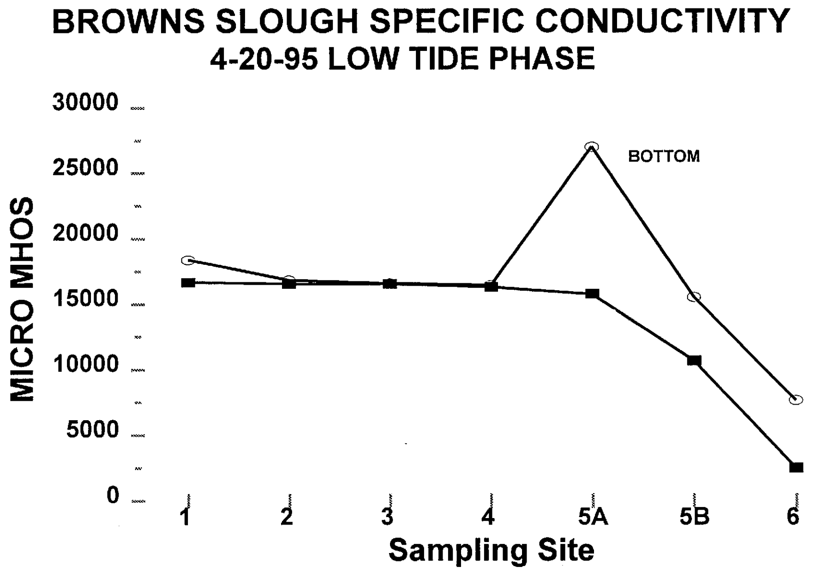


Figure 13. Specific conductivity of water in the Browns Slough Study Area taken on April 20, 1995 during low tide. Samples collected at the bottom of the water column are shown as open ellipses while samples collected near the surface are shown as filled boxes. The cross levee is between Site 3 and 4.

An interesting feature on the 12th is that above the cross levee at site 4 the profile is highly stratified whereas below the cross levee at site 3, the vertical profile is homogeneous. The latter is probably due to the outflow from the pipes causing turbulence that effectively mixes the profile. On the 20th both 3 and 4 are homogeneous but sites 5a, 5b and 6 are still stratified. This vertical mixing at the downstream site at the cross levee is evident most of the time for all parameters and tide phases. Since, the downstream site is the discharging side, the downstream side is site 3 for outgoing tides and site 4 for incoming tides. This is true even though incoming tides only flow through the single manually gated pipe whereas outgoing tides are also flowing through the tow tide gated pipes.

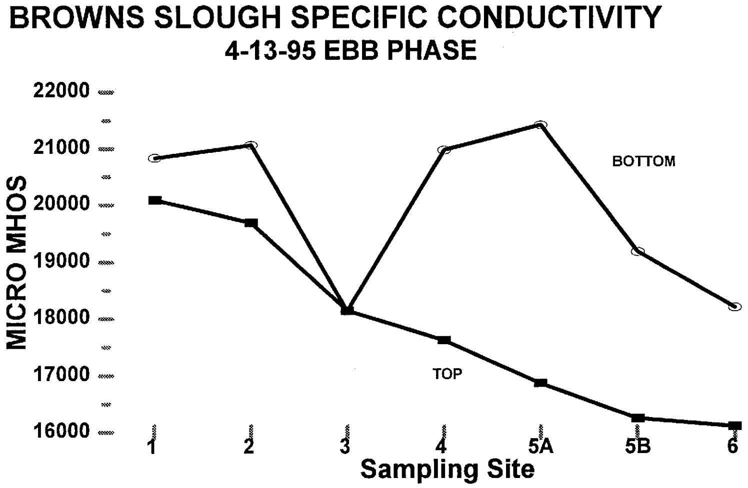


Figure 14. Specific conductivity of water in the Browns Slough Study Area taken on April 13, 1995 during ebb tide. Samples collected at the bottom of the water column are shown as open ellipses while samples collected near the surface are shown as filled boxes. The cross levee is between Site 3 and 4.

Figure 14 (conductivity, ebb phase on 4-13-95) illustrates that the slough profile can be highly stratified at times between top and bottom salinities, and therefore water densities can also be highly stratified. An interesting feature is that the juncture of the two curves at site 3 is on the slope of the top water curve. This means that either the bottom layer is very thin and adds little volume to the mix or it isn't moving during this ebb.

Also note the much different case in Figure 15 for the ebb phase on 4-20-95. There is little stratification evident except in the scour hole at the bottom of 5A. The overall conductivity is between 15000 and 17000 μmhos compared with between 16000 and 21500 μmhos on 4-13-95 in Figure 14. The Skagit River flow must have quite a variable effect on the local salinity from day to day and phase to phase. The highest conductivity (24474 μmhos) on the bay side occurred on 4-12-95 at site 2 at the bottom during high tide. The highest overall conductivity occurred on 4-20-95 at site 5A at the bottom of the scour hole at low tide and was 27040 μmhos. See Figure 15.

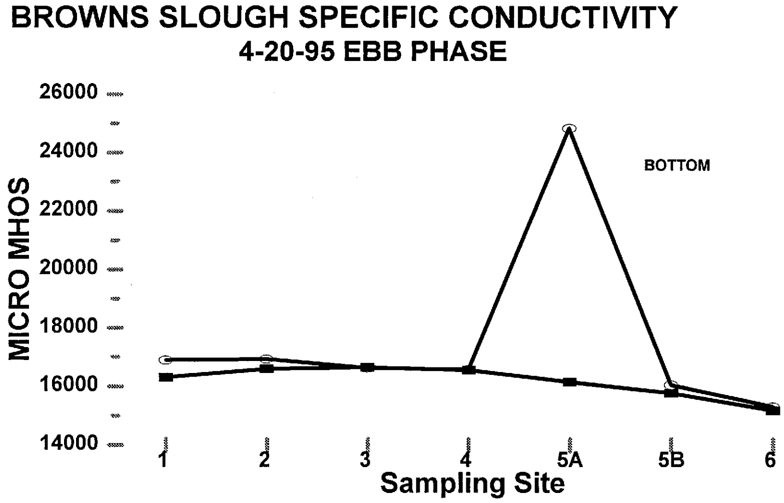


Figure 15. Specific conductivity of water in the Browns Slough Study Area taken on April 20, 1995 during ebb tide. Samples collected at the bottom of the water column are shown as open ellipses while samples collected near the surface are shown as filled boxes. The cross levee is between Site 3 and 4.

DISCUSSION AND CONCLUSIONS

SALMON ABUNDANCE IMMEDIATELY UP AND DOWNSTREAM OF THE CROSS LEVEE

The goal of this study was to determine the effectiveness of the manually gated culvert on fish passage through the cross levee. To accomplish this per Wasserman (1993), we compared juvenile chinook and chum abundance[1] from two sites, one immediately downstream of the cross levee and another immediately upstream (Sites 3 and 4, respectively, see Figure 3). As specified in documents involved with the permitting process of the project, these data were to be expressed as a percentage of the weekly catch by tidal stage, and depending on the results, different mitigation actions were required depending on the following range of differences between Sites 3 and 4:

- Site 4 values are 75-100% of Site 3 values,
- Site 4 values fall below 75% but are greater than 25% of Site 3, and
- Site 4 values fall below 25% of Site 3.

Our results show the average proportion of juvenile chinook at Site 4 was greater than Site 3 on three of the four tidal stages sampled (Table 3). This outcome was not anticipated in the documents discussing mitigation based on this study's results. Only at

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[1] We used only juvenile chinook and chum data for this analysis because the other salmon species were not as numerous.

low tide was the average proportion of juvenile chinook at Site 4 less than Site 3. For juvenile chum, the average value at Site 4 was less than Site 3 on three of the four tidal stages sampled (Table 3). Only at high tide was the Site 4 value greater than Site 3. In all cases (both chinook and chum) where Site 4 values were less than Site 3, the difference in values fell into the middle category listed in the mitigation plan (i.e., 25 – 75%), which if followed, would require mitigation actions.

Our results also demonstrate that juvenile chinook and chum abundance was highly variable throughout the entire study area (Figures 7 and 8). This was the case even after accounting for variability due to differences in habitat type, tidal stage, and sampling date. We also found the sampling level was insufficient to detect the specified range of fish use difference between Sites 3 and 4 with reasonable statistical power[2].

Because of these issues, we suggest that a conclusion regarding the effectiveness of the manually gated culvert on fish passage through the cross levee (and the decision whether mitigation is necessary) be drawn by including data collected throughout the entire study area, not just comparing Sites 3 and 4 as shown in Table 3. We believe that these data (discussed in the following section) support a conclusion that the cross levee with its manually gated culvert operated in the full open position allows for very significant upstream and downstream fish passage.

FISH USE THROUGHOUT THE STUDY AREA

This study found eleven fish species present in the tidally influenced portion of Browns Slough and all eleven species were captured upstream of the cross levee (Table 1). Significant proportions of most fish species captured in the study area were from sites upstream of the cross levee (Table 1B). Anadromous fish captured in this study (chinook, chum, coho, cutthroat) could not access the study area by simply migrating downstream because Browns Slough is isolated from the North Fork Skagit River by levees. However, anadromous fish and other estuarine fish could access Browns Slough from its downstream side, via Skagit Bay. In order for these fish to be captured at sample sites upstream of the cross levee, they had to pass through the cross levee[3]. This was apparently done very successfully, given the results shown in Table 1B where hundreds of juvenile chinook and chum salmon, and thousands of smelt were captured upstream of the cross levee during our study.

While this study only looked at fish abundance over a six week period in 1995, data collected by Skagit System Cooperative (SSC) in 1996 and 1997 over the entire estuarine rearing period for juvenile chinook (~4½ months) are helpful in understanding fish use upstream and downstream of the cross levee. The later, more extensive data, show a very

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[2] That is, we have a high likelihood of committing a Type II statistical error (false acceptance of the null hypothesis).

[3] Three-spined Stickleback might be an exception. Only stickleback are common in the diked off sloughs of Fir Island, so some of these fish could have populated the sampling sites upstream of the cross levee from areas in Browns Slough further upstream.

close correlation in the timing curves of juvenile chinook upstream and downstream of the cross levee, over two seasons (Figure 16). Fish were able to find, occupy and outmigrate habitat upstream of the cross levee in a similar pattern as those that did not navigate the culvert in the cross levee. These results support the idea that the culvert in the cross levee, with the manual gate operated in the full open position, is not a problem for fish passage.

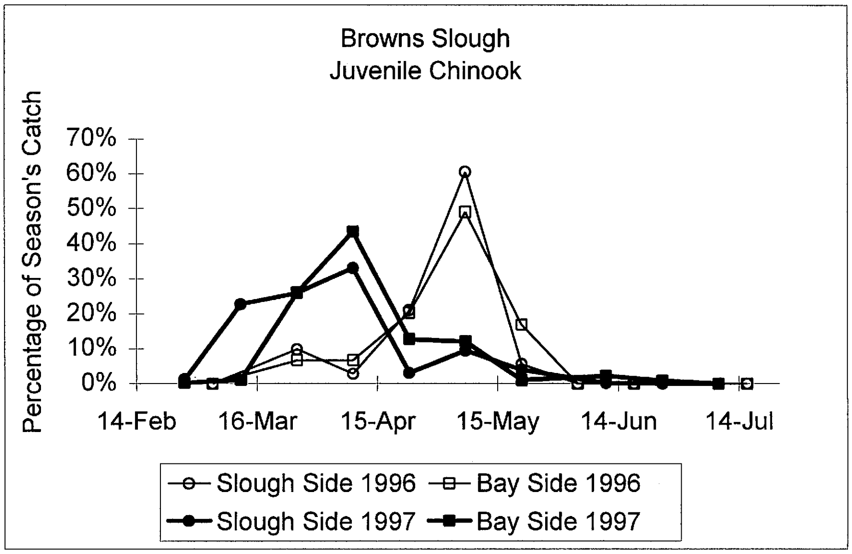

Figure 16. Trend in juvenile chinook abundance up and downstream of the cross levee through the entire estuarine rearing season, 1996 and 1997. Data from Skagit System Cooperative.

CHINOOK (AGE 0+) FORK LENGTH

The length data results appear also to be consistent with the idea that the culvert in the cross levee, with the manual gate operated in the full open position, is not a problem for fish passage and does not adversely affect the quality of habitat upstream of the cross levee.

Other researchers have observed a seasonal increase in the average length of juvenile chinook captured in estuarine habitat which was attributed to individual fish growth during its estuarine residence period (e.g., Congelton *et al.* 1981, Hayman *et al.* 1996, Levy and Northcote 1982). Larsen (1995) found the residence period for individual juvenile chinook in saltmarsh areas of the Skagit to be up to 26 days. Therefore, we expected to observe an increase in the mean fork length of juvenile chinook over time in this study (Table 4, Figure 9).

Individual fish growth is a result of the specific conditions of habitat occupied by the individual as well as the competition with other individuals occupying the same habitat. The fact that the mean fork length of chinook collected upstream of the cross levee (Slough

Side) was similar[4] to those collected downstream of the cross levee (Bay Side) is consistent with the idea that fish growth on either side of the cross levee is similar and/or passage rates through the cross levee are high.

If fish growth actually is similar on either side of the cross levee then the combination of various habitat conditions and competition would likely be similar – something generally supported by our water quality data. If the passage rate is high and growth rates are different, then fish must be passing back and forth frequently enough to mask any difference in growth rates on either side of the cross levee. If this case is true, we should conclude the culvert is effective for fish passage, and then use habitat and water quality data to determine whether the cross levee is adversely impacting habitat quality.

Considering all the available data (fish abundance, water quality, habitat conditions) it appears that the juvenile chinook length results reflect what we would expect with good access through the cross levee and similar habitat conditions on either side. Only in isolated areas, not in the immediate area of the cross levee, are habitat conditions drastically different. The cause is due to a difference in channel geometry (e.g., the scour hole site - 5A).

CHINOOK AND CHUM VARIABILITY WITHIN SAMPLING SITES

We observed high variability in the catches of juvenile chinook and chum within all beach seine sites. We attempted to minimize sources of variability by selecting beach seine set locations that were similar in habitat characteristics, by setting the net the same way each time, pairing or standardizing data by sampling date, and stratifying by tidal stage. However, we were unable to measure capture efficiency at sampling sites and remain within the budget allocated for this study.

It has been shown that beach seine catch efficiencies can differ by fish species, season, and a variety of habitat variables (Allen *et al.* 1992, Pierce *et al.* 1990, Parsley *et al.* 1989, Lyons 1986). However, we attempted to account for these variables in our analysis methods so it is unlikely that by using catchability coefficients, developed for each site to adjust beach seine catches, we would alter our conclusion regarding the effectiveness of fish passage through the cross levee.

Congleton *et al.* (1981) calculated a catchability coefficient for beach seine methodology used in tidal channels of the Skagit River. They did not identify any increase or decrease in catchability over any sampling series that included sampling at six different sites, so all data were combined. Mean catchability for their twenty foot long beach seine was estimated at 62% (SE = 7%, n = 50).

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[4] We do not know why fish were similar in size on either side of the cross levee until the last week of sampling and whether this trend continued.

Levy and Northcote (1981) examined juvenile chinook distribution using a more precise method (fyke traps and mark/recapture techniques) to estimate density. They simultaneously captured chinook on the ebb tide at six different sites within a single blind ended channel. Coefficient of variation (CV) ranged from 56% to 150% for individual sites over three sampling periods and 45% to 110% between the six sites on the same day.

Based on the above discussion, we assume that a high level of variability in chinook and chum abundance (i.e., CVs approximating 100%) is normal when sampling tidal habitats. This may be due to the schooling behavior we observed, which would tend to increase variability. However, we have no way to test this, or correct for it, except by increasing sampling levels to accommodate it. We expect that Congleton *et al.* (1981) beach seine catchability results are representative of our study. Therefore, our density estimates are assumed to be consistently underestimated, but relatively constant between sites of the same habitat type.

WATER QUALITY

The overall quality of the measured water parameters immediately above and below the cross levee appears to be similar. Where measured parameters exceeded state standards, the excursions did not appear to be caused or exacerbated by the cross levee.

The flow through the levee's culverts does act as a mixing device that homogenizes the water column of the immediate receiving site.

Temperature excursions beyond maximum standards for marine waters appeared to be due to natural causes such as solar radiation into shallow waters and the incoming tide being warmed by sweeping over sun heated mud flats. Excursions beyond maximum standards in the slough, especially at stations 5 and 6 on 5-3-95 at low tide, are probably due to solar heated ditch water emerging from the tide gates. Some of the temperature profiles in Table 2-1 are not easily explained. They are probably caused by some combination of (1) when in the tide phase measurements were taken, (2) what the magnitude of the tide change was, and (3) how much drainage water had accumulated in the ditch above the tide gate. None of these factors are a result of the cross levee.

The source or cause of the above standard excursions for pH is unknown, but may be due to the explosion of growth of diatoms in the spring. The algae consume carbon dioxide in the water, which pushes the form of carbon dioxide towards the carbonate end of the spectrum and raises the pH[5]. Therefore, we have reason to expect high pH readings in the spring, but the question of whether the pH actually exceeded 9.0 or whether there was a meter inaccuracy or calibration error, will have to await further measurements.

Another study of interest was conducted in 1992 and included data at Browns Slough (Entranco 1993). It showed pH rising from 7.0 in January to 8.6 in May. At the same time, water temperature rose from 7.5°C to 15°C and ammonia decreased from 0.13 mg/L to 0.02 mg/L and nitrite/nitrate dropped from 0.45 mg/L to 0.02 mg/L. This pattern appears to support the idea that increased insolation and higher temperatures allowed the diatom populations to increase their numbers by consuming the nitrogen based nutrients and pushed the pH into the more basic end of the range.

The scour hole at Site 5A allows density stratification. This appears to resist mixing with the upper water column at times, and results in the DO being depleted; for example, to 3.7 mg/L on 4-21-95 flood phase and to 3.8 mg/L on the 4-20-95 low tide phase. The stratification is due to the higher density water indicated by the higher conductivity measurements of 26647 and 27040 µmhos respectively at the bottom of the profile. Also of interest is the temperature inversion. The temperature of the water at the bottom of the scour hole can be 4 to 5 degrees C warmer than the surface water. Figure 18 illustrates this inversion for the 4-20-95 low tide phase. Figure 17 shows the corresponding oxygen depletion in the scour hole and Figure 13 displays the higher conductivity readings in the hole.

No water quality transition at the cross levee appeared to be sufficient or sustained long enough to prevent fish passage through the cross levee. Chinook and chum salmon were well represented at all sites above the cross levee as discussed above.

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[5] Regarding the chemistry of sea water, Sverdrup *et al.* (1962) state that carbon dioxide (CO_2) can exist in the following forms in sea water and that under any given set of conditions equilibria will prevail:

$$CO_2 \text{ (dissolved)} \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- \text{ (bicarbonate)} \leftrightarrow CO_3^= \text{ (carbonate)}$$

The pH level encountered in the sea is between about 7.5 and 8.4 with the higher values generally encountered at or near the surface. Where the water is in equilibrium with the CO_2 in the atmosphere, the pH is between 8.1 and 8.3, but higher values may occur when the photo synthetic activity of plants has reduced the content of CO_2. Under the peculiar conditions that may prevail in tide pools, bays, and estuaries, the pH sometimes exceeds the values cited above.

