Technical Report No. 02-05

Wasilla Creek Stream Condition Evaluation

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August 2002

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

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
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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WASILLA CREEK STREAM CONDITION EVALUATION

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ABSTRACT

This study was conducted to evaluate potential impacts to water quality and fish habitat within Wasilla Creek in support of the Alaska Nonpoint Source Pollution program. Wasilla Creek is located between Palmer and Wasilla, Alaska. Principal historic land use has been agricultural. Agriculture and livestock grazing continue to be major land uses in the area, with increasing urban development. Physical, chemical, and biological parameters were measured at eight sampling stations distributed throughout the drainage. Sampling stations were selected, based upon the qualitative appearance of the riparian vegetation and channel geometry, to represent both the natural reference and impacted condition. Current and historic land use has caused a change in the riparian vegetative community from open mixed spruce and birch forest to closed alder shrub. Extensive grazing and land clearing at one station has caused increased erosion and deposition of fine sediment. The portion of the streambed composed of fine sediment (particles less than 2.0 mm) has increased from 10% to 15% to 38%. The deposition of fine sediment has caused the channel to meander, further accelerating bank erosion. Water samples show increasing concentrations of both nitrogen and phosphorus from upstream to downstream with peaks in nitrogen at stations adjacent to livestock grazing pastures. Evaluation of the relative number of stream invertebrates indicates an alteration of the biotic community from upstream to downstream that may or may not be related to agriculture. Protection and restoration efforts should be focused on avoiding any future loss of riparian vegetation, restoring the natural riparian plant community, and direct restoration of streambanks eroding due to land clearing and livestock grazing.

Key words: livestock, grazing, fine sediment, Wasilla Creek, invertebrates.

INTRODUCTION

Wasilla Creek is located between Palmer and Wasilla, Alaska, within the Matanuska-Susitna Borough. Wasilla Creek is a 3rd order stream (USGS 1:23,00 map) that originates in the Talkeetna Mountains and flows 44 km into Cook Inlet at Palmer Slough. The upper 6 km are within the Matanuska Valley Moose Range. Most of the stream length is within rural agriculture and low to medium-density urban development.

Human settlement of the Palmer-Wasilla area and the Wasilla Creek drainage began with federal experimental farms in the 1930s. Housing development was accelerated further with construction of the George Parks Highway in the early 1970s.

Most of the land use in the Wasilla Creek drainage at this time is agriculture based. However, there are a number of housing subdivisions and some industrial areas, mainly gravel pits. In addition, four main roads linking Palmer and Wasilla cross Wasilla Creek. This project was designed, in support of the Alaska Nonpoint Source Pollution Strategy, to provide baseline data describing the physical, chemical, and biotic characteristics and to evaluate potential impacts due to human land-use practices, primarily agriculture and livestock grazing.

METHODS

SAMPLING LOCATIONS

Eight sampling stations were established on Wasilla Creek near Wasilla, Alaska. Four stations were located at sites where little or no immediate impacts were evident (Stations 1, 5, 7, and 8) and four stations where riparian or channel modifications were obvious (Figure 1). Each sampling station was 100-m long. Additional water sampling sites were established to distribute water collection locations evenly from station 1 to station 8.

WATER CHEMISTRY

Selective water chemistry constituents were determined for all eight sample sites in the fall of 2001 (August, September, and October) and spring of 2002 (April, May, and June). Depth-integrated samples were collected for laboratory analysis of turbidity, conductivity, pH, alkalinity, nitrate nitrogen, dissolved reactive phosphorus, and total phosphorus. Water samples were collected in clean 250-ml Nalgene bottles.

