Technical Report No. 01-7

Chester Creek Stream Condition Evaluation

Jeffrey C. Davis and Gay A. Muhlberg

July 2001

Alaska Department of Fish and Game
Habitat and Restoration Division

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Habitat and Restoration Manuscripts, Technical Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm
Micrometer	µm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
micro Sems	µS
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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ABSTRACT

Chester Creek is located within the city of Anchorage, Alaska. The drainage has been altered over the years through residential and commercial development. Most of the tributaries currently flow through culverts or constructed channels. Impacts to Chester Creek include channelization, storm drain discharge, and residential and commercial runoff. Anadromous fish access is restricted at the mouth and juvenile fish movement is limited within the drainage by culverts at a number of locations. Stream restoration projects are currently being designed to address many of these problems. In order to prioritize restoration projects and evaluate the success of restoration efforts, a study was conducted to characterize many of the physical, chemical, and biological characteristics of the stream. Stream parameters were measured at 10 locations distributed throughout the drainage representing both channelized and non-channelized sections. There was a general increase in conductivity, hardness, and alkalinity from upstream to downstream. Channelized sites had lower width to depth ratios, less undercut bank, and reduced flow variability when compared to non-channelized sites. Periphyton chlorophyll-*a*, benthic organic matter, and large woody debris did not vary longitudinally or with channelization. Sediment size was gravel and cobble at most sites with substrate size slightly larger than expected at the upstream stations and slightly smaller than expected at others based upon estimates of stream energy. A Mayfly, *Baetis sp.* were common at the upstream stations but were absent within the developed areas, channelized sites were dominated by Oligochaetes with a concomitant reduction in Chironomidae and Trichoptera. The fish community was composed of rainbow trout, Dolly Varden char, and coho salmon. The number of coho salmon juveniles captured is less than observed previously. Restoration should focus on fish passage, channel mophometry, storm water runoff and water quality; and the maintenance and expansion of riparian vegetation.

Key words: Urban stream, channel shape, invertebrates, riparian areas, salmonids, water quality, monitoring, Anchorage, Alaska.

INTRODUCTION

Chester Creek flows approximately 16.1 km (10 miles) from the Chugach Mountains in Southcentral Alaska to Cook Inlet, through the Municipality of Anchorage, the largest city in the State. Chester Creek drains approximately 7,770 hectares (30 mi^2). Residential development is extensive downstream of the Fort Richardson military boundary with commercial development increasing below University Drive. Large sections of Chester Creek have been modified to facilitate wetland drainage for development. In 1971 a dam with a concrete weir to control flow was constructed across the Chester Creek estuary forming the Westchester Lagoon impoundment. The fish passage structure associated with dam construction was never effective, thereby severely limiting returning anadromous fish passage into Chester Creek from Cook Inlet.

Chester Creek is on the State's 303(d) list (prepared for compliance with section 303(d) of the Federal Water Pollution Control Act) of impaired water bodies based upon concentrations of fecal coliforms; however, water quality in Chester Creek is limited due to a number of factors. These include sedimentation, channelization, bank damage, loss of riparian areas, and a disconnection between the stream and riparian areas. Chester Creek is a priority restoration stream; however, previous to now, a thorough evaluation of current physical, biological, and chemical conditions has not been conducted.

There are many different plans currently in progress to restore Chester Creek. Fine sediment inputs should decrease as the Municipality of Anchorage works toward implementation of best management practices in accordance with their NPDES permit. The U.S. Army Corps of Engineers in cooperation with the municipality, and State and Federal resource agencies, is proposing a number of instream restoration projects within the watershed including restoring fish passage from Cook Inlet. The Alaska Department of Environmental Conservation will be developing Total Maximum Daily Load criteria for the stream. All of these activities are directed toward restoring the fish use, habitat, and water quality conditions of Chester Creek. Evaluation of the effectiveness of restoration projects requires understanding current conditions. Restoration activities and progress to improve water quality can only be evaluated by comparing present with future conditions. A thorough evaluation of the current condition of Chester Creek is needed prior to the expenditure of considerable resources on restoration projects.

The objective of this study was to describe the current condition of Chester Creek, thereby providing the information necessary to evaluate the effectiveness of future restoration projects. In addition, where possible, determine where restoration efforts should be focused.

METHODS

SAMPLING LOCATIONS

Ten sampling stations were located on Chester Creek, within the Municipality of Anchorage, Alaska. Based upon stream reconnaissance, Chester Creek was divided into four reaches (Frissel et al. 1986) and the sampling stations were distributed among these reaches (Figure 1). Each sampling station was 100-m long. The latitude and longitude of the upstream and downstream ends of each station was recorded by GPS (Garmin 12 XL). Station descriptions and locations are shown in Table 1. Stations 1, 2, 5, 6, and 7 were at non-channelized locations and the remainder at channelized sites.

WATER CHEMISTRY

Selective water chemistry constituents were determined for all 10 sample sites in the Fall of 2000 (August, September, and October) and Spring of 2001 (April, May, and June). Conductivity and pH were determined in the field using a Hydrolab. Depth-integrated samples were collected for laboratory analysis of alkalinity, hardness, nitrate nitrogen, dissolved reactive phosphorus, and total reactive phosphorus. Water samples were collected in clean 250-ml nalgene bottles, returned to the laboratory where they were preserved and stored until analyzed. Samples were preserved by freezing for alkalinity, hardness, and phosphorus analyses and by acidification for nitrate (APHA 1995).

Alkalinity was determined by the Titration method (2320 B.); hardness, EDTA Titrimetric (2340 C); nitrate, Cadmium reduction (4500-NO3 E); and phosphorus, Asorbic acid (4500-P E) (APHA 1995). Nitrate and both dissolved and total phosphorus samples were analyzed using HACH premixed reagents and spectrophotometer, except for April and May, 2001, when samples were analyzed by automated cadmium reduction (Nitrate-N) at the ADF&G laboratory in Soldotna, Alaska. One of every 10 samples was analyzed twice to determine method precision and known standards were used to determine accuracy (Appendix A).

PHYSICAL CHARACTERISTICS

Discharge was determined on one date at all 10 sampling locations by the conventional current meter method (Rantz et al. 1982).

Stowaway temperature loggers were placed at sampling stations 2, 4, 6, and 8 on July 14, 2000. Temperature was recorded every 4 hours and data loggers downloaded as Excel files every 2 to 3 months through 8 June, 2001.

Water velocity was measured at 20 random locations within each 100-m sampling location in August 2000. Water velocity was measured at 0.6 depth using a top-set rod and Model 1205 Price-type mini current meter. The meter was spin-tested before each use.

Substratum size distribution was determined once within each sampling location by

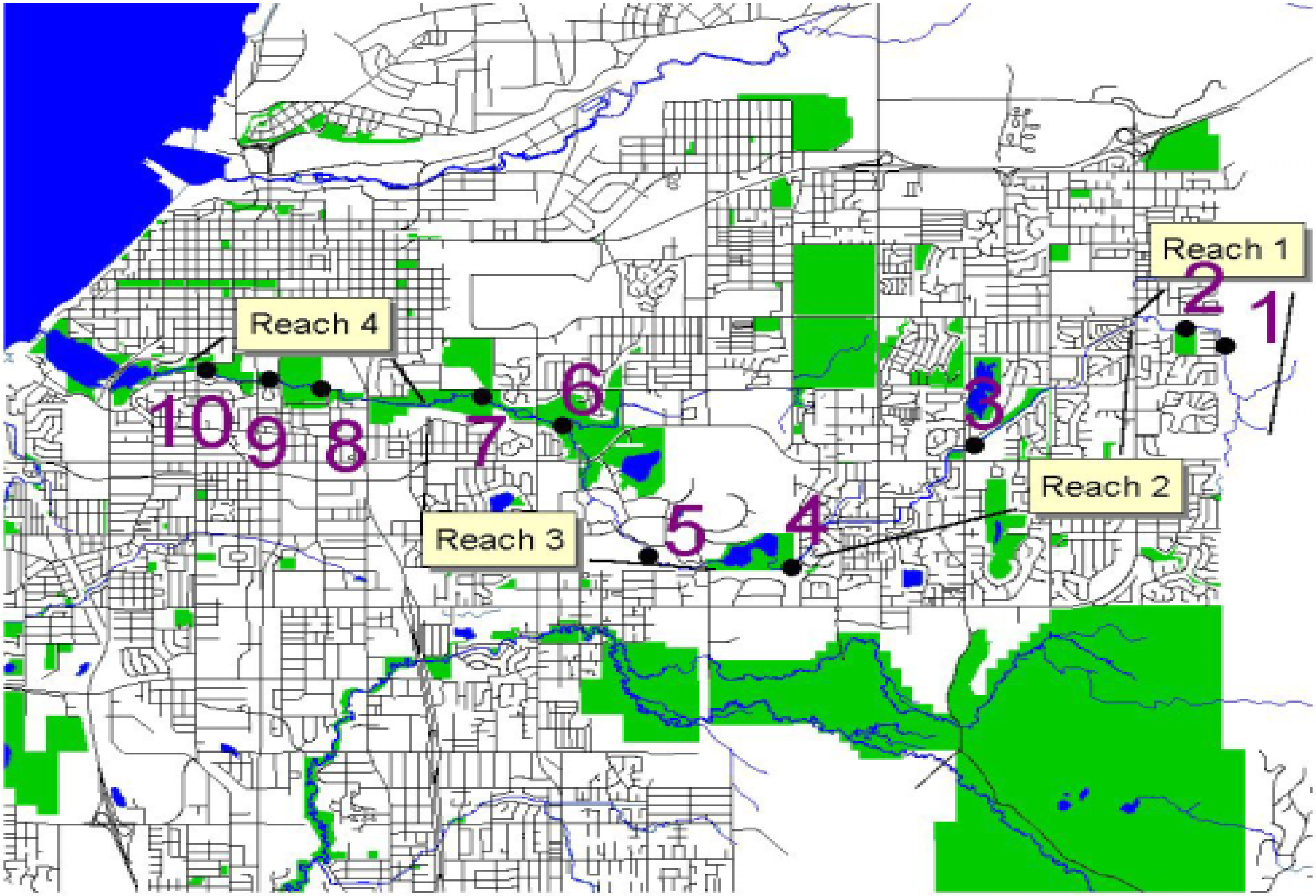

Figure 1. Map of Chester Creek drainage showing sampling reaches and stations.

Table 1. Locations of the 10 Chester Creek sampling stations.

Reach/Station	Upstream Latitude/Longitude	Downstream Latitude/Longitude	Description
Reach 1			Headwaters to Muldoon Road.
Station 1	61.20620 N, 149.71546 W	61.20705 N, 149.71524 W	Upstream of Fort Richardson Boundary.
Station 2	61.20907 N, 149.71871 W	61.20919 N, 149.72031 W	Between Early view Drive and Windsong Park
Reach 2			Muldoon Road to University Lake.
Station 3	61.19845 N, 149.75709 W	61.19845 N, 149.75709 W	Baptist Temple, Northern Lights Blvd and Baxter Road.
Station 4	61.18516 N, 149.79119 W	61.18520 N, 149.79283 W	Upstream of University Lake, behind Native Medical Center.
Reach 3			Outlet of University Lake to the Eastern end of Eastchester Park.
Station 5	61.18594 N, 149.81604 W	61.18653 N, 149.81684 W	Behind Providence Hospital, upstream of University Drive.
Station 6	61.19929 N, 149.83159 W	61.19988 N, 149.83247 W	Upstream of Lake Otis Parkway. Confluence with Middle Fork.
Station 7	61.20208 N, 149.84436 W	61.20212 N, 149.84600 W	Downstream of Hilstrand Pond and the North Fork.
Reach 4			Eastchester Park to Westchester Lagoon.
Station 8	61.20321 N, 149.87073 W	61.20316 N, 149.87249 W	South of Mulcahy Stadium.
Station 9	61.20395 N, 149.88169 W	61.20396 N, 149.88370 W	Between A and C Streets.
Station 10	61.20485 N, 149.89318 W	61.20512 N, 149.89508 W	Upstream of Arctic Blvd.

Wolman pebble counts (Wolman 1954) as modified by Bevenger and King (1995). The intermediate axis of 100 stones, selected in a systematically-random manner, was measured using a substrate sampler developed by the USFS. The substrate sampler is an aluminum rectangle with square openings corresponding to the different size classes. The percent each stone was embedded within the stream was estimated to the nearest 10 percent by observation and the texture of the stone surface.

