1996 LONGFIN SMELT (*Spirinchus thaleichthys*) SPAWNING SURVEY IN THE CEDAR RIVER AND FOUR LAKE WASHINGTON TRIBUTARIES

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INTRODUCTION

The U.S. Army Corps of Engineers, Seattle District (Corps) and the City of Renton, Washington are conducting a cost-shared Section 205 flood control feasibility study to determine the feasibility of constructing a flood control project along the lowest mile of the Cedar River in Renton, Washington. Flood control options include dredging the lower mile of the river. Dredging may have adverse environmental impacts on smelt (*Spirinchus thaleichthys*) spawning habitat in the lower Cedar River and for this reason three years of studies were undertaken to determine the physical habitat preferences and requirements of spawning longfin smelt and survival of the eggs (Harza, 1994; Sibley & Brocksmith, 1996; this report).

Longfin smelt are typically anadromous; however, in Lake Washington they are landlocked (dwell only in freshwater). The only other known population of lake-dwelling longfin smelt occurs in Harrison Lake, BC. A river-dwelling population has been reported in the lower Fraser River, BC (Scott & Crossman, 1973). Moulton (1970) surveyed the Cedar River and eight other tributaries to Lake Washington: May, Coal, Juanita, Thornton, McAleer, Lyon, Swamp and Denny Creeks. He found smelt eggs present in the Cedar River, May, Coal and Juanita Creeks. He found 99.5% of the eggs in the Cedar River; however, much more sampling effort was directed towards the Cedar River than the other tributaries. Based on this work, the popular wisdom has been that greater than 90% of the smelt in Lake Washington spawn in the Cedar River.

The population of longfin smelt in Lake Washington was first identified in 1959 (Dryfoos, 1965). The population prior to that date was possibly very small and was not observed, considered too unimportant to mention, or it was introduced prior to the 1950s. Since that time, the population has increased dramatically to the point where today smelt are the most numerous pelagic fish species in Lake Washington (Chigbu, 1993). There is a large difference in abundance between the even year and odd year age classes, with the even year class approximately 1 order of magnitude greater in abundance. It is not known why there is such a difference, which was first documented by Moulton (1970). His review of Dryfoos (1965) data indicates that even in the early 1960s, the even year class was more abundant but a dramatic increase occurred in 1966 and 1968. Moulton speculated the increase may have been due to the diversion of sewage from the lake in 1963. Chigbu & Sibley (1994) theorized that the prevalence of deformities in odd year classes may have contributed to their low population size. It has also been speculated that the increase could have occurred due to dredging in the Cedar River which may have harmed the odd year class, but not the even year class. However, the only known dredging event during the 1960s occurred in 1962 and 1963. Moulton did not find that the odd year class declined, but that the even year class dramatically increased. It is equally possible that ideal spawning and incubation conditions occurred in the Cedar River in 1964 and/or 1966. Flow analysis by Chigbu (unpublished data) indicates that Cedar River flows during the smelt spawning season in odd years in the 1960s were significantly higher than during even years, which could have caused unusually high egg and larval mortalities.

Previous studies have been conducted during both "high" (even) and "low" (odd) smelt years. Moulton (1970) found smelt eggs distributed up to the "public highway" bridge (2000 meters from the mouth), but did not find any eggs further upstream (sampled during 1969 and 1970). Since Moulton's study (1970), no other sampling for smelt eggs was conducted until Harza Northwest[1] (1994) conducted limited sampling in the Cedar River on 14 and 15 April 1994. They sampled at several transects up to the I-405 bridge. No eggs were found above 1100 m from the mouth (just downstream of the south Boeing bridge). Sibley & Brocksmith (1996) sampled during the spring of 1995 and found smelt eggs concentrated in the 300-1200 meter distance from the Cedar River mouth, but two eggs and 8 larvae were captured above 1200 m at 1600 m and the I-405 bridge (approximate distance 2400 m from the mouth).

The purpose of this final year of study is to 1) further refine previously observed distribution of smelt spawning in the Cedar River in a high population year; 2) determine if smelt spawning occurs in the deeper water areas of the Cedar River mouth and delta; 3) determine the relative use of other tributaries by smelt; and 4) determine experimentally in the lab preferred spawning substrate.

METHODS

Sampling Area and Dates

Sampling was conducted from February 10 - May 20, 1996. The Cedar River and four smaller tributaries to Lake Washington were sampled; May, Coal, Juanita and McAleer Creeks. Table 1 shows the dates each creek was sampled. These creeks were sampled because May, Coal and Juanita all had had eggs previously found. McAleer Creek was sampled to determine if there was a north-end tributary with spawners. Initially, Thornton Creek was investigated for possible sampling in order to provide a second north-end tributary, however, the channel is heavily riprapped with large boulders and was nearly impossible to sample with a Surber sampler. Hence, it was not included in this study. Two Lake Washington beaches (see Figure) were sampled in February and March, but the effort was abandoned later in the study, due to lack of eggs and heavy algae growth.

Table 1. Sampling dates for each tributary sampled. Each sampling period began on the date indicated and sampling typically occurred over a two-day period.

DATE	McAleer	May	Coal	Juanita	Cedar R.	Delta	Lake
1/30/96		X		X			
2/5/96					X	X	X
2/16/96			X		X		
2/28/96	X	X	X	X	X	X	X
3/20/96	X	X	X	X	X	X	X
4/10/96	X	X	X	X	X	X	X
4/30/96	X	X	X	X	X	X	
5/15/96	X	X	X	X	X	X	

The level of Lake Washington is maintained by the Corps at 20 feet elevation mean sea level (MSL) during the winter for flood control and is refilled to 22 feet during the summer to provide

[1] Contractor hired by City of Renton during the reconnaissance phase of the Cedar River 205 Study.