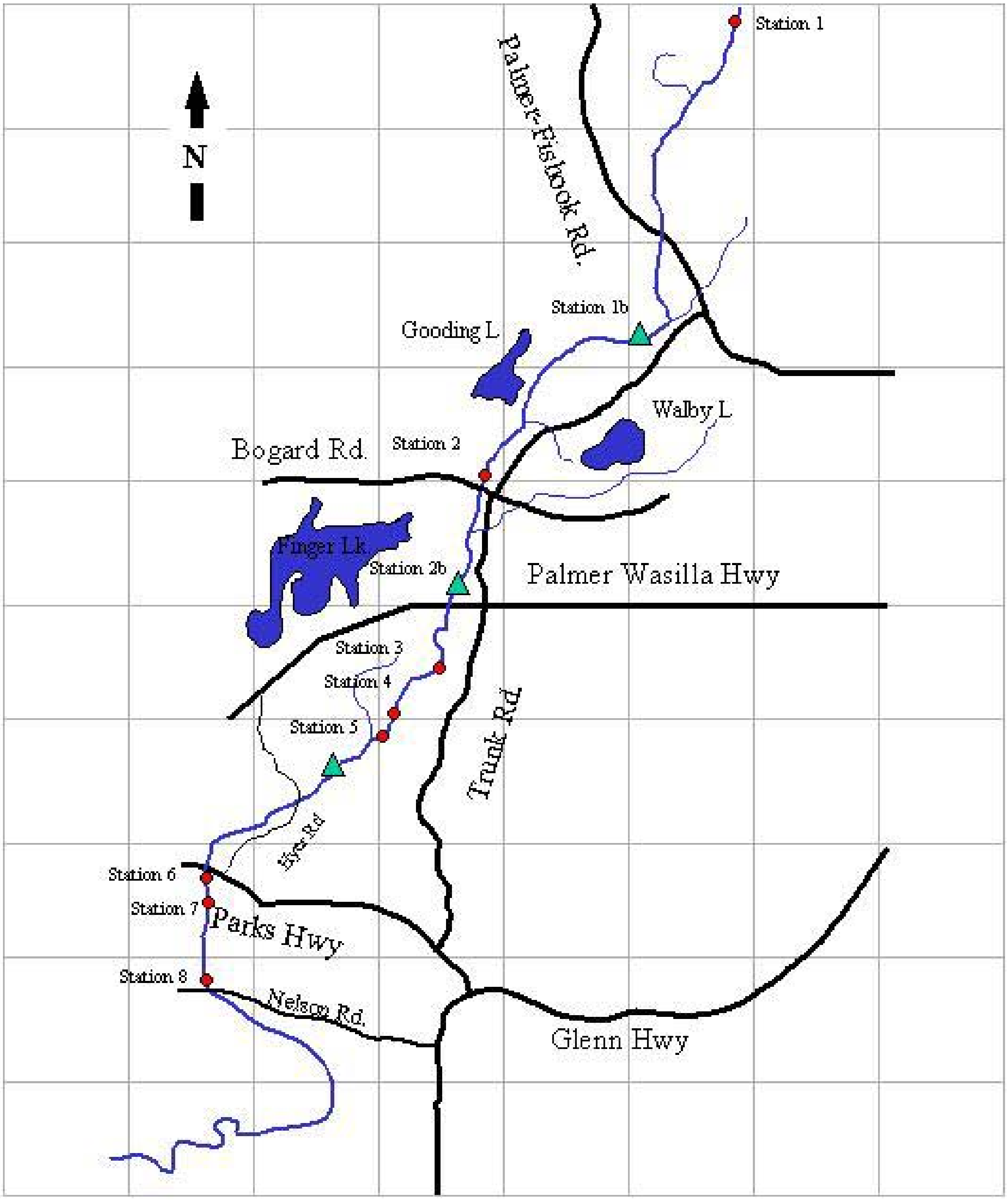


Figure 1. Wasilla Creek showing sampling stations (●). Triangles are located at additional water sampling locations.

Water samples were shipped to the Alaska Department of Fish and Game (ADF&G) laboratory in Soldotna, Alaska, where they were preserved until analyzed. Samples were analyzed as described in Koenings et al. (1987). One out of every eight samples was analyzed twice to determine method precision, and known standards were used to determine accuracy.

PHYSICAL CHARACTERISTICS

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

Stowaway temperature loggers were placed at sampling stations 1, 2, 3, and 7 on July 18, 2001. Temperature was recorded every four hours and data loggers downloaded as Excel files every two to three months through June 2002.

Water velocity was measured at 20 random locations within each 100-m sampling location in August 2001. 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. Shannon-Weaver diversity index was used to evaluate the variability in velocities within a station. (Shepherd and Hey 2001).

Substratum size distribution was determined once within each sampling location by Wolman pebble counts (Wolman 1954) as modified by Bevenger and King (1995). The intermediate axis of 100 stones, selected in a systematically random manner, were measured using a substrate sampler developed by the U.S. Forest Service. The substrate sampler is an aluminum rectangle with square openings corresponding to the different size classes.

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 five 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 as the sum of the pieces scores and five times the sum of the dam values within a sampling station (Davis et al. 2001).

Channel cross-sectional morphometry was determined at five 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. More frequent measurements were recorded at locations where vertical elevations changed rapidly. Vertical elevations displayed on a leveling rod were read using a laser level. 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. Streambed slope was calculated as the slope of the line regressing the low point at each transect with downstream distance. Water surface slope was calculated using water surface elevation and downstream distance.