Large woody debris (LWD) and debris dams were counted once within each sampling station. The number of LWD pieces (>10 cm diameter and >1-m in length) and debris dams (three or more LWD pieces together) were counted separately. LWD pieces were ranked from 1 to 5 for seven different categories: length/bankfull width, diameter, zone, type, structure, stability, and orientation. Debris dams were also ranked from 1 to 5 based upon 5 categories: length/bankfull width, height/bankfull depth, location, structure, and stability. Higher ranks correspond with greater stream influence. A large woody debris index (LWDI) was calculated by summing the 7 rank values for all pieces and 5 times the sum the 5 rank values for all dams within a sampling station (Davis et al. 2001).

Channel cross-sectional morphometry was determined at 5 transects within each sampling station located at 20-m intervals. Horizontal distance across the stream was measured using a 50-meter tape extended across the stream channel and secured to both the right and left banks above the maximum slope break. Vertical elevations were recorded at distances of 30 to 50 cm along the meter tape. More frequent measurements were recorded at locations where vertical elevations changed rapidly. Vertical elevations displayed on a leveling rod were read using a hand level placed on a 1.8-m monopod. Undercut bank distance was measured for both banks at each transect with a meter stick from the point of farthest protrusion to farthest undercut with the meter stick horizontal and level. Channel slope was determined from the difference in elevations recorded in mid-channel, between successive transects. Sampling station slope was the mean of 4 measurements. Precision was determined by repeating cross-sectional measurements at every 10th transect using different technicians.

The fish habitat within each sampling station was evaluated qualitatively using the Alaska Stream Condition Index (ASCI) habitat assessment procedures (Major et al. 1998). Habitat assessment data sheets were completed in the field and score selection was determined by consensus among 3 biologists. Precision was determined through the replicate assessment of one station by a different group of biologists.

BIOTIC CHARACTERISTICS

Benthic organic matter (BOM) was sampled by dislodging material from the stream bed to a depth of 10 cm, and sieving the suspended material from the flowing water in nested nets secured to a Surber-sampler frame (0.09 m^2) held on the stream bottom. The pore size of the inner net was 1 mm and the outer net 0.125 mm. Therefore, the organic matter was divided into coarse particulate organic matter (CPOM) and fine particulate organic matter (FPOM) size fractions. The organic material within the nets was transferred to whirl-pak bags and preserved with 95% ethanol. The ash free dry mass (AFDM) of the organic matter was determined gravimetrically (APHA 1995 method 10200 I.5.)

The abundance of attached algae was determined by collecting periphyton growing naturally on stones and determining the concentration of chlorophyll-*a*. Periphyton was sampled from 5 randomly selected stones within each sampling reach in August and

October, 2000. The periphyton enclosed within the diameter of 30-cc syringe was dislodged with a small brush, removed by suction, and collected on a Whatman GF/C filter. Labeled samples were kept in the dark, frozen, and stored in the laboratory until analyses. The filtered samples were analyzed for chlorophyll-*a* by acetone extraction and flourometery correcting for pheophytin through acidification (APHA 1995 method 10200 H).

The invertebrate community was sampled at all 10 sites in September 2000. Invertebrates were collected by the ASCI methods. Invertebrates collected in a D-net with 350-μm mesh net (composite of 20 kicks or jabs) were preserved in 95% ethanol until identified. A subsample consisting of 300 organism (+/- 20%) were identified to the lowest taxonomic level practicable, primarily genus. Multiple metrics were calculated as well as ASCI values for each station.

Fish population and community estimates were determined through multiple-pass collection efforts on the 8th and 19th of September. Fish were collected with a portable electrofisher (Smith-Root Model 12) working from downstream to upstream through a 40-m section of each station. Three passes were made at each station and captured fish were held in separate buckets of water for each pass. All fish were identified in the field and measured (fork length) except for sculpin (*Cotus*) which were not measured.

RESULTS

WATER CHEMISTRY

Station water chemistry data are shown in Table 2 through Table 11. Alkalinity, hardness, conductivity, and pH all tended to increase from upstream to downstream. Conductivity was near 100 μS/cm at station 1 and doubled by station 10. Station pH generally increased by roughly 0.4 units from upstream to downstream.

The lowest nitrate-N concentrations were in August at all stations; however, variability was low among months and stations. Concentrations ranged from 0.1 to 0.8 mg/L considering all dates and stations and were highest in the Spring.

The accuracy of total phosphorus analyses was quite low at 0.2 mg/L including all samples when using the HACH meter. Total phosphorus concentrations ranged from 0.0 to 0.6 for samples analyzed with the HACH meter compared to a range 0.01 to 0.06 for samples analyzed at the laboratory in Soldotna. Molar ratios of nitrate-N to total phosphorus are relatively high suggesting potential phosphorus limitation.

PHYSICAL CHARACTERISTICS

Sampling stations replicated channelized (stations 3, 4, 8, 9, 10) and non-channelized (stations 1, 2, 5, 6, 7) sites. The sampling station physical characteristics are shown in Table 12 and Table 13. Some of the morphological parameters differed between channelized and non-channelized stream reaches. These included hydraulic radius, width depth ratio, and bank undercut. Non-channelized reaches were deeper than channelized reaches. The mean hydraulic radius for channelized reaches was 0.2 m and 0.3 m for non-channelized reaches. The ratio of channel width to depth was much greater in channelized (mean = 28) than non-channelized areas (mean = 10). Similarly the distance that banks were undercut was considerably higher at non-channelized sites. The mean bank undercut distance in non-channelized sites was over two times greater than channelized sites (0.18 cm compared to 0.07 cm). All of these differences were statistically significant (t-test, $p<0.05$).

Table 2. Station 1 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	149			30	103	95
Hardness (mg $CaCO_3$/L)	54			61	55	52
Conductivity (µS/cm)	104.0	99.6	94.5	116.1	118.6	107.1
pH	7.56	7.62	7.56	7.10	7.50	7.26
Nitrate NO_3-N (mg/l)	0.7	0.7		0.2	0.3	0.3
Dissolved $P0_4$-P (mg/l)	0.003	0.003		0.13	0.08	0.02
Total $P0_4$-P (mg/l)	0.009	0.024		0.64	0.03	0.23
N/P (molar)	198	70		1	21	3

Table 3. Station 2 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	139			60	118	96
Hardness (mg $CaCO_3$/L)	54			61	58	52
Conductivity (µS/cm)	104.2	99.4	94.8	116.60	118.6	108.4
pH	7.75	7.72	7.64	7.08	7.47	7.38
Nitrate NO_3-N (mg/l)	0.7	0.7		0.2	0.3	0.3
Dissolved $P0_4$-P (mg/l)	0.003	0.003		0.03	0.03	0.03
Total $P0_4$-P (mg/l)	0.007	0.021		0.29	0.07	0.26
N/P (molar)	253	73		2	9	3

Table 4. Station 3 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	122			90	123	95
Hardness (mg $CaCO_3$/L)	58			65	68	61
Conductivity (µS/cm)	149.5	130.5	112.5	130.4	144.8	130.6
pH	7.87	7.97	7.75	7.47	7.72	7.71
Nitrate NO_3-N (mg/l)	0.7	0.6		0.2	0.3	0.4
Dissolved $P0_4$-P (mg/l)	0.003	0.004		0.05	0.04	0.05
Total $P0_4$-P (mg/l)	0.032	0.019		0.00	0.05	0.31
N/P (molar)	50.9	71.4			15.1	2.7

Table 5. Station 4 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	151			40	130	128
Hardness (mg $CaCO_3$/L)	72			65	74	71
Conductivity (µS/cm)	191.6	171.6	148.2	123.8	179.6	162.70
pH	7.73	7.75	7.66	7.33	7.61	7.61
Nitrate NO_3-N (mg/l)	0.6	0.5		0.2	0.3	0.4
Dissolved $P0_4$-P (mg/l)	0.007	0.004		0.13	0.07	0.03
Total $P0_4$-P (mg/l)	0.057	0.022		0.00	0.04	0.19
N/P (molar)	23.0	55.5			18.3	4.7

Table 6. Station 5 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	147			50	131	129
Hardness (mg $CaCO_3$/L)	67			69	74	77
Conductivity (µS/cm)	183.0	168.8	166.8	154.80	177.50	163.50
pH	7.26	7.71	8.36	7.55	7.75	7.49
Nitrate NO_3-N (mg/l)	0.6	0.4		0.2	0.3	0.3
Dissolved $P0_4$-P (mg/l)	0.011	0.005		0.03	0.03	0.03
Total $P0_4$-P (mg/l)	0.063	0.026		0.41	0.04	0.25
N/P (molar)	20.4	37.7		1.3	14.3	2.4

Table 7. Station 6 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	157			70	144	139
Hardness (mg $CaCO_3$/L)	69			73	84	84
Conductivity (µS/cm)	212.6	188.2	198.6	159.0	215.1	195.9
pH	7.77	7.77	7.88	7.50	7.75	7.67
Nitrate NO_3-N (mg/l)	0.6	0.6		0.2	0.4	0.4
Dissolved $P0_4$-P (mg/l)	0.005	0.004		0.16	0.05	0.01
Total $P0_4$-P (mg/l)	0.035	0.021		0.21	0.015	0.22
N/P (molar)	38.3	64.7		2.5	57.1	3.8

Table 8. Station 7 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	159			50	149	149
Hardness (mg $CaCO_3$/L)	81			69	87	87
Conductivity (µS/cm)	213.3	198.2	>200	153.5	216.5	193.0
pH	7.77	7.69	8.04	7.53	7.78	7.4
Nitrate NO_3-N (mg/l)	0.6	0.6		0.2	0.3	0.4
Dissolved $P0_4$-P (mg/l)	0.005	0.004		0.05	0.04	0.03
Total $P0_4$-P (mg/l)	0.040	0.024		0.34	0.05	0.23
N/P (molar)	35.6	57.7		1.6	15.0	4.3

Table 9. Station 8 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	161			40	141	154
Hardness (mg $CaCO_3$/L)	86			65	87	93
Conductivity (µS/cm)	223.0	>200	>200	153.5	222.9	208.6
pH	7.77	7.82	8.00	7.61	7.86	7.67
Nitrate NO_3-N (mg/l)	0.8	0.7		0.1	0.4	0.5
Dissolved $P0_4$-P (mg/l)	0.005	0.004		0.10	0.10	0.02
Total $P0_4$-P (mg/l)	0.040	0.023		0.03	0.02	0.18
N/P (molar)	46.0	67.2		11.9	45.7	6.9

Table 10. Station 9 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	152			40	141	150
Hardness (mg $CaCO_3$/L)	85			65	87	94
Conductivity (µS/cm)	211.0	>200	>200	155.3	233.2	213.0
pH	7.74	8.18	8.03	7.62	7.88	7.77
Nitrate NO_3-N (mg/l)	0.8	0.7		0.2	0.4	0.6
Dissolved $P0_4$-P (mg/l)	0.005	0.004		0.01	0.04	0.02
Total $P0_4$-P (mg/l)	0.048	0.021		0.00	0.04	0.15
N/P (molar)	39.2	73.5			23.4	8.5

Table 11. Station 10 water chemistry.

	4/1/01	5/1/01	6/1/01	8/4/00	9/6/00	10/12/00
Alkalinity (mg $CaCO_3$/L)	152			70	147	153
Hardness (mg $CaCO_3$/L)	89			69	93	94
Conductivity (µS/cm)	229.0	>200	>200	155.2	236.6	215.1
pH	7.70	7.75	8.02	7.63	7.89	7.77
Nitrate NO_3-N (mg/l)	0.8	0.7		0.1	0.4	0.5
Dissolved $P0_4$-P (mg/l)	0.006	0.004		0.23	0.04	0.01
Total $P0_4$-P (mg/l)	0.053	0.020		0.01	0.02	0.21
N/P (molar)	32.6	74.3		16.0	44.6	4.8

Average water velocity did not differ among stations, but the variability in water velocity did when channelized sites were compared with the non-channelized (Table 13). The average water velocity (n = 20) at each station was about 0.5 m/s. The maximum average water velocity was measured at station 7 (0.71 m/s) and the minimum at station 5 (0.36 m/s). The variability in water velocity within a station was determined by calculating the coefficient of variation (CV) from the 20 measurements. The average CV for channelized sites was 0.32 compared with 0.44 for non-channelized sites.

The substrate particle size distribution for each sampling station is shown in Table 12 and Figure 2. The median particle size for sites 3, 4, and 6 through 9 were very similar near 30 mm. Particle size for these sites ranged from medium gravel to small cobble with little or no boulders. The upstream stations 1 and 2 were composed of a combination of sand to fine gravel, cobbles, and boulders. Increases in fine sediment less than 2 mm were measured at station 5 with 30% of the substrate in this size class. Station 10 also was composed of smaller particles than most of the other sites with a D50 of 18 mm and most of the substrate composed of fine to medium sized gravel.