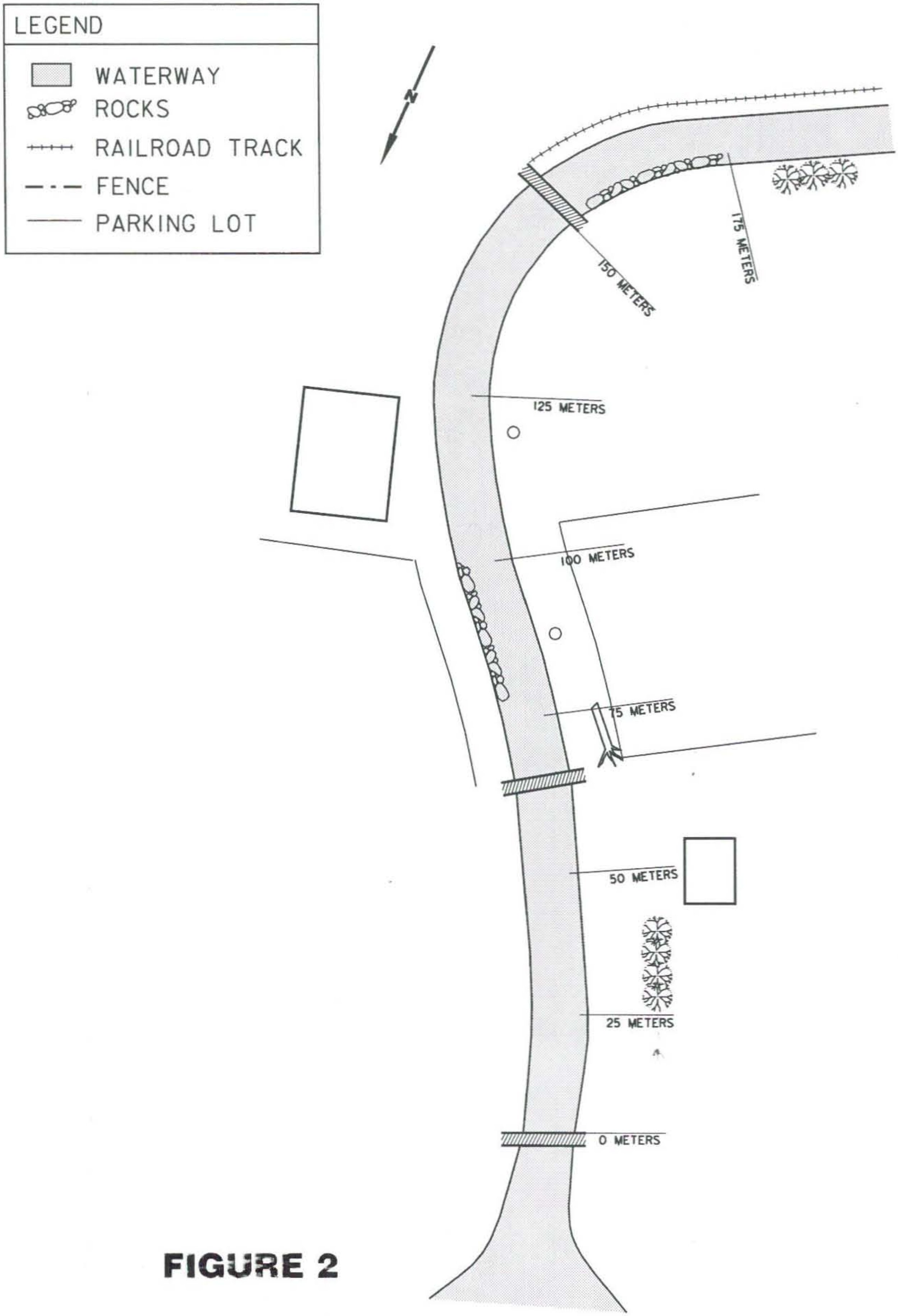

FIGURE 2

MAY CREEK – 1996 SMELT STUDY

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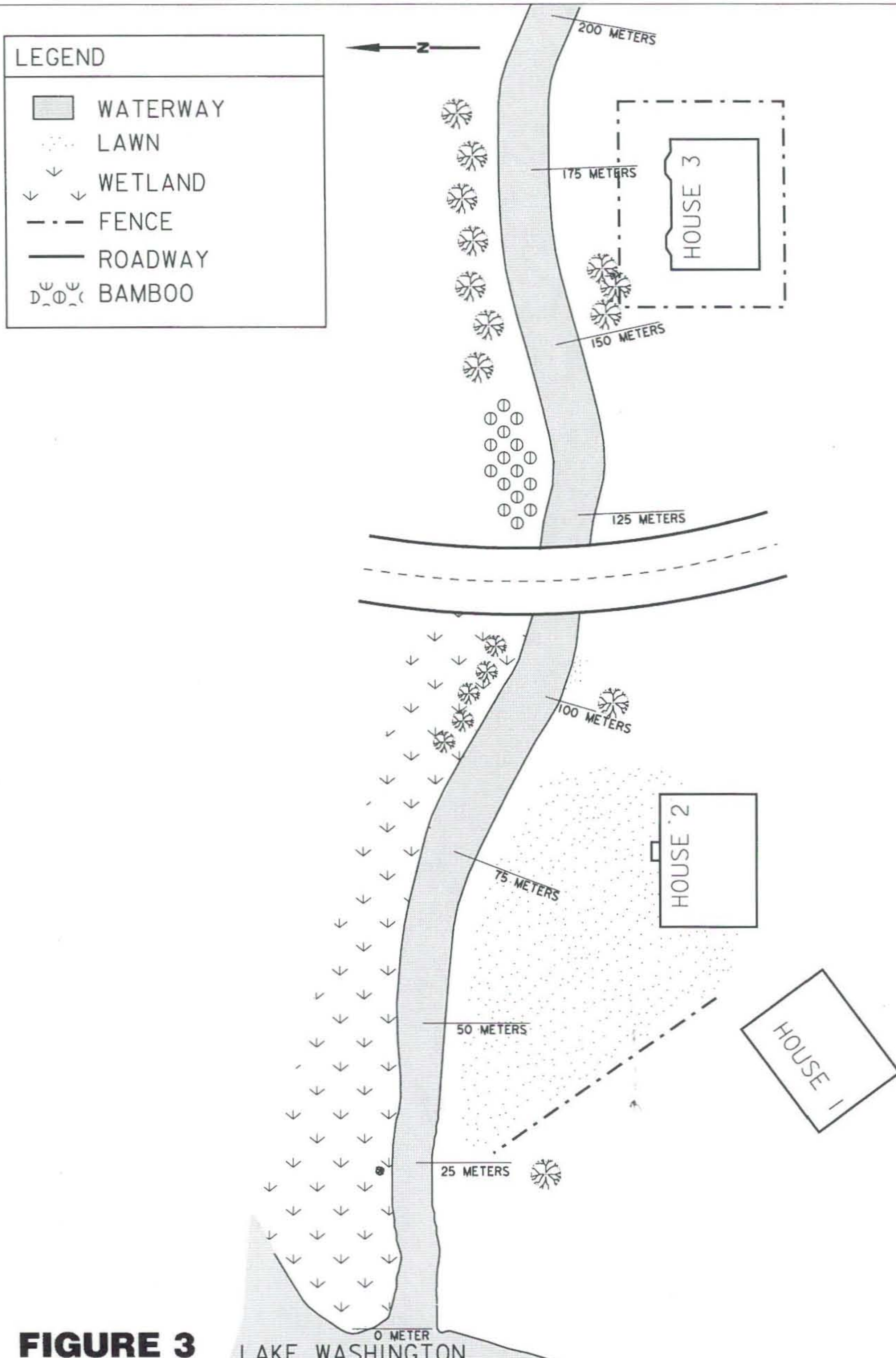

FIGURE 3

COAL CREEK – 1996 SMELT STUDY

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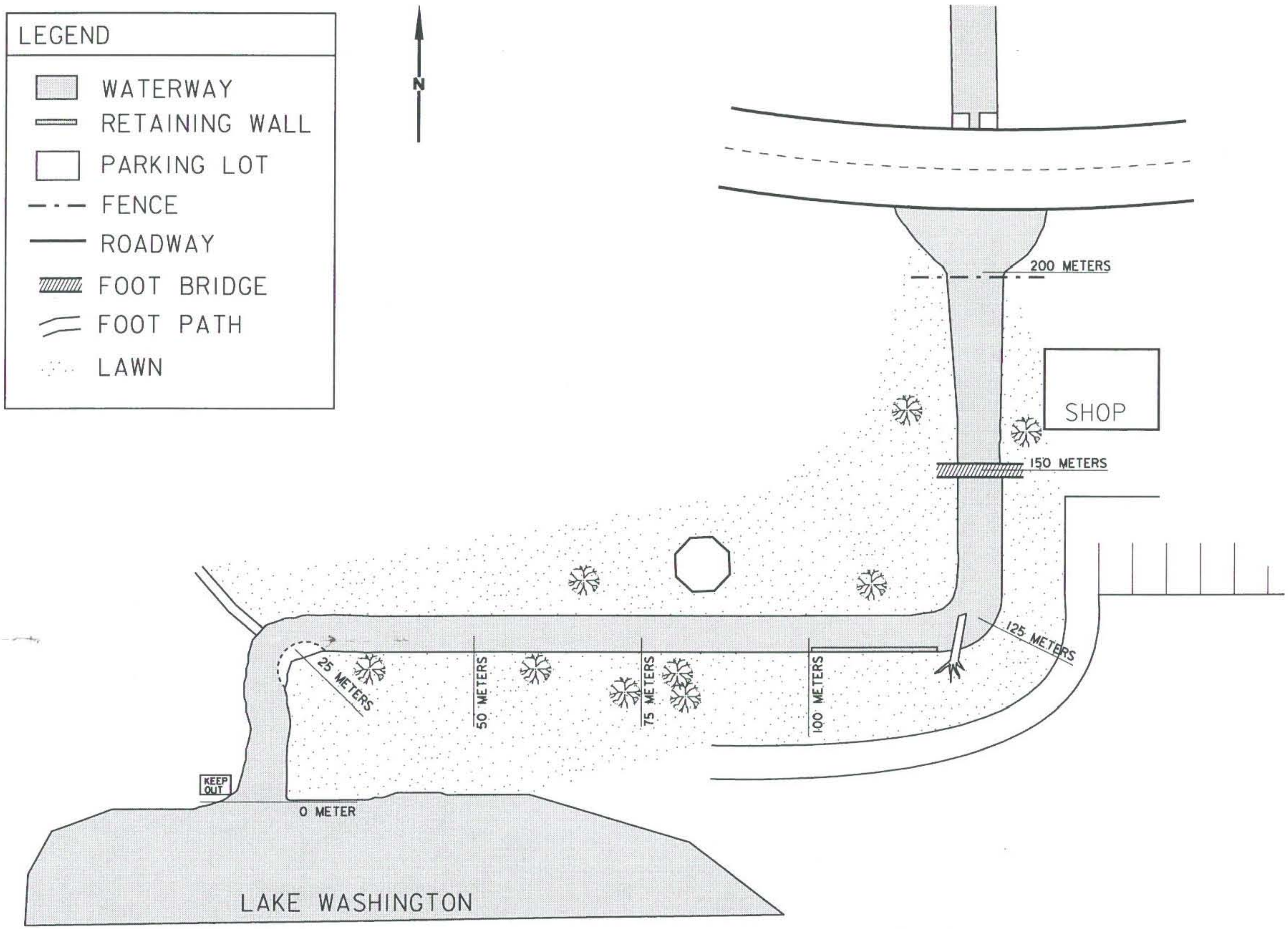