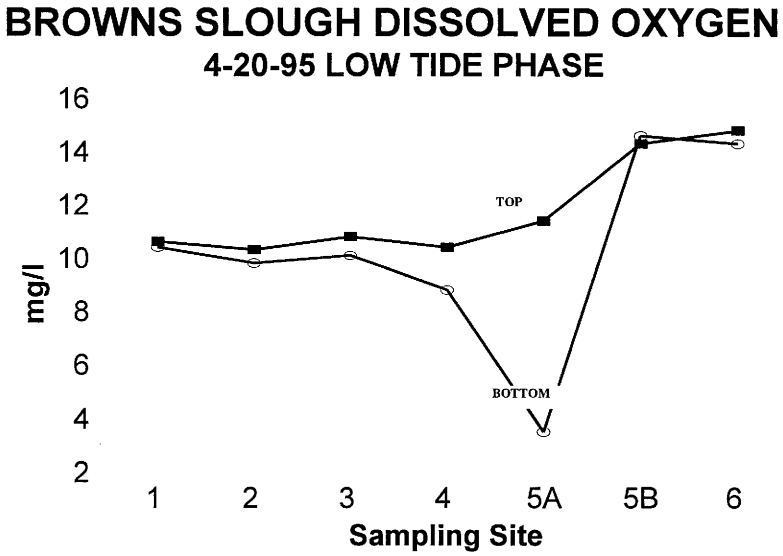

Figure 17. Dissolved oxygen in the water at the Browns Slough Study Area on April 20, 1995 during low tide. Readings taken at the bottom of the water column are shown as open ellipses while readings made near the surface are shown as filled boxes. The cross levee is between Sites 3 and 4.

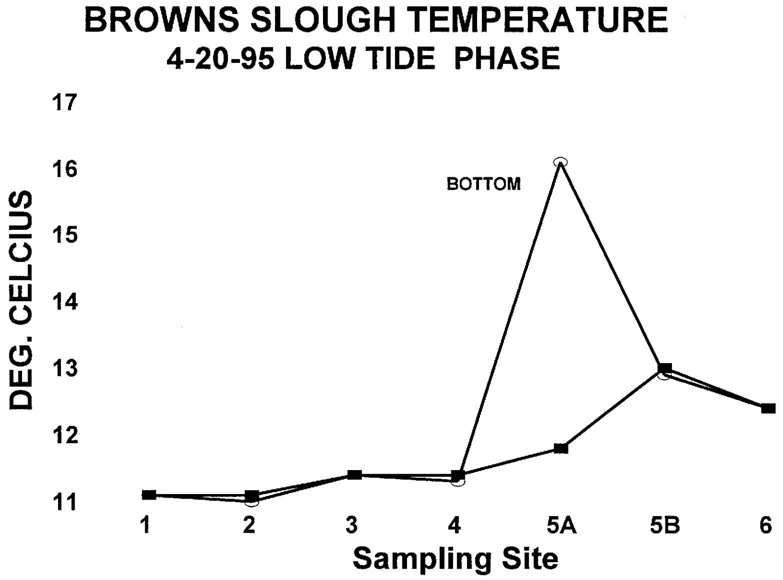

Figure 18. Water temperature at the Browns Slough Study Area on April 20, 1995 during low tide. Readings taken at the bottom of the water column are shown as open ellipses while readings made near the surface are shown as filled boxes. The cross levee is between Sites 3 and 4.

HABITAT LOSS AND MODIFICATION

Several types of habitat loss and modification have occurred within the study area since the conditions depicted by the 1988 aerial photo (Figure 2). First, building the cross levee with only tidegates converted the area upstream of the cross levee from tidally influenced blind channel and saltmarsh habitat to palustrine openwater and freshwater marsh habitat. Under these conditions salmonids were excluded from accessing the habitat. Following the installation of the manually gated culvert, the estuarine habitat types of the pre-cross levee period appear to have been restored, due to partial restoration of tidal hydrology. However, a net loss of estuarine habitat area (approximately 0.08 ha) due to the footprint of the cross levee still persists.

Second, because the culvert in the cross levee limits the volume of water that can pass through it, water surface elevation is reduced on the slough side of the cross levee for tidal heights above 9 feet (Figure 5). The period that habitat above the 9 foot level is inundated is also reduced because water conveyance through the cross levee downstream (toward Skagit Bay) is greater than upstream. This is due to the presence of two tidegated culverts, in addition to manually gated culvert, in the cross levee. Together, these result in a smaller inundated area, and shorter periods of time when fish and other aquatic organisms can access tidally inundated areas upstream of the cross levee.

We suspect the most pronounced direct impact on salmonids is to juvenile chum because of the importance of inundated marsh areas for feeding (Congleton 1978). He found the most intense period of feeding by juvenile chum in the Skagit Delta to be in submerged marsh areas at high tide, where chum foraged prey associated with the marsh substrate, rather than drift. These areas were submerged for a period of about 4 hours and to the depth of 0.3 to 1.0 meters. The cross levee (as currently constructed) reduces both the period and level of inundation of marsh habitat, thus reducing the opportunity for juvenile chum to forage on any given high tide cycle. A long-term reduction may result in a reduction in quantity of regularly inundated saltmarsh habitat.

IMPLICATIONS FOR ESTUARINE HABITAT RESTORATION

While this study did not directly monitor a habitat restoration project, several of its findings have relevance to restoring estuarine habitat for salmonids. At Browns Slough, juvenile salmon presence upstream of the cross levee depended on fish seeding from the Skagit Bay side of the culvert, not the upstream side. Also, our 1995 sampling occurred in the first spring after the manually gated culvert was installed. Prior to this, tidegates in the cross levee only allowed for water drainage to Skagit Bay and denied estuarine fish access to the area for four years.

Our results show that juvenile chinook and chum can find and occupy estuary habitat if it is made accessible. Also, juvenile salmonid access to estuary habitat can be gained from the downstream side of an obstruction (e.g., dike) by using a culvert that allows for some level of tidal inundation yet maintains some drainage function and flood protection to adjacent land, a restoration technique that could have wide application.

Also, the fish use results of this study are encouraging for restoration due to earlier thoughts that the site was relatively "inaccessible" to migrating salmon fry. Congleton *et al.* (1981) estimated that approximately one third of the juvenile chinook (1.1 million) and chum (3.1 million) outmigrating the Skagit in the spring of 1979 used 990 ha of "saltmarsh" area. This 990 ha area was closely associated with river channels of the North and South Fork Deltas. They noted another 260 ha of "saltmarsh" lying between the North and South Fork Deltas that was not contiguous to active river channels. This area (including Browns Slough) was thought to be relatively inaccessible to migrating salmon fry. Hayman *et al.* (1996) found that Browns Slough had intermediate densities of juvenile chinook (not the lowest) when compared with similar sites within the North or South Fork Deltas.

IMPLICATIONS FOR MONITORING

Overall, the study was successful in addressing its objectives. However, we were forced to rely on contextual evidence and determine whether it was consistent with the hypothesis that fish are passing through the cross levee. This is in contrast with rigorous hypothesis testing. Future monitoring efforts should take advantage of the following findings to improve the likelihood of successfully answering monitoring questions.

The mitigation planning documents for the Browns Slough Cross Levee Project did not anticipate the high level of variability in fish data collected by beach seine. We found it is easier to detect differences in fish abundance between habitat types, than between sites within the same habitat type. Thus, with such few samples, we were unable to detect differences or reasonably "accept" the null hypothesis because statistical power was poor. We now know to expect variability where the coefficient of variation approximates 100%. Using an average fish density of 12.5 fish/m^2 and a desire to detect a difference as small as 25% between two sites (as was desired in the mitigation plan), we would need approximately 300 samples. This study planned on collecting 24 samples. Future monitoring should account for these factors if differences in fish abundance are part of the monitoring objectives.

We also had insufficient samples to establish whether fish growth or survival was different on either side of cross levee and how the cross levee influences this. However, we don't think these issues are problems for juvenile chinook and chum. This judgement is based on similarities up and downstream of the cross levee in abundance (Figures 8 and 9, Table 1B), fish growth as inferred from fork length data (Figure 9), and chinook timing similarities (Figure 16). However, future monitoring should explicitly measure these factors if they are important monitoring objectives.

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APPENDIX 1. BEACH SEINE DATA

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Appendix 1. Table 7. Juvenile chinook (age 0+) density and percentage of daily catch in channel habitat.

Appendix 1. Table 8. Juvenile chum (age 0+) density and percentage of daily catch in channel habitat.

Apendix 1. Table 1. Habitat characteristics and beach seine catch of salmon and trout by site, date, and tidal stage.

Site	Date	Time	Tidal Stage	Max. water depth (m)	Habitat Type	Set Area (m^2)	Chinook (age 0+)	Chinook (age 1+)	Chum (age 0+)	Coho (age 1+)	Cut-throat
1A	04/07	08:15	flood	1.55	channel	72	20	0	23	0	0
1A	04/13	14:15	flood	1.52	channel	72	5	0	42	0	0
1A	04/13	16:40	high	0.55	marsh	140	0	0	2	0	0
1A	04/13	09:45	low	1.52	channel	72	1	0	24	0	0
1A	04/21	12:35	ebb	1.10	channel	72	0	0	12	0	0
1A	04/21	07:45	flood	1.52	channel	72	0	0	3	0	0
1A	04/21	10:30	high	0.30	marsh	36	0	0	10	0	0
1A	04/21	15:20	low	0.79	channel	72	4	0	7	0	0
1A	04/28	08:15	ebb	1.25	channel	72	2	0	29	0	0
1A	04/28	15:30	flood	1.22	channel	72	11	0	35	0	0
1A	04/28	06:20	high	0.34	marsh	72	0	0	25	0	0
1A	05/03	09:30	ebb	1.49	channel	72	1	0	7	0	0
1A	05/03	08:20	high	0.21	marsh	36	0	0	3	0	0
1A	05/03	08:25	high	1.37	channel	72	2	0	99	0	0
1A	05/03	06:20	high	0.15	marsh	36	0	0	3	0	0
1A	05/03	12:25	low	1.19	channel	72	0	0	10	0	0
1A	05/10	16:10	ebb	1.46	channel	72	0	1	0	0	0
1A	05/10	12:45	flood	1.55	channel	72	0	0	2	0	0
1A	05/10	14:35	high	1.83	channel	72	1	0	2	0	0
1A	05/10	10:00	low	1.52	channel	72	7	1	6	0	0
2A	04/07	08:30	flood	2.23	channel	72	5	0	3	0	0
2A	04/13	14:40	flood	2.29	channel	72	5	0	19	0	0
2A	04/13	16:50	high	0.55	marsh	140	0	0	15	0	0
2A	04/13	10:05	low	1.71	channel	72	6	0	6	0	0
2A	04/21	12:50	ebb	1.95	channel	72	2	0	1	0	0
2A	04/21	08:05	flood	2.38	channel	72	9	0	1	0	0
2A	04/21	10:35	high	2.44	channel	72	2	0	0	0	0
2A	04/21	15:30	low	1.49	channel	72	3	0	5	0	0
2A	04/28	08:40	ebb	1.55	channel	72	7	0	28	0	0
2A	04/28	15:50	flood	1.83	channel	72	20	0	3	0	0
2A	04/28	06:40	high	0.30	marsh	72	0	0	27	0	0
2A	05/03	09:45	ebb	1.89	channel	72	3	0	1	0	0
2A	05/03	06:35	high	2.59	channel	72	0	0	22	0	0
2A	05/03	13:10	low	1.28	channel	72	2	0	24	0	0
2A	05/10	16:20	ebb	1.52	channel	72	1	0	1	0	0
2A	05/10	13:05	flood	1.92	channel	72	3	0	0	0	0
2A	05/10	14:45	high	2.32	channel	72	1	0	1	0	0
2A	05/10	10:19	low	1.65	channel	72	9	1	1	0	0

Apendix 1. Table 1 continued

Site	Date	Time	Tidal Stage	Max. water depth (m)	Habitat Type	Set Area (m^2)	Chinook (age 0+)	Chinook (age 1+)	Chum (age 0+)	Coho (age 1+)	Cut-throat
3A	04/07	09:20	flood	1.22	channel	72	7	0	2	0	0
3A	04/13	15:10	flood	1.13	channel	72	6	0	1	0	0
3A	04/21	13:25	ebb	1.89	channel	72	0	0	0	0	0
3A	04/21	08:35	flood	0.76	channel	72	4	0	7	0	0
3A	04/28	09:05	ebb	1.68	channel	140	2	0	34	0	0
3A	04/28	16:15	flood	1.13	channel	72	4	1	20	0	0
3A	04/28	07:00	high	0.91	channel	72	11	0	8	1	0
3A	05/03	06:50	high	1.13	channel	72	0	0	5	0	0
3A	05/10	15:15	high	1.22	channel	72	6	0	3	0	0
3B	04/13	15:00	flood	2.50	channel	72	0	0	6	0	0
3B	04/13	17:05	high	1.71	channel	72	14	0	11	0	0
3B	04/13	10:25	low	1.37	channel	72	173	0	292	0	0
3B	04/21	13:10	ebb	1.19	channel	72	2	0	4	0	0
3B	04/21	08:25	flood	2.23	channel	72	3	0	0	0	0
3B	04/21	10:55	high	1.04	channel	72	0	0	0	0	0
3B	04/21	15:55	low	1.71	channel	72	3	0	1	0	0
3B	04/28	16:20	flood	1.98	channel	72	3	0	45	0	0
3B	05/03	10:00	ebb	2.01	channel	72	17	0	22	2	0
3B	05/03	06:55	high	2.59	channel	72	6	0	51	0	0
3B	05/03	13:25	low	1.62	channel	140	14	0	14	1	0
3B	05/10	16:35	ebb	2.23	channel	72	1	0	0	0	0
3B	05/10	13:15	flood	2.16	channel	72	5	0	0	0	0
3B	05/10	15:00	high	2.13	channel	72	3	0	2	0	0
3B	05/10	10:42	low	1.65	channel	72	2	0	4	0	0
3C	04/13	18:00	high	0.43	marsh	460	4	0	115	0	0
3C	05/03	08:15	high	0.15	marsh	140	0	0	10	0	0
4A	04/07	09:50	flood	1.34	channel	100	14	0	4	0	0
4A	04/13	15:30	flood	3.11	channel	100	3	0	2	1	0
4A	04/13	17:15	high	0.55	marsh	140	2	0	6	0	0
4A	04/13	10:50	low	1.71	channel	100	8	0	10	0	0
4A	04/21	13:40	ebb	1.92	channel	100	2	0	2	0	0
4A	04/21	08:55	flood	2.90	channel	100	23	0	18	0	0
4A	04/21	11:05	high	2.10	channel	72	10	0	7	0	0
4A	04/21	16:00	low	2.04	channel	100	18	0	11	0	0
4A	04/28	09:40	ebb	1.95	channel	100	4	0	12	0	1
4A	04/28	16:30	flood	1.22	channel	100	22	0	4	0	0
4A	04/28	07:30	high	1.34	channel	72	8	0	1	0	0
4A	05/03	10:25	ebb	1.95	channel	100	31	0	10	0	0
4A	05/03	07:25	high	1.37	channel	72	1	0	4	1	0
4A	05/03	14:15	low	1.95	channel	100	13	0	28	0	0
4A	05/10	16:50	ebb	1.34	channel	100	3	0	3	0	0
4A	05/10	13:30	flood	1.49	channel	100	1	0	2	0	0
4A	05/10	15:25	high	1.65	channel	72	1	0	0	0	1
4A	05/10	11:15	low	2.04	channel	100	2	0	0	0	0

Apendix 1. Table 1 continued

Site	Date	Time	Tidal Stage	Max. water depth (m)	Habitat Type	Set Area (m^2)	Chinook (age 0+)	Chinook (age 1+)	Chum (age 0+)	Coho (age 1+)	Cut-throat
4B	04/13	11:10	low	1.43	channel	72	22	0	1	0	0
4B	04/28	09:20	ebb	1.83	channel	72	41	1	2	0	0
4B	04/28	07:20	high	2.07	channel	72	21	0	1	0	0
4B	05/03	10:20	ebb	1.83	channel	72	5	0	13	0	0
4B	05/03	07:15	high	2.26	channel	72	18	0	53	0	0
4B	05/03	14:00	low	0.91	channel	72	53	0	9	0	0
4B	05/10	13:45	flood	1.52	channel	72	9	0	1	1	1
4B	05/10	15:20	high	1.86	channel	72	1	0	3	0	0
4B	05/10	11:00	low	0.82	channel	72	7	0	0	0	0
5A	04/07	10:00	flood	3.17	impounded	72	1	0	3	0	0
5A	04/13	15:45	flood	4.75	impounded	72	6	0	8	0	0
5A	04/13	17:25	high	0.43	marsh	72	0	0	15	0	0
5A	04/13	11:30	low	4.08	impounded	72	2	0	7	0	0
5A	04/21	14:00	ebb	4.02	impounded	72	2	0	0	0	0
5A	04/21	09:10	flood	4.85	impounded	72	4	0	0	0	0
5A	04/21	11:15	high	4.66	impounded	72	6	0	2	0	0
5A	04/21	16:25	low	3.87	impounded	72	2	0	0	0	0
5A	04/28	16:45	flood	3.99	impounded	72	6	0	0	0	0
5A	04/28	07:40	high	3.96	impounded	72	8	0	0	0	0
5A	05/03	10:40	ebb	3.60	impounded	72	17	0	13	0	0
5A	05/03	07:30	high	3.69	impounded	72	5	0	38	1	1
5A	05/03	14:25	low	3.23	impounded	72	7	0	5	0	0
5A	05/10	17:05	ebb	4.33	impounded	72	1	0	7	0	0
5A	05/10	13:55	flood	3.72	impounded	72	2	0	4	0	0
5A	05/10	15:30	high	3.78	impounded	72	2	0	0	0	0
5A	05/10	11:47	low	5.00	impounded	72	12	0	1	0	0
5B	04/07	10:15	flood	2.04	channel	72	9	0	6	0	0
5B	04/13	15:55	flood	1.71	channel	72	9	0	17	0	0
5B	04/13	17:35	high	1.68	channel	72	19	0	4	0	0
5B	04/13	11:45	low	0.88	channel	72	14	0	15	1	0
5B	04/21	14:10	ebb	0.98	channel	72	24	0	8	1	0
5B	04/21	09:15	flood	1.58	channel	72	4	0	4	0	0
5B	04/21	11:25	high	1.62	channel	72	13	1	1	0	0
5B	04/21	16:40	low	0.76	channel	72	2	0	7	0	0
5B	04/28	10:15	ebb	0.85	channel	72	10	0	15	0	0
5B	04/28	16:55	flood	1.68	channel	72	0	0	0	0	0
5B	04/28	07:50	high	1.22	channel	72	3	0	6	0	0
5B	05/03	10:50	ebb	1.10	channel	72	15	0	6	0	0
5B	05/03	07:45	high	2.01	channel	72	5	0	16	1	0
5B	05/03	14:35	low	0.91	channel	72	41	0	1	0	0
5B	05/10	17:10	ebb	1.46	channel	72	14	1	29	0	0
5B	05/10	14:00	flood	1.71	channel	72	10	0	2	0	0
5B	05/10	15:45	high	1.34	channel	72	20	0	0	0	0
5B	05/10	12:00	low	0.76	channel	72	39	0	6	0	0

Apendix 1. Table 1 continued

Site	Date	Time	Tidal Stage	Max. water depth (m)	Habitat Type	Set Area (m^2)	Chinook (age 0+)	Chinook (age 1+)	Chum (age 0+)	Coho (age 1+)	Cut-throat
6A	04/07	10:35	flood	1.16	channel	72	5	0	8	0	0
6A	04/13	16:10	flood	1.49	channel	72	2	0	8	0	0
6A	04/13	17:50	high	1.80	channel	72	0	0	2	0	0
6A	04/13	12:20	low	0.46	channel	72	5	0	6	0	0
6A	04/21	14:30	ebb	0.43	channel	72	0	0	7	0	0
6A	04/21	09:30	flood	1.25	channel	72	6	0	38	0	0
6A	04/21	11:40	high	1.22	channel	72	1	0	0	0	0
6A	04/21	17:00	low	0.30	channel	72	0	0	3	0	0
6A	04/28	10:30	ebb	0.37	channel	72	1	0	1	0	0
6A	04/28	17:00	flood	1.55	channel	72	6	1	14	0	0
6A	04/28	08:00	high	0.98	channel	72	6	0	2	0	0
6A	05/03	11:05	ebb	0.61	channel	72	1	0	23	0	0
6A	05/03	07:55	high	1.68	channel	72	2	2	2	0	0
6A	05/03	14:45	low	0.43	channel	72	2	0	1	0	0
6A	05/10	17:30	ebb	1.28	channel	72	11	0	57	0	0
6A	05/10	14:15	flood	1.25	channel	72	2	0	33	0	0
6A	05/10	15:55	high	1.22	channel	72	13	0	49	0	0
6A	05/10	12:10	low	0.61	channel	72	1	0	81	0	0

Apendix 1. Table 2. Beach seine catch of non-salmon/trout species by site, date, and tidal stage.