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 one 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 five randomly selected stones within each sampling reach in August 2001. The periphyton enclosed within the diameter of a 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 analysis. 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 eight sites in early September 2001. Invertebrates were collected by the ASCI methods (Major and Barbor 2001). 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 organisms (+/- 20%) was 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 from 10 to 12 September. Fish were collected with a portable electrofisher (Smith-Root Model 12) working from downstream to upstream through a 20-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.

The riparian plant community was classified at each sampling station using the categories of Vireck et al. (1992). Separate classifications were given to distinct zones moving lateral from the stream channel.

RESULTS

RIPARIAN VEGETATION

Station 1 was the farthest upstream sampling site and was located above most agricultural and housing development (Figure 1). Station 1 was accessed from the Glenn Highway to Soapstone Road to Norman Road to a dirt road under the powerline. Based upon the lack of any obvious riparian or channel alterations, Station 1 was selected as a reference site. The riparian vegetation was classified as open mixed birch spruce forest. The understory of this forest type is composed of *Calamagrositis*, *Spirea*, *Vaccinium* and *Ledum* (Figure 2). There were some cottonwoods within the floodplain. Willow and alder were present in small patches adjacent to the stream channel.

Figure 2. Photograph of station 1 riparian vegetation.

Station 2 was located just upstream of Bogard Road. At this location Wasilla Creek flows through a pasture that supports a small herd of cattle. Cattle use of the stream and riparian area is not restricted. The lower portion of the sampling reach appears to have been channelized, perhaps to accommodate road construction. The riparian vegetation has been modified considerably by grazing. The riparian vegetation was classified as Open Balsam Poplar Forest (Figure 3). Alder and browsed cottonwoods and willows were common in the understory (Figure 4). Although grazed, the riparian zone was well vegetated (Figure 5 and Figure 6).

Figure 3. Open Balsam Poplar forest adjacent to station 2.

Figure 4. Zone of alder and willow along the stream margin of station 2.

Station 3 was located downstream of the Palmer-Wasilla Highway. Heavy grazing and land clearing adjacent to station 3 resulted in modifications to the riparian vegetation (Figure 7). Most of the riparian area along this station was grazed to a low grass cover. This livestock-modified vegetative community is not addressed in the classification methodology. The vegetation had been completely removed at some locations due to trampling by livestock (Figure 8). The remnant riparian vegetation was classified as closed and open tall alder shrub (Figure 9). The understory was dominated by *Equisetum*.

Figure 5. Zone of sedges along stream margin of station 2.

Figure 6. Browsed cottonwoods within station 2.

Figure 7. Heavily grazed riparian area of station 3.

Figure 8. Denuded portions of station 3.

Figure 9. Open alder shrub community of station 3.

Figure 10. Closed alder shrub riparian community of station 4.

Figure 11. Riparian vegetation of station 4 showing bank trampling.

Station 4 also was considered an impacted site to livestock grazing. The riparian plant community was classified as closed alder shrub (Figure 10). Some older birch and cottonwood were present. The stream banks were trampled in many locations (Figure 11).

Figure 12. Open mixed forest of station 5.

Figure 13. Closed alder shrub of station 5.

Station 5 was located 1 km downstream of the impacted stations 3 and 4; however, the riparian zone and stream channel appeared to be unmodified. The riparian vegetation was classified as open spruce birch forest (Figure 12). Willows and alders were common along the stream margins with occasional closed alder shrub communities dominating the first five meters lateral to the stream (Figure 13). The stream banks were composed primarily of *Calamagrostis* as seen at station 1 (Figure 14).

Station 6 was located between the Parks Highway Bridge and the railroad crossing. The riparian vegetation at this site had been modified by land clearing and had been the site of a used car dealership previous to this study.

Figure 14. Steam banks of station 5.

Figure 16. Cleared riparian area of station 6

Figure 15. Closed alder community of station 6.

Figure 17. Station 7 riparian community.

The riparian vegetation was limited to a one to two meter zone of *Calamagrostis* and alders followed by gravel parking or a closed alder shrub (Figure 15 and Figure 16).

The riparian vegetation and channel geometry of stations 7 and 8 were considered unimpacted. The riparian vegetation was open to closed mixed spruce birch forest (Figure 17 and Figure 18). However, at both stations there were zones of closed alder shrub adjacent to the stream extending up to five meters laterally.