FIGURE 4 JUANITA CREEK – 1996 SMELT STUDY

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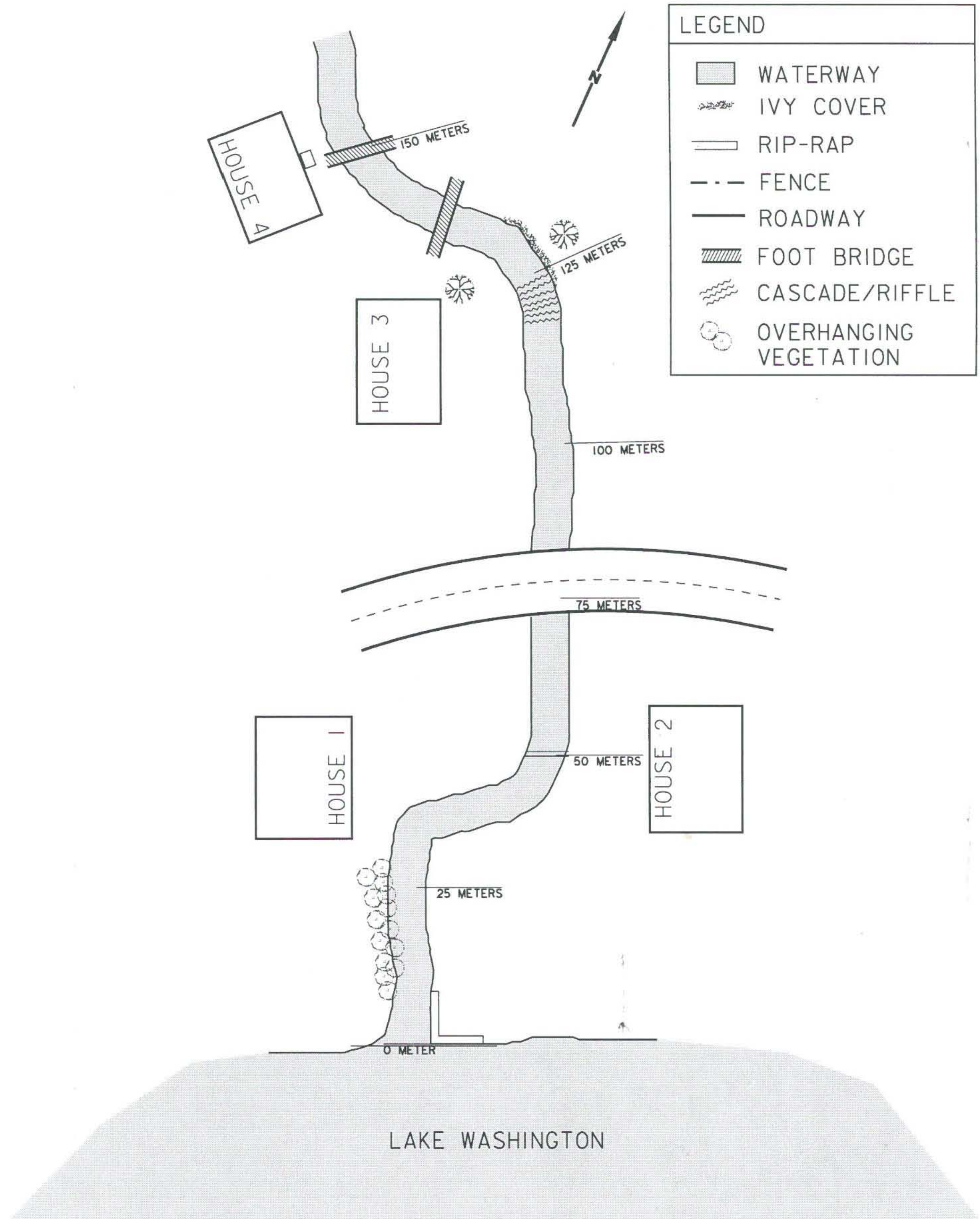

FIGURE 5

McALEER CREEK – 1996 SMELT STUDY

NOT TO SCALE

sufficient water for operation of the locks and fish ladder. Refill begins on February 15 and full pool is reached generally in the first week of May. The rising level of Lake Washington caused the mouths of the Cedar River, Juanita Creek and McAleer Creek to become inundated by the lake backwater and subsequently created difficulties for sampling. The depths increased dramatically and the substrate became significantly muddier in these locations due to the lack of normal stream velocities.

Cedar River.
The Cedar River was sampled every 300 m, starting at the north Boeing bridge at the mouth up to 1800 m (see Figure 1). This sampling scheme replicates several of the sites sampled by Sibley & Brocksmith (1996) with additional evenly spaced sites upstream. Additional samples were collected on the delta in Lake Washington and at the Renton Community Center (approximately 2400 m upstream from the mouth). Flows in the Cedar River ranged from 394-1830 cubic feet per second (cfs) (11-51 cubic meters per second) during days sampled. A flood of 8100 cfs (226.8 cms) occurred on the Cedar River on February 8 and 9, after the initial sampling conducted on February 5, 1996. During the month of February, flows were generally too high in the Cedar River to sample all reference points.

The substrate at the sites was visually estimated and varied from large gravels and cobbles to small gravel and finally sands at the mouth and on the delta. The substrate changed over the course of the study, however, because the high flows in February carried large gravels through the entire lower mile and out onto the delta. Subsequent lower flows deposited progressively finer materials towards the mouth. Low velocity areas where there are backwater pools typically had silt substrate. Sediment samples in 1994 (Corps) ranged from 15-93% fine material (less than 0.85mm) throughout the lower mile. During the latter half of the study, the lake backwater extended 300-400 meters upstream of the mouth. Banks are armored on both sides throughout most of the project area. Very little overhanging vegetation exists and is generally non-native. Gravel bars extend over significant portions of the channel along portions of the study length. Some woody debris and side channels exist, mostly small. The delta has numerous large logs and other woody debris

May Creek. (See Figure 2) May Creek was sampled from the first bridge (mouth and delta approximately 20 meters further downstream) up to 200 meters at 50 m intervals. This entire reach is within the Barbee Mills property in Kennydale. Large gravels exist throughout its length. The banks are armored and there is no riparian woody vegetation (except willow cuttings had been recently planted along the banks). Several bridges cross the creek for mill traffic purposes. The mouth of May Creek did not become inundated with the Lake Washington summer pool raise and moderate stream velocities were maintained throughout the study.

Coal Creek. (See Figure 3) Coal Creek was sampled from the mouth up to 200 meters at 50 m intervals. The entire reach is in a residential neighborhood near Lake Washington. King County has created a buffer zone for the entire length of Coal Creek and hence the riparian vegetation was largely intact. Fine gravel and coarse sands were the typical substrate over most of the reach, with some larger gravels at 200 m and above. As its name implies many pieces of coal are evident in the streambed. An undeveloped wetland extends along the right bank from the first road bridge (approx. 100 m) to the creek mouth. The mouth of Coal Creek did not become inundated with the Lake Washington summer pool raise and moderate stream velocities were maintained throughout the study.

Juanita Creek. (See Figure 4) Juanita Creek was sampled from the mouth up to 200 meters at 50 m intervals. These lowest 200 m are in Juanita Beach Park and very low gradient. Upstream of the park the creek goes into a large box culvert under a major road. A large pool exists downstream of the box culvert created by a small rock weir. The water became deep over the sampling season, up to 100 m because of the backwater from the Lake Washington summer pool raise. Large amounts of organic debris settles in the first 100 m. The sides are mostly armored and steep and little riparian vegetation exists. The park is maintained for lawn and playgrounds and native woody vegetation has largely been removed. The upper 100 m has a small gravel substrate.

McAleer Creek. (See Figure 5) McAleer was sampled from the mouth up to 150 meters at 50 m intervals. This lowest reach passes through a residential neighborhood with large lots. Native and non-native shrubs and trees line the banks. One pool exists at about 100 m from the mouth. The waters are deep below 100 m from the Lake Washington summer pool raise. The banks are mostly armored with riprap or concrete bulkheads.

Sampling Procedures

A 0.1 m^2 Surber net, with 0.75 mm mesh, was used to collect the samples in the Cedar River and tributaries (egg size is approximately 1 mm). A 0.025 m^3 Van Veen grab was used at 0 m in the Cedar and on the delta because the sites were too deep (>1 m) to use the surber net. Three Van Veen samples were combined at each location to approximate the surber net surface area sample. Figures 6 and 7 show diagrams of the surber net and Van Veen grab.