Site	Date	Tidal Stage	Smelt	3-spine Stickleback	Staghorn Sculpin	Prickly Sculpin	Starry Flounder	Shiner Perch	Peamouth Chub
1A	04/07	flood	0	2	2	0	1	0	0
1A	04/13	flood	352	4	1	0	0	0	0
1A	04/13	high	0	10	0	0	0	0	0
1A	04/13	low	277	0	0	0	0	0	0
1A	04/21	ebb	0	1	0	0	0	0	0
1A	04/21	flood	0	0	1	0	0	0	0
1A	04/21	high	0	0	2	0	0	0	0
1A	04/21	low	1	4	0	0	0	0	0
1A	04/28	ebb	137	0	1	0	0	0	0
1A	04/28	flood	1000*	present	present	0	0	0	0
1A	04/28	high	6	0	0	0	0	0	0
1A	05/03	ebb	4	0	0	0	4	0	0
1A	05/03	high	0	0	0	0	0	0	0
1A	05/03	high	1	2	1	0	5	0	0
1A	05/03	high	0	0	0	0	0	0	0
1A	05/03	low	0	0	0	0	4	0	0
1A	05/10	ebb	0	26	13	0	5	19	0
1A	05/10	flood	0	11	12	0	0	6	0
1A	05/10	high	44	2	9	0	0	19	0
1A	05/10	low	0	186	17	0	10	3	0
2A	04/07	flood	0	0	1	0	0	0	0
2A	04/13	flood	204	16	1	0	0	0	0
2A	04/13	high	0	1	0	0	0	0	0
2A	04/13	low	15	1	3	0	0	0	0
2A	04/21	ebb	0	0	0	0	0	0	0
2A	04/21	flood	25	0	0	0	2	0	0
2A	04/21	high	0	0	1	0	0	0	0
2A	04/21	low	0	1	0	0	0	0	0
2A	04/28	ebb	132	3	2	0	1	0	0
2A	04/28	flood	1000*	present	present	0	present	0	0
2A	04/28	high	0	0	0	0	0	0	0
2A	05/03	ebb	0	3	3	0	0	0	0
2A	05/03	high	0	0	1	0	0	0	0
2A	05/03	low	0	2	2	0	0	0	0
2A	05/10	ebb	0	3	15	0	5	30	0
2A	05/10	flood	0	37	6	0	5	45	2
2A	05/10	high	2	1	10	0	12	7	0
2A	05/10	low	0	10	11	0	6	6	0

* estimated

Apendix 1. Table 2 continued

Site	Date	Tidal Stage	Smelt	3-spine Stickleback	Staghorn Sculpin	Prickly Sculpin	Starry Flounder	Shiner Perch	Peamouth Chub
3A	04/07	flood	35	7	12	0	1	0	0
3A	04/13	flood	42	1	6	0	0	0	0
3A	04/21	ebb	0	1	0	0	2	0	0
3A	04/21	flood	1	2	2	0	0	0	0
3A	04/28	ebb	8	45	15	0	15	9	0
3A	04/28	flood	18	0	9	0	1	0	0
3A	04/28	high	1000*	1000*	50	0	1	0	0
3A	05/03	high	0	3	1	0	4	0	0
3A	05/10	high	0	16	10	0	18	23	0
3B	04/13	flood	2	4	2	0	2	0	0
3B	04/13	high	24	10	2	0	1	0	0
3B	04/13	low	1	22	11	0	0	0	0
3B	04/21	ebb	0	4	40	0	8	0	0
3B	04/21	flood	0	7	4	0	4	0	0
3B	04/21	high	0	0	15	0	1	0	0
3B	04/21	low	1	1	48	2	1	0	0
3B	04/28	flood	0	30	10	0	3	0	0
3B	05/03	ebb	0	7	42	0	11	0	0
3B	05/03	high	0	254	3	0	6	0	0
3B	05/03	low	0	4	28	0	1	0	0
3B	05/10	ebb	0	2	15	0	6	109	0
3B	05/10	flood	1	2	16	0	8	7	0
3B	05/10	high	0	6	15	0	2	2	0
3B	05/10	low	0	1	7	0	6	328	59
3C	04/13	high	1	13	0	0	0	0	0
3C	05/03	high	0	0	3	0	0	0	0
4A	04/07	flood	0	7	0	0	1	0	0
4A	04/13	flood	4	2	9	0	0	0	0
4A	04/13	high	1	119	1	0	0	0	0
4A	04/13	low	2	149	3	0	3	0	0
4A	04/21	ebb	2	15	5	0	0	0	0
4A	04/21	flood	1	2	6	0	1	0	0
4A	04/21	high	0	2	6	0	1	0	0
4A	04/21	low	121	19	3	0	2	0	0
4A	04/28	ebb	1	223	5	0	1	0	0
4A	04/28	flood	0	35	6	0	0	0	0
4A	04/28	high	1	30	7	0	1	0	0
4A	05/03	ebb	0	25	19	1	0	0	0
4A	05/03	high	0	2	3	0	1	0	0
4A	05/03	low	1	3	16	0	0	0	0
4A	05/10	ebb	4	500*	24	0	1	5	0
4A	05/10	flood	0	15	18	0	1	1	0
4A	05/10	high	3	7	17	0	2	0	5
4A	05/10	low	8	1	0	0	11	1	1

* estimated

Apendix 1. Table 2 continued

Site	Date	Tidal Stage	Smelt	3-spine Stickleback	Staghorn Sculpin	Prickly Sculpin	Starry Flounder	Shiner Perch	Peamouth Chub
4B	04/13	low	2	3	1	0	0	0	0
4B	04/28	ebb	1	3	19	0	5	0	0
4B	04/28	high	na	na	na	na	na	na	na
4B	05/03	ebb	0	2	8	0	2	0	2
4B	05/03	high	0	2	2	0	0	0	2
4B	05/03	low	0	2	6	0	4	0	0
4B	05/10	flood	206	0	1	0	3	4	0
4B	05/10	high	53	6	0	0	2	1	0
4B	05/10	low	16	300*	4	0	7	3	14
5A	04/07	flood	176	6	0	0	0	0	0
5A	04/13	flood	2	6	0	0	2	0	0
5A	04/13	high	0	2	0	0	0	0	0
5A	04/13	low	720	1	0	0	0	0	0
5A	04/21	ebb	0	1	1	0	1	0	0
5A	04/21	flood	0	50	0	0	0	0	0
5A	04/21	high	1	12	1	0	0	0	0
5A	04/21	low	0	1	1	0	0	0	0
5A	04/28	flood	0	8	8	0	0	0	0
5A	04/28	high	38	1	0	0	0	0	0
5A	05/03	ebb	0	37	1	0	0	0	0
5A	05/03	high	0	4	0	0	2	0	0
5A	05/03	low	0	1	1	0	0	0	0
5A	05/10	ebb	200*	37	3	0	0	0	0
5A	05/10	flood	180	3	0	0	2	0	0
5A	05/10	high	0	0	3	0	2	1	0
5A	05/10	low	500*	20	1	0	0	0	1
5B	04/07	flood	1	15	0	0	0	0	0
5B	04/13	flood	17	11	0	0	0	0	0
5B	04/13	high	43	108	0	0	0	0	0
5B	04/13	low	6	171	1	0	0	0	0
5B	04/21	ebb	0	96	0	0	0	0	0
5B	04/21	flood	0	4	0	0	0	0	0
5B	04/21	high	0	6	0	0	0	0	0
5B	04/21	low	0	163	0	0	0	0	0
5B	04/28	ebb	2	6	5	0	1	2	0
5B	04/28	flood	58	8	0	0	1	0	0
5B	04/28	high	224	1	1	2	0	0	0
5B	05/03	ebb	32	45	5	0	2	0	0
5B	05/03	high	4	6	6	0	0	0	0
5B	05/03	low	19	231	7	0	3	0	0
5B	05/10	ebb	170	300*	6	0	5	2	5
5B	05/10	flood	17	23	13	0	4	0	0
5B	05/10	high	0	42	16	0	2	0	0
5B	05/10	low	0	45	23	0	0	3	6

* estimated

Apendix 1. Table 2 continued

Site	Date	Tidal Stage	Smelt	3-spine Stickleback	Staghorn Sculpin	Prickly Sculpin	Starry Flounder	Shiner Perch	Peamouth Chub
6A	04/07	flood	0	36	0	0	0	0	0
6A	04/13	flood	46	9	1	0	1	0	0
6A	04/13	high	198	124	1	0	0	0	0
6A	04/13	low	37	1117	1	0	0	0	0
6A	04/21	ebb	0	301	1	0	0	0	0
6A	04/21	flood	0	88	0	0	0	0	0
6A	04/21	high	0	68	0	0	0	0	0
6A	04/21	low	0	48	0	0	0	0	0
6A	04/28	ebb	1	9	5	0	9	0	0
6A	04/28	flood	285	40	6	0	2	0	0
6A	04/28	high	139	36	2	0	1	0	0
6A	05/03	ebb	0	354	4	0	1	0	0
6A	05/03	high	0	39	3	0	2	0	0
6A	05/03	low	0	2500*	0	0	0	0	0
6A	05/10	ebb	4	500*	3	0	3	0	0
6A	05/10	flood	0	97	2	0	2	0	2
6A	05/10	high	0	0	8	0	3	0	1
6A	05/10	low	0	1000*	0	0	4	0	0

* estimated

Appendix 1. Table 3.

Chum 0+ density (fish/100m^2)

Date	**Tidal Stage**	**Site 5A impounded habitat**	**Site 5B channel habitat**	**diff. 5A-5B**
04/21	ebb	0.0	11.1	-11.1
05/03	ebb	18.1	8.3	9.7
05/10	ebb	9.7	40.3	-30.6
04/13	flood	11.1	23.6	-12.5
04/21	flood	0.0	5.6	-5.6
04/28	flood	0.0	0.0	0.0
05/10	flood	5.6	2.8	2.8
04/21	high	2.8	1.4	1.4
04/28	high	0.0	8.3	-8.3
05/03	high	52.8	22.2	30.6
05/10	high	0.0	0.0	0.0
04/13	low	9.7	20.8	-11.1
04/21	low	0.0	9.7	-9.7
05/03	low	6.9	1.4	5.6
05/10	low	1.4	8.3	-6.9
	mean	7.9	10.9	-3.1
	SD	13.6	11.3	13.4
	n	15	15	
	CV	173%	103%	
	P	0.392		

t-Test: Paired Two-Sample for Means

	Impounded	***Channel***
Mean	7.9	10.9
Variance	184.5	127.6
Observations	15	15
Pearson Correlation	0.433171611	
Pooled Variance	156.047913	
Hypothesized Mean Difference	0	
df	14	
t	-0.88408465	
P(T<=t) one-tail	0.195790321	
t Critical one-tail	1.761310135	
P(T<=t) two-tail	0.391580642	
t Critical two-tail	2.144786687	

Appendix 1. Table 4.

Chum 0+ density (fish/100m^2) at high tide

Date	Site	channel habitat	marsh habitat	Site	Diff. Channel minus Marsh
04/13	3B	15.3	25.0	3C	-9.7
04/13	5B	5.6	20.8	5A	-15.3
04/21	2	0.0	27.8	1	-27.8
04/28	3A	11.1	37.5	2	-26.4
05/03	1	137.5	8.3	1	129.2
05/03	2	30.6	8.3	1	22.3
05/03	3B	70.8	7.1	3C	63.7
mean		38.7	19.3		19.4
SD		49.6	11.8		58.3
n		7	7		
CV		128%	61%		
P		0.41			

t-Test: Paired Two-Sample for Means

	Channel	*Marsh*
Mean	38.7	19.3
Variance	2460.6	138.1
Observations	7	7
Pearson Correlation	-0.687218	
Pooled Variance	1299.353	
Hypothesized Mean Difference	0	
df	6	
t	0.881774	
P(T<=t) one-tail	0.205914	
t Critical one-tail	1.94318	
P(T<=t) two-tail	**0.411827**	
t Critical two-tail	2.446912	

Appendix 1. Table 5.

Chinook 0+ density (fish/100m^2)

Date	**Tidal Stage**	**Site 5A impounded habitat**	**Site 5B channel habitat**	**diff. 5A-5B**
04/21	ebb	2.8	33.3	-30.6
05/03	ebb	23.6	20.8	2.8
05/10	ebb	1.4	19.4	-18.1
04/13	flood	8.3	12.5	-4.2
04/21	flood	5.6	5.6	0.0
04/28	flood	8.3	0.0	8.3
05/10	flood	2.8	13.9	-11.1
04/21	high	8.3	18.1	-9.7
04/28	high	11.1	4.2	6.9
05/03	high	6.9	6.9	0.0
05/10	high	2.8	27.8	-25.0
04/13	low	2.8	19.4	-16.7
04/21	low	2.8	2.8	0.0
05/03	low	9.7	56.9	-47.2
05/10	low	16.7	54.2	-37.5
	mean	7.6	19.7	-12.1
	SD	6.1	17.3	16.8
	n	15	15	
	CV	80%	88%	
	P	0.014		

t-Test: Paired Two-Sample for Means

	Impounded	***Channel***
Mean	7.6	19.7
Variance	36.9	299.6
Observations	15	15
Pearson Correlation	0.257669237	
Pooled Variance	168.2466196	
Hypothesized Mean Difference	0	
df	14	
t	-2.79592663	
P(T<=t) one-tail	0.007147228	
t Critical one-tail	1.761310135	
P(T<=t) two-tail	**0.014294456**	
t Critical two-tail	2.144786687	

Appendix 1. Table 6.

Chinook 0+ density (fish/100m^2) at high tide

Date	**Site**	**channel habitat**	**marsh habitat**	**Site**	**Diff. Channel minus Marsh**
04/13	3B	19.4	0.9	3C	18.5
04/13	5B	26.4	0.0	5A	26.4
04/21	2	2.8	0.0	1	2.8
04/28	3A	15.3	0.0	2	15.3
05/03	1	2.8	0.0	1	2.8
05/03	2	0.0	0.0	1	0.0
05/03	3B	8.3	0.0	3C	8.3
mean		10.7	0.1		10.6
SD		9.9	0.3		9.8
n		7	7		
CV		92%	265%		
P		0.029			

t-Test: Paired Two-Sample for Means

	Channel	*Marsh*
Mean	10.7	0.1
Variance	98.2	0.1
Observations	7	7
Pearson Correlation	0.388484	
Pooled Variance	49.15581	
Hypothesized Mean Difference	0	
df	6	
t	2.863057	
P(T<=t) one-tail	0.014343	
t Critical one-tail	1.94318	
P(T<=t) two-tail	**0.028687**	
t Critical two-tail	2.446912	

Appendix 1. Table 7. Chinook density (fish / 100 m^2) in channel habitat of Browns Slough and percentage of daily catch.

Ebb Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/21/95	0.0	2.8	2.8	2.0	33.3	0.0
04/28/95	2.8	9.7		4.0	13.9	1.4
05/03/95	1.4	4.2	23.6	31.0	20.8	1.4
05/10/95	0.0	1.4	1.4	3.0	19.4	15.3
mean	1.0	4.5	9.3	10.0	21.9	4.5
SD	1.3	3.7	12.4	14.0	8.2	7.2
CV	128%	81%	134%	140%	38%	160%

Flood Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/07/95	27.8	6.9		14.0	12.5	6.9
04/13/95	6.9	6.9	0.0	3.0	12.5	2.8
04/21/95	0.0	12.5	4.2	23.0	5.6	8.3
04/28/95	15.3	27.8	4.2	22.0	0.0	8.3
05/10/95	0.0	4.2	6.9	1.0	13.9	2.8
mean	10.0	11.7	3.8	12.6	8.9	5.8
SD	11.8	9.5	2.9	10.3	5.9	2.8
CV	118%	81%	75%	82%	67%	49%

High Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/13/95			19.4		26.4	0.0
04/21/95		2.8	0.0	13.9	18.1	1.4
04/28/95				11.1	4.2	8.3
05/03/95	2.8	0.0	8.3	1.4	6.9	2.8
05/10/95	1.4	1.4	4.2	1.4	27.8	18.1
mean	2.1	1.4	8.0	6.9	16.7	6.1
SD		1.4	8.4	6.5	10.8	7.4
CV		100%	105%	94%	65%	121%

LowTide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/13/95	1.4	8.3	240.3	8.0	19.4	6.9
04/21/95	5.6	4.2	4.2	18.0	2.8	0.0
05/03/95	0.0	2.8	10.0	13.0	56.9	2.8
05/10/95	9.7	12.5	2.8	2.0	54.2	1.4
mean	4.2	6.9	64.3	10.3	33.3	2.8
SD	4.4	4.4	117.4	6.8	26.6	3.0
CV	105%	63%	182%	67%	80%	108%

Ebb Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/21/95	0%	7%	7%	5%	81%	0%
04/28/95						
05/03/95	2%	5%	29%	38%	25%	2%
05/10/95	0%	3%	3%	7%	48%	38%
mean	1%	5%	13%	17%	52%	13%
max	2%	7%	29%	38%	81%	38%
min	0%	3%	3%	5%	25%	0%

FloodTide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/07/95						
04/13/95	22%	22%	0%	9%	39%	9%
04/21/95	0%	23%	8%	43%	10%	16%
04/28/95	20%	36%	5%	28%	0%	11%
05/10/95	0%	14%	24%	3%	48%	10%
mean	10%	24%	9%	21%	24%	11%
max	22%	36%	24%	43%	48%	16%
min	0%	14%	0%	3%	0%	9%

High Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/13/95						
04/21/95		8%	0%	38%	50%	4%
04/28/95						
05/03/95	13%	0%	37%	6%	31%	13%
05/10/95	3%	3%	8%	3%	51%	33%
mean	8%	3%	15%	16%	44%	17%
max	13%	8%	37%	38%	51%	33%
min	3%	0%	0%	3%	31%	4%

Low Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/13/95	0%	3%	84%	3%	7%	2%
04/21/95	16%	12%	12%	52%	8%	0%
05/03/95	0%	3%	12%	15%	67%	3%
05/10/95	12%	15%	3%	2%	66%	2%
mean	7%	8%	28%	18%	37%	2%
max	16%	15%	84%	52%	67%	3%
min	0%	3%	3%	2%	7%	0%

Appendix 1. Table 8. Chum density (fish / 100 m^2) in channel habitat of Browns Slough and percentage of daily catch.