Substrate and channel stability was evaluated by comparing the estimated particle size in motion at bankfull flows with the particle size distribution at each station. The estimated maximum particle size in motion, Riffle Stability Index (RSI), in mm, was determined from the tractive force equation of Kappesser (1993) converted to metric units. That is:

$$RSI = 9.82\rho RS$$

where ρ = the density of water (1000 kg/m3), R = hydraulic radius (m) and S = slope (Table 12). The estimated particle size in motion was compared to the substrate size distribution for each sampling station to determine whether the substrate was smaller or larger than expected suggesting aggradation or degradation, respectively. The estimated particle size in motion is affected primarily by hydraulic radius. Therefore, larger substrate can be predicted to be moved in the non-channelized portions of Chester Creek where the hydraulic radius is greater and a larger particle size distribution is expected.

At the non-channelized stations 1 and 2 the substrate was larger than expected with approximately 20% of the substrate estimated to be in motion during bankfull flows. The substrate at the non-channelized stations 6 and 7 was near expected size with roughly 50% estimated in motion. Station 5, while non-channelized, was composed of a large amount of fine material, 85% in motion during bankfull flows, suggesting large fine-sediment inputs and aggradation. The ability of sediment to be transported through the channelized sites was very low because of the low tractive force of these wide shallow channels. Therefore, the substrate at these stations was larger than expected with less than 15% of the substrate expected to be in transport during bankfull flows. The one exception was station 10, the farthest downstream site, where the RSI was higher and substrate smaller.

Median embeddedness ranged from near 30 to 70% among stations. Similar to the increases in fine sediment, substrate embeddedness was highest at stations 5 and 10 with median values at 65 to 70% (Figure 3). Embeddedness was also relatively high (>50%) at stations 3 and 9, with the remainder of the sites having median values below 50%. There were no clear longitudinal patterns in embeddedness, nor were values distinctly different between channelized and non-channelized sites.

Table 12. Channel and substratum characteristics at the 10 sampling stations. w/d is the ratio of stream width to depth.

	Width (m)	Mean Depth (m)	w/d ratio	Area (m^2)	Wetted Perimeter (m)	Hydraulic Radius (m) (Area/Perimeter)	Undercut Right (m)	Undercut Left (m)	Slope	D50 (mm)	RSI-D (mm)	Cumulative Percent < RSI
Station 1	2.57	0.30	8.89	0.95	3.10	0.31	0.19	0.12	0.007	95	22.5	22%
Station 2	2.28	0.28	8.30	0.82	2.91	0.28	0.17	0.12	0.013	100	34.8	18%
Station 3	4.06	0.18	22.52	0.92	4.63	0.20	0.11	0.09	0.003	45	6.5	14%
Station 4	3.69	0.16	23.52	0.79	3.93	0.21	0.05	0.13	0.008	38	15.7	5%
Station 5	4.35	0.39	11.39	2.04	5.66	0.37	0.20	0.24	0.008	8	28.1	85%
Station 6	2.62	0.34	8.04	1.05	3.39	0.31	0.30	0.33	0.012	28	35.3	59%
Station 7	3.44	0.28	14.46	1.17	4.70	0.26	0.14	0.05	0.011	30	28.1	50%
Station 8	5.22	0.23	22.83	1.34	6.81	0.22	0.08	0.05	0.005	30	9.9	9%
Station 9	6.19	0.20	34.00	1.40	6.59	0.22	0.07	0.05	0.003	30	6.6	8%
Station 10	7.40	0.22	38.58	1.67	7.79	0.23	0.06	0.04	0.008	18	17.1	51%

Table 13. Discharge, velocity, and large woody debris data for each sampling station. Stdev is the standard deviation, CV is the coefficient of variation, and LWDI is the large woody debris index.

Site	**Discharge (m^3/s)**	**Area (m^2)**	**Average Velocity (m/s)**	Range	Stdev	CV	**LWDI Score**	**Pieces (No.)**	**Dams (No.)**
Station 1	0.26	0.56	0.57	1.02	0.30	0.52	260	10	1
Station 2	0.23	0.64	0.47	0.88	0.22	0.47	139	2	1
Station 3	0.33	0.85	0.44	0.70	0.18	0.40	81	1	1
Station 4	0.43	1.27	0.58	0.53	0.14	0.25	117	3	1
Station 5	0.46	1.05	0.36	0.64	0.17	0.46	1138	16	11
Station 6	0.63	1.42	0.58	0.89	0.23	0.40	194	8	1
Station 7	0.71	0.83	0.71	0.71	0.23	0.33	82	2	1
Station 8	0.70	1.83	0.66	0.71	0.21	0.33	115	2	1
Station 9	0.73	1.52	0.63	0.88	0.23	0.37	400	0	5
Station 10	0.72	2.39	0.55	0.53	0.14	0.25	175	5	2

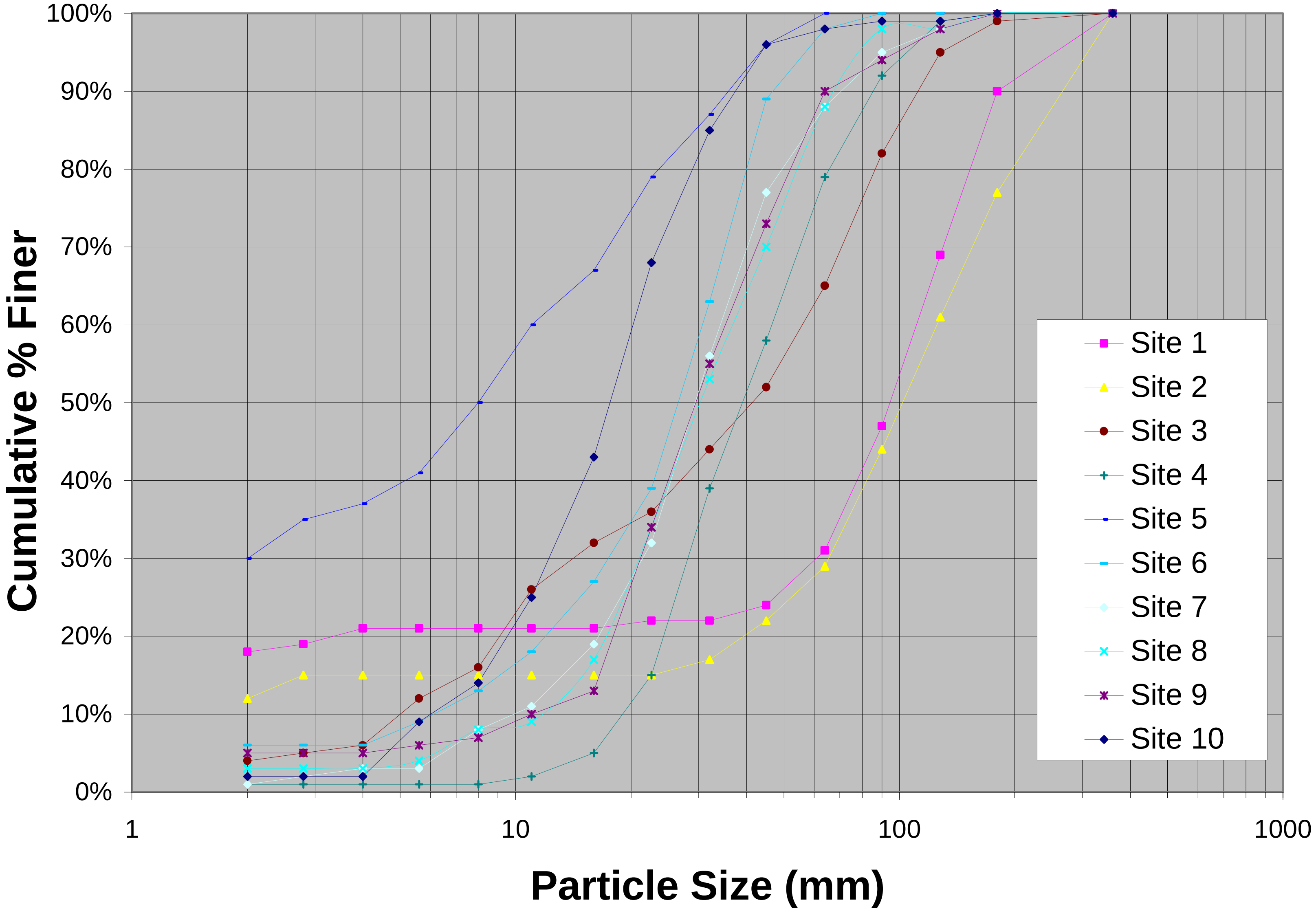

Figure 2. Cumulative sediment particle size for the ten Chester Creek sampling stations.

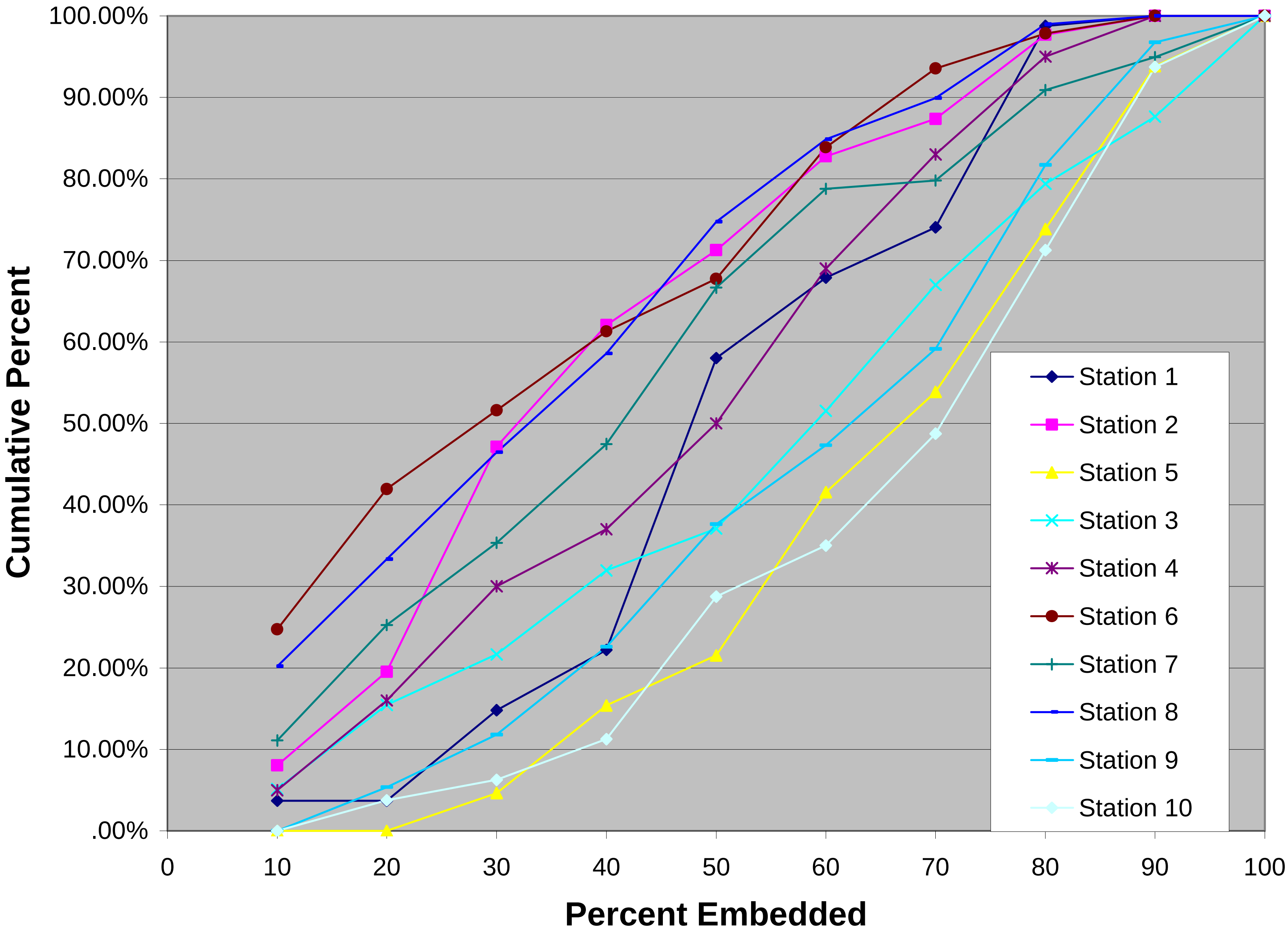

Figure 3. Cumulative percent of particles within a station embedded by percentage.

The total number of large woody debris pieces, debris dams, and the large woody debris index did not vary in any recognizable pattern among stations (Table 13). The number of woody debris pieces ranged from 0 to 0.1 m^{-1}. All debris pieces were less than 20-cm in diameter. Debris dams were uncommon with rarely more than one small dam within each 100-m sampling station, except for station 5, which had 11 debris dams. The large woody debris index also was greatest at station 5 at 1,138 or 11.38 m^{-1} with values ranging down to 0.81 m^{-1} at station 3.