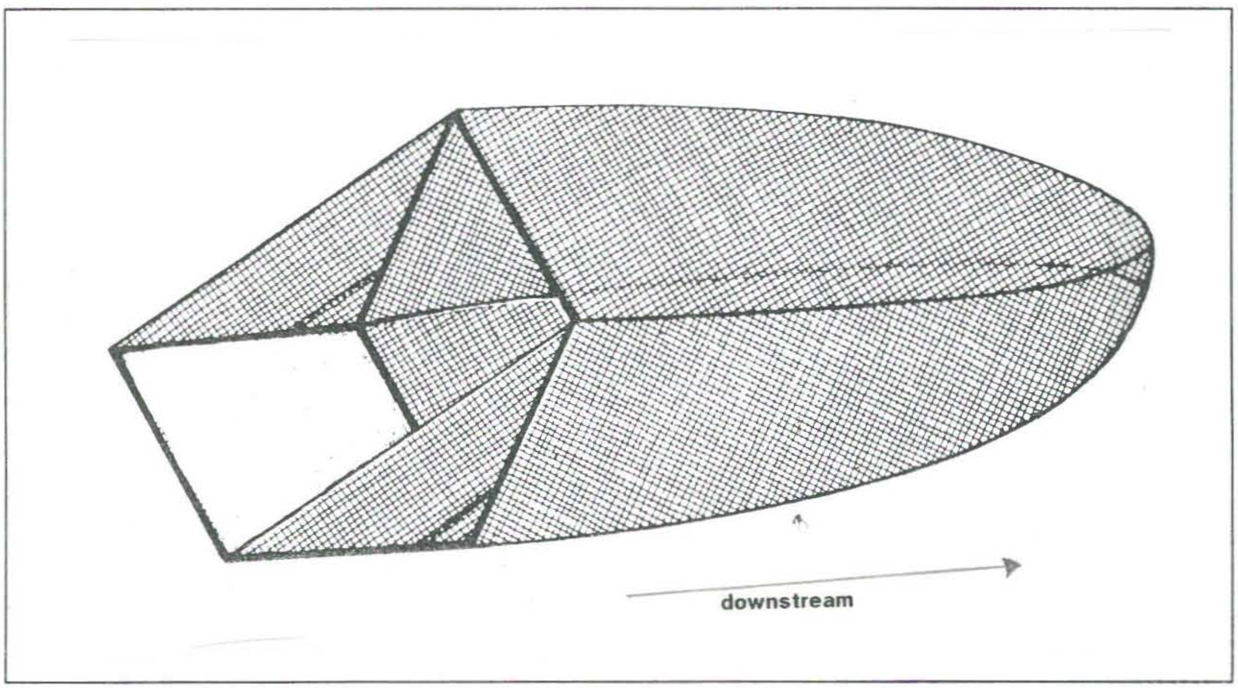

Figure 6. Diagram of a surber sampling net.

The proposed protocol was to sample at 3 locations across the channel at each 300 meter transect (in the Cedar River), however, less than 3 samples were taken during high flow days when the current was too high to sample all the way across the channel. One sample was typically taken near the right bank, one near the center of the channel and one near the left bank. This distribution of samples produced a range of velocities, depths and substrates. surber samples were not taken in areas too deep to sample (maximum depth 1 m). One sample was taken at each transect in the other tributaries. The substrate was stirred and scrubbed to a depth of 5 cm by hand or stick (if >0.6 m) for 1-2 minutes to release the eggs from the sediments into the surber net. Occasionally, the sediment would consist of many large rocks. Rocks larger than 5 mm were scrubbed for eggs and discarded. A small mesh (<0.5mm) aquarium net was placed behind the surber net to capture eggs that might pass through the mesh in high velocity areas.

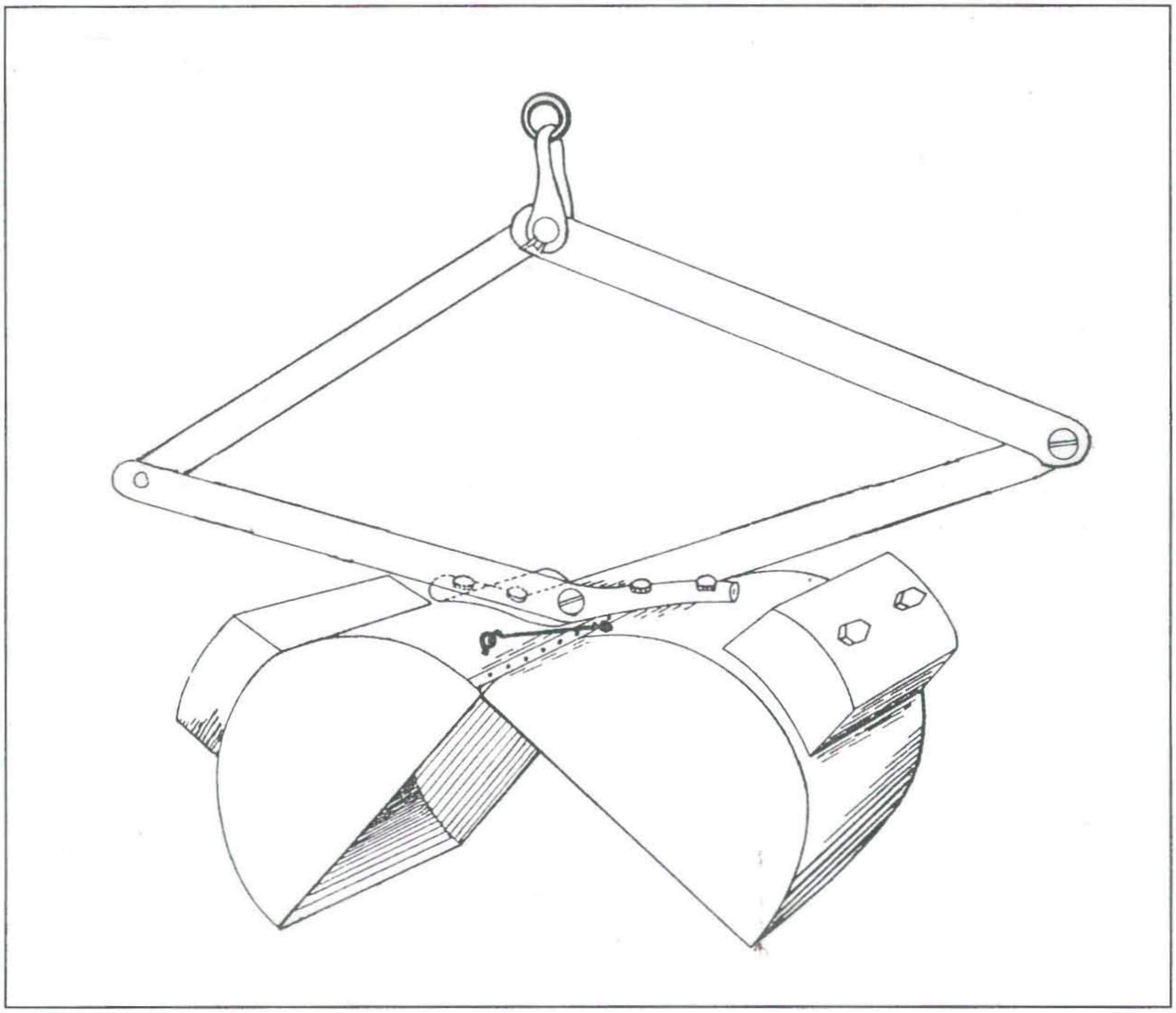

Figure 7. Diagram of a Van Veen grab in the open position.

In the majority of cases, no eggs were found in the aquarium net. Eggs were found to stay generally within the plastic mesh of the surber net. Samples were poured into plastic bottles, labeled and preserved in a 5% formalin solution. Water remaining in the sample that may have diluted the formalin solution was drained off, checked for eggs and discarded, prior to preservation.

Three 0.09 m^2 drift nets (mesh size 0.5 mm) were utilized to sample for the possibility of drifting smelt eggs (see Figure 8 for diagram of the drift nets used). During the sampling periods in March, April and May, one drift net was placed at 300 m, 900 m and 1800 m from the mouth of the Cedar River for one hour. The drift nets were held in place by rebar posts at the bottom of the river. The samples were collected and preserved in formalin similar to the other samples. The volumes of water strained by the drift nets were different at the three locations because the water velocities were different. However, the drift net catch gives information on the presence or absence of eggs and larvae drifting in the system.