Ebb Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/21/95	16.7	1.4	5.6	2.0	11.1	9.7
04/28/95	40.3	38.9		12.0	20.8	1.4
05/03/95	9.7	1.4	30.6	10.0	8.3	31.9
05/10/95	0.0	1.4	0.0	3.0	40.3	79.2
mean	16.7	10.8	12.1	6.8	20.1	30.6
SD	17.2	18.8	16.3	5.0	14.5	34.9
CV	103%	174%	135%	74%	72%	114%

FloodTide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/07/95	31.9	4.2		4.0	8.3	11.1
04/13/95	58.3	26.4	8.3	2.0	23.6	11.1
04/21/95	4.2	1.4	0.0	18.0	5.6	52.8
04/28/95	48.6	4.2	62.5	4.0	0.0	19.4
05/10/95	2.8	0.0	0.0	2.0	2.8	45.8
mean	29.2	7.2	17.7	6.0	8.1	28.1
SD	25.3	10.9	30.1	6.8	9.2	19.8
CV	87%	150%	170%	113%	115%	71%

High Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/13/95			15.3		5.6	2.8
04/21/95		0.0	0.0	9.7	1.4	0.0
04/28/95				1.4	8.3	2.8
05/03/95	51.4	30.6	70.9	5.6	22.2	2.8
05/10/95	2.8	1.4	2.8	0.0	0.0	68.1
mean	27.1	10.6	22.2	4.2	7.5	15.3
SD	34.4	17.3	33.1	4.4	8.9	29.5
CV	127%	162%	149%	105%	118%	193%

Low Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/13/95	33.3	8.3	405.6	10.0	20.8	8.3
04/21/95	9.7	6.9	1.4	11.0	9.7	4.2
05/03/95	13.9	33.3	10.0	28.0	1.4	1.4
05/10/95	8.3	1.4	5.6	0.0	8.3	112.5
mean	16.3	12.5	105.6	12.3	10.1	31.6
SD	11.6	14.2	200.0	11.6	8.0	54.0
CV	71%	114%	189%	95%	80%	171%

Ebb Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/21/95	36%	3%	12%	4%	24%	21%
04/28/95						
05/03/95	11%	2%	33%	11%	9%	35%
05/10/95	0%	1%	0%	2%	33%	64%
mean	15%	2%	15%	6%	22%	40%
max	36%	3%	33%	11%	33%	64%
min	0%	1%	0%	2%	9%	21%

FloodTide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/07/95						
04/13/95	45%	20%	6%	2%	18%	9%
04/21/95	5%	2%	0%	22%	7%	64%
04/28/95	35%	3%	45%	3%	0%	14%
05/10/95	5%	0%	0%	4%	5%	86%
mean	23%	6%	13%	8%	8%	43%
max	45%	20%	45%	22%	18%	86%
min	5%	0%	0%	2%	0%	9%

High Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/13/95						
04/21/95		0%	0%	88%	13%	0%
04/28/95						
05/03/95	28%	17%	39%	3%	12%	2%
05/10/95	4%	2%	4%	0%	0%	91%
mean	16%	6%	14%	30%	8%	31%
max	28%	17%	39%	88%	13%	91%
min	4%	0%	0%	0%	0%	0%

Low Tide

Date	Site 1A	Site 2A	Site 3	Site 4	Site 5B	Site 6A
04/13/95	7%	2%	83%	2%	4%	2%
04/21/95	23%	16%	3%	26%	23%	10%
05/03/95	16%	38%	11%	32%	2%	2%
05/10/95	6%	1%	4%	0%	6%	83%
mean	13%	14%	26%	15%	9%	24%
max	23%	38%	83%	32%	23%	83%
min	6%	1%	3%	0%	2%	2%

04/20/95	8.4	8.4	8.3	8.3	8.1	8.1	8.1	pH	bottom	ebb
04/20/95	8.4	8.4	8.3	8.3	8.2	8.1	8.1	pH	top	ebb
04/28/95	8.1	8.1	8.2	8.1	7.8	7.2	8.0	pH	top	ebb
05/03/95	8.0	8.1	8.1	8.1	8.1	8.0	7.9	pH	top	ebb
05/09/95	9.3	9.4	9.2	9.4	9.1	9.0	8.9	pH	top	ebb
04/12/95	8.5	8.6	8.5	8.4	8.3	8.3	8.3	pH	top	flood
04/12/95	8.9	8.7	8.7	8.4	8.5	8.5	8.3	pH	bottom	flood
04/21/95	▨	▨	▨	8.3	8.1	8.0	8.2	pH	top	flood
04/21/95	▨	▨	▨	8.3	8.0	8.1	8.0	pH	bottom	flood
04/27/95	8.4	8.4	8.5	8.5	8.6	8.9	8.4	pH	top	flood
05/04/95	8.5	8.5	8.5	8.3	8.2	8.1	7.8	pH	top	flood
04/12/95	8.7	8.6	8.7	8.7	8.4	8.4	8.4	pH	top	high
04/12/95	8.9	8.8	8.9	8.7	8.6	8.5	8.4	pH	bottom	high
04/20/95	8.0	8.3	8.4	8.4	8.2	8.3	8.2	pH	bottom	high
04/20/95	8.3	8.4	8.4	8.4	8.4	8.3	8.1	pH	top	high
05/03/95	8.3	8.4	8.3	8.1	8.0	7.9	7.5	pH	top	high
05/09/95	9.0	9.2	9.2	9.2	9.0	8.8	8.8	pH	top	high
04/12/95	8.0	▨	8.1	8.1	8.2	8.2	8.2	pH	top	low
04/12/95	▨	8.6	8.1	8.3	8.5	8.3	▨	pH	bottom	low
04/20/95	8.3	8.4	8.2	8.2	8.1	8.3	8.5	pH	top	low
04/20/95	8.1	8.3	8.2	8.3	8.0	8.1	8.4	pH	bottom	low
04/27/95	8.3	8.5	8.2	8.2	8.3	8.1	8.2	pH	top	low
05/03/95	7.9	8.2	8.1	8.0	8.2	8.3	8.3	pH	top	low
04/13/95	9.5	9.5	9.6	9.5	9.5	9.8	9.9	temp.	bottom	ebb
04/13/95	9.4	9.5	9.6	9.6	9.7	9.7	9.5	temp.	top	ebb
04/20/95	10.7	10.9	11.1	11.1	16.0	11.2	11.3	temp.	bottom	ebb
04/20/95	10.6	10.7	11.1	11.2	11.1	11.2	11.2	temp.	top	ebb
04/28/95	15.0	15.1	14.6	14.6	14.3	13.8	15.4	temp.	top	ebb
05/03/95	11.3	11.5	12.5	12.7	12.8	12.9	13.1	temp.	top	ebb
05/09/95	19.2	19.2	19.2	19.6	18.2	18.8	19.4	temp.	top	ebb
04/12/95	10.2	9.6	10.8	10.7	9.4	9.8	11.1	temp.	bottom	flood
04/12/95	10.6	10.7	10.8	10.7	10.7	10.6	11.2	temp.	top	flood
04/21/95	▨	▨	▨	12.2	11.5	11.2	11.3	temp.	top	flood
04/21/95	▨	▨	▨	12.2	15.9	12.2	11.7	temp.	bottom	flood
04/27/95	17.9	17.6	16.7	15.9	16.4	19.3	17.7	temp.	top	flood
05/04/95	13.2	13.3	14.6	15.6	16.2	15.7	13.9	temp.	top	flood
04/12/95	10.7	10.7	10.6	10.6	10.4	11.0	10.5	temp.	top	high
04/12/95	10.0	9.1	10.3	10.6	10.4	10.2	10.3	temp.	bottom	high
04/20/95	9.7	10.1	10.4	10.4	10.6	10.9	10.9	temp.	top	high
04/20/95	9.7	11.9	10.7	11.1	15.8	11.4	11.3	temp.	bottom	high
05/03/95	11.6	10.7	11.0	11.5	12.8	12.6	12.9	temp.	top	high
05/09/95	18.9	19.0	19.5	19.2	17.8	17.8	18.4	temp.	top	high
04/12/95	9.3	▨	10.0	10.1	10.3	10.7	10.8	temp.	top	low
04/12/95	▨	9.1	9.9	9.6	9.5	10.6	▨	temp.	bottom	low
04/20/95	11.2	11.1	11.5	11.4	16.2	13.0	12.5	temp.	bottom	low
04/20/95	11.2	11.2	11.5	11.5	11.9	13.1	12.5	temp.	top	low
04/27/95	16.3	16.5	16.9	16.7	17.2	17.5	17.4	temp.	top	low
05/03/95	14.4	13.6	15.1	15.5	14.2	19.3	18.7	temp.	top	low

▨ DENOTES MISSING DATA

APPENDIX 2. WATER QUALITY DATA

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Appendix Table 2-1. Table of data for each water quality parameter by date, site, and tidal stage.

Appendix Table 2-2. Table of parameter averages by tidal phase.

Appendix Table 2-3. Table of parameter variability (standard deviation) for each tidal phase.

Appendix Table 2-4. Table of extremes for each parameter.

Appendix Table 2-5. Table of difference in parameter values between sites 3 and 4.

Appendix Table 2-6 and 2-7. Tables of parameter differences between sites 3 and 4.

Appendix Figures 2-1 through 2-24. Parameter averages and variability by site and tidal stage.

Appendix Figures 2-25 through 2-28. Maximum and minimum values for each parameter by site.

Table 2-1. Brown Slough Water Quality Data

Date	Site1	Site2	Site3	Site4	Site5A	Site5B	Site6	Water Quality parameter	Location in water column	tidal stage
04/13/95	10.9	10.7	11.5	9.9	9.6	10.9	10.7	D.O.	bottom	ebb
04/13/95	11.1	10.9	10.9	10.5	10.5	10.5	10.5	D.O.	top	ebb
04/20/95	10.3	10.3	10.8	10.8	6.1	11.7	11.7	D.O.	bottom	ebb
04/20/95	10.6	10.5	10.8	10.5	10.6	11.4	11.6	D.O.	top	ebb
04/28/95	7.5	8.2	9.5	9.9	9.4	9.8	7.8	D.O.	top	ebb
05/03/95	11.6	10.9	10.8	10.4	9.1	9.4	7.6	D.O.	top	ebb
05/09/95	10.8	11.1	10.3	11.5	10.0	11.3	11.3	D.O.	top	ebb
04/12/95	12.9	10.8	12.5	11.9	10.5	12.1	14.3	D.O.	bottom	flood
04/12/95	12.4	11.8	12.2	12.1	12.1	12.5	13.9	D.O.	top	flood
04/21/95				10.4	8.7	9.8	10.1	D.O.	top	flood
04/21/95				10.2	3.7	8.3	8.3	D.O.	bottom	flood
04/27/95	13.1	11.2	13.3	10.6	10.6	11.5	15.5	D.O.	top	flood
05/04/95	8.6	8.8	9.1	7.7	7.6	7.4	8.4	D.O.	top	flood
04/12/95	12.6	12.1	12.4	12.6	11.4	13.0	11.9	D.O.	top	high
04/12/95	13.7	11.8	12.3	12.3	11.9	11.8	11.1	D.O.	bottom	high
04/20/95	11.4	10.8	10.8	10.7	10.6	10.5	10.0	D.O.	top	high
04/20/95	10.5	9.2	10.1	9.7	6.8	10.2	10.0	D.O.	bottom	high
05/03/95	9.2	11.1	9.7	9.3	9.6	9.8	9.0	D.O.	top	high
05/09/95	11.1	9.7	11.5	11.1	10.3	10.7	10.7	D.O.	top	high
04/12/95	10.9		10.8	11.1	11.6	13.7	15.4	D.O.	top	low
04/12/95		10.7	10.5	11.0	9.9	13.0		D.O.	bottom	low
04/20/95	10.9	10.6	11.1	10.7	11.7	14.6	15.1	D.O.	top	low
04/20/95	10.7	10.1	10.4	9.1	3.8	14.9	14.6	D.O.	bottom	low
04/27/95	9.0	8.9	12.0	11.9	13.1	12.3	14.5	D.O.	top	low
05/03/95	9.9	10.2	11.7	11.6	10.1	11.7	15.3	D.O.	top	low
04/13/95	20835	21068	18137	20990	21430	19191	18212	Spec. Con.	bottom	ebb
04/13/95	20092	19693	18145	17626	16872	16250	16115	Spec. Con.	top	ebb
04/20/95	16892	16919	16620	16567	24825	16045	15304	Spec. Con.	bottom	ebb
04/20/95	16302	16594	16638	16544	16139	15772	15171	Spec. Con.	top	ebb
04/28/95	20281	20376	19382	19386	18906	17921	19772	Spec. Con.	top	ebb
05/03/95	12156	13004	15024	15404	15549	15502	15371	Spec. Con.	top	ebb
05/09/95	10479	10383	11416	11504	12895	12752	12329	Spec. Con.	top	ebb
04/12/95	23126	23774	20743	18804	19880	18842	10983	Spec. Con.	bottom	flood
04/12/95	18543	18224	18744	18796	11202	13017	9449	Spec. Con.	top	flood
04/21/95				17720	15862	5118	10490	Spec. Con.	top	flood
04/21/95				17740	26647	16266	14059	Spec. Con.	bottom	flood
04/27/95	17443	18419	21111	22320	22842	21865	17510	Spec. Con.	top	flood
05/04/95	19907	20247	19226	17405	16081	15716	14986	Spec. Con.	top	flood
04/12/95	20269	20134	21259	21200	16263	11428	16749	Spec. Con.	top	high
04/12/95	23711	24474	22876	21245	20052	19680	18657	Spec. Con.	bottom	high
04/20/95	15813	15852	15997	15995	16229	16523	15945	Spec. Con.	top	high
04/20/95	16973	17470	16483	16563	25614	16751	16478	Spec. Con.	bottom	high
05/03/95	13743	11055	11584	13393	15538	15500	15901	Spec. Con.	top	high
05/09/95	10659	10747	10531	11233	12953	13106	12914	Spec. Con.	top	high
04/12/95	21810		13577	11910	10725	9082	6003	Spec. Con.	top	low
04/12/95		24432	13696	19071	19935	14025		Spec. Con.	bottom	low
04/20/95	16659	16539	16557	16319	15779	10679	2496	Spec. Con.	top	low
04/20/95	18379	16823	16589	16446	27040	15536	7666	Spec. Con.	bottom	low
04/27/95	22472	21800	19733	20488	13587	12202	8968	Spec. Con.	top	low
05/03/95	14039	14995	15633	15574	15900	10617	8537	Spec. Con.	top	low
04/13/95	8.3	8.3	8.1	8.3	8.3	7.9	7.8	pH	bottom	ebb
04/13/95	8.3	8.3	8.1	8.2	8.2	7.9	7.9	pH	top	ebb

Table 2-2. Parameter means at each station for each tide phase.

BROWNS SLOUGH-HIGH TIDE AVERAGES

	TEMP	pH	SP CON	SALINIT	D O	DEPTH
STATION	Deg C		u Mhos	ppt	mg/l	METERS
1	11.8	8.5	16861	9.9	11.4	1.49
2	11.9	8.6	16622	9.8	10.8	1.58
3	12.1	8.7	16455	9.7	11.1	1.40
4	12.2	8.6	16604	9.8	11.0	1.22
5A	13.0	8.4	17775	10.5	10.1	2.01
5B	12.3	8.4	15498	9.0	11.0	1.16
6	12.4	8.2	16107	9.4	10.5	0.98

BROWNS SLOUGH-LOW TIDE AVERAGES

	TEMP	pH	SP CON	SALINIT	D O	DEPTH
STATION	Deg C		u Mhos	ppt	mg/l	METERS
1	12.5	8.1	18672	11.2	10.3	0.82
2	12.3	8.4	18918	11.2	10.1	1.13
3	12.5	8.2	15964	9.4	11.1	0.88
4	12.5	8.2	16635	9.7	10.9	0.94
5A	13.2	8.2	17161	10.2	10.0	1.62
5B	14.0	8.2	12024	6.9	13.4	0.52
6	14.4	8.3	6734	3.7	15.0	0.40

BROWNS SLOUGH-FLOOD FLOW AVERAGES

	TEMP	pH	SP CON	SALINIT	D O	DEPTH
STATION	Deg C		u Mhos	ppt	mg/l	METERS
1	13.0	8.6	19755	11.7	11.8	1.13
2	12.8	8.6	20166	12.0	10.7	1.13
3	13.2	8.6	19956	12.0	11.8	1.07
4	12.9	8.4	18798	11.0	10.5	0.79
5A	13.4	8.3	18752	11.2	8.9	1.89
5B	13.1	8.3	15137	8.8	10.3	0.79
6	12.8	8.2	12913	7.3	11.8	0.58

BROWNS SLOUGH-EBB FLOW AVERAGES

	TEMP	pH	SP CON	SALINIT	D O	DEPTH
STATION	Deg C		u Mhos	ppt	mg/l	METERS
1	12.2	8.4	16720	9.8	10.4	1.0
2	12.3	8.4	16862	9.9	10.4	1.2
3	12.5	8.3	16480	9.6	10.7	0.9
4	12.6	8.4	16860	9.9	10.5	1.1
5A	13.1	8.3	18088	10.7	9.3	1.6
5B	12.5	8.0	16205	9.3	10.7	0.7
6	12.4	8.1	16039	9.4	10.2	0.6

Table 2-3. Parameter standard deviations at each station for each tide phase.

BROWNS SLOUGH-HIGH TIDE STANDARD DEVIATIONS

	TEMP	pH	SP CON	SALINIT	D O	DEPTH
STATION	Deg C		u Mhos	ppt	mg/l	METERS
1	3.6	0.39	4644	2.9	1.6	1.15
2	3.6	0.34	5307	3.4	1.1	1.44
3	3.6	0.35	4967	3.1	1.1	1.23
4	3.4	0.38	4054	2.6	1.3	1.07
5A	3.2	0.34	4462	2.9	1.8	1.69
5B	2.8	0.29	2912	1.8	1.2	0.74
6	3.1	0.43	1861	1.2	1.0	0.53

BROWNS SLOUGH-LOW TIDE STANDARD DEVIATIONS

	TEMP	pH	SP CON	SALINIT	D O	DEPTH
STATION	Deg C		u Mhos	ppt	mg/l	METERS
1	2.5	0.16	3159	2.2	0.7	0.66
2	2.5	0.14	3582	2.3	0.6	0.79
3	2.6	0.05	2078	1.4	0.6	0.68
4	2.7	0.11	2719	1.7	1.1	0.79
5A	2.9	0.17	5212	3.3	3.0	1.66
5B	3.3	0.10	2190	1.3	1.2	0.23
6	3.1	0.11	2350	1.4	0.4	0.68

BROWNS SLOUGH-FLOOD FLOW STANDARD DEVIATION

	TEMP	pH	SP CON	SALINIT	D O	DEPTH
STATION	Deg C		u Mhos	ppt	mg/l	METERS
1	3.1	0.20	2133	1.4	1.8	1.12
2	3.1	0.10	2228	1.5	1.1	1.17
3	2.5	0.10	994	0.8	1.6	1.07
4	2.1	0.10	1665	0.9	1.4	0.43
5A	2.9	0.20	5047	3.2	2.7	1.87
5B	3.3	0.30	5252	3.2	1.9	0.43
6	2.4	0.20	2838	1.7	2.9	0.15

BROWNS SLOUGH-EBB FLOW STANDARD DEVIATIONS

	TEMP	pH	SP CON	SALINIT	D O	DEPTH
STATION	Deg C		u Mhos	ppt	mg/l	METERS
1	3.3	0.39	3798	2.4	1.2	0.81
2	3.3	0.41	3684	2.3	0.9	0.83
3	3.2	0.37	2442	1.5	0.6	0.66
4	3.3	0.42	2803	1.8	0.5	0.82
5A	3.0	0.37	3702	2.4	1.4	1.38
5B	2.9	0.49	1871	1.0	0.8	0.25
6	3.3	0.34	2209	1.4	1.6	0.21

Table 2-4. Extreme parameter measurements for each station and when they occurred.