Figure 18. Station 8 riparian community of closed spruce birch forest.

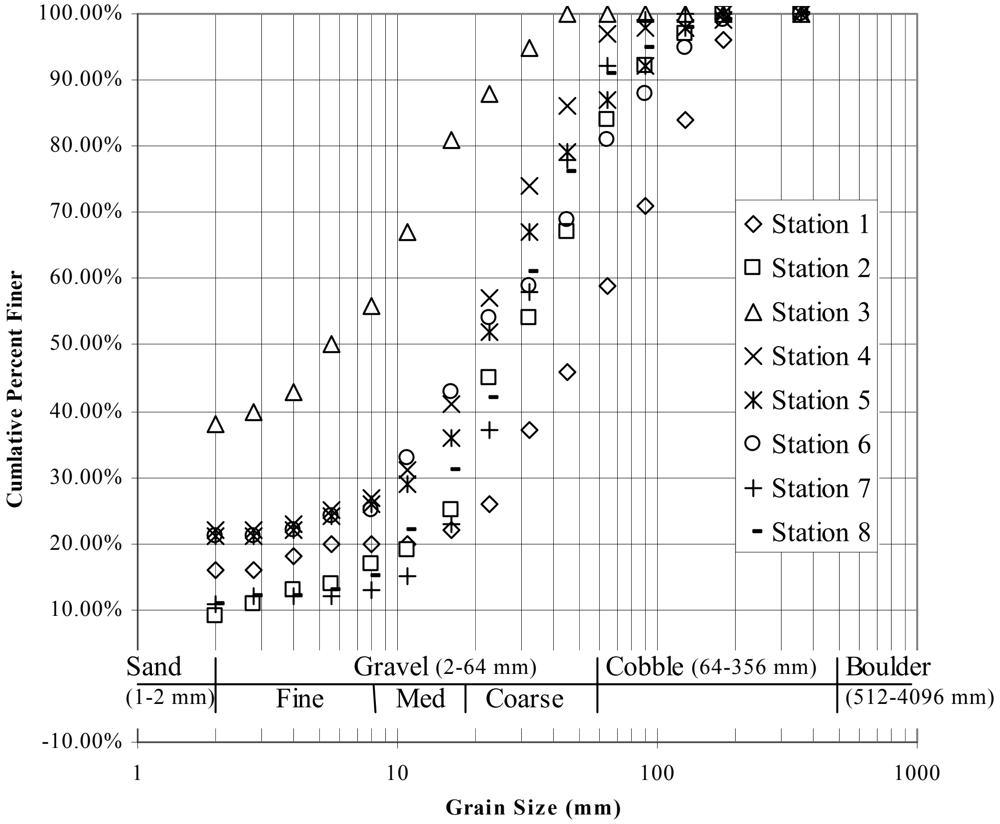


Figure 19. Substratum size distribution.

PHYSICAL CHARACTERISTICS

The substratum size distribution for all sites is shown in Figure 19 and Table 1. The size distribution at station 1 was larger and at station 3 smaller than most other stations.

Station 1 substratum was primarily cobble and gravel. The estimated maximum particle size in motion during bankfull flows, referred to as the critical grain size (mm), was determined using the tractive force equation of Kappesser (1993). The critical grain size was 20.3 mm. Comparison with the substratum size distribution graph shows that slightly more than 20% of the substrate is in motion during bankfull flows; therefore, the substratum is larger than would be expected based upon channel geometry and slope.

The substratum at the impacted station 3 was considerably smaller than all other stations, with nearly 40% of the substrate less than two mm. Based upon the critical grain size, the substrate is much smaller than expected due to channel shape and slope with an estimated 70% of the substrate in motion during bankfull flows. The three stations downstream of station 3 all had greater than 20% of the substrate composed of fine sediment (< 2 mm).

Table 1. Statistical description of substratum size for the 8 sampling stations.

Station	D20 (mm)	D50 (mm)	D80 (mm)	Critical Grain Size (mm)	D50-Critical
1	5	60	100	20.3	39.7
2	11	25	60	8.7	16.3
3	2	5.6	16	12.0	-6.4
4	2	20	40	11.1	8.9
5	2	21	45	8.5	12.5
6	2	20	60	13.1	6.9
7	14	30	48	19.5	10.5
8	10	28	50	21.1	6.9

Stream channel parameters for each station are given in Table 2. Average stream channel widths for all sites were between four and six meters. There were no consistent differences in ratios of width to depth (w/d). The w/d ratio at stations 2 and 4 (livestock-grazed sites) was greater than reference sites. But the w/d ratio at station 3 (the other livestock grazed site) was less than reference sites. The largest difference in channel parameters among sites was the considerably lower water surface slope at station 3. Except for station 3, stream water (or energy) slope was greater than 0.5% for all stations with slightly higher slopes (1.1 to 1.4%) for stations 1 and 8, respectively. Stream water slope at station 3 was only 0.27%.