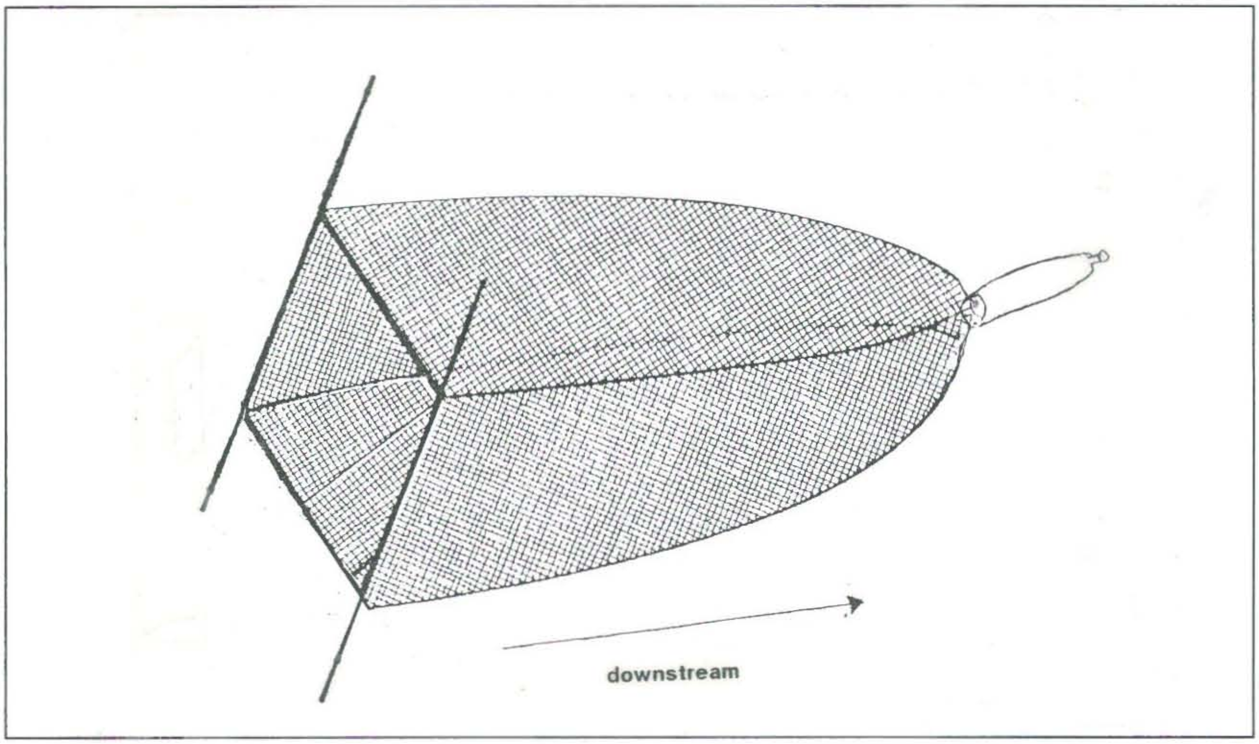

Figure 8. Diagram of a drift net, with collection bottle, placed on rebar posts.

An 0.09 m^2 plastic furnace filter (artificial substrate) was placed in each of the tributaries during February and March to further supplement surber sampling. These artificial substrates were experimented with to ensure we were not missing eggs that we were unable to capture in the surber net. They were placed at 50 m from the mouth and collected at the next sampling period (approximate time in water 1 month). The filters were anchored to the substrate by rebar bent into a "U" shape. The filters were then shaken into the surber net and the contents collected and processed. This sampling method was not continued after March due to the large volumes of sediment and organic material trapped by the filters that hindered egg analysis.

Samples were analyzed to determine number of eggs present and if they were alive or dead. A Bausch and Lomb zoom dissecting scope was used for egg counting. Egg samples were statistically analyzed by using a Spearman's rank correlation to correlate egg abundance with depth, velocity, substrate size and distance upstream from the mouth of each stream. A Spearman's correlation was used because egg abundance was not normally distributed (many zero values). In order to conduct the analyses, substrate size was assigned a number from 1-5 for the correlation calculations, with silt=1, sand=2, mixed sand/gravel=3, small gravel=4, and large gravel=5. The transects were also assigned a number from 1-9 (1=delta, 9=Carko).

Physico-chemical Measurements

Depth and velocity were measured at each surber and Van Veen sample location. Substrate size was determined by visual observation during sampling at each site. Distance from the right or left bank was measured to each sampling location.

A Hydrolab Data Sonde 3© was placed at the mouth of the Cedar River on the left Boeing bridge abutment from February 5 - June 15, 1996 to measure temperature, pH, and dissolved oxygen. Unfortunately, due to battery malfunction data was only collected during from February 7 through April 7. Flow information for the Cedar River was obtained from the U.S. Geological Survey.

Spawning in Artificial Streams

In addition to the in situ sampling of eggs, adult smelt were collected at the Cedar River as they ascended the river to spawn on the nights of March 26 and 27. Small aquarium dip nets (0.5mm mesh) and longhandled aquaculture nets (6 mm mesh) were used to capture smelt in shallow water. Approximately 40 adults were taken by drift net and transported to the UW Fisheries hatchery area where two 2'HX3'WX10'L raceways were set up pumping Lake Washington water continuously through them. The water depth was 18 inches in both raceways and the water flow was maintained at approximately 6 gallons/minute. The velocity in the raceways could not be measured because there were some swirling currents. Overall, the velocity was very low. The raceways were tilted slightly, to allow better flow-through, at approximately a 0.4% slope.

Sediments from the Cedar River had been placed in the raceways with half the trough (5' long) with large/small gravel mixed and the other half sand (see Figure 9). 16 adult smelt were placed in each of two raceways (8 males/8 females) and monitored periodically until the majority had either spawned or died (approximately 5 days). 9 egg samples were taken in each raceway in each type of sediment (total of 36 samples). These samples were preserved and analyzed as described above. This experiment was repeated on April 10, with adult smelt captured at the WDFW fry trap. 14 fish were placed in each of the raceways at UW (7 males/7 females) and in approximately 5 days, 36 egg samples were again taken with 9 samples in each raceway in each type of sediment.

RESULTS

Occurrence of Eggs

All sampling methods (Surber, Van Veen, drift nets, artificial substrates) were very successful at collecting smelt eggs under a variety of velocities and depths. Eggs were found in all of the tributaries sampled and in the Cedar River (see Appendix Table). No eggs were found at the Lake Washington beaches. A total of 6670 eggs were collected in the Cedar River and 167 eggs were collected on the delta; approximately 91% of all eggs collected. 42 eggs were