MAXIMUM READING AT EACH STATION

STATION	DATE	TIDE	TEMP	DATE	TIDE	pH	DATE	TIDE	SC	DATE	TIDE	DO
			DEG C			pH			uMhos			mg/L
1	509	EFS	19.2	509	EFS	9.3	412	HTB	23711	412	HTB	13.7
2	509	EFS	19.2	509	EFS	#9.4#	412	HTB	24474	412	HTS	12.1
3	509	HTS	19.5	509	HTS/EFS	9.2	412	HTB	22876	427	FFS	13.3
4	509	EFS	#19.6#	509	EFS	#9.4#	427	FFS	22320	412	HTS	12.6
5A	509	EFS	18.2	509	EFS	9.1	420	LTB	#27040#	427	LTS	13.1
5B	503/427	LTS/FFS	19.3	509	EFS	9.0	427	FFS	21865	420	LTB	14.9
6	509	EFS	19.4	509	EFS	8.9	428	EFS	19772	427	FFS	#15.5#

#__# DENOTES THE OVERALL PARAMETER MAXIMUM

MINIMUM READING AT EACH STATION

STATION	DATE	TIDE	TEMP	DATE	TIDE	pH	DATE	TIDE	SC	DATE	TIDE	DO
			DEG C			pH			uMhos			mg/L
1	412	LTB	9.3	503	LTS	7.9	509	EFS	10479	428	EFS	7.5
2	412	HTB/LTB	#9.1#	428/503	EFS	8.1	509	EFS	10383	428	EFS	8.2
3	413	EFS/B	9.6	*	**	8.1	509	HTS	10531	504	FFS	9.1
4	413	EFB	9.5	503	LTS	8.0	509	HTS	11233	504	FFS	7.7
5A	412	FFB	9.4	428	EFS	7.8	412	LTS	10725	421	FFB	#3.7#
5B	413	EFS	9.7	428	EFS	#7.2#	421	FFS	5118	504	FFS	7.4
6	413	EFS	9.5	503	HTS	7.5	420	LTS	#2496#	503	EFS	7.6

*412,413,503

**LTS,B/EFS,B

#__# DENOTES THE OVERALL PARAMETER MINIMUM

DATE: FIRST DIGIT=MONTH, NEXT 2 DIGITS = DAY

TIDE:
LTS = LOW TIDE, SURFACE READING
HTB = HIGHTIDE, BOTTOM READING
EF = EBB FLOW READING
FF = FLOOD FLOW READING

Table 2-5. Differences in parameter values between stations 3 and 4.

DO Date	Site3	3-4 ABS VALUE	Site4	Location in water column	Tidal stage	pH Date	Site3	3-4 ABS VALUE	Site4	Location in water column	tidal stage
04/13/95	11.5	1.6	9.9	bottom	ebb	04/13/95	8.1	0.2	8.3	bottom	ebb
04/13/95	10.9	0.4	10.5	top	ebb	04/13/95	8.1	0.1	8.2	top	ebb
04/20/95	10.8	0.0	10.8	bottom	ebb	04/20/95	8.3	0.0	8.3	bottom	ebb
04/20/95	10.8	0.3	10.5	top	ebb	04/20/95	8.3	0.0	8.3	top	ebb
04/28/95	9.5	0.4	9.9	top	ebb	04/28/95	8.2	0.1	8.1	top	ebb
05/03/95	10.8	0.4	10.4	top	ebb	05/03/95	8.1	0.0	8.1	top	ebb
05/09/95	10.3	1.2	11.5	top	ebb	05/09/95	9.2	0.2	9.4	top	ebb
04/12/95	12.5	0.6	11.9	bottom	flood	04/12/95	8.5	0.1	8.4	top	flood
04/12/95	12.2	0.1	12.1	top	flood	04/12/95	8.7	0.3	8.4	bottom	flood
04/27/95	13.3	2.7	10.6	top	flood	04/27/95	8.5	0.0	8.5	top	flood
05/04/95	9.1	1.4	7.7	top	flood	05/04/95	8.5	0.2	8.3	top	flood
04/12/95	12.4	0.2	12.6	top	high	04/12/95	8.7	0.0	8.7	top	high
04/12/95	12.3	0.0	12.3	bottom	high	04/12/95	8.9	0.2	8.7	bottom	high
04/20/95	10.8	0.1	10.7	top	high	04/20/95	8.4	0.0	8.4	bottom	high
04/20/95	10.1	0.4	9.7	bottom	high	04/20/95	8.4	0.0	8.4	top	high
05/03/95	9.7	0.4	9.3	top	high	05/03/95	8.3	0.2	8.1	top	high
05/09/95	11.5	0.4	11.1	top	high	05/09/95	9.2	0.0	9.2	top	high
04/12/95	10.8	0.3	11.1	top	low	04/12/95	8.1	0.0	8.1	top	low
04/12/95	10.5	0.5	11.0	bottom	low	04/12/95	8.1	0.2	8.3	bottom	low
04/20/95	11.1	0.4	10.7	top	low	04/20/95	8.2	0.0	8.2	top	low
04/20/95	10.4	1.3	9.1	bottom	low	04/20/95	8.2	0.1	8.3	bottom	low
04/27/95	12.0	0.1	11.9	top	low	04/27/95	8.2	0.0	8.2	top	low
05/03/95	11.7	0.1	11.6	top	low	05/03/95	8.1	0.1	8.0	top	low

COND Date	Site3	3-4 ABS VALUE	Site4	Location in water column	tidal stage	TEMP Date	Site3	3-4 ABS VALUE	Site4	Location in water column	tidal stage
04/13/95	18137	2853.0	20990	bottom	ebb	04/13/95	9.6	0.1	9.5	bottom	ebb
04/13/95	18145	519.0	17626	top	ebb	04/13/95	9.6	0.0	9.6	top	ebb
04/20/95	16620	53.0	16567	bottom	ebb	04/20/95	11.1	0.0	11.1	bottom	ebb
04/20/95	16638	94.0	16544	top	ebb	04/20/95	11.1	0.1	11.2	top	ebb
04/28/95	19382	4.0	19386	top	ebb	04/28/95	14.6	0.0	14.6	top	ebb
05/03/95	15024	380.0	15404	top	ebb	05/03/95	12.5	0.2	12.7	top	ebb
05/09/95	11416	88.0	11504	top	ebb	05/09/95	19.2	0.4	19.6	top	ebb
04/12/95	20743	1939.0	18804	bottom	flood	04/12/95	10.8	0.1	10.7	bottom	flood
04/12/95	18744	52.0	18796	top	flood	04/12/95	10.8	0.1	10.7	top	flood
04/27/95	21111	1209.0	22320	top	flood	04/27/95	16.7	0.8	15.9	top	flood
05/04/95	19226	1821.0	17405	top	flood	05/04/95	14.6	1.0	15.6	top	flood
04/12/95	21259	59.0	21200	top	high	04/12/95	10.6	0.0	10.6	top	high
04/12/95	22876	1631.0	21245	bottom	high	04/12/95	10.3	0.3	10.6	bottom	high
04/20/95	15997	2.0	15995	top	high	04/20/95	10.4	0.0	10.4	top	high
04/20/95	16483	80.0	16563	bottom	high	04/20/95	10.7	0.4	11.1	bottom	high
05/03/95	11584	1809.0	13393	top	high	05/03/95	11.0	0.5	11.5	top	high
05/09/95	10531	702.0	11233	top	high	05/09/95	19.5	0.3	19.2	top	high
04/12/95	13577	1667.0	11910	top	low	04/12/95	10.0	0.1	10.1	top	low
04/12/95	13696	5375.0	19071	bottom	low	04/12/95	9.9	0.3	9.6	bottom	low
04/20/95	16557	238.0	16319	top	low	04/20/95	11.5	0.1	11.4	bottom	low
04/20/95	16589	143.0	16446	bottom	low	04/20/95	11.5	0.0	11.5	top	low
04/27/95	19733	755.0	20488	top	low	04/27/95	16.9	0.2	16.7	top	low
05/03/95	15633	59.0	15574	top	low	05/03/95	15.1	0.4	15.5	top	low

Table 2-6

PARAMETER DIFFERENCES BETWEEN STATIONS 3 & 4

TOP AND BOTTOM DATA INCLUDED

DISSOLVED OXYGEN	**EBB**	**FLOOD**	**HIGH**	**LOW**
Mean	0.61	1.20	0.25	0.45
Standard Deviation	0.57	1.13	0.18	0.45
Minimum	0	0.1	0	0.1
Maximum	1.6	2.7	0.4	1.3
Count	7	4	6	6
SPECIFIC CONDUCTANCE	**EBB**	**FLOOD**	**HIGH**	**LOW**
Mean	570	1255	714	1373
Standard Deviation	1024	864	822	2050
Minimum	4	52	2	59
Maximum	2853	1939	1809	5375
Count	7	4	6	6
pH				
	EBB	**FLOOD**	**HIGH**	**LOW**
Mean	0.09	0.15	0.07	0.07
Standard Deviation	0.09	0.13	0.10	0.08
Minimum	0	0	0	0
Maximum	0.2	0.3	0.2	0.2
Count	7	4	6	6
TEMPERATURE				
	EBB	**FLOOD**	**HIGH**	**LOW**
Mean	0.11	0.50	0.30	0.18
Standard Deviation	0.15	0.47	0.19	0.15
Minimum	0	0.1	0	0
Maximum	0.4	1	0.5	0.4
Count	7	4	5	6

Table 2-7

PARAMETER DIFFERENCES BETWEEN STATIONS 3 & 4

TOP READINGS ONLY

DISSOLVED OXYGEN	**EBB**	**FLOOD**	**HIGH**	**LOW**
Mean	0.54	1.40	0.27	0.22
Standard Deviation	0.37	1.30	0.15	0.15
Minimum	0.30	0.10	0.10	0.10
Maximum	1.20	2.70	0.40	0.40
Count	5	3	4	4
SPECIFIC CONDUCTANCE	**EBB**	**FLOOD**	**HIGH**	**LOW**
Mean	217	1027	643	680
Standard Deviation	221	898	840	721
Minimum	4	52	2	59
Maximum	519	1821	1809	1667
Count	5	3	4	4
pH				
	EBB	**FLOOD**	**HIGH**	**LOW**
Mean	0.08	0.10	0.05	0.02
Standard Deviation	0.08	0.10	0.10	0.05
Minimum	0.00	0.00	0.00	0.00
Maximum	0.20	0.20	0.20	0.10
Count	5	3	4	4
TEMPERATURE				
	EBB	**FLOOD**	**HIGH**	**LOW**
Mean	0.14	0.63	0.20	0.17
Standard Deviation	0.17	0.47	0.24	0.17
Minimum	0.00	0.10	0.00	0.00
Maximum	0.40	1.00	0.50	0.40
Count	5	3	4	4

Figure 2-1. Mean water temperature at each station during the high tide monitoring. Error bars are plus and minus one standard deviation from the mean.

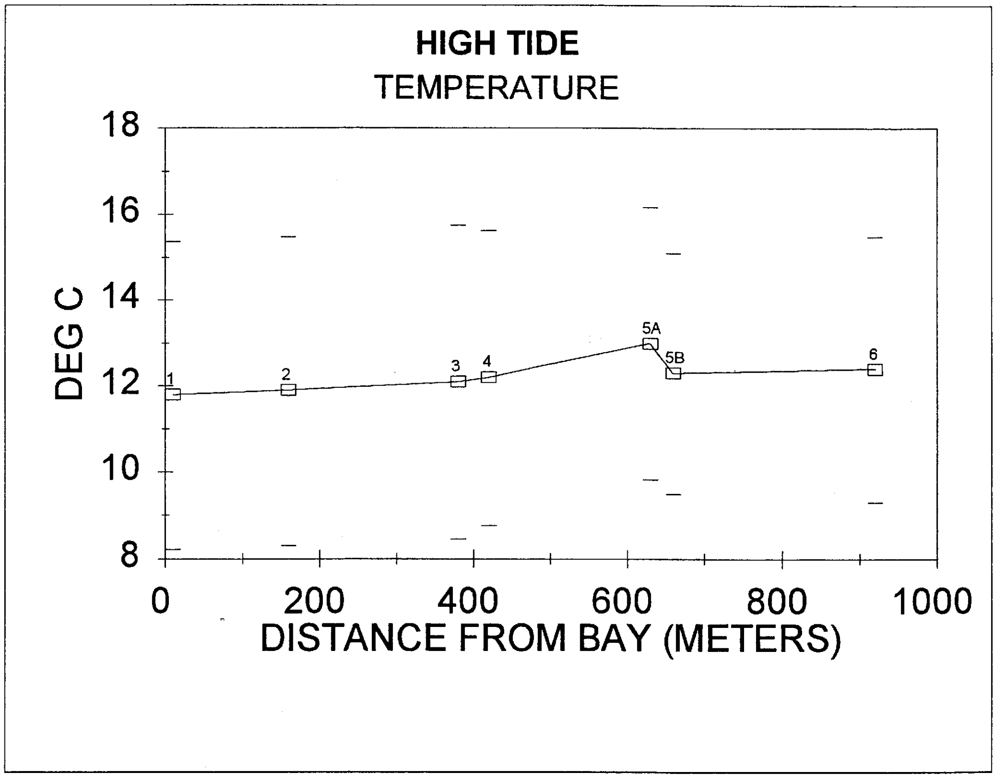

Figure 2-2. Mean water pH at each station during the high tide monitoring. Error bars are plus and minus one standard deviation from the mean.

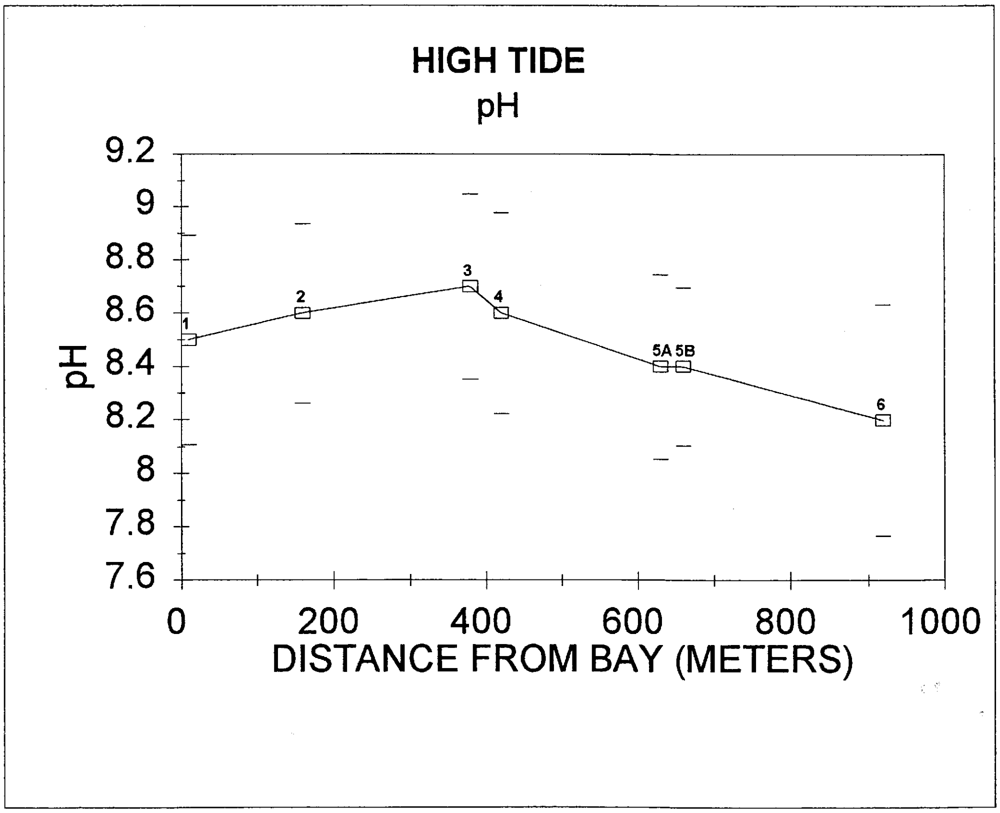

Figure 2-3. Mean water specific conductance at each station during the high tide monitoring. Error bars are plus and minus one standard deviation from the mean.

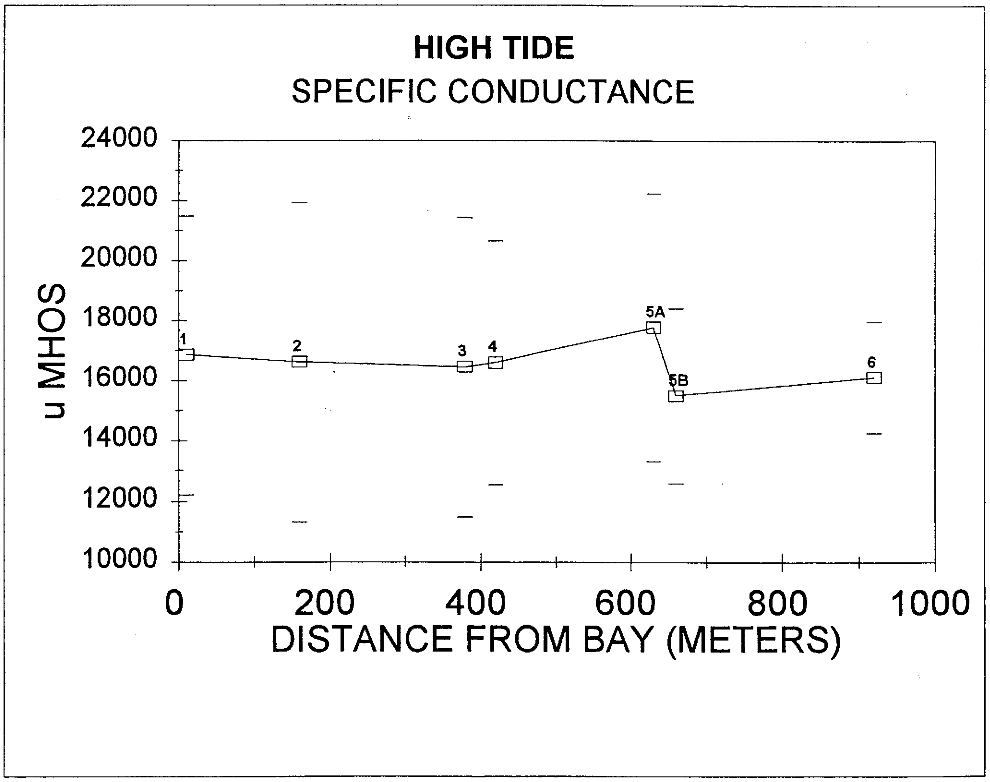

Figure 2-4. Mean water salinity at each station during the high tide monitoring. Error bars are plus and minus one standard deviation from the mean.

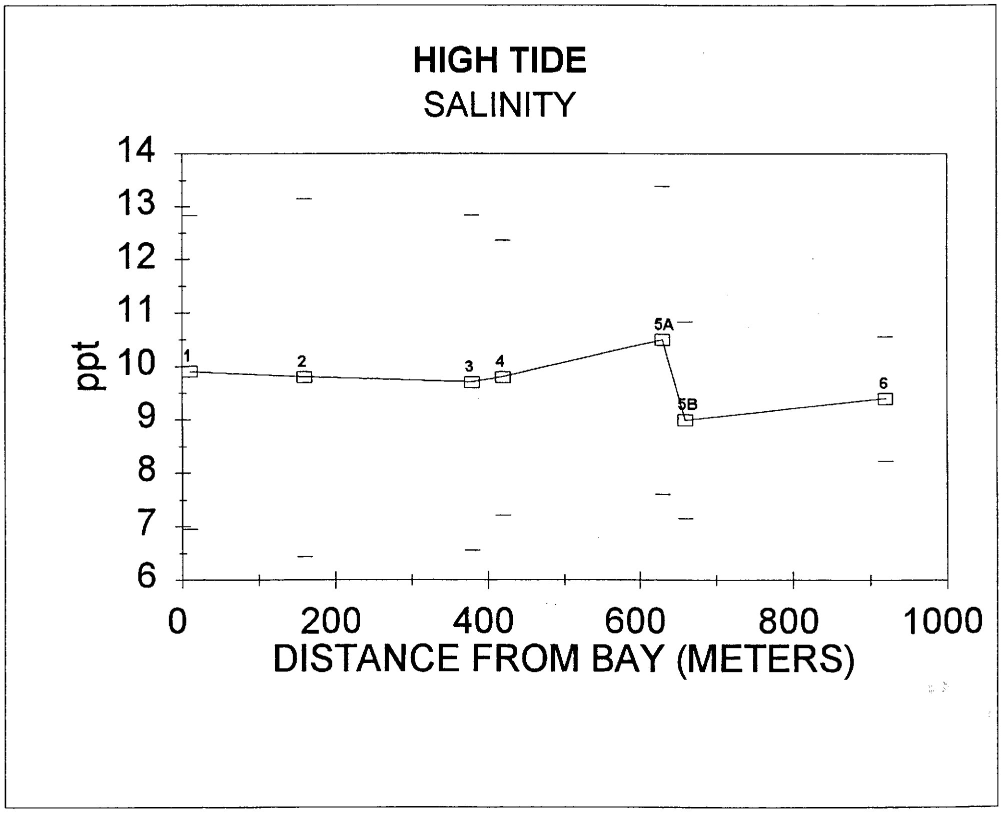

Figure 2-5. Mean water dissolved oxygen at each station during the high tide monitoring. Error bars are plus and minus one standard deviation from the mean.