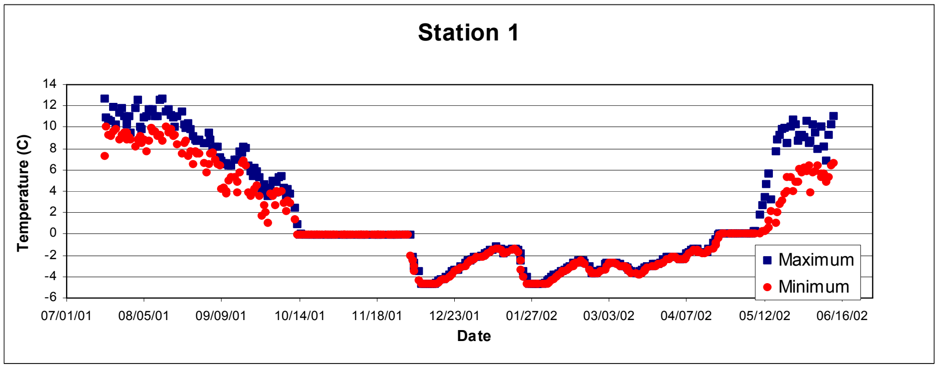
Water temperature data are shown in Figure 20. Station 1 had the daily and seasonal maximum and minimum temperatures with maximum mid-summer values of near 13 degrees C and minimum of –4.7 during the winter. Temperature data for station 7 are not available because the logger was destroyed by ice.

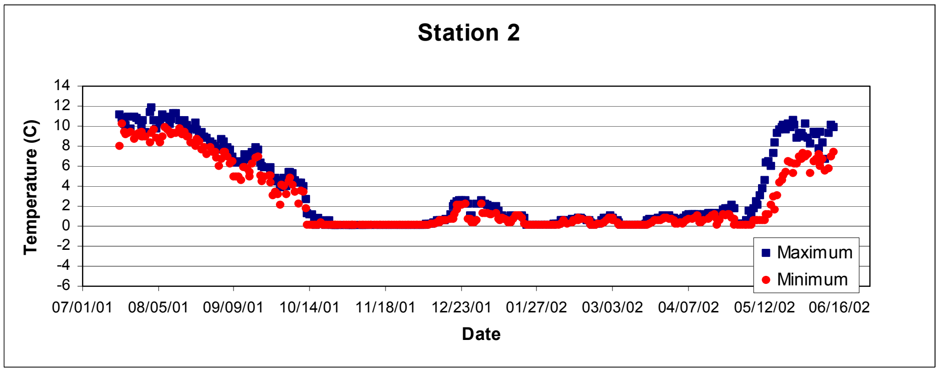
Average water velocities are shown in Table 3. The Shannon-Weiner Diversity index (H') was used to evaluate the variability in stream flows within five different categories (0.2 m/s intervals from 0 to 1.0 m/s). Diversity relative to maximum diversity (J') also was determined. There were no apparent trends in water velocity or the diversity of flows among stations.

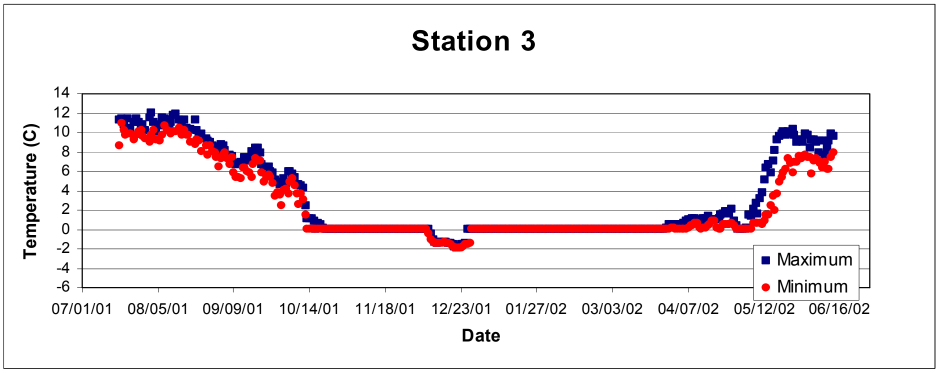
Stream discharge was measured on different days, so comparison among sites is difficult. However, discharge ranged from 0.42 to 0.77 m^3/s (14.9 to 27.3 cfs). Stream flow at station 6 (0.61 m^3/s) (August 7, 2002) was close to that at station 1 (0.59 m^3/s) (July 31, 2002). There were no large storm events between measurements.