Stream water temperature data are shown in Figure 4 through Figure 7. The highest stream water temperature recorded was 15.2ºC at station 8 in August. In comparison, the highest temperature recorded at station 2 (farthest upstream) was 12.5ºC in May of 2001. The total cumulative degree-days (sum of mean daily temperature > 0) for four stations are shown in Figure 8. Total cumulative degree-days was nearly doubled between the upstream station 2 (873) and downstream station 8 (1,504).

BIOTIC CHARACTERISTICS

Periphyton chlorophyll-*a* concentrations are shown in Table 14 and Figure 9. Stream algae increased at all stations from August to October. The differences in mean chlorophyll-*a* concentrations from August to October were statistically significant (Paired t-test, $p < 0.10$). Algal abundance also tended to increase downstream particularly in August. Algal abundance was weakly related to concentrations of nitrate-N in both August and October (Figure 10).

The amount of organic matter within the streambed was similar among sites in both September and October with no longitudinal trend observed. Benthic organic matter did vary between September and October. There was more FPOM than CPOM in September prior to leaf fall and more CPOM than FPOM after (Table 14) as CPOM increased significantly (t-test $p < 0.05$). On average there was an approximately 6-fold increase in CPOM between the September and October sampling dates.

The macroinvertebrate community metric values, ASCI score, and habitat score for the 10 sampling stations are shown in Table 15. There were no longitudinal trends in the metrics except for the percent Ephemeroptera (mayflies). Ephemeroptera were common at the upstream stations 1 and 2 making up 15 to 20 percent of the community; however, they were less than 5% of the community at the remainder of the sites. The predominant Ephemeroptera were *Baetis* and *Ephemerella.* While there were no other longitudinal metric trends, some invertebrate community metrics differed significantly between channelized and non-channelized sites (Figure 11). At channelized sites the invertebrate community was dominated by Oligochaeta (40 to 70%). At non-channelized sites these organisms never exceeded 30% of the community. The percent of the community composed of Chironomidae (midges), EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera), Trichoptera (caddis flies), and Pelecepoda (bivalves) was greater in non-channelized sites than channelized sites.

Three different species of salmonids (Salmonidae) were captured in Chester Creek: coho salmon (*Oncorhynchus kisutch*), rainbow trout (*Oncorhynchus mykis*), and Dolly Varden char (*Salvelinus malma*). Adult coho salmon were observed at stations 5 (2 fish), station 6 (1 fish), and station 7 (carcass). Coho juveniles were captured at the non-channelized stations 1, 2, 5, and 7 (Table 16). A total of 22 coho juveniles were captured with the maximum number captured at station 2 (13 fish) (Figure 12). Coho juveniles ranged in size from 44 to 150 mm (Figure 13).

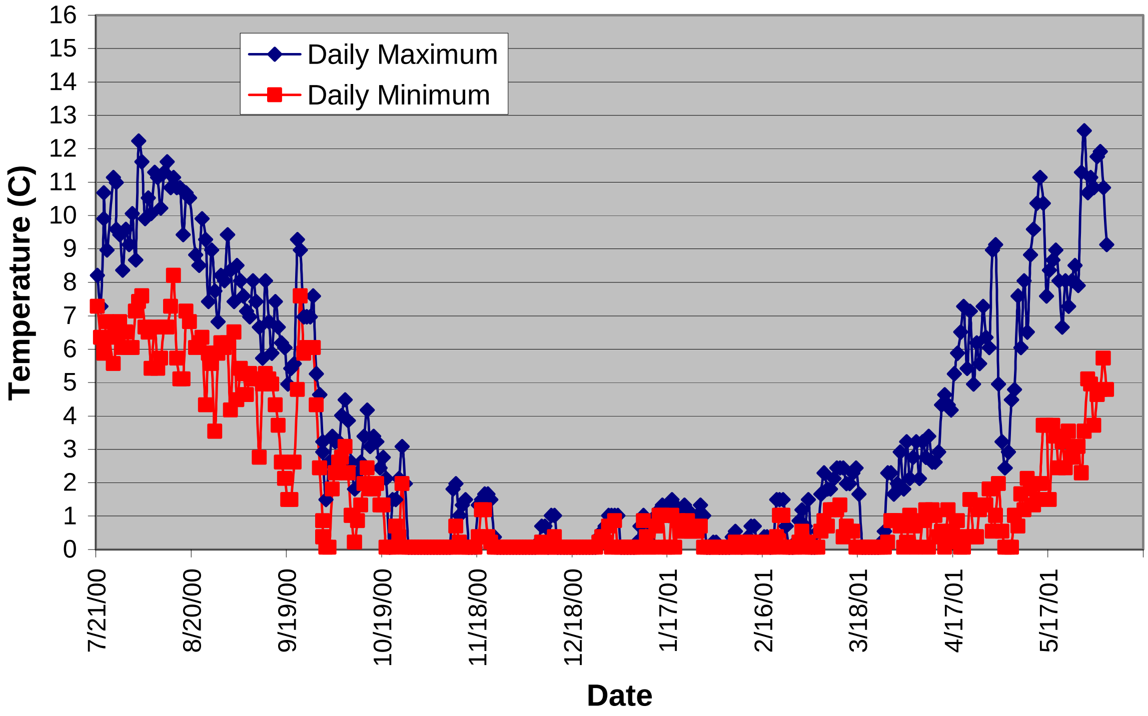

Figure 4. Station 2 annual stream water temperatures.

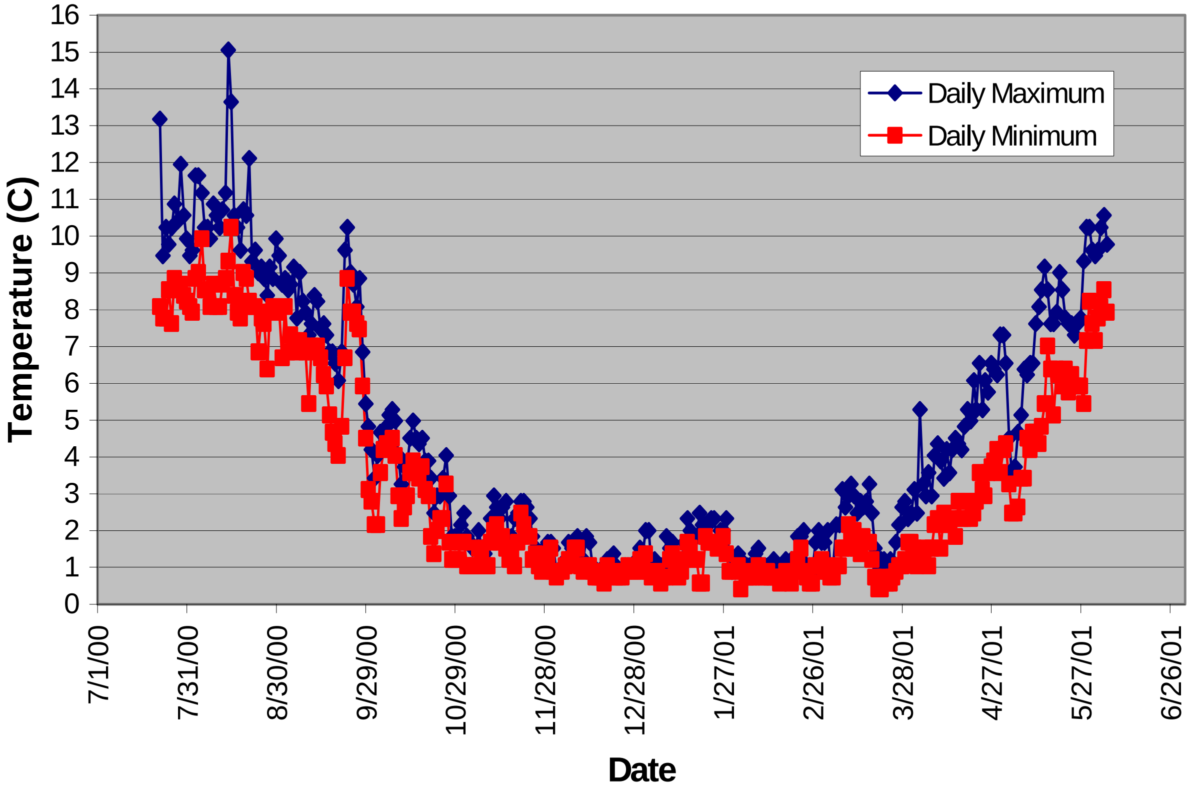

Figure 5. Station 4 annual stream water temperature.

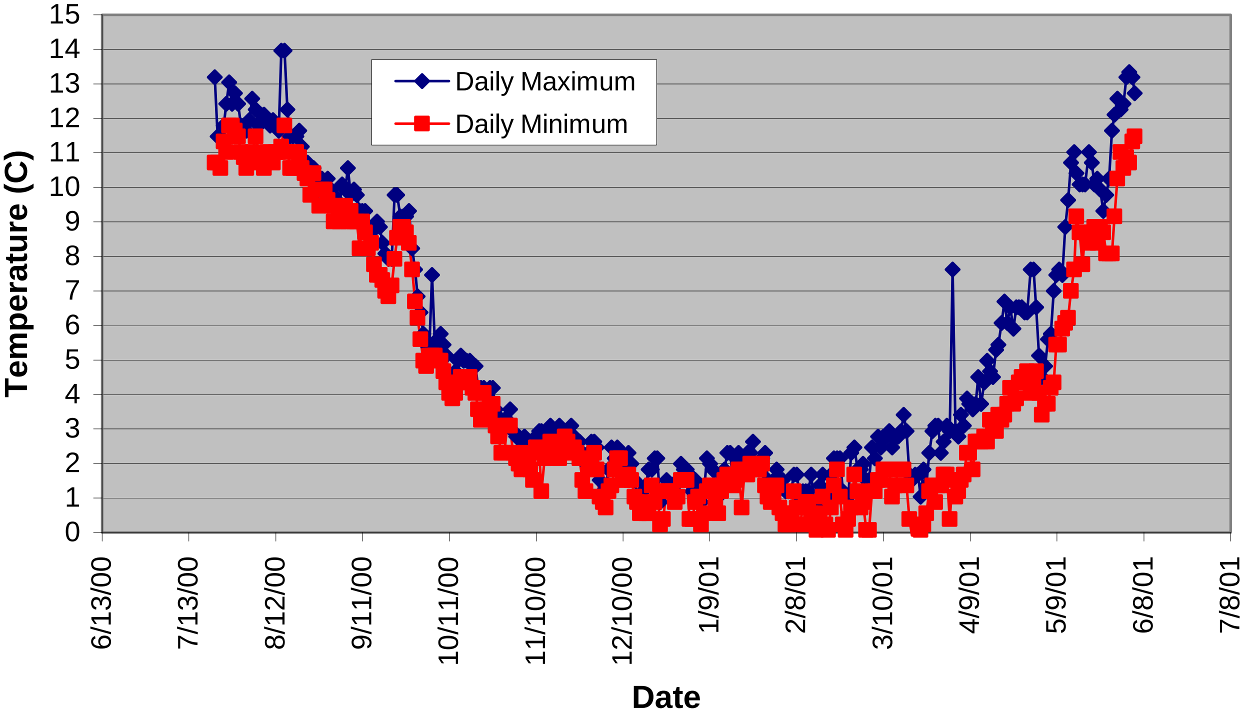

Figure 6. Station 6 annual stream water temperature.