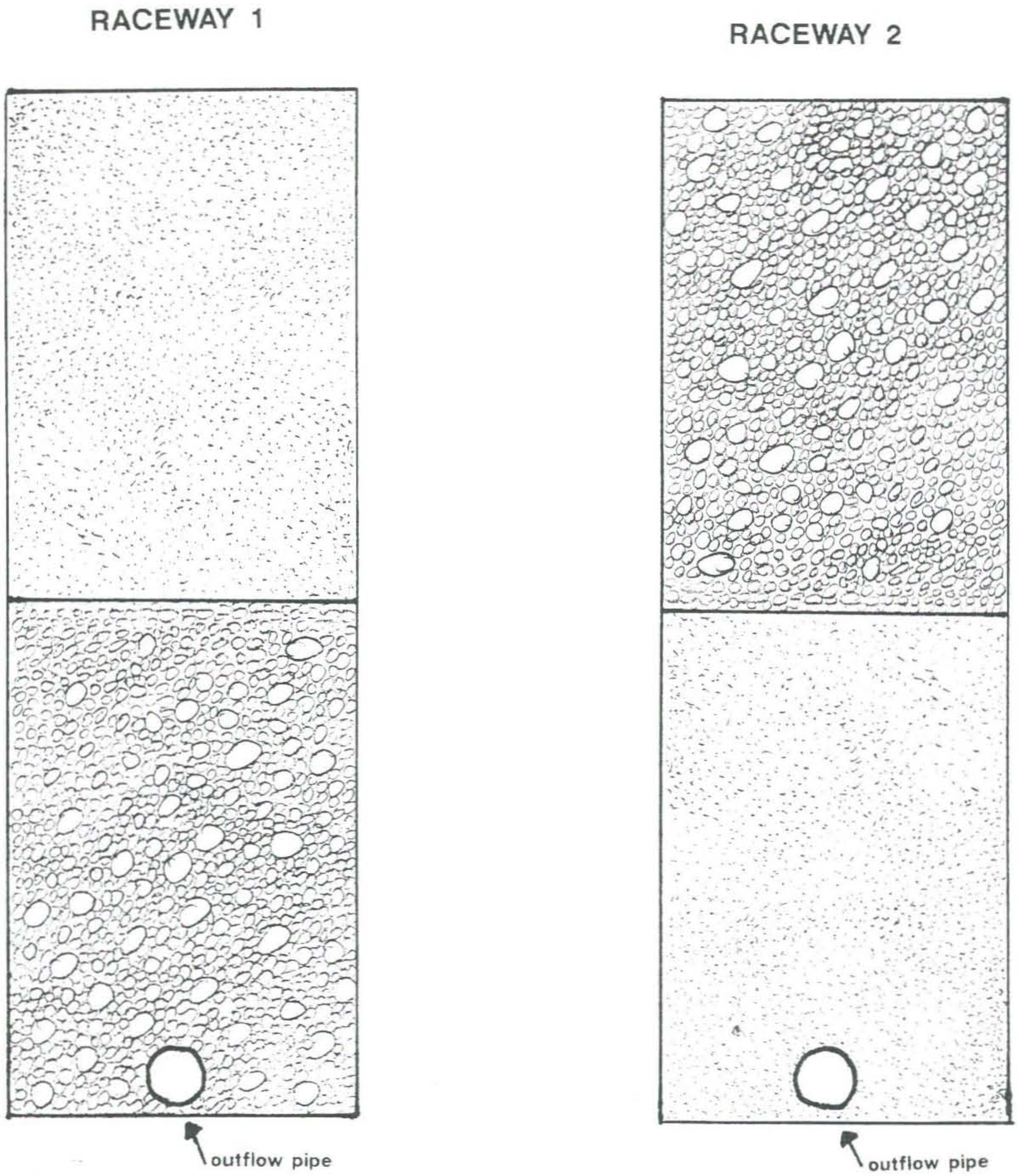

Figure 9. Artificial streams, as viewed from above, with sand substrate and mixed gravel substrate in opposite halves of each raceway.

collected in May Creek, 492 in Coal Creek, 77 in Juanita Creek and 38 in McAleer Creek. Eggs were found in Juanita Creek at the earliest sampling period, January 30,1996. No eggs were found in the other small tributaries until the March 20 sampling. Eggs were collected in the Cedar River samples during all sampling periods, with the largest number collected during the 1 May sampling (n=2146). However, this number was skewed by the large number of eggs collected at 0 meters (n=1827). The eggs collected in May were typically "eyed" so it is likely they were spawned in April.

The vast majority of eggs collected in the Cedar River were collected from the mouth to 900 meters (99%). Only 5 eggs were collected upstream of 900. Figure 10, below, shows the cumulative percent of eggs (during all months) sampled from the delta (-50 m) to 2600 m upstream. Ninety-nine percent of all eggs collected were at or below 900 m. A significant number of eggs (n=237) were collected by drift net located at the 900 meter transect, which indicates that at least 4% of all eggs collected were spawned above 900 meters and drifted downstream. A significant number of drifting eggs were also captured at 300 meters (n=302) as well. No eggs were captured by drift net at 1800 meters. It is likely that up to 10% of the run may spawn above 900 meters but their eggs drift downstream to slower velocity areas.

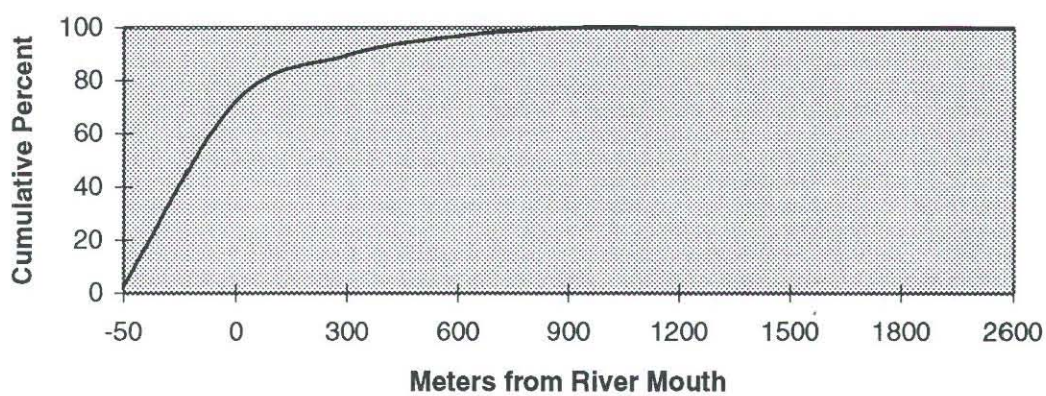

Figure 10. Cumulative percent of smelt eggs collected at each transect from the delta (-50 meters) to above the I-405 bridge.

Relationships Between Egg Abundance and Depth, Substrate Size, Velocity and Distance Upstream

Spearman rank correlations were calculated on egg abundance vs. depth, substrate, velocity and transect number (distance from mouth). Cedar River samples were analyzed separately from the tributaries because the tributary samples had very few eggs. Only Cedar River transects with at least one egg found during the sampling season were included in the analyses (1800 m and 2600 m transects were dropped). Table 1 shows correlation coefficients for the Cedar comparisons; one set with the delta samples included and one set without the delta samples. Egg abundance was significantly negatively correlated with substrate, velocity and distance from the river mouth. A weak positive correlation was found for depth.

Table 1. Spearman rank correlation coefficients (rho) for smelt egg abundance versus depth, substrate, velocity and transect # in the Cedar River and tributaries, with and without delta samples included. Raw data from 1994 and 1995 sampling was also analyzed and correlation coefficients are given. Last row is correlation coefficients for all Cedar River data from 1994-1996 combined (Harza, 1994; Sibley & Brocksmith, 1996). Values in bold are significant correlations.

Data Set	Depth	Substrate	Velocity	Transect #
delta-1500 m	0.2142	**-0.4743**	**-0.4017**	**-0.4066**
0-1500 m	**0.3298**	**-0.5194**	**-0.5427**	**-0.6514**
delta only	-0.2636	-0.2256	-0.0378	NA
other tributaries	0.0446	**-0.2993**	**-0.2864**	-0.1529
1994 Cedar[a]	**-0.5678**	**-0.6873**	**-0.4665**	**-0.9266**
1995 Cedar[b]	0.1943	NA	**-0.4647**	**-0.6029**
1994-1996 comb	0.0657	NA	**-0.4367**	**-0.5763**

a. From Harza (1994).
b. From Sibley & Brocksmith (1996).

Spearman rank correlation coefficients were also calculated for the raw data from 1994 (Harza, 1994) and 1995 (Sibley & Brocksmith, 1996) and then the combined data from 1994-1996 egg sampling (Table 1). A correlation coefficient was not calculated for substrate for the 1995 data because of so many mising values. Significant negative correlations were obtained for velocity and transect. Strong negative correlations were found with depth and substrate in Harza's (1994) data, which is not found in the 1995 (Sibley & Brocksmith, 1996) data. Harza only sampled depths less than 0.75 m.

The eggs were frequently adhered to sand grains (see photos in Figure 10). In the artificial spawning experiments at UW, significantly more eggs were collected in the sand substrates than the gravel substrates. A Kruskal-Wallis nonparametric analysis of variance was conducted on the mean number of eggs in each type of substrate and the result was a significant difference between substrate types (see Table 2). The Spearman rank correlation coefficient for eggs vs. substrate type in the UW experiments was -0.5333, which was highly significant. Significantly more eggs were found in the finer substrate, sand.

Table 2. Kruskal-Wallis Analysis of Variance (ANOVA) table for gravel versus sand substrate in the UW artificial stream experiment.

Source	DF	SS	MS	F	P
Between	1	5614.37	5614.37	56.36	0.0000
Within	48	4781.63	99.6174		
Total	49	10396.0			

<u>Adult Collection and Observations on Nighttime Distribution.</u>

The flow at the Cedar River on the collection day was approximately 400 cfs. Under these conditions it was found that most of the smelt were located along the sides of the river and associated with cover. This was also the case with electrofishing done earlier in the month (R. Tabor, USFWS, pers. comm.). However, smelt were found all across the channel during the night we collected with dip nets and they effectively swam upstream, evading our nets. The night we collected with dip nets and they effectively swam upstream, evading our nets. The defense mechanism for these fish seemed to be to swim upstream, dart erratically, and most often, turn downstream and use the current to help avoid the nets. The most efficient technique was to slowly place the net near the fish from the side and make a quick scooping motion. Quick motions from behind, or too far away and stabbing at the fish with the net from above did not work well. Most of the fish caught early in the night were males, as reported by Moulton (1970), with the females ascending after 2200 hours. Fyke nets proved unsuccessful at capturing smelt on the Cedar River delta, likely because the delta covers such a large area that the smelt easily avoided the net.

The adult smelt in the artificial streams were not monitored for prolonged periods. However, whenever they were observed, they were all swimming/resting above the sand substrate pointed into the current.