Table 2. Wasilla Creek stream channel parameters. Ucut=undercut banks, n=Manning's "n".

Station	Width (m)	Mean Depth (m)	w/d	Perimeter (m)	Area (m^2)	Hydraulic Radius (m)	Ucut Lt. (m)	Ucut Rt (m)	Rough "n"	Bed Slope	Water Slope
1	5.33	0.26	20.8	5.54	1.36	0.27	0.018	0.198	0.084	0.0078	0.0114
2	5.40	0.19	28.5	5.52	1.02	0.19	0.124	0.068	0.033	0.0047	0.0056
3	5.13	0.29	17.8	5.58	1.48	0.27	0.138	0.118	0.059	0.0046	0.0027
4	6.02	0.20	29.8	6.14	1.21	0.20	0.128	0.202	0.080	0.0036	0.0055
5	4.50	0.16	28.6	4.58	0.71	0.16	0.202	0.124	0.038	0.0040	0.0052
6	5.69	0.23	25.1	5.88	1.29	0.23	0.186	0.182	0.063	0.0063	0.0059
7	5.06	0.26	19.3	5.23	1.33	0.25	0.192	0.076	0.081	0.0107	0.0079
8	4.25	0.17	24.3	4.80	0.74	0.15	0.060	0.096	0.051	0.0120	0.0146


Station 1
Temperature (C)
14
12
10
8
6
4
2
0
-2
-4
-6
07/01/01
08/05/01
09/09/01
10/14/01
11/18/01
12/23/01
01/27/02
03/03/02
04/07/02
05/12/02
06/16/02
Date
■ Maximum
● Minimum


Station 2
Temperature (C)
14
12
10
8
6
4
2
0
-2
-4
-6
07/01/01
08/05/01
09/09/01
10/14/01
11/18/01
12/23/01
01/27/02
03/03/02
04/07/02
05/12/02
06/16/02
Date
■ Maximum
● Minimum


Station 3
Temperature (C)
14
12
10
8
6
4
2
0
-2
-4
-6
07/01/01
08/05/01
09/09/01
10/14/01
11/18/01
12/23/01
01/27/02
03/03/02
04/07/02
05/12/02
06/16/02
Date
■ Maximum
● Minimum

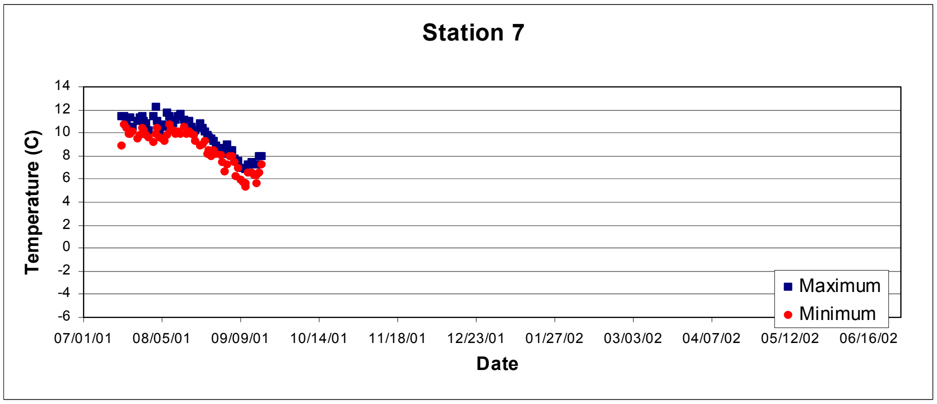

Station 7
Temperature (C)
14
12
10
8
6
4
2
0
-2
-4
-6
07/01/01
08/05/01
09/09/01
10/14/01
11/18/01
12/23/01
01/27/02
03/03/02
04/07/02
05/12/02
06/16/02
Date
■ Maximum
● Minimum

Figure 20. Wasilla Creek stream water temperatures from July 18, 2001, through June 13, 2002.

Table 3. Stream water velocities and diversity.