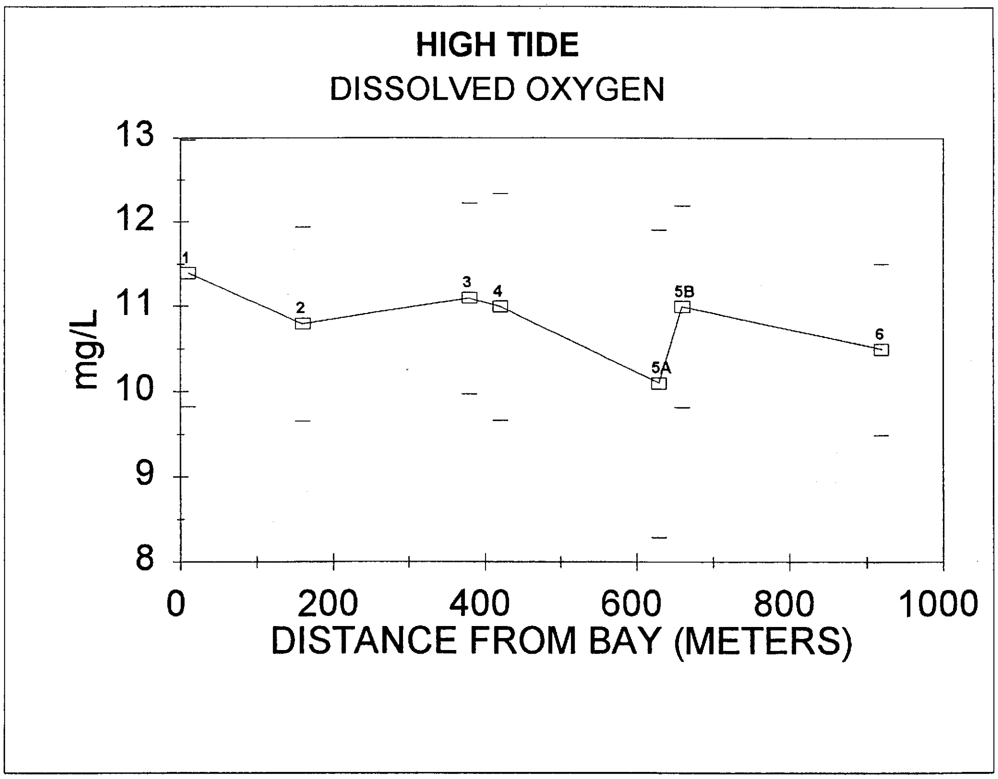

Figure 2-6. Mean water depth at each station during the high tide monitoring. Error bars are plus and minus one standard deviation from the mean.

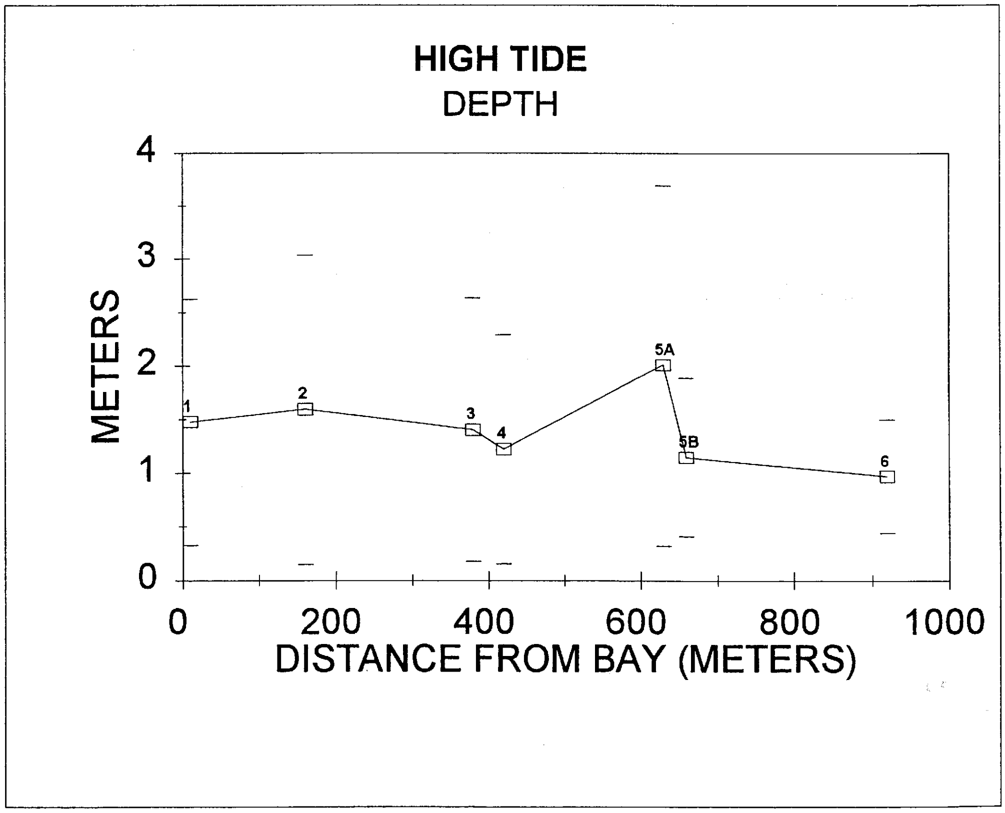

Figure 2-7. Mean water temperature at each station during the low tide monitoring. Error bars are plus and minus one standard deviation from the mean.

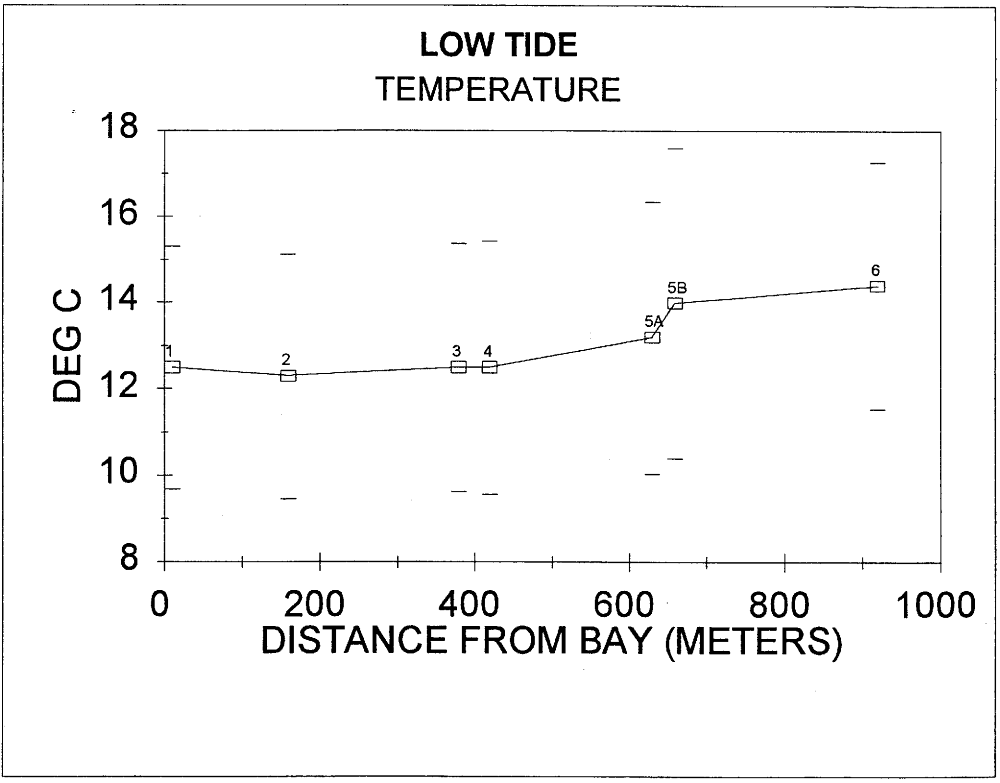

Figure 2-8. Mean water pH at each station during the low tide monitoring. Error bars are plus and minus one standard deviation from the mean.

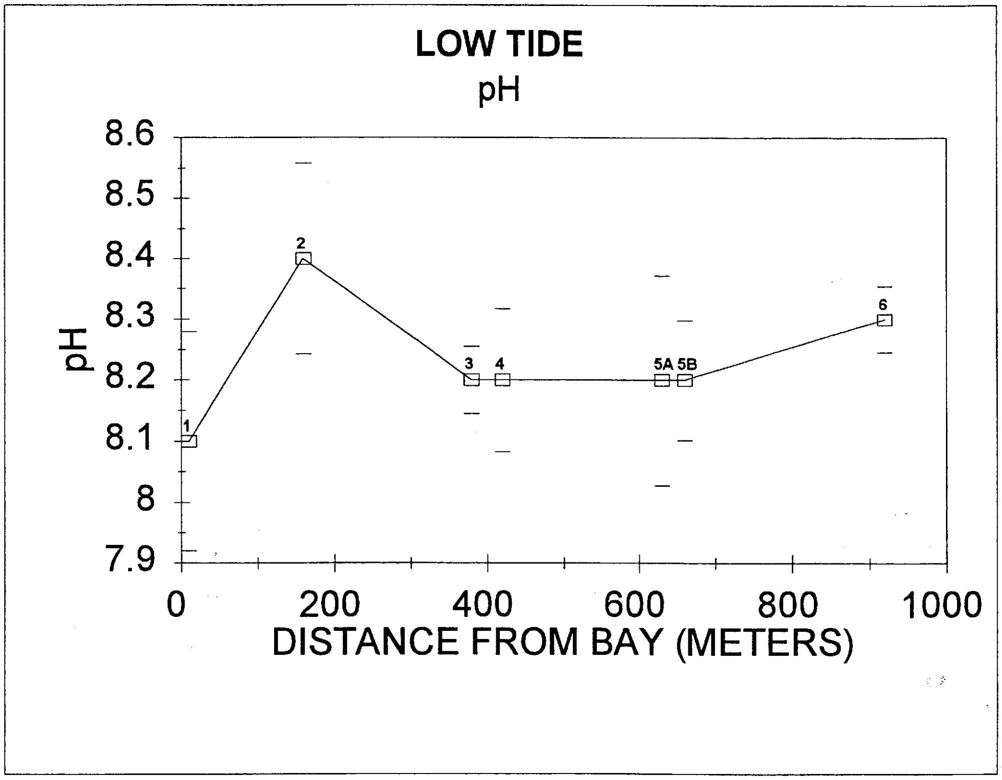

Figure 2-9. Mean water specific conductance at each station during the low tide monitoring. Error bars are plus and minus one standard deviation from the mean.

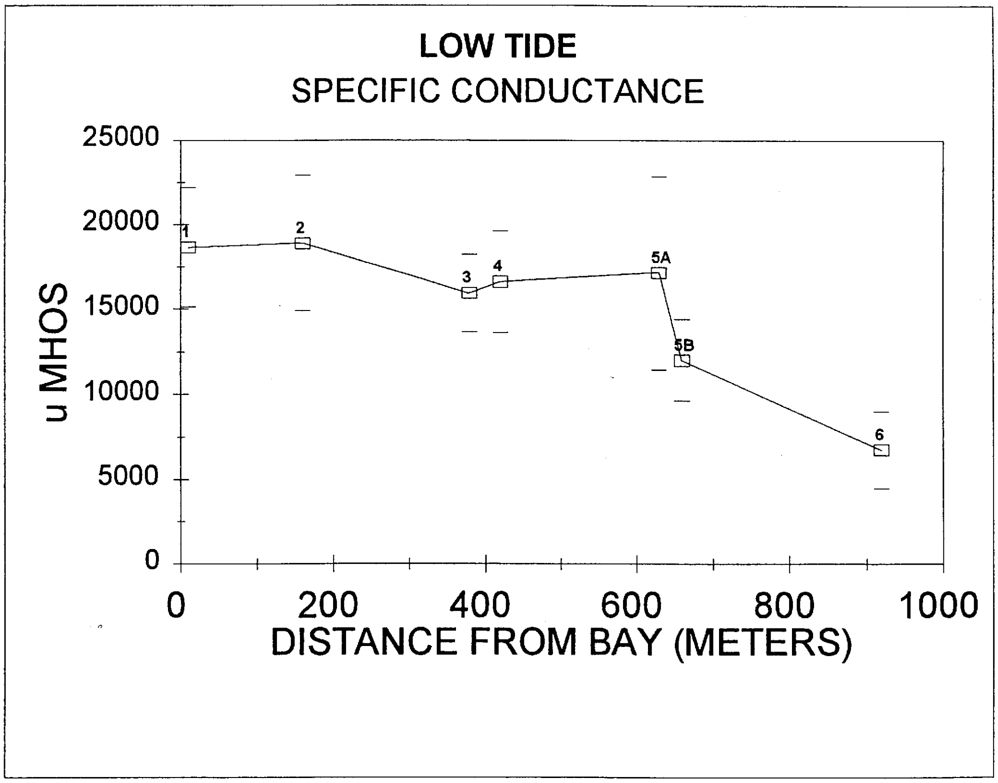

Figure 2-10. Mean water salinity at each station during the low tide monitoring. Error bars are plus and minus one standard deviation from the mean.

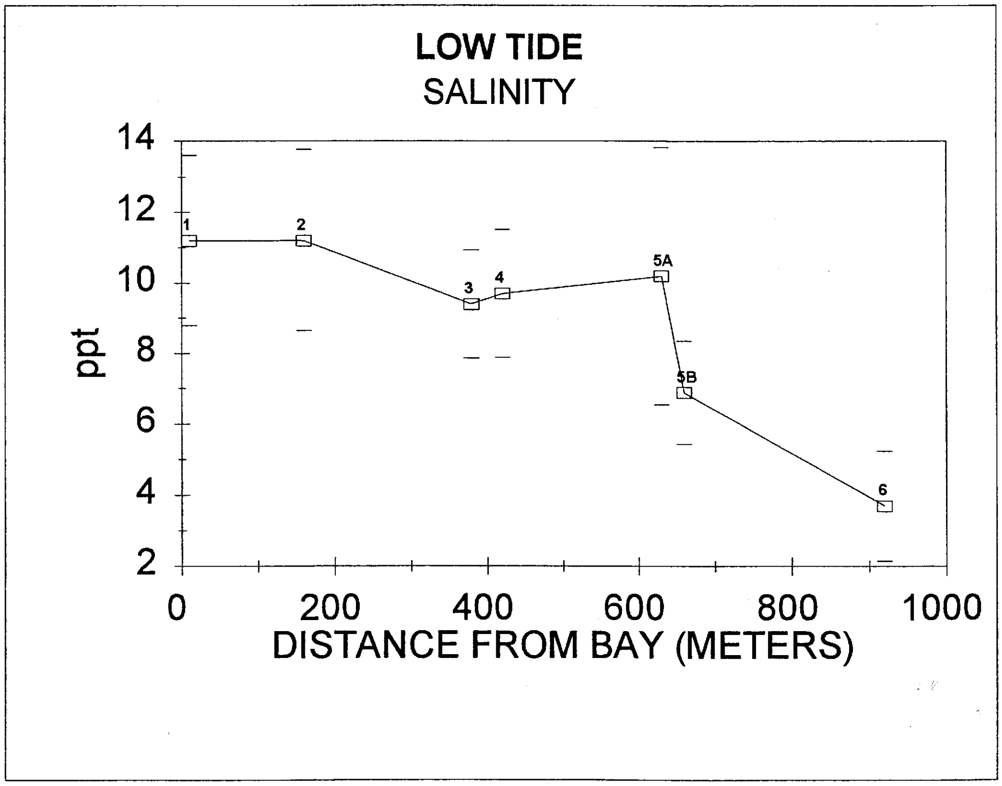

Figure 2-11. Mean water dissolved oxygen at each station during the low tide monitoring. Error bars are plus and minus one standard deviation from the mean.

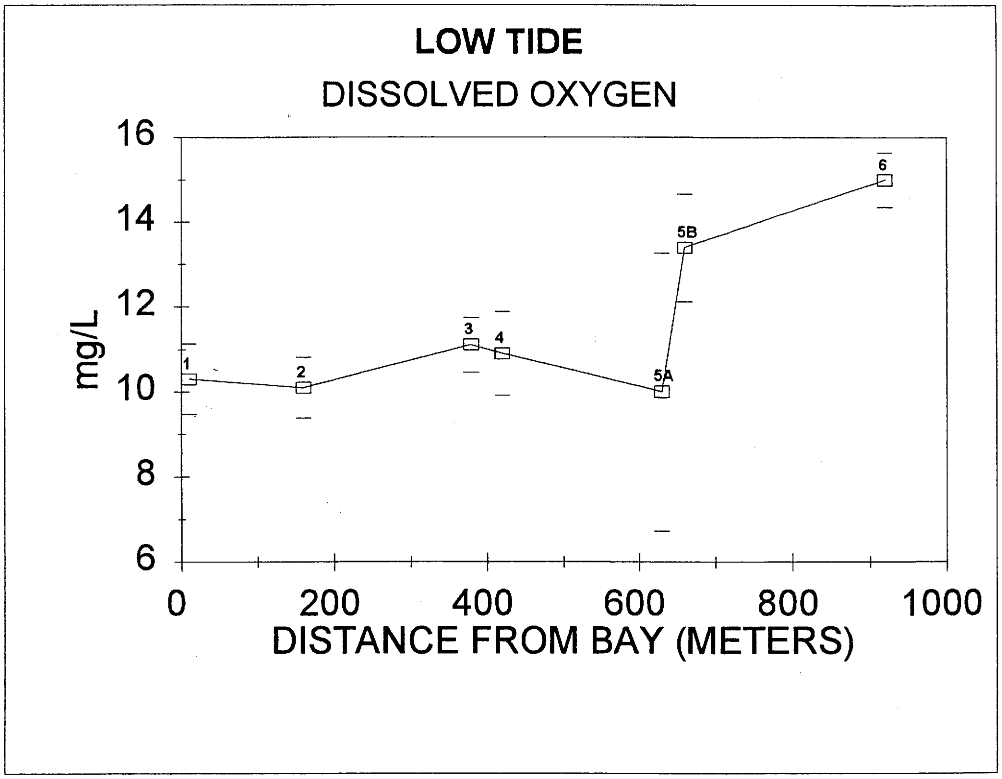

Figure 2-12. Mean water depth at each station during the low tide monitoring. Error bars are plus and minus one standard deviation from the mean.

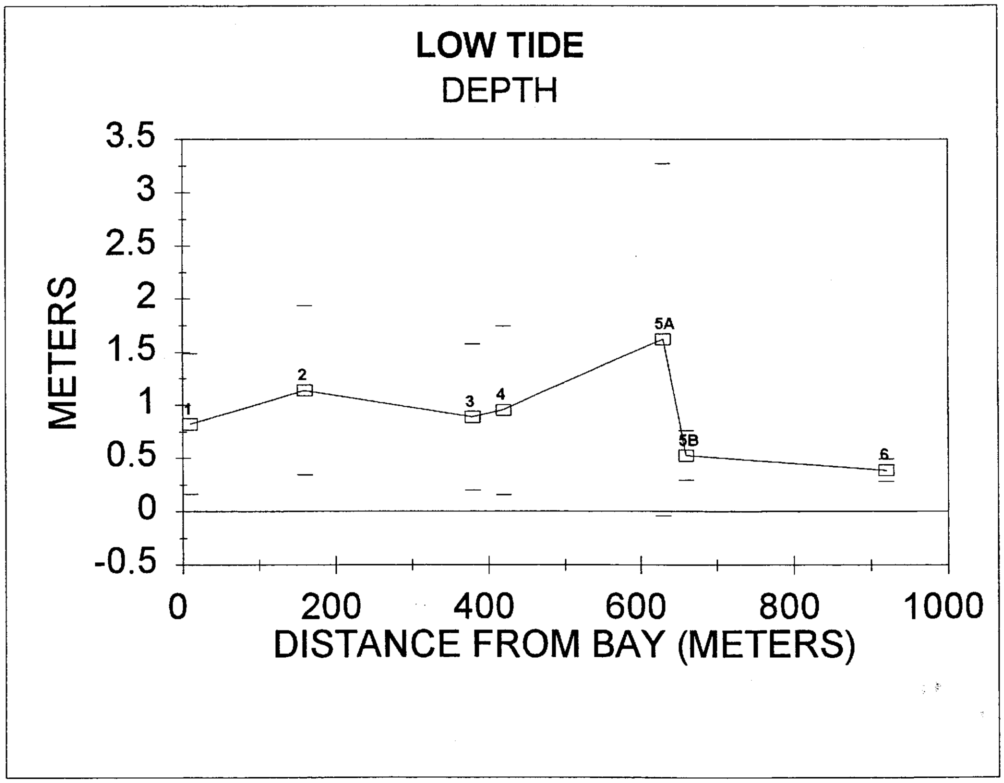

Figure 2-13. Mean water temperature at each station during the ebb flow monitoring. Error bars are plus and minus one standard deviation from the mean.