DISCUSSION

This study was the first to document the presence of smelt eggs in a north-end tributary to Lake Washington; McAleer Creek. The abundance was low, but comparable to the other small tributaries; May, Coal and Juanita Creeks. The presence of spawning smelt so distant from the Cedar River suggests that previous findings of smelt in the other tributaries nearer the Cedar River did not represent straying, but rather distinct spawning populations. Ripe smelt were also captured, in spring, 1996, near the mouth of the Sammamish Slough (E. Warner, MIT, pers. comm.) which may indicate that other northern tributaries have spawning populations. However, compared to the high abundances of spawning smelt and eggs in the Cedar River, these other tributary spawners represent at most 10% of the Lake Washington longfin smelt population.

Smelt eggs were collected from areas with gravel, sand or mixed substrate. However, significant negative correlations were observed between egg abundance and substrate size. Studies conducted by several workers on *Osmerus* sp. (Langlois, 1935; Ivanova & Palovkova, 1972; MacCrimmon et al., 1983; Dudnik & Shchukina, 1990) suggest that smelt spawn on a variety of substrate types such as sand, gravel, stones, vegetation and mixed substrates. Ivanova & Polovkova (1972) studied landlocked *Osmerus eperlanus* and found these smelt to prefer to spawn in both the lake and its tributaries in sand or on vegetation. Depths for spawning ranged from 3-5 meters in their study (much deeper than the mouth of the Cedar River).

Smelt egg drift can be substantial, especially at night during spawning activity, or when the flows are high (Johnston & Cheverie, 1988). It appears from the drift net catch that egg drift can be significant (8% of all eggs collected in the Cedar River captured in drift nets). This can cause eggs spawned upstream, in areas with gravel substrate, to be carried downstream. Nellbring (1989) found other smelt species (*Osmerus* sp.) eggs to drift significantly, with approximate 60% survival of drifting eggs. We found survival of eggs captured in the drift nets to range from 17-100 percent. Nellbring (1989) found a survival range for egg to larval stage in the literature (*Osmerus* sp.) to be 1-7%. It is possible that a significant number of the eggs collected near the Cedar River mouth and delta were deposited by drift, rather than adult

Figure 11. Smelt eggs collected in the Cedar River; note sand grains adhered to some eggs.

smelt spawning in these locations. It is unknown to what extent this influenced egg distrubution in this study. However, the artificial stream experiments strongly suggest that smelt prefer to spawn on a substrate of sand rather than a mixture of small, medium and large gravel. Low velocities, such as were present in the artificial stream did not appear to hinder spawning in any way.

Harza (1994) and Sibley & Brocksmith (1996) did not find significant correlations between egg abundance and water depth, velocity or substrate. However, our analysis of their data indicates that their findings confirm the negative correlations we found between egg abundance and velocity and distance upstream from the lake. This study had significantly more samples than the previous studies and was conducted during a high smelt year and is likely more representative of the maximum range of smelt spawning in the Cedar River and other Lake Washington tributaries. Because smelt do not excavate "redds" and spawn long after dark, it is very difficult to know exactly what physical parameters they cue to for spawning. In our observations of adults in the Cedar River, our presence (use of flashlights, etc.) was very disruptive and we could not observe their natural behavior. Also, the small size of the smelt and their eggs allows for a great deal of movement between areas of the river, depending on water flows, that potentially skewed our data. However, in spite of the egg drift, that no doubt occurred, survival of eggs from deeper water areas (up to 2 meters) appears to be within the normal range of other smelt species.

The results from this study and the two previous studies (Harza, 1994; Sibley & Brocksmith, 1996), indicate that smelt prefer to spawn in lower velocity areas with a sandy to small gravel substrate. In addition, 90%, or more, of the smelt in the Cedar River appear to spawn downstream of 900 meters from the lake. It does not appear that a flood control project, that may extend the slow-velocity lake backwater upstream an additional 200-400 meters, will negatively affect smelt spawning because the majority of the smelt already spawn in similar conditions to that which will be created. In order to further determine what impacts the flood control project has on longfin smelt spawning and survival, monitoring studies to determine the percent survival of smelt eggs from various water depths and substrates should be conducted.

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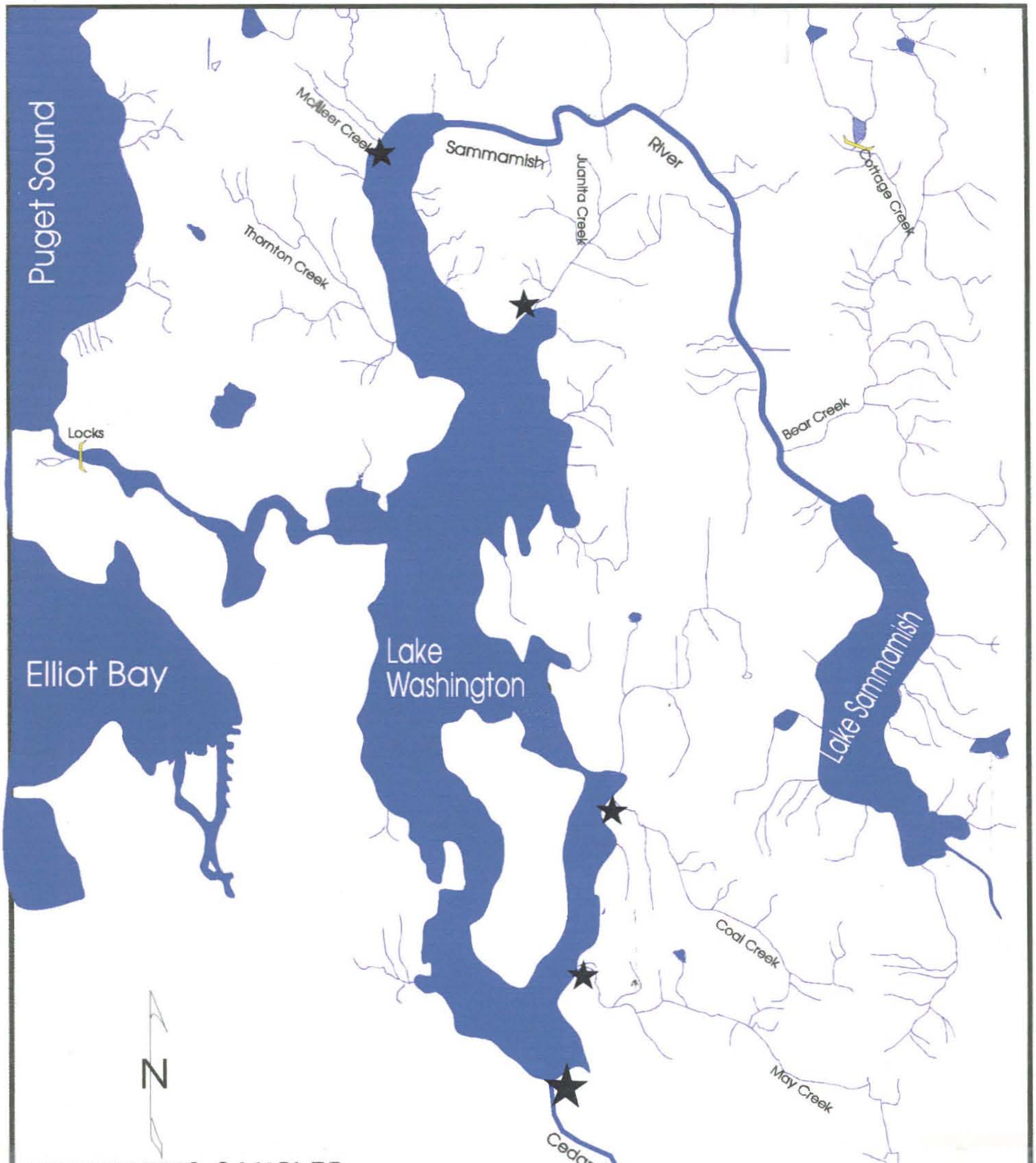
APPENDIX A. SAMPLING DATA IN CHRONOLOGICAL ORDER