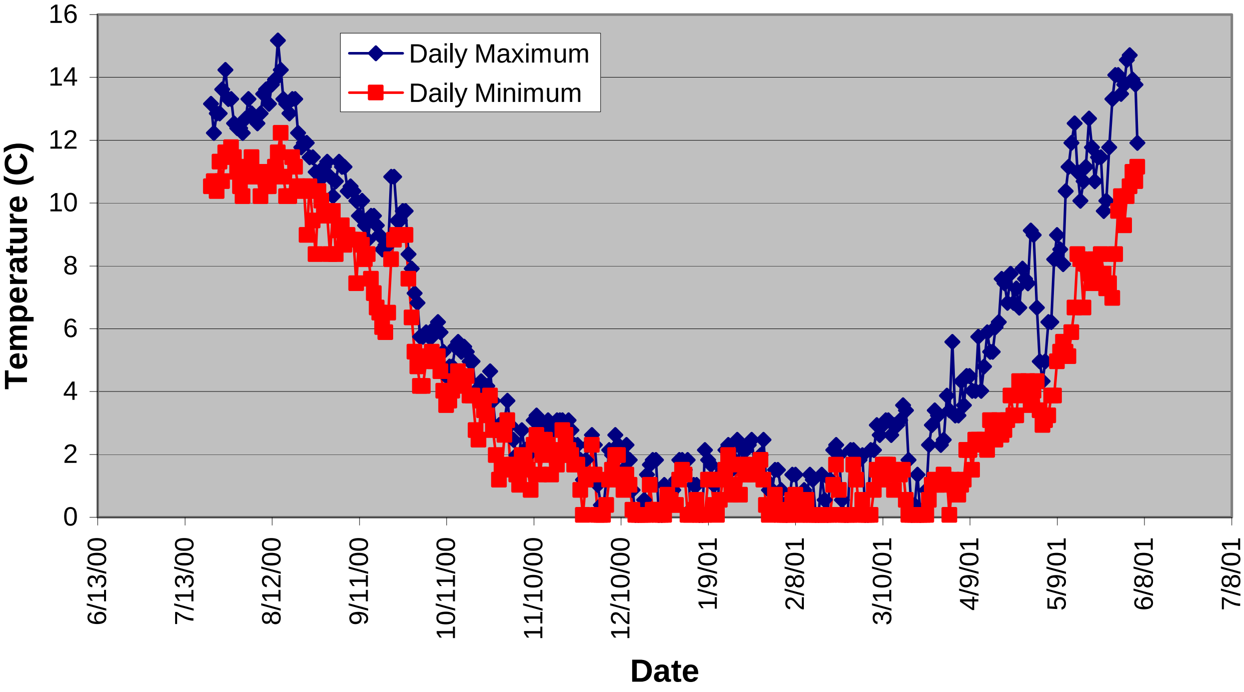

Figure 7. Station 8 annual stream water temperature.

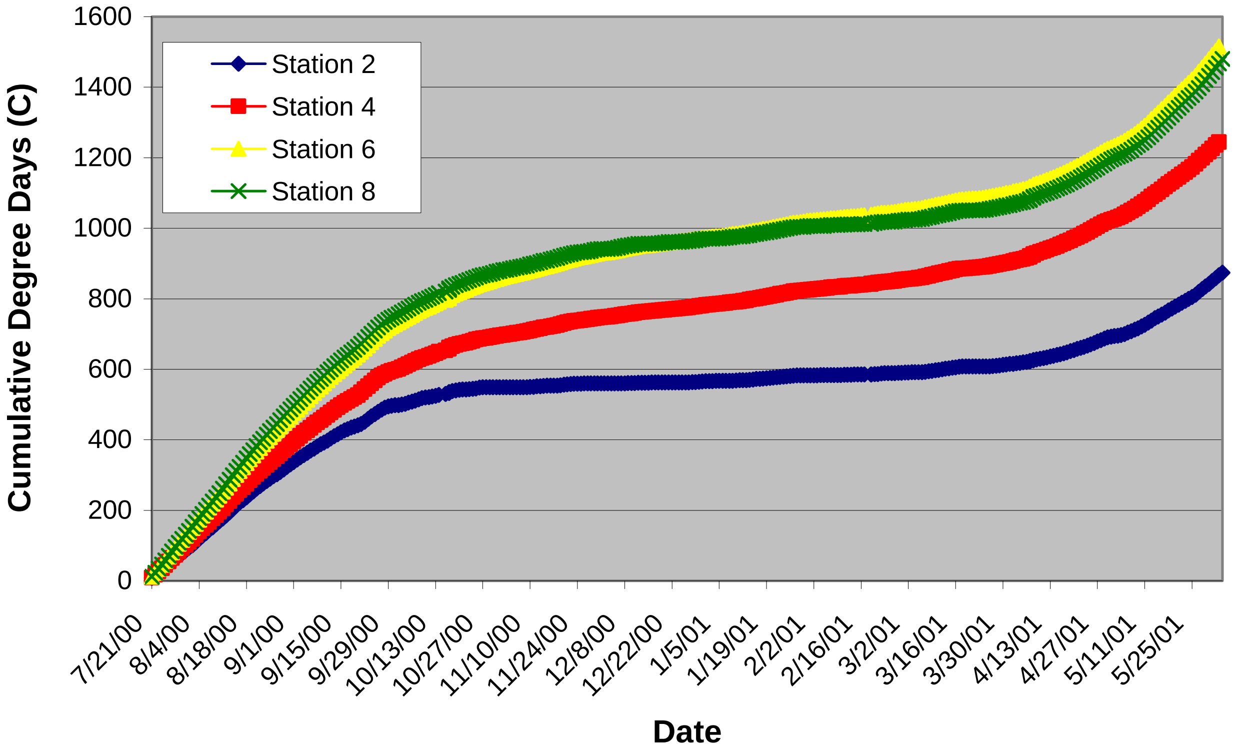

Figure 8. Cumulative degree days for the sampling Stations.

Table 14. Chlorophyll-*a*, CPOM, and FPOM (SD).

	Chl.-a (mg/m^2)		**CPOM (g/m^2)**		**FPOM (g/m^2)**	
	August	**October**	**Sept.**	**October**	**Sept.**	**October**
Station 1	2.61 (1.43)	8.18 (5.60)	4.21 (3.34)	24.32 (20.65)	9.45 (11.25)	17.89 (14.12)
Station 2	2.47 (1.77)	19.34 (10.65)				
Station 3	29.09 (24.46)	48.6 (17.02	2.82 (1.23)	11.76 (20.22)	8.76 (1.98)	6.25 (2.63)
Station 4	47.75 (52.86)	78.98 (31.13)				
Station 5	5.45 (1.50)	46.07 (41.74)				
Station 6	55.39 (25.66)	72.38 (8.39)	5.96 (6.12)	7.62 (8.50)	12.13 (5.34)	8.98 (3.75)
Station 7	23.15 (18.29)	133.14 (32.01)				
Station 8	45.30 (26.57)	144.16 (65.62)				
Station 9	25.27 (11.76)	63.60 (29.46)				
Station 10	21.89 (7.95)	160.07 (115.1)	2.49 (0.51)	14.72 (16.96)	8.78 (1.89)	10.51 (4.43)

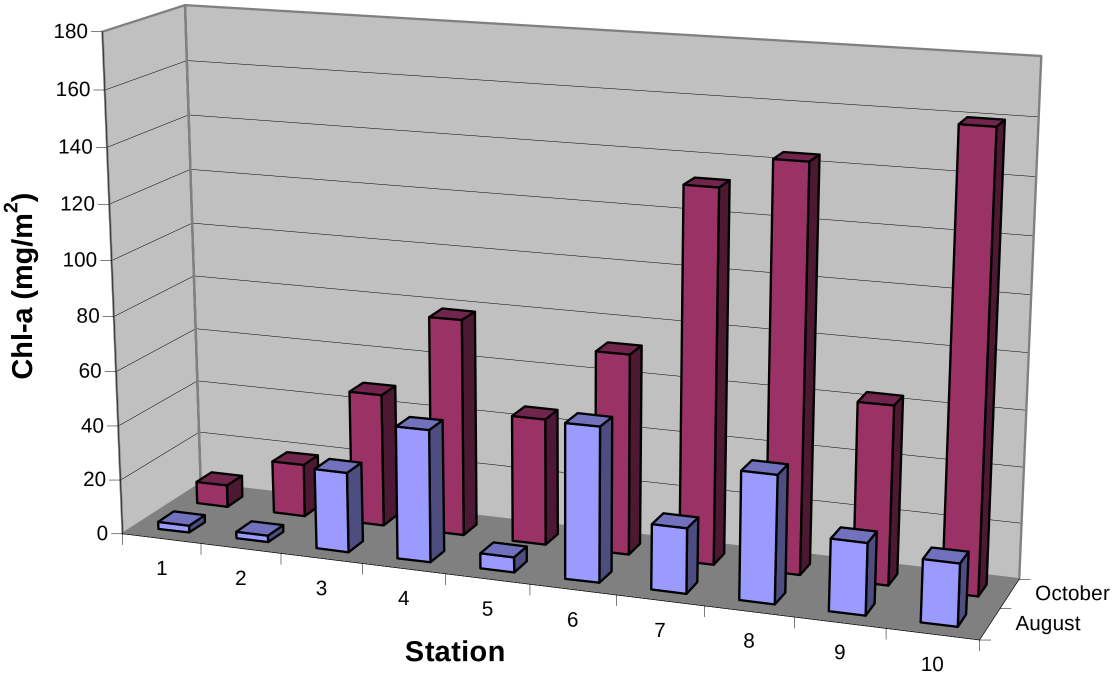

Figure 9. Algal chlorophyll-*a* for each station in August and October 2000.

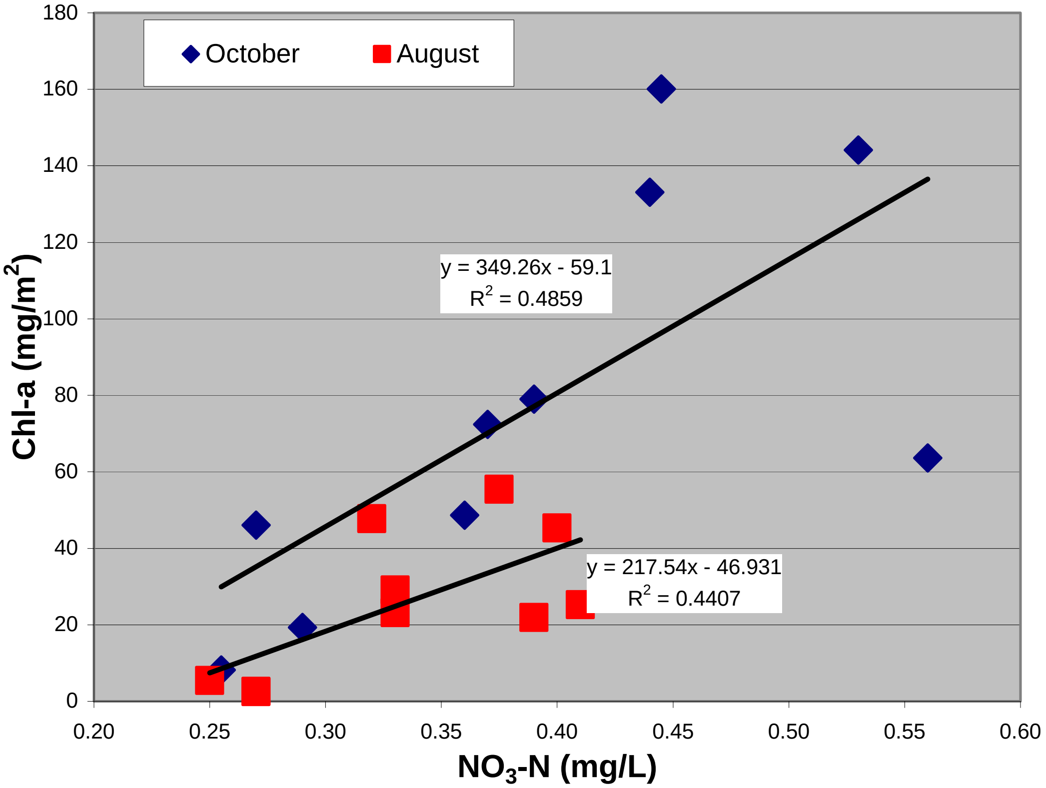

Figure 10. Chlorophyll-*a* concentrations as a function of nitrate nitrogen.

A total of 63 Dolly Varden were captured from the 10 Chester Creek sampling stations. Dolly Varden were the most numerous species at the upstream stations declining downstream and absent below station 5. Over 60% of the total Dolly Varden captured were at station 1. The size distribution of Dolly Varden is shown in Figure 14. Approximately 10% of the Dolly Varden captured were greater than 200-mm long.

Rainbow trout were the most common species found in Chester Creek, with a total of 237 fish captured. Few rainbow were captured upstream of Muldoon Road (Stations 1 and 2). The size distribution of captured rainbow trout is shown in Figure 15. Approximately 4 to 5% of the captured fish were greater than 200-mm in length and were captured at stations 1, 3, 5, and 7.

DISCUSSION

The biological community within Chester Creek is affected by both physical and chemical modifications. These modifications do not all vary the same among stations; therefore, there are different multiple interacting impacts at most sampling stations. The primary and most obvious physical change to Chester Creek is channelization. Channelized sites were characterized by shallow wide channels with a reduction in undercut banks and homogenous flows. Though not quantified, channelized sites lacked side channels and other forms of habitat complexity. Qualitatively, habitat scored lower at channelized sites (less than 140) when compared to non-channelized sites (greater than 165). The invertebrate community also appeared to respond to the change in conductivity, which tended to increase in a downstream direction.