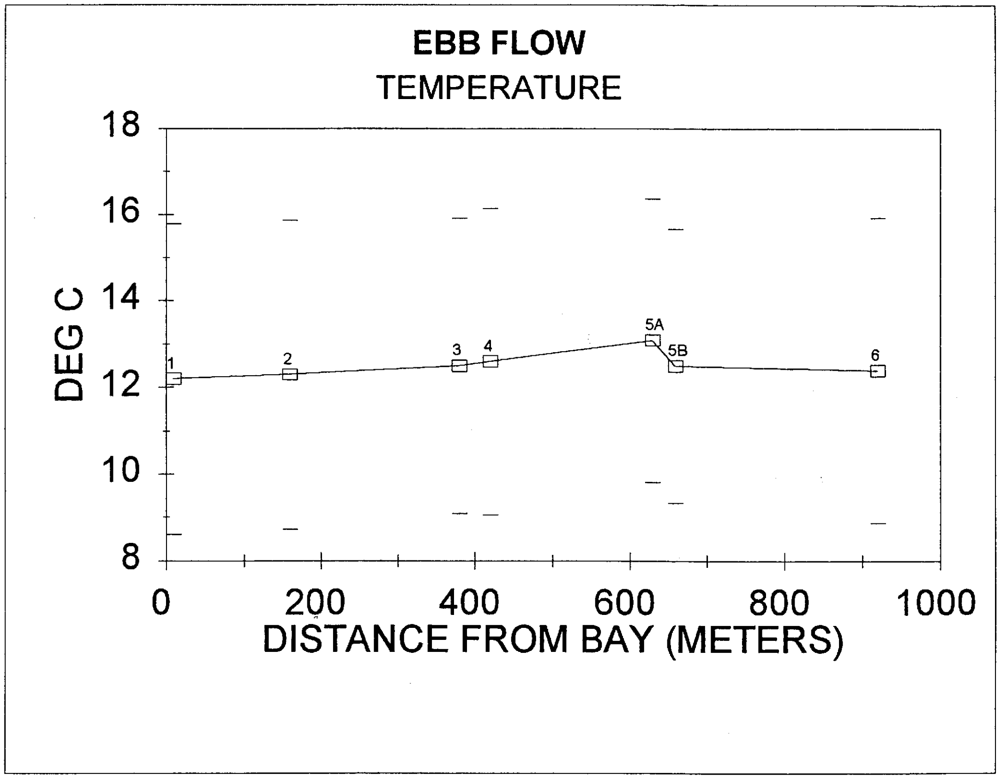

Figure 2-14. Mean water pH at each station during the ebb flow monitoring. Error bars are plus and minus one standard deviation from the mean.

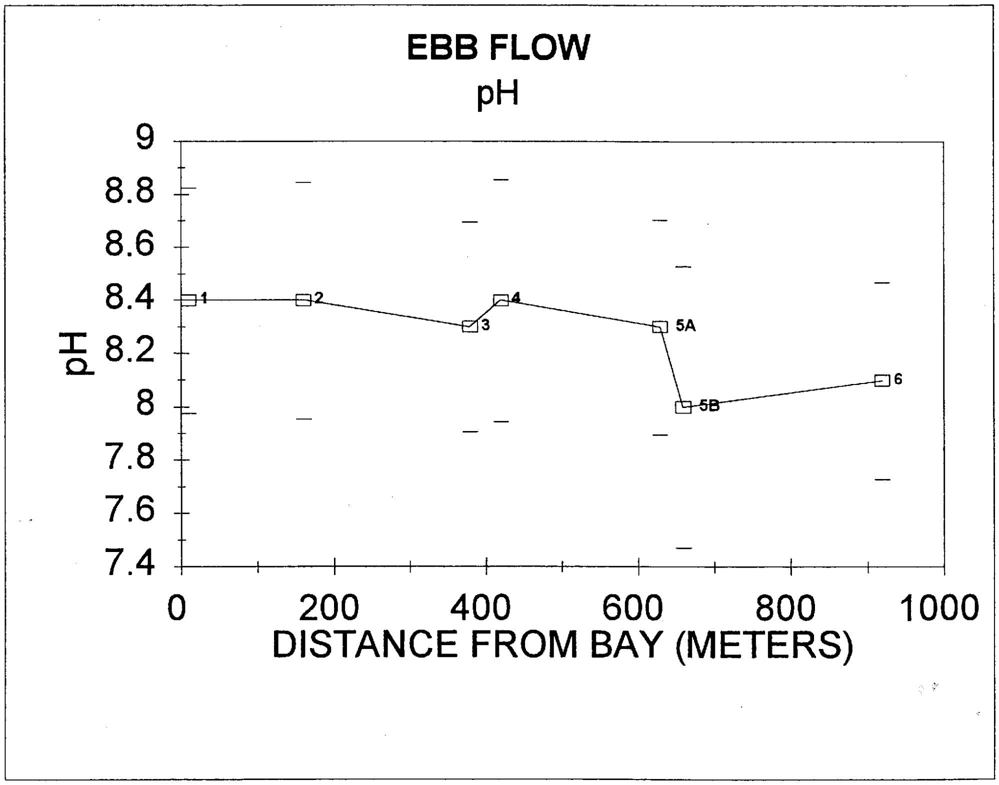

Figure 2-15. Mean water specific conductance at each station during the ebb flow monitoring. Error bars are plus and minus one standard deviation from the mean.

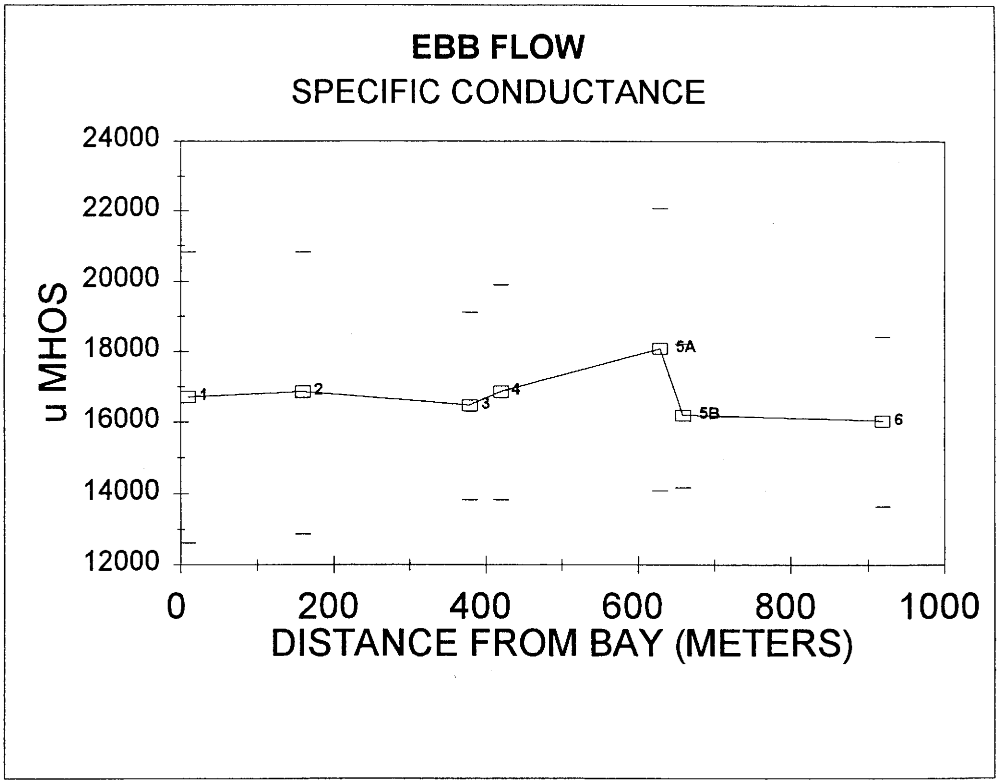

Figure 2-16. Mean water salinity at each station during the ebb flow monitoring. Error bars are plus and minus one standard deviation from the mean.

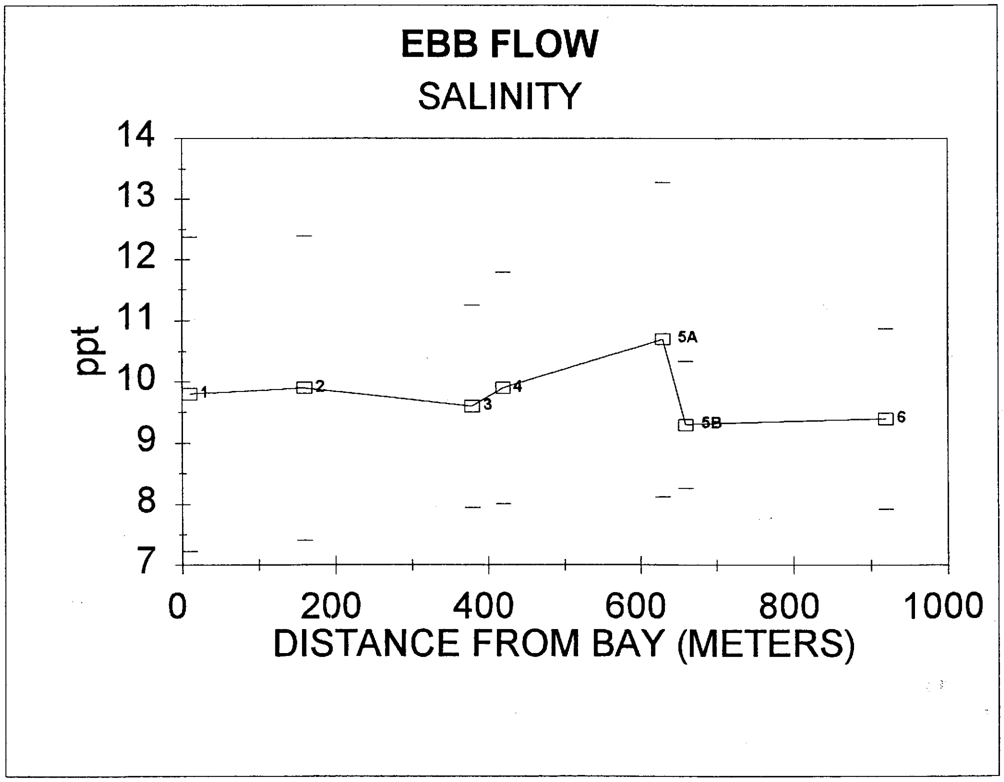

Figure 2-17. Mean water dissolved oxygen at each station during the ebb flow monitoring. Error bars are plus and minus one standard deviation from the mean.

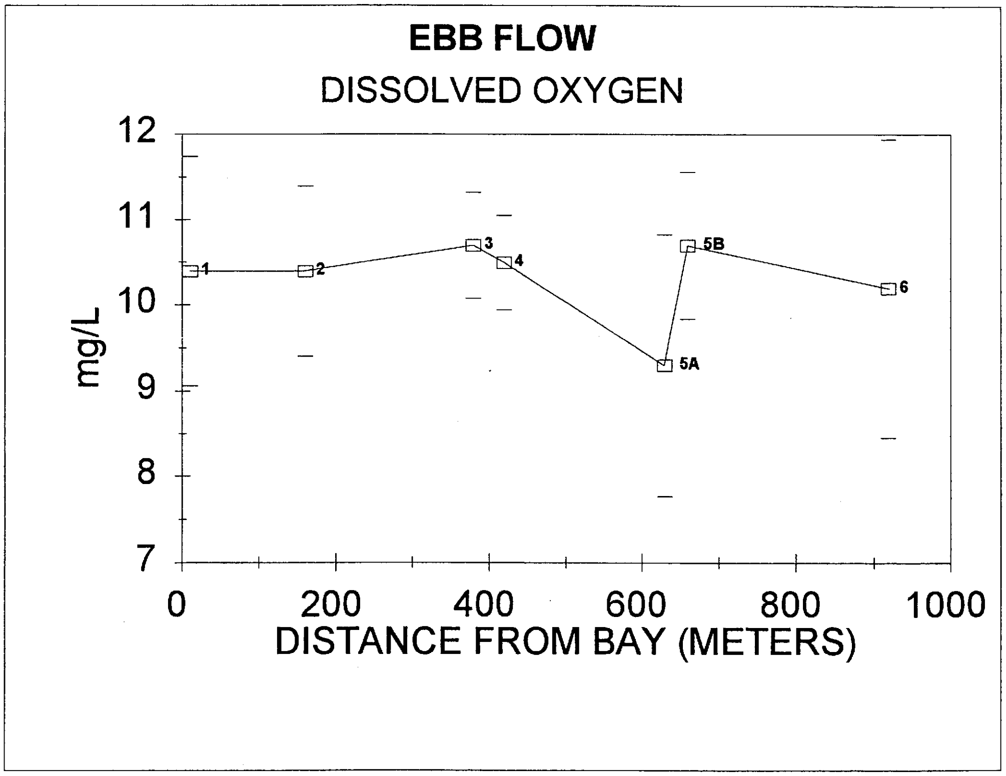

Figure 2-18. Mean water depth at each station during the ebb flow monitoring. Error bars are plus and minus one standard deviation from the mean.

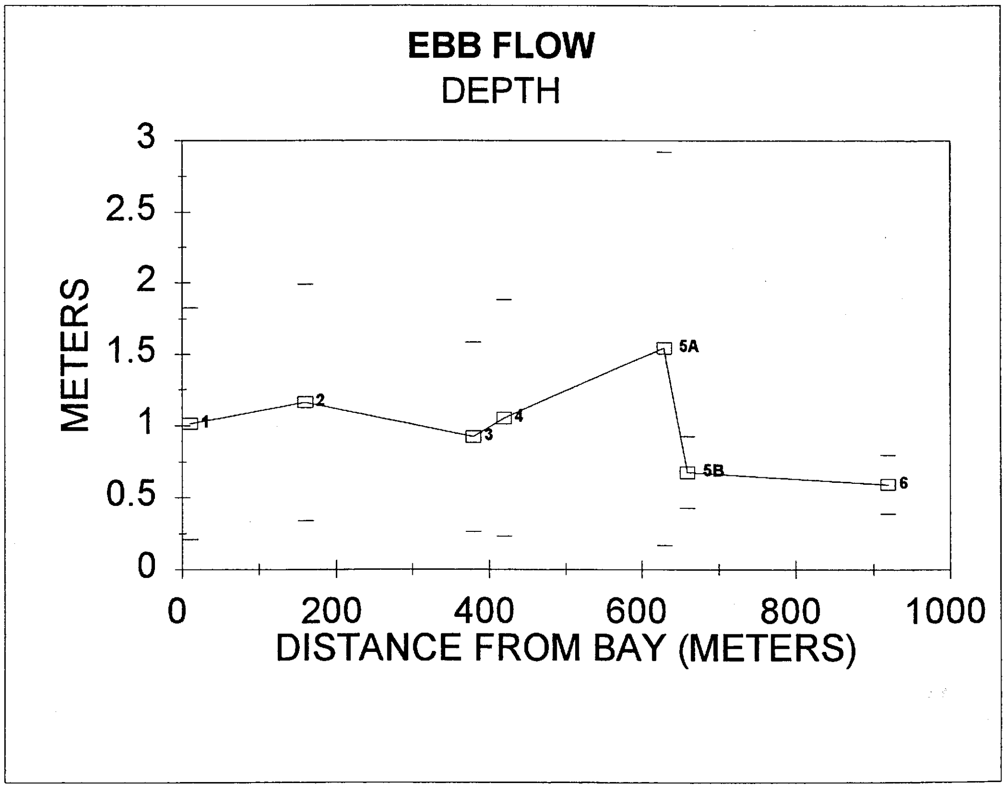

Figure 2-19. Mean water temperature at each station during the flood flow monitoring. Error bars are plus and minus one standard deviation from the mean.

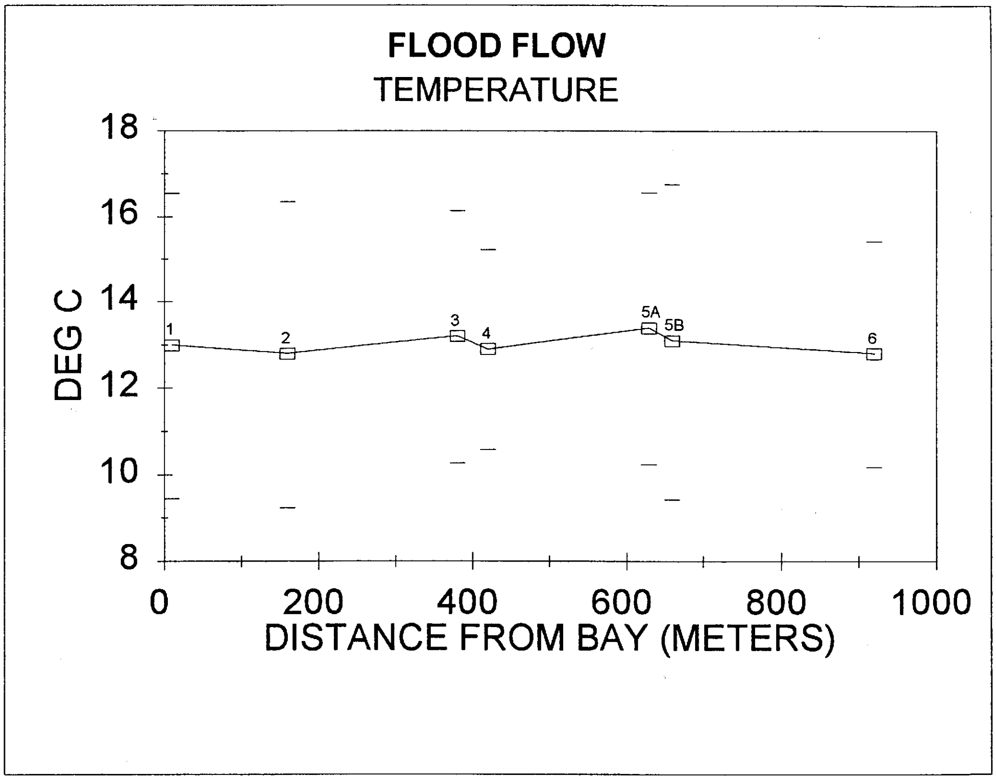

Figure 2-20. Mean water pH at each station during the flood flow monitoring. Error bars are plus and minus one standard deviation from the mean.