Station	Mean Velocity (m/s)	Standard Deviation	H'	J'
1	0.47	0.28	0.68	0.97
2	0.60	0.24	0.63	0.90
3	0.49	0.21	0.63	0.90
4	0.45	0.18	0.57	0.81
5	0.49	0.22	0.59	0.84
6	0.48	0.23	0.59	0.84
7	0.56	0.22	0.65	0.92
8	0.41	0.24	0.64	0.91

BIOTIC CHARACTERISTICS

Benthic organic matter collected in August is shown in Table 4. The primary difference among sites was the abundance of fine particulate organic matter (FPOM) at station 3. FPOM was significantly higher at station 3 than all other stations except station 4 (ANOVA and Tukey multiple comparisons test alpha = 0.05).

Benthic chlorophyll-a concentrations were low for most stations except station 2 and to a lesser extent, station 8 (Table 5). The amount of chlorophyll-a was significantly greater at station 2 than all other stations except 8 (ANOVA and Tukey multiple comparisons test alpha = 0.05).

The amount of large woody debris was similar among sites with no apparent difference when comparing sites with different riparian plant communities (Table 6).

Table 4. Organic matter for each station as coarse and fine fraction.

Station	CPOM AFDM (g/m^2)	FPOM AFDM (g/m^2)	Total AFDM (g/m^2)	FPOM/ CPOM
1	3.84	10.5	14.31	2.72
2	4.05	8.4	12.45	2.08
3	4.43	26.8	31.20	6.04
4	7.33	16.7	24.00	2.28
5	3.14	8.0	11.10	2.54
6	7.34	9.1	16.48	1.25
7	4.67	9.0	13.66	1.93
8	6.73	10.5	17.25	1.56

Table 5. Mean chlorophyll-a and phaeophytin concentrations (n = 5).

Station	Chl-a (mg/m^2)	Phaeophytin (mg/m^2)	Chl/Phaeophytin
1	1.50	0.04	36.33
2	10.91	0.65	59.22
3	1.85	0.22	10.47
4	2.25	0.41	6.12
5	2.31	0.21	11.97
6	1.42	0.10	15.35
7	1.11	0.05	21.16
8	5.66	0.28	42.51

Table 6. The total number of large woody debris pieces, debris dams and index scores for the 100-m sampling reaches.

Station	LWD Index Score	Pieces	Dams
1	404	5	3
2	167	10	0
3	643	8	8
4	720	10	6
5	420	9	3
6	528	5	6
7	855	10	7
8	644	6	5

Table 7. Results of fish sampling efforts for each Wasilla Creek sampling station. DV= Dolly Varden.

Station	Total Captured	Total Salmonids	Total Coho	Total King	Total DV	Total Sculpin	Portion Coho	Portion King	Portion DV	Portion Sculpin	DV: Sculpin	Salmonid Pop. Est.
1	91	86	75	8	3	5	0.82	0.09	0.03	0.05	0.60	164
2	96	91	60	31	0	5	0.63	0.32	0.00	0.05	0.00	99
3	69	48	18	28	2	21	0.26	0.41	0.03	0.30	0.10	122
4	47	38	10	26	2	9	0.21	0.55	0.04	0.19	0.22	50
5	62	51	15	35	1	11	0.24	0.56	0.02	0.18	0.09	63
6	93	62	25	37	0	31	0.27	0.40	0.00	0.33	0.00	64
7	63	45	24	15	6	18	0.38	0.24	0.10	0.29	0.33	58
8	79	50	25	23	2	29	0.32	0.29	0.03	0.37	0.07	50

Juvenile fish sampling results are shown in Table 7. Both chinook (*Oncorhynchus tshawytcha*) and coho salmon (*Oncorhynchus kisutch*) were captured at all sampling stations. Coho salmon dominated the fish community at stations 1 and 2, while chinook salmon tended to be more common at stations 3 through 6. Sculpin (*Cotus sp.*) were rare at stations 1 and 2 making up 5% of the community, but common in the samples at the remaining stations.

The size frequency distribution of coho and chinook salmon is shown in Figure 21. At the sample time (September) there appeared to be two age classes of coho, with a median fork length of 40 to 44 mm for age 0, and near 60 mm for age 1 fish. Only one age class of chinook was observed with a median fork length of 58 to 60 mm for age 0.

WATER QUALITY

The results of the water chemistry analyses for all stations and dates is shown in Table 8. Water samples could not be taken at some stations in April due to ice cover. Wasilla Creek is a clear-water stream. Turbidity is less than five nephelopmetric turbidity units (NTU) under normal conditions.