Date	Ref Point	Depth	Velocity (m/s)	Substrate	# Eggs	% Alive	Notes
2/5/96	delta	0.35 m	0.29	sand	4	0	
2/5/96	delta	0.4 m	0.19	gravel	0		
2/5/96	delta	0.35 m	0.0045	sand, org debris	0		
2/5/96	delta	0.54 m	0.194	large gravel	0		
2/5/96	delta	0.35 m	0.105	sand/lg gravel	0		
2/5/96	delta	0.4 m	0.185	fine gravel/lg gravel	5		3 larvae
2/5/96	delta	0.65 m	0.082	gravel	1	100	
2/5/96	000 m	2 m	NS	large gravel	9	89	
2/5/96	000 m	1.3 m	NS	sm gravel/sand	9	33	
2/5/96	300 m	0.45 m	0.413	small gravel	14		
2/5/96	700 m	0.6 m	1.04	sm gravel	0		
2/5/96	Carko	0.2 m	NS	fine gravel/sand	0		
2/28/96	Carko	0.38 m	0.25	sand	0		
2/28/96	Carko	0.5 m	0.949	med gravel	0		
2/28/96	Carko	0.65 m	0.907	med gravel	0		
2/29/96	300 m + 24	0.6 m	0.71	med/large gravel	1		
2/29/96	300 m + 24	0.7 m	0.975	med/large gravel	0		
2/29/96	600 m	0.55 m	1.32	med gravel	0		
2/29/96	delta	0.49 m	0.14		0		
2/29/96	delta	0.25 m	0.279	sand, cobbles	2		
2/29/96	delta	0.3 m	0.382	sand, cobbles	13		
2/29/96	0 m	1.2 m	0.0125	sand, wood	6		
2/29/96	0 m	1.7 m	0.28		306		
2/29/96	1700 m + 5.2	0.42 m	0.9625		1		
2/29/96	1500 m	0.48 m	1.02		0		
2/29/96	1500 m	0.6 m	0.89		0		
2/29/96	1200 m	0.35 m	0.72	med gravel	0		
2/29/96	1200 m	0.43 m	0.99	med gravel	0		
2/29/96	900 m	0.35 m	0.93		0		
2/29/96	900 m	0.4 m	0.9		0		
3/20/96	Carko	0.25 m	0.96		0		
3/20/96	Carko	0.6 m	1.36		0		
3/22/96	300 m	0.72 m	0.27		16		1 larvae
3/22/96	300 m	0.8 m	0.3		54		1 larvae
3/22/96	300 m + 15	0.8 m	0.3		6		
3/22/96	600 m	0.18 m	0.47		26		
3/22/96	600 m	0.27 m	0.54		57	81	
3/22/96	600 m	0.6 m	0.99		38	37	
3/22/96	900 m	0.15 m	0.58		7	83	
3/22/96	900 m	0.45 m	0.87		15	62	
3/22/96	900 m	0.65 m	1.1		26	79	
3/22/96	1200 m	0.45 m	0.67		0	66	
3/22/96	1200 m	0.8 m	0.79		0	71	
3/22/96	1200 m	0.2 m	0.29		0	73	
3/22/96	1500 m	0.25 m	0.56		0	100	
3/22/96	1500 m	0.45 m	0.95		0		
3/22/96	1500 m	0.65 m	1.08		0		
3/22/96	1800 m	0.8 m	1.16		0		
3/22/96	1800 m	0.35 m	0.85		0		
3/22/96	1800 m	0.4 m	0.7		0		
3/22/96	delta	0.35 m	0.12	cobbles with sand	2		
3/22/96	delta	0.4 m	0.13	cobbles/sand	3		
3/22/96	delta	0.45 m	0.067	gravel/sand	3		
3/22/96	delta		0.065	med gravel	0		
3/22/96	delta	0.3 m	0	fine grave/silt	1	50	
4/10/96	Carko	0.25 m	0.71	small gravel	0		
4/10/96	Carko	0.6 m	1.21	lg gravel/sand	0	100	
4/10/96	Carko	0.18 m	0.825	cobbles	0		
4/10/96	300 m	0.9 m	0.23				
4/10/96	600 m	0.6 m	0.11	sand/silt	287	58	
4/10/96	600 m	0.55 m	0.6	cobbles/sand	29	85	1 larvae
4/10/96	600 m	0.35 m	0.48	large gravel	39		2 larvae
4/11/96	delta	0.45 m	0	sand	0		
4/11/96	delta	0.5 m	0	lg gravel/sand	99		
4/11/96	delta	0.35 m	0	sandy	26		
4/11/96	0 m	1.6 m	0	sand/lg gravel	2		
4/11/96	0 m	2.0 m	0	sand/lg gravel	1	59	1 larvae
4/11/96	300 m	1.05 m	0.35		920	55	42 larvae
4/11/96	900 m	0.15 m	0.53	small gravel	4	69	2 larvae
4/11/96	900 m	0.4 m	0.64	cobbles/sand	45		
4/11/96	900 m	0.25 m	0.42	sand	93	3	11 larvae
4/11/96	1200 m	0.4 m	0	silty backwater	0	4	
4/11/96	1200 m	0.3 m	0.5	gravel/cobbles	0	0	

Date	Ref Point	Depth	Velocity (m/s)	Substrate	# Eggs	% Alive	Notes
4/11/96	1200 m	0.7 m	0.48	sand/lg gravel	1	100	
4/11/96	1500 m	0.1 m	0.19	small gravel	2	87	
4/11/96	1500 m	0.45 m	0.68	med gravel/sand	0	75	
4/11/96	1500 m	0.6 m	1.09	lg gravel	0	71	
4/11/96	1800 m	0.4 m	0.68	med gravel	0	89	
4/11/96	1800 m	0.4 m	0.97	lg gravel	0		
4/11/96	1800 m	0.55 m	0.99	lg gravel	0		
4/10/96	800 m		NS		6	0	
4/30/96	carko	0.3 m	0.69	sand/sm gravel	0		
4/30/96	carko	0.6 m	1.125	med/lg gravel	0		
4/30/96	600 m	0.8 m	0.27	sand/sm gravel	4		
4/30/96	600 m	0.75 m	0.94	med gravel	0		
4/30/96	600 m	0.27 m	0.54	med gravel	0		
4/30/96	600 m	0.56 m	0.16	silt/sand	13		
4/30/96	900 m	0.41 m	0.6	sm gravel	0	17	
4/30/96	900 m	0.45 m	0.8	sm/lg gravel mixed	0	22	
5/1/96	900 m	0.6 m	0.64	sm gravel	1	77	3 larvae
5/1/96	1200 m	0.21 m	0.6	med/lg gravel	0		
5/1/96	1200 m	0.57 m	0.76	lg gravel/cobbles	0		
5/1/96	1200 m	0.8 m	0.78	sm gravel	0		
5/1/96	1500 m	0.21 m	0.4	med gravel	0	100	
5/1/96	1500 m	0.48 m	0.94	lg gravel	0		
5/1/96	1500 m	0.7 m	0.96	lg gravel	0		
5/1/96	1800 m	0.37 m	0.83	med/lg gravel	0	23	
5/1/96	1800 m	0.68 m	0.38	sand/silt	0		
5/1/96	1800 m	0.65 m	0.845	lg gravel	0		
5/1/96	300 m	0.75 m	0.52		4	100	
5/1/96	300 m	0.8 m	0.43	med gravel	0		
5/1/96	delta	0.35 m	0	sand/silt	2		
5/1/96	delta	0.55 m	0.118	sand/gravel	1		
5/1/96	delta	0.62 m	0.155	sand/gravel	1		
5/1/96	0 m	1.03 m	0.02	sand	293		42 larvae
5/1/96	0 m	2 m	0.2	sand/wood	1827		323 larvae
5/1/96	300 +30	0.69 m	0.06	sand over gravel	1		
5/15/96	carko	0.5 m	0.19	sand	0		
5/15/96	carko	0.47 m	1.16	med gravel	0		
5/15/96	600 m	0.85 m	NS	sand over gravel	4	100	
5/15/96	600 m	0.5 m	0.95	med gravel/sand	0		1 larvae
5/15/96	600 m	0.4 m	0.82	med gravel/sand	0	50	
5/16/96	900 m	0.52 m	NS	sm gravel/sand	0	0	
5/16/96	900 m	0.57 m	0.625	sm/med gravel	0	0	
5/16/96	900 m	0.53 m	0.46	sand/sm gravel	0	87	4 larvae
5/16/96	1200 m	0.23 m	0.45	lg gravel	0	95	
5/16/96	1200 m	0.56 m	0.98	lg gravel	0	0	
5/16/96	1200 m	0.88 m	0.74	sand/sm gravel	0		
5/16/96	1500 m	0.32 m	0.53	sand/sm gravel	0	100	
5/16/96	1500 m	0.61 m	1.06	med/lg gravel	0		
5/16/96	1800 m	0.55 m	0.85	med gravel	0		
5/16/96	1800 m	0.61 m	NS		0		
5/16/96	1800 m	0.79 m	0.92	cobbles	0	25	
5/16/96	300 m + 20	0.43 m	0.0045	silt	2		
5/16/96	300 m + 20	0.86 m	0.023	sand over lg gravel	18		
5/16/96	delta	0.52 m	0.004	silt	3		
5/16/96	delta	0.37 m	0.146	t/sand over sm grav	1		
5/16/96	delta	0.64 m	0.2	sand over gravel	0		
5/16/96	0 m	1.56 m	0.045	sand	271		7 larvae
5/16/96	0 m	2 m	0.29	sand	1673		
						0	
						0	
						97	
						~90	



TRIBUTARIES SAMPLED
SMELT SPAWNING SURVEY 1996