The amount of allochthonous food resources (benthic organic matter) did not vary between channelized and non-channelized sites either prior to, or following leaf fall. This is probably due to the existence of vegetated streamside zones of Chester Creek even in the more developed regions. The quantity of benthic organic matter, 11 to 42 g/m^2, is similar to other Alaskan streams. Although few measurements are available for Southcentral streams, Cowan and Oswood (1983) reported values form 7 to 38 g AFDM/m^2 for streams near Fairbanks, Alaska. Similarly Davis et al. (1998) reported maximum total BOM values of near 30 g AFDM/m^2 for unmined interior Alaska streams.

Although both nitrogen and phosphorus concentrations increased downstream and were weakly correlated with periphyton chlorophyll-*a* concentrations, these nutrients are most likely above concentrations that saturate algal production. Therefore, differences in periphyton chlorophyll-*a* are more likely due to differences in sunlight. Previous studies have shown that algal productivity can be limited by low concentrations of nutrients. The nutrients most often determined limiting are nitrogen and phosphorus. Algae have been found to be limited by instream nitrogen concentrations below 0.10 to 0.55 mg/L (Grimm and Fisher 1986, Lohman et al. 1991). These concentrations are well below concentrations measured in Chester Creek. Similarly, phosphorus has been found to be limiting below concentrations of 0.006 mg/L (Mulholland et al. 1990; Bothwell 1989) which are an order of magnitude lower than measured Chester Creek concentrations.

The abundance of phosphorus and nitrogen would explain the high algal concentrations in Chester Creek when compared to other Alaskan streams. Concentrations of chlorophyll-*a* were lowest at Station 1 in August (2.61 mg/L), and highest at Station 10

Table 15. Invertebrate community metric values and ASCI score for each sampling station (Sept 2000).

	Number of Taxa	No. of Ephemeroptera	No. of Plecoptera	No. of Trichoptera	%EPT	% Chironomidae	% Dominant Taxa	ASCI Score	% Oligochaeta	% Ephemeroptera	%Plecoptera	%Trichoptera	% Collector filterers	% Collector gathers	% Omnivores	% Predators	% Scrapers	% Shredders	Habitat Score
Station 1	18	2	2	3	25.5	57.3	57.3	26	1.3	15.4	2.1	7.3	4.4	6.0	76.8	12.8	0.0	0.0	184
Station 2	18	1	2	3	40.0	32.4	32.4	32	4.8	21.0	7.6	10.5	6.7	34.3	41.9	13.3	0.0	3.8	178
Station 3	12	1	2	3	10.2	18.6	63.8	24	63.8	0.6	2.8	6.2	2.3	63.8	21.5	5.6	0.0	6.2	120
Station 4	17	1	2	4	11.4	23.9	55.7	26	55.7	4.5	3.4	2.3	2.3	55.7	30.7	11.0	0.0	0.4	129
Station 5	17	1	1	3	14.1	41.8	41.8	26	5.9	2.4	2.9	5.3	24.1	5.9	45.7	11.8	4.7	9.4	177
Station 6	16	1	2	3	17.2	40.1	40.1	24	26.2	0.4	4.9	12.0	12.0	26.2	50.9	6.7	0.4	3.7	168
Station 7	17	1	2	3	24.7	51.0	51.0	26	12.1	2.0	10.1	12.6	5.1	12.1	62.1	8.6	0.0	12.1	166
Station 8	18	0	4	3	19.0	37.9	37.9	30	37.4	0.0	12.6	6.3	0.6	37.4	44.3	9.2	0.6	6.9	141
Station 9	16	0	3	3	21.2	14.7	57.1	30	57.1	0.0	18.6	2.2	1.3	57.4	17.0	6.1	0.4	6.1	139
Station 10	15	1	3	1	4.1	20.7	67.5	26	67.5	1.2	2.4	0.6	4.1	67.5	22.5	4.1	0.0	1.2	129

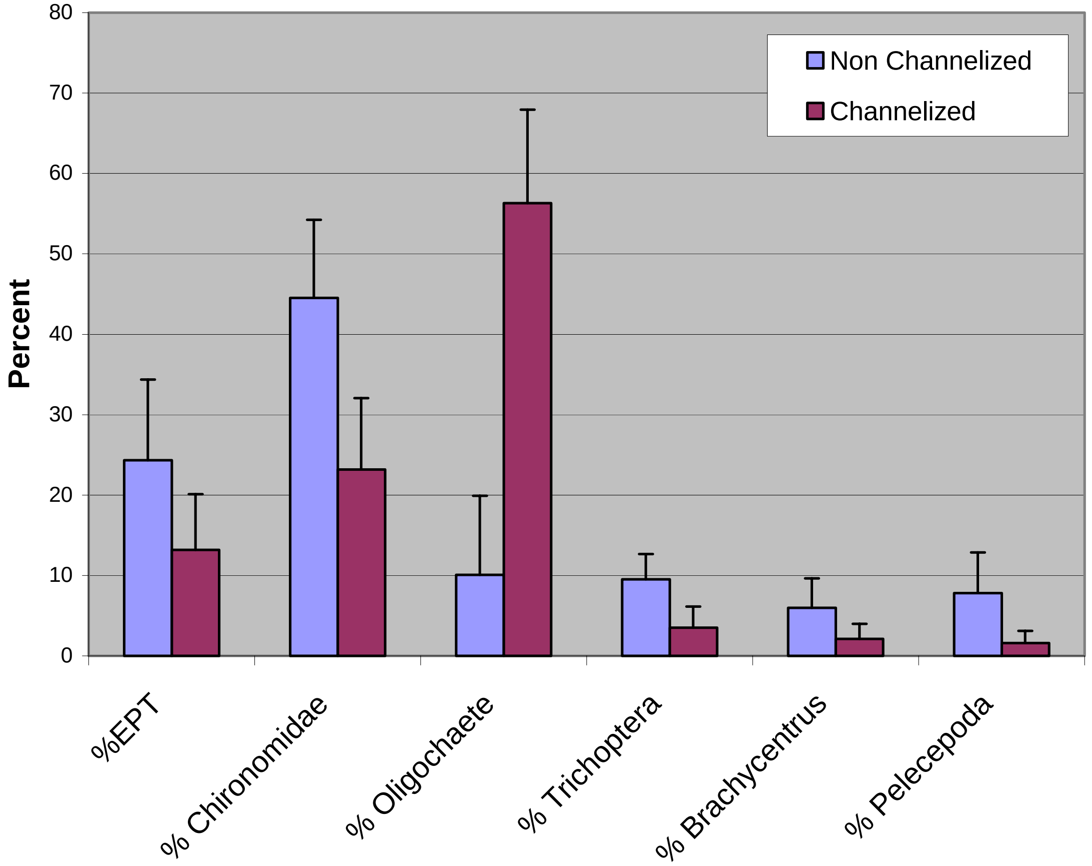

Figure 11. Comparison of selected invertebrate community metrics between channelized and non-channelized stations.

in October (160 mg/L). In comparison, most reported chlorophyll-*a* concentrations within Alaska have ranged between 1 and 10 mg/m^2. Concentrations in Chester Creek were often near 50 mg/L during August and generally near 100 mg/L in October, well above commonly reported values.

Light limitation of algal biomass is supported by the differences observed at each site between August and October. Statistical comparisons (paired t-test) showed a significant increase in chlorophyll-*a* concentrations following leaf fall. The relatively low chlorophyll-*a* concentrations at some sites during October could be due to channel morphological differences that affect light input. The loss of leaves at station 1 from August to October would not be likely to result in increased solar radiation due to the small narrow incised channel. In contrast, solar radiation is likely to increase considerably following leaf fall in the wide and shallow open channelized sites in the lower portion of the drainage, which is consistent with the large increases in algal biomass and light limitation. Of these lower stations, chlorophyll-*a* concentrations are lowest at station 9. This may be due to the deeply confined condition of the stream at this station with banks approximately 5 to 7 meters high. Additionally, filamentous green algae were commonly observed at more open locations along Chester Creek in the spring.

The invertebrate community responded to both physical and chemical changes.

Table 16. Individual and total salmonid catch and density for each sampling station.

	Coho		Rainbow		Dolly Varden		Total Salmonids				
	Catch	No./m^2	Catch	No./m^2	Catch	No./m^2	Catch	No./m^2	Est.	No./m^2	90% CI
Station 1	6	0.058	2	0.019	40	0.019	48	0.467	71	1.382	56-250
Station 2	13	0.143	0	0.000	9	0.000	22	0.242	25	0.549	20-infi
Station 3	0	0.000	10	0.062	2	0.062	12	0.074	12	0.148	11-infi
Station 4	0	0.041	16	0.014	4	0.014	20	0.325	26	0.963	23-36
Station 5	2	0.011	34	0.195	8	0.195	44	0.253	259	2.978	57-infi
Station 6	0	0.000	13	0.124	0	0.124	13	0.124	125	2.385	10-infi
Station 7	1	0.007	42	0.305	0	0.305	43	0.312	67.9	0.986	43-infi
Station 8	0	0.000	18	0.086	0	0.086	18	0.086	519	4.975	16-infi
Station 9	0	0.000	59	0.238	0	0.238	59	0.238	70.42	0.569	59-infi
Station 10	0	0.000	43	0.145	0	0.145	43	0.145	74.6	0.504	43-infi

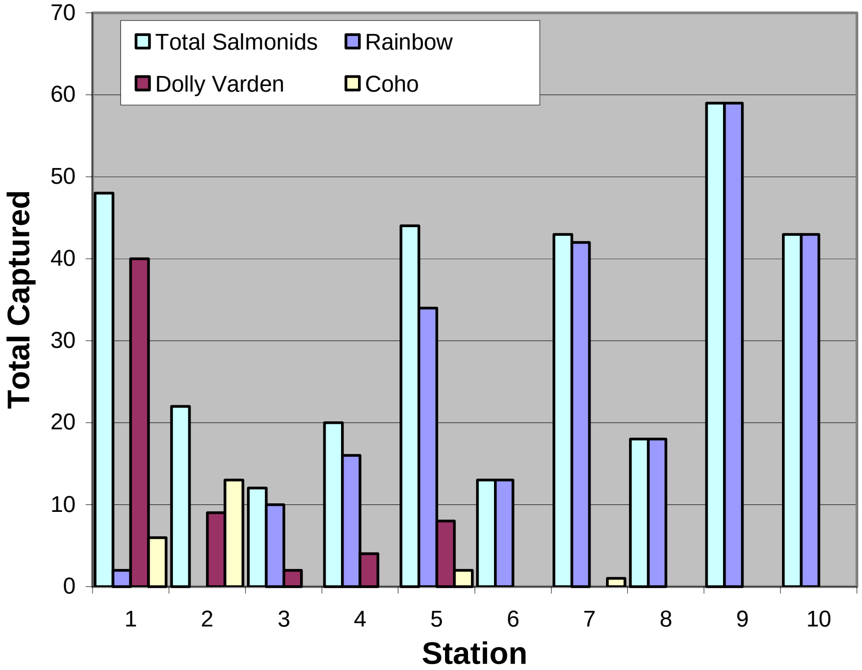

Figure 12. Total number of salmonids and individual species captured at each sampling station.

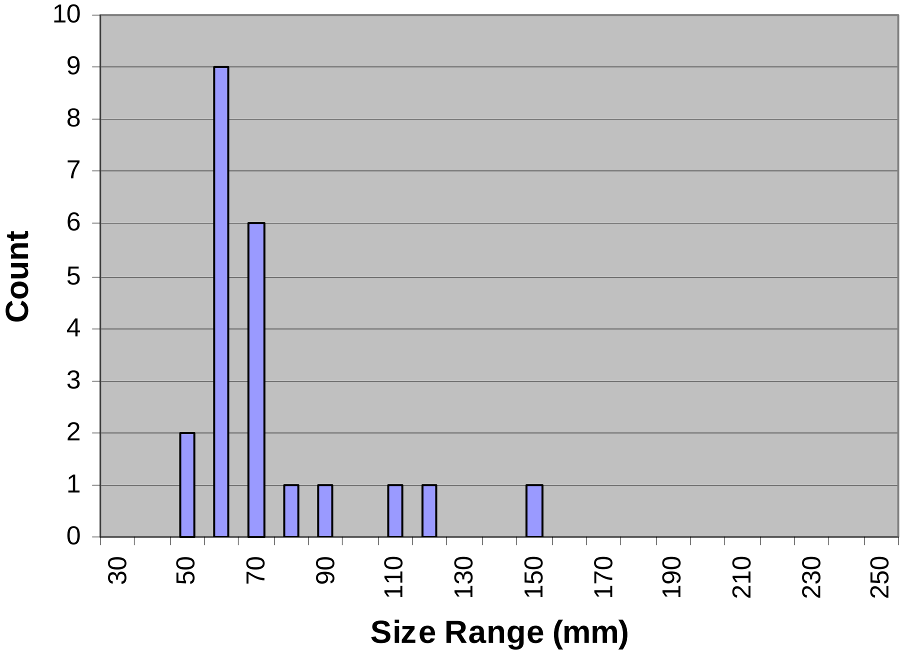

Figure 13. Size distribution of coho salmon.