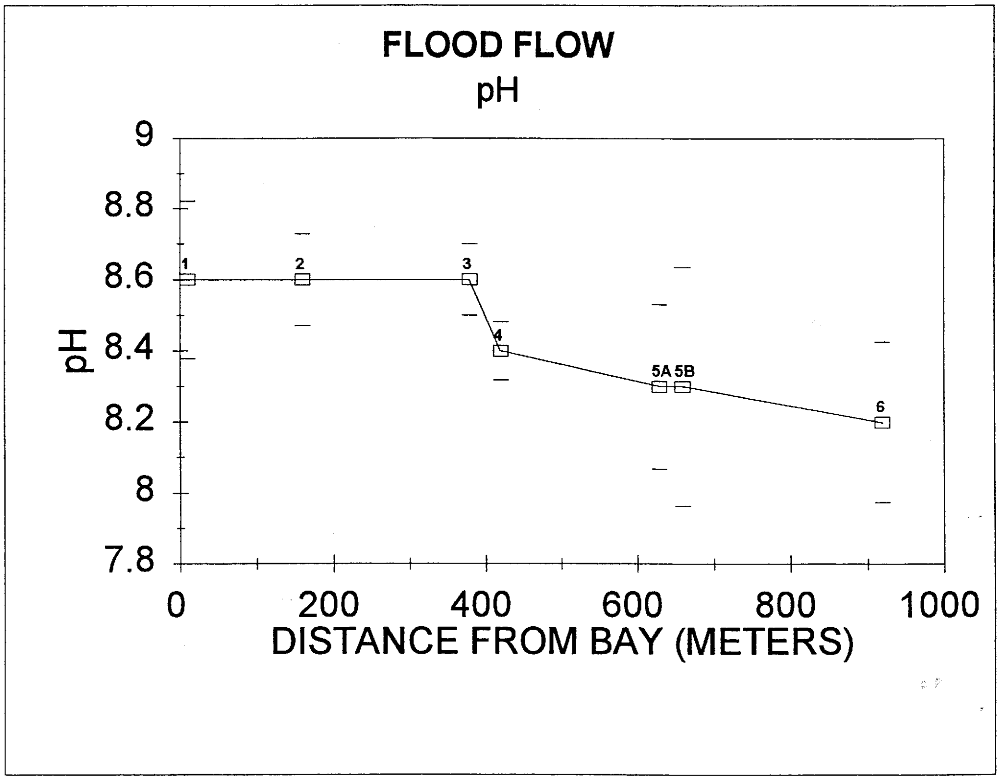

Figure 2-21. Mean water specific conductance at each station during the flood flow monitoring. Error bars are plus and minus one standard deviation from the mean.

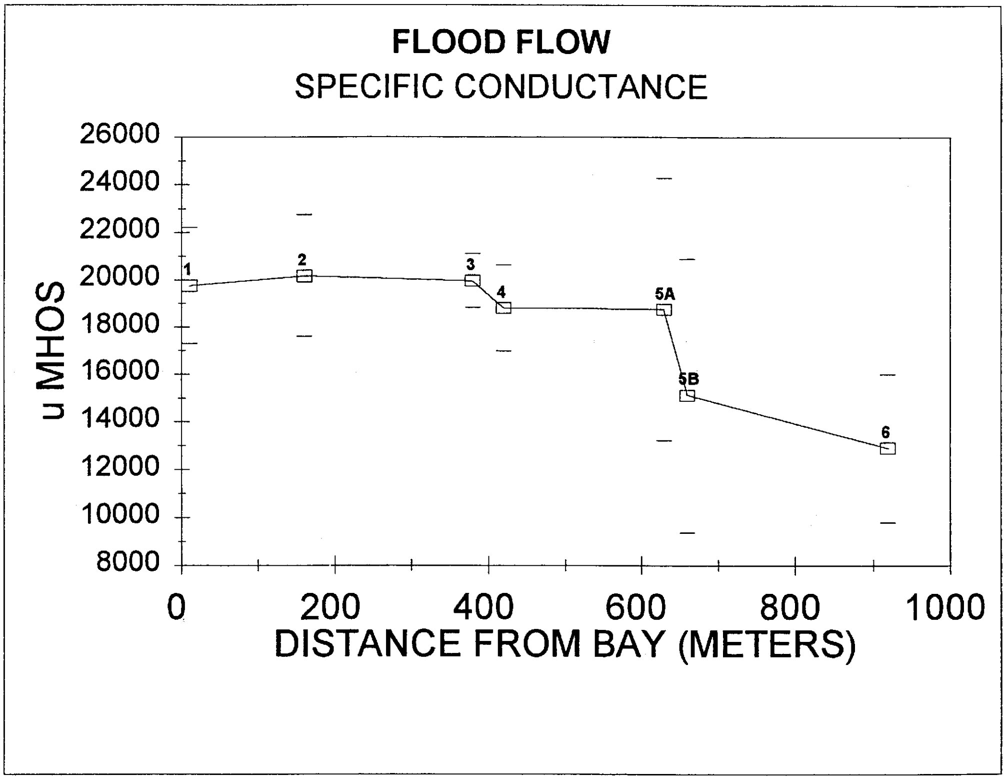

Figure 2-22. Mean water salinity at each station during the flood flow monitoring. Error bars are plus and minus one standard deviation from the mean.

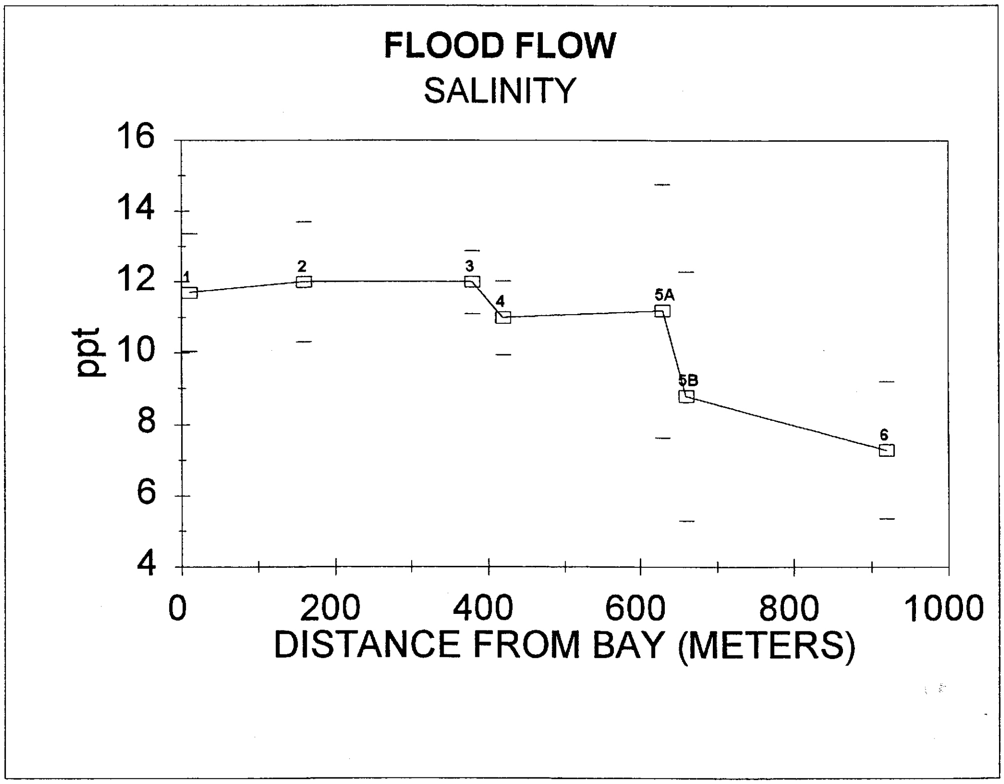

Figure 2-23. Mean water dissloved oxygen at each station during the flood flow monitoring. Error bars are plus and minus one standard deviation from the mean.

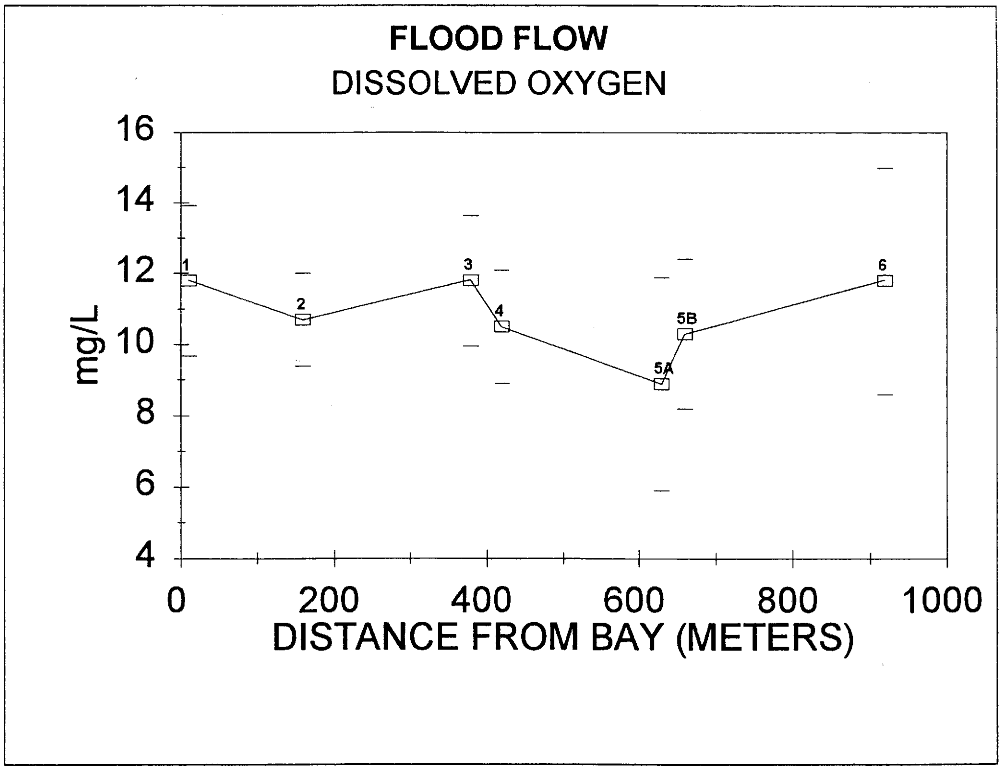

Figure 2-24. Mean water depth at each station during the flood flow monitoring. Error bars are plus and minus one standard deviation from the mean.

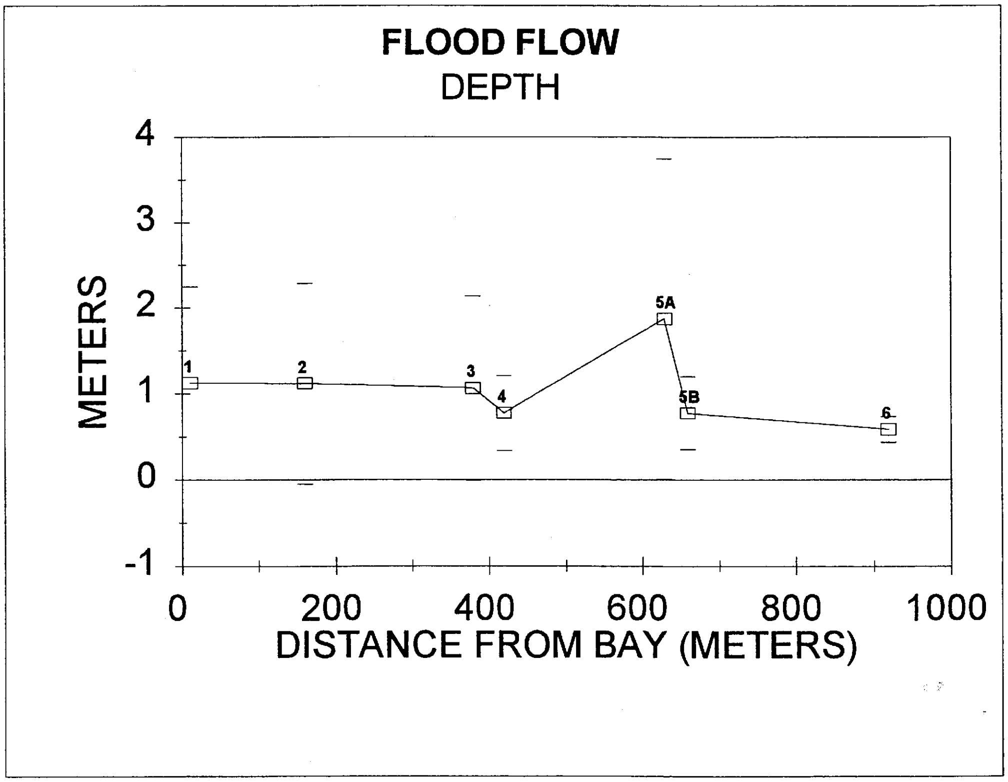

Figure 2-25. Maximum and minimum temperature readings at each station.

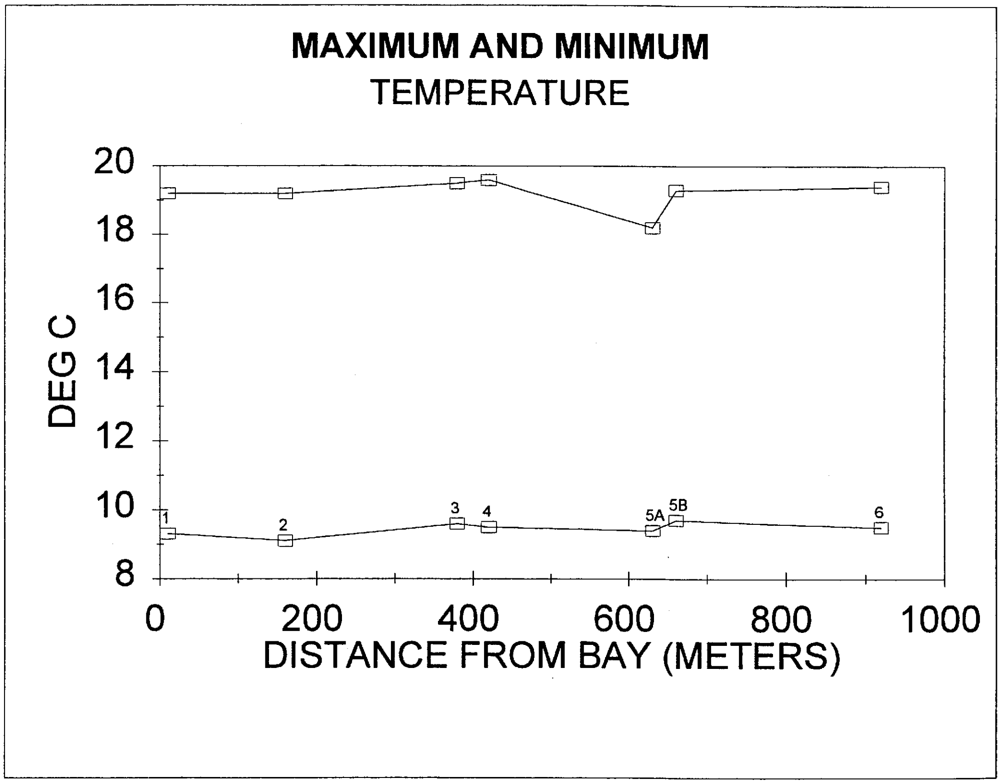

Figure 2-26. Maximum and minimum readings at each station.

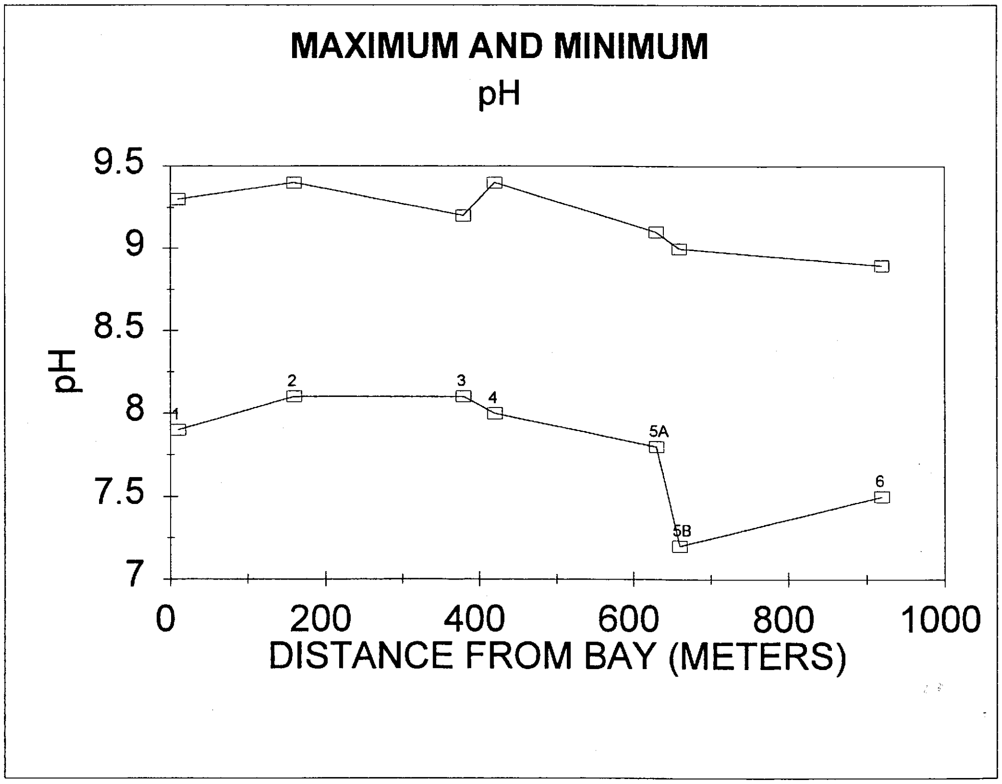

Figure 2-27. Maximum and minimum specific conductance readings at each station.

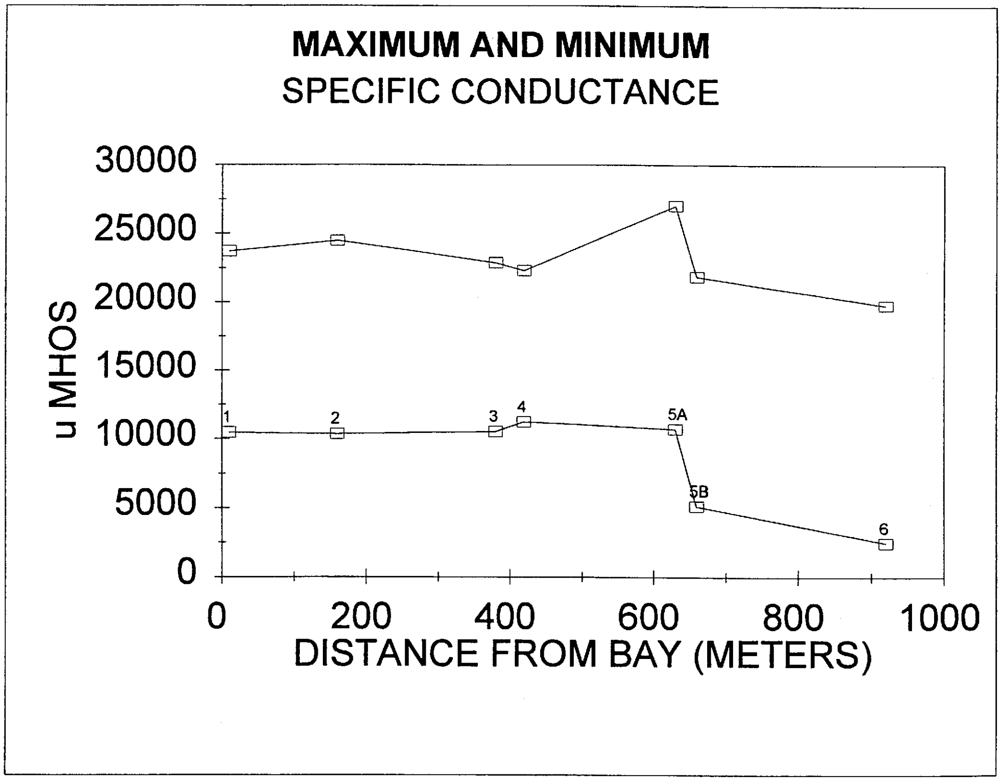

Figure 2-28. Maximum and minimum dissolved oxygen readings at each station.