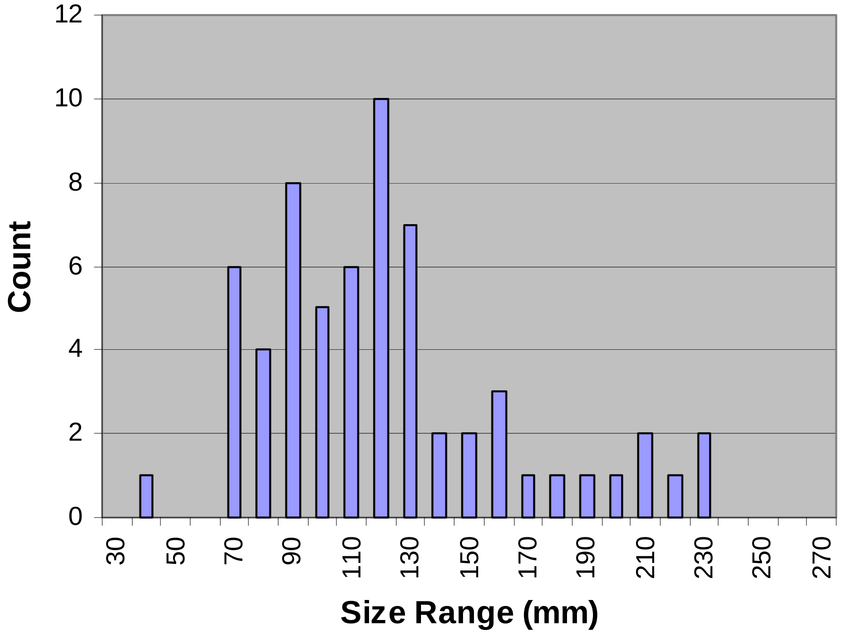

Figure 14. Size distribution of Dolly Varden.

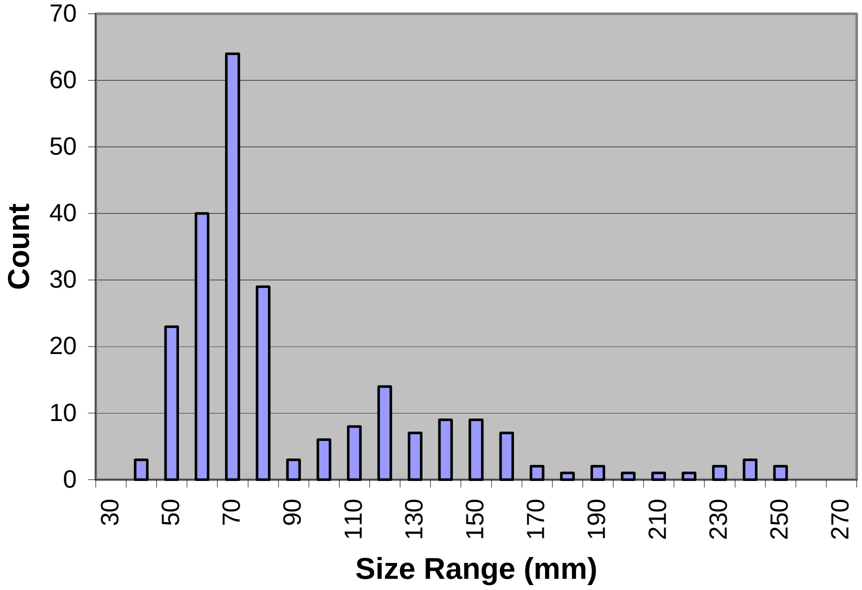

Figure 15. Size distribution of rainbow trout.

The invertebrate community was different at non-channelized compared to channelized sites. The percent of the community made up of organisms of the EPT orders was higher at non-channelized sites and was significant ($p = 0.07$); however, the differences were small with a means of 24.3% and 13.2% for non-channelized and channelized sites, respectively. The small difference in this metric is consistent with previous macroinvertebrate data reported by Major et al. (2000 Table A-6). These investigators collected monthly samples from May through October at a reference site (above Muldoon) and a stressed site (above Arctic). The mean percent EPT value from the reference site was 20.2, which was less than the mean of 30.7 obtained from the stressed site.

The limited differences between the percent EPT becomes clearer when looking at the individual EPT orders, which appeared to be responding to different factors. The percent Ephemeroptera were not different when comparing channelized and non-channelized stations, but appeared to be affected by either chemical or hydrologic factors downstream of Muldoon Road. The percent Ephemeroptera is an order of magnitude higher at the upstream stations 1 and 2 compared to the remainder of the sites including the non-channelized locations. This implies that some factor, other than those caused by channel form, is limiting the ability of *Baetis* to survive at some point below Muldoon Road.

Water chemistry may be causing the absence of *Baetis* at downstream stations. The conductivity of stream water increased in a downstream direction indication the continued input of ions throughout the drainage. The USGS is currently conducting more detailed water and sediment chemistry studies within the drainage that may further explain the distribution of aquatic biota.

The percent Trichoptera were significantly different between channelized and non-channelized sites. One anomaly was the non-channelized station 5 where the percent Trichoptera value was the lowest and more similar to values obtained at channelized sites. Station 5 differed from the other non-channelized sites by the large percent of the substrate composed of fine material, which likely is cause for the reduction in Trichoptera at this station.

There was a very large difference in the percent Chironomidae and Oligochaeta when comparing channelized and non-channelized stations, with no trends seen within either of these groups. The percent Chironomidae was higher at the more natural non-channelized stations. Chironomidae also made up a larger portion of the invertebrate community at the previously sampled reference sites (60% mean of 6 monthly values) compared to the stressed sites (40%) of Major et al. (2000 Table A-6). This is contrary to the common interpretation of this metric and its current application in the ASCI where an increase in Chironomidae is considered an indication of impairment (Major et al. 1998).

The percent Oligochaeta was considerably higher at channelized sites consistent with the common interpretation of this metric. The average percent Oligochaeta was 56% at channelized stations. In comparison the average at non-channelized stations was 10%. As such the percent Oligochaeta appear to be a good predictor of impairment within the Chester Creek drainage.

The ASCI score as currently applied was not a good predictor of impairment within the Chester Creek drainage. This was due to the percent Chironomidae and the percent dominant taxa. Chironomidae increased at the less modified sites thereby resulting in a lower ASCI value. The percent dominant taxa was high at all sites because it was redundant with the percent Chironomidae at the non-channelized sites and with the percent Oligochaeta at channelized sites.

The community composition of salmonids within Chester Creek has changed over the past 20 years. Rainbow trout were the most common fish caught within the Chester Creek drainage. Rainbow trout are not native to Chester Creek. These fish were introduced during 1971 through 1973 and were intended to establish a reproducing population. Rainbow trout were estimated at a density of 7 fish per stream mile from sampling conducted in 1974 (ADF&G 1974) compared to a current average estimate of 368 per mile. Rainbow trout have been stocked into the Chester Creek drainage for a number of years, primarily catchable fish but also fry and fingerlings (Table 17). Only sterile fish have been released in recent years. As the most recent release of juvenile fish was 6 years ago, the small fish captured in this study (40 to 80 mm) more likely represent the results of a reproducing population.

Dolly Varden were the second most common species found currently in Chester Creek at a population density estimated at 157 per stream mile, similar to the 1974 estimate of 104 (ADF&G 1974). Coho salmon currently are the least abundant, whereas they were the most common fish species captured in the early 1970s. The coho population density was estimated at 34 per stream mile in 2001 compared to 217 in 1974.

The coho population has been affected by the migration barrier at the inlet due to the construction of the dam and concrete weir in 1971 creating Westchester Lagoon. Juvenile fish movement throughout the drainage also is limited by a number of culverts that are migration barriers (See Appendix B).

Water quality including fine sediment deposition is also likely affecting spawning and rearing coho habitat. The concentration of semivolatile organic compounds, cadmium, lead, and zinc in Chester Creek sediments and total PCBs, cadmium, lead, and zinc in sculpin tissues are higher than background levels (Frenzel 2000). These elements have the potential to affect fish, particularly at more sensitive life stages. Water temperatures in Chester Creek approached the legal limits for migration (15ºC) (18 AAC 70) during July and August, which may coincide briefly with coho migration. Stream temperature often exceeded the limit for spawning and incubation (13ºC) but not from October through May.

Table 17. Rainbow release data for the Chester Creek drainage.

Year	Adults	Juveniles
1971		520
1972		500
1973	1,000	
1988	4,509	5,013
1989	4,467	
1990	5,011	
1991	2,458	
1992	7,970	
1993	4,606	
1994	4,741	
1995	0	8,135
1996	4,975	
1997	2,611	
1998	1,000	
1999	1,000	
2000	1,000	

Total salmonid density based on total catches did not vary between channelized and non-channelized sites. Coho salmon juveniles were captured only at non-channelized sites but the number of fish was too low to make any statistical comparisons. The highest number of coho juveniles were found at station 2 above residential development; however this is likely because the majority of spawning occurs in the same area.

Salmonid distribution did vary longitudinally with Dolly Varden more abundant upstream and rainbow downstream. The cause of this distribution; however, is unknown and can not be definitively linked to any of the habitat variables measured within this study.

Total salmonid numbers were positively correlated with the LWDI. This correlation was particularly strong for the channelized sites (Figure 16). Based upon observation, the only cover and flow variability available in channelized sites was caused by woody debris and fish were predominantly captured where they were in close association with wood.

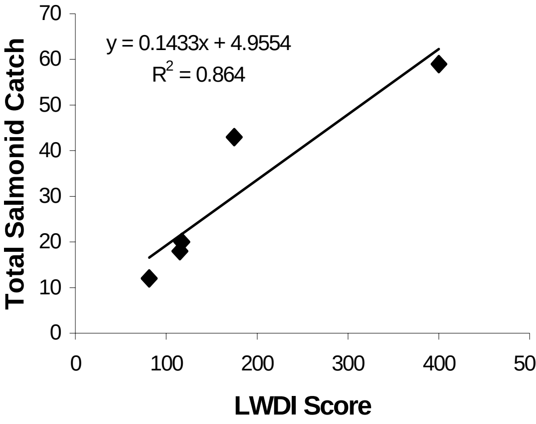

Figure 16. Relationship between woody debris score and salmonid catch at channelized stations.

The retention of vegetation along Chester Creek has maintained similar inputs of organic material and woody debris. The riparian vegetation also is limiting the amount of light and heat reaching the stream. Without the riparian vegetation excessive algal accumulations could occur due to nutrient concentrations above saturation and shallow water in the channelized reaches. Shallow water allows more light to reach algae colonizing the stream bottom. The loss of riparian vegetation also would likely result in water temperatures high enough to affect salmonid distribution and development as well as reductions in organic matter and woody debris input.

Fine sediment accumulation was evident only at sites where stream energy was reduced allowing deposition. Among the stations sampled, fine sediment deposition was greatest at the station with the highest woody debris accumulation. That is, the accumulation of sediment where water velocity is reduced implies that there is a large quantity of fine sediment in transport within Chester Creek.

The invertebrate community appears to be affected by at least three factors. Water quality appears to be affecting the distribution of *Baetis*, limiting this genus to the stations above Muldoon Road. Channelization results in an increase in Oligochaetes, and a decrease in Chironomidae and Trichoptera. Fine sediment accumulations appear to further limit the distribution of Trichoptera.

The number of coho salmon juveniles within Chester Creek has declined when compared with data collected previously. This apparent reduction in coho salmon is most likely due to adult and juvenile migration barriers.

Based upon the information obtained through this study, restoration efforts should first be directed at removing migration barriers. Adult coho salmon must be able to access the currently available spawning habitat in the upper drainage. Removal of barriers to juvenile fish would allow for the movement to preferred habitats throughout the drainage.

Restoration efforts should then be focused upon the channelized stream sections. The channels should be modified so that ratios of width to depth and slopes approximate the same parameters at non-channelized stations. This would result in a more natural invertebrate community, increase cover provided by undercut banks and water depth, and provide diverse flow habitats. Deeper narrower channels would have more energy available for the transportation of fine sediment. In many locations modified channels could be constructed within the confines of the current channels and at stream locations publicly owned.

The major tributaries of Chester Creek were not investigated through this study. However, based upon observation, the loss of fish habitat due to migration barriers and channelization may be even more extensive in these smaller channels. In particular, it appears that the North Fork could be returned to its natural channel. Further investigations should be conducted on the other tributaries to evaluate potential fish-passage barriers and channel modifications.

Restoring the stream channels to their natural shape will increase the transport of fine sediment through the drainage; however, efforts to reduce sediment input through storm drains and other sources needs to continue. This study showed an increase in fish use of areas where large woody debris was present; however, overall fish production may be affected by the negative effect to the invertebrate community caused by sedimentation at these same locations. The retention and further development of riparian vegetation and contiguous wetlands could help to reduce sediment input. Riparian areas and wetlands are efficient sediment and nutrient traps; however, most of the storm runoff throughout the drainage bypasses these areas and is collected and discharged directly into the stream. Allowing riparian areas to function as natural sediment traps by discharging diffused storm water through these areas may be one way to reduce sediment input.

Diverting diffused storm-water flow through riparian areas and wetlands may also ameliorate the hydrologic and associated water quality impacts common to urban streams. Within Southcentral Alaska small increases in impervious surfaces appear to cause changes to the biotic community (USGS personal communication). The affects of hydromodification may explain the loss of *Baetis* species below Muldoon as documented in this study. Maintaining and enhancing the hydrologic functions of riparian areas and wetlands may be a way of reducing the effects of increased impervious surfaces.

In addition to hydrologic functions, stream structure and function could be improved by maintaining and enhancing the riparian vegetation. Data from this study suggest that the riparian vegetation along Chester Creek limits algal growth and stream water temperatures. The riparian vegetation within non-channelized sites provides undercut banks and diverse habitat and woody debris which is particularly important at habitat limited channelized sites.

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APPENDIX A. QUALITY ASSURANCE RESULTS

Appendix A. Quality Assurance Results

Water Chemistry. The accuracy of laboratory water chemistry analyses was determined through the analysis of known standards (APHA method 1030 C). The precision of analyses was determined through replicate sampling. Quality assurance results for water chemistry are shown in the follow table. Values reported within the report reflect the accuracy of the analyses. The accuracy was within the range previously determined necessary for the project.

Table A-1. Average, standard deviation (s) of difference between known standard and analyses (accuracy) and between replicates (precision) (n= number of samples).

	Accuracy			**Precision**		
Measure	Average	s	n	Average	s	n
Alkalinity	1.93	1.36	3	2.1	1.99	3
Hardness	1.16	1.5	3	0	0	3
Nitrate-N	0.048	0.033	4	0.034	0.029	10
Phosphate-P	0.180	0.235	7	0.034	0.053	7

Water Velocity. Replicate 40-second counts were conducted and did not vary by more than 1, which is within the acceptance criteria range.

Substratum. Replicate data are shown in the following table. The maximum difference in cumulative percent is below the acceptance criteria outlined for this study.

Table A-2. Comparison between original and replicate pebble count data.

Station 4			**Replicate**		
Size Class (mm)	Number	Cumulative %	Number	Cumulative %	Difference
2	11	11.00%	4	4.00%	7%
2.8	0	11.00%	1	5.00%	6%
4	2	13.00%	1	6.00%	7%
5.6	3	16.00%	6	12.00%	4%
8	2	18.00%	4	16.00%	2%
11	9	27.00%	10	26.00%	1%
16	14	41.00%	6	32.00%	9%
22.6	7	48.00%	4	36.00%	12%
32	4	52.00%	8	44.00%	8%
45	5	57.00%	8	52.00%	5%

Station 4			Replicate		
64	16	73.00%	13	65.00%	8%
90	18	91.00%	17	82.00%	9%
128	4	95.00%	13	95.00%	0%
180	2	97.00%	5	100.00%	-3%
360	3	100.00%	0	100.00%	0%

Cross-sectional morphometry. The following table shows the difference in channel characteristics between original measurements and replicates. The average and standard deviation are given for each column. For example width measurements varied on average by 0.11-m. The cross-sectional area varied on average 0.28-m.

Table A-3. Differences between channel characteristics calculated from original and replicate data.

	Width (m)	Mean Depth (m)	W/D	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Right Undercut (m)	Left Undercut (m)
1	0.22	0.02	1.71	0.01	0.19	0.02	0.00	0.00
2	0.06	0.05	4.73	0.34	0.01	0.06	0.00	0.01
3	0.05	0.02	0.71	0.05	0.06	0.01	0.04	0.01
4	0.10	0.04	0.97	0.09	0.08	0.01	0.05	0.17
5	0.10	0.11	6.56	0.89	0.05	0.15	0.02	0.08
Ave	0.11	0.05	2.93	0.28	0.08	0.05	0.02	0.05
Stdev	0.07	0.04	2.58	0.37	0.07	0.06	0.02	0.07

Habitat Scores. The following tables show the habitat scores obtained in September 2000, and May, 2001, and the difference between the two scores. The largest differences were at the sites with the lowest overall habitat scores. Scores obtained in May were generally lower than scores from September. This may be due to differences in vegetation and flows.

Table A-4. Qualitative habitat scores for each station, replicate scores, and the difference between original and replicate.

	Station									
Habitat Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Substrate/Cover	19	19	19	15	17	14	11	15	15	10
2. Embeddedness	19	19	15	15	15	11	11	15	15	10
3. Velocity/Depth combinations	14	13	5	5	19	16	13	11	15	15
4. Sediment Deposition	20	19	18	19	13	15	16	18	17	14
5. Channel Flow Status	19	19	19	19	20	19	19	17	19	19
6. Channel Alteration	20	20	3	8	19	19	19	8	8	11
7. Frequency of Riffles or bends	15	17	3	3	19	19	17	8	6	15
8. Bank Stability	20	19	16	14	18	19	20	16	15	14
9. Bank Vegetative Protection	20	19	16	14	18	19	20	16	15	14
10. Riparian Zone Width	18	14	6	17	19	17	20	17	14	7
Total	184	178	120	129	177	168	166	141	139	129
% Possible	92	89	60	65	88.5	84	83	70.5	69.5	65

Optimal > or =	83
Suboptimal > or =	57
Marginal > or =	35
Poor <	33

Replicate	**Station**									
Habitat Parameter	1	2	3	4	5	6	7	8	9	10
1. Substrate/Cover	18	17	15	11	8	14	16	10	9	8
2. Embeddedness	19	17	13	11	4	12	14	7	9	4
3. Velocity/Depth combinations	14	16	7	7	5	11	13	3	5	7
4. Sediment Deposition	16	16	17	16	1	12	18	6	8	8
5. Channel Flow Status	20	20	18	16	19	19	19	18	18	18

6. Channel Alteration	20	20	9	9	17	17	17	6	5	2
7. Frequency of Riffles or bends	15	15	8	5	15	16	17	2	7	6
8. Bank Stability	20	17	18	18	14	15	18	6	11	3
9. Bank Vegetative Protection	20	17	10	8	16	15	18	5	7	2
10. Riparian Zone Width	19	15	4	15	18	13	18	6	4	2
Total	181	170	119	116	117	144	168	69	83	60
% Possible	91	85	59.5	58	58.5	72	84	34.5	41.5	30

Difference	**Station**									
Habitat Parameter	1	2	3	4	5	6	7	8	9	10
1. Substrate/Cover	1	2	4	4	9	0	5	5	6	2
2. Embeddedness	0	2	2	4	11	1	3	8	6	6
3. Velocity/Depth combinations	0	3	2	2	14	5	0	8	10	8
4. Sediment Deposition	4	3	1	3	12	3	2	12	9	6
5. Channel Flow Status	1	1	1	3	1	0	0	1	1	1
6. Channel Alteration	0	0	6	1	2	2	2	2	3	9
7. Frequency of Riffles or bends	0	2	5	2	4	3	0	6	1	9
8. Bank Stability	0	2	2	4	4	4	2	10	4	11
9. Bank Vegetative Protection	0	2	6	6	2	4	2	11	8	12
10. Riparian Zone Width	1	1	2	2	1	4	2	11	10	5
Total	3	8	1	13	60	24	-2	72	56	69

Invertebrates. Precision of invertebrate data was determined by calculating the difference between metrics from the original and replicate data (Table A-5).

Table A-5. Difference between station 9 and station 9 replicate invertebrate metrics.

Metric	Site 9	Replicate	Difference
Number of Taxa	17.0	16.0	1.0
No. of Ephemeroptera	1.0	0.0	1.0

Metric	Site 9	Replicate	Difference
No. of Plecoptera	4.0	3.0	1.0
No. of Trichoptera	2.0	3.0	-1.0
%EPT	51.4	21.2	30.1
% Chironomidae	18.4	14.7	3.7
% Dominant Taxa	21.1	57.1	-36.1
ASCI sum	32.0	30.0	2.0
% Oligochaeta	21.1	57.1	-36.1
% Ephemeroptera	7.6	0.0	7.6
%Plecoptera	40.5	18.6	21.9
%Trichoptera	3.2	2.2	1.1
% collector filterers	1.6	1.3	0.3
% collector gathers	28.6	57.4	-28.7
% omnivores (generalists)	21.1	17.0	4.1
% predators	18.9	6.1	12.8
% Brachycentrus	2.7	1.7	1.0
% Pelycepoda	1.6	0.9	0.8

APPENDIX B. CHESTER CREEK CROSSING STRUCTURE SURVEY

Appendix B. Chester Creek Crossing Structure Survey

A culvert inventory was conducted on Chester Creek to evaluate fish passage and channel modification due to culvert crossing structures. A survey of Chester Creek was conducted and the culverts located. The latitude and longitude were recorded on a Garmin XL GPS. The culvert type and size were determined. At most locations fish passage was determined based upon estimated water velocity and outlet leap heights. Channel and culvert elevations were surveyed at four locations: Seward Highway, Lake Otis Parkway, Mallard Drive, and Muldoon Road. Surveyed elevations were entered into Fish-Xing. The program was used to determine whether the culvert would block the passage of 55-mm long juvenile coho salmon.

Table B-1 describes the culvert locations, type and estimated fish passage. Additional information for surveyed culverts is given in Table B2. Also attached is the culvert report for Mallard Drive generated from the Fish-Xing program.

Table B-1. Culvert locations, type, and estimate of fish passage.

Location	Latitude	Longitude	Type	Predicted Passage Capability
Arctic Blvd	61.20524	149.89584	Arch, w=10.0-ft, h=4.9-ft	Good
Seward Highway	61.20217	149.86410	6.5-ft CMP	Blockage: Velocity too high
Lake Otis			Twin 6.0-ft CMPs	Blockage: Leap, Velocity to high
Northern Lights	61.19571	149.82695	Twin 4.8-ft CMPs	Good
Mallard @ UAA	61.19305	149.82728	4-ft CMP	Blockage: Velocity too high
36th @ UAA	61.18966	149.82171	Twin 5.5-ft CMPs	Good
Providence access Rd.	61.18858	149.82163	6.0-ft CMP	Questionable: Velocity too high
Providence East Loop	61.18557	149.81369	5.5-ft CMP	Questionable: Velocity too high
Bragaw	61.18566	149.80797	Twin 6.5-ft CMPs	Good
Weselyn Rd	61.18609	149.79003	Twin 5.5-ft CMPs	Good
Knights Way	61.18825	149.78738	Twin 5.5-ft CMPs	Good
Checkmate	61.18970	149.7837	Twin 6.5-ft CMPs	Good
Boniface Blvd	61.18973	149.77655	9.0-ft CMP	Questionable: Velocity at

Location	Latitude	Longitude	Type	Predicted Passage Capability
				outlet too high
Lee St.	61.18978	149.77361	Twin 6.5-ft CMPs Concrete Headwall	Good
Sylvia	61.19130	149.77084	4.0-ft CMP with 1-ft overflow	Questionable: Velocity too high
Crique	61.19117	149.77152	4.0-ft CMP	Questionable: Velocity too high
Campbell Airstrip	61.19343	149.76707	Twin 4.0-ft CMPs	Good
Carnaby	61.19387	149.76586	5.0-ft CMP	Questionable: Velocity
Northern Lights at Baxter	61.19680	149.76099	6.8-ft CMP	Good
Baxter	61.19680	149.66099	Twin 6.5-ft CMPs	Good
Muldoon Road	61.21047	149.73058	Twin 3.6-ft CMPs	Questionable: Inlet Velocity

Table B-2. Size and velocity for surveyed culverts.

Location	Width (ft)	Length (ft)	Inlet Depth/Vel. (ft/s)	Outlet Depth/Vel. (ft/s)	Culvert Width/Stream Width
Mallard Drive	3.5	84	-/1.80	-/6.82	1.03
Lake Otis 1 of 2 (Right Bank)	6.0	80	1.5/2.72	1.0/5.74	1.2
Lake Otis 2 of 2 (Left Bank)	6.0	79	1.3/3.29	0.7/4.5	1.2
Muldoon Road 1 of 2 (Right Bank)	3.6	136	1.1/1.40	Buried	0.72
Muldoon Road 2 of 2 (Left Bank)	3.6	136	1.1/3.99	2.3/1.29	0.72
Seward Highway	6.8	203	-/-	-/-	0.34