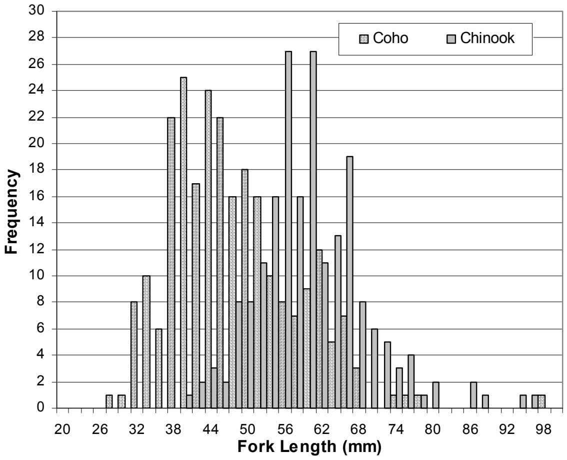


Figure 21. Size-frequency distribution of juvenile coho and chinook salmon in Wasilla Creek.

Turbidity increased during spring runoff and spates. For example, turbidity range increased to 35 to 50 NTU during spring runoff in June 2002. Turbidity and discharge were measured at station 6 during a storm on September 6, 2001. Discharge doubled from 0.61 to 1.61 m^3/s and turbidity increased from less than five to 62 NTU.

Stream water remained near neutral at a pH of 7.4 to 7.5 for most stations and dates. Stream water pH became more acidic (below 7.0) during spring runoff.

Table 8. Wasilla Creek water chemistry date for July, August, and September (2001) and April, May, and June (2002).

Date	Station	Turbidity (NTU)	Specific Conductance (μmhos/cm)	pH (Units)	Alkalinity (mg/L-$CaCO_3$)	Total-P (μg/L P)	Dissolved reactive-P (μg/L P)	Nitrate+ nitrite (μg/L N)	Molar N:P (no untis)
7/25/01	1	4.0	102	7.4	49.2	16.1	4.9	200.8	90.6
7/25/01	1b	3.2	126	7.4	59.8	16.2	5.2	184.0	78.2
7/25/01	2	3.2	133	7.5	62.2	18.1	5.5	294.4	118.3
7/25/01	2b	3.9	150	7.4	69.4	21.1	6.0	215.9	79.5
7/25/01	3	4.0	150	7.5	68.9	21.5	4.9	278.7	125.7
7/25/01	5	4.5	150	7.5	68.7	24.7	5.8	196.5	74.9
7/25/01	6	4.9	170	7.5	78.0	29.4	6.7	241.1	79.5
7/25/01	8	4.1	177	7.5	81.0	31.5	7.5	311.2	91.7
8/22/01	1	3.1	109	7.4	69.8	15.2	5.8	196.3	74.8
8/22/01	1b	2.2	147	7.5	69.9	13.4	6.3	268.6	94.2
8/22/01	2	3.1	148	7.5	76.0	13.8	7.2	329.2	101.1
8/22/01	2b	2.6	168	7.5	76.2	18.6	7.8	227.1	64.4
8/22/01	3	3.1	168	7.6	77.4	17.1	7.3	346.1	104.8
8/22/01	5	3.0	168	7.6	77.4	14.1	7.9	336.9	94.3
8/22/01	6	2.2	187	7.5	86.1	15.8	9.9	343.0	76.6
8/22/01	8	2.7	201	7.6	91.3	16.6	10.7	272.6	56.3
9/19/01	1	4.5	109	7.2	53.2	23.1	6.3	229.3	80.5
9/19/01	1b	4.5	137	7.3	64.7	17.0	6.6	273.9	91.7
9/19/01	2	4.2	146	7.4	68.3	16.1	7.4	323.7	96.7
9/19/01	2b	3.6	162	7.4	74.4	18.5	8.1	347.6	94.9
9/19/01	3	5.2	163	7.4	74.1	30.3	8.4	353.6	93.1
9/19/01	5	2.5	168	7.5	76.8	24.0	9.3	262.7	62.4
9/19/01	6	5.5	191	7.4	86.5	63.0	11.1	332.2	66.2
9/19/01	8	5.8	200	7.5	91.3	28.5	10.6	378.9	79.0
4/16/02	1								
4/16/02	1b	0.7	200	6.8	92.4	5.6	3.8	406.2	236.3
4/16/02	2	0.5	173	7.2	83.8	6.4	5.0	397.0	175.5
4/16/02	2b	1.3	184	7.2	85.3	7.5	6.3	499.0	175.1
4/16/02	3								
4/16/02	5	0.5	203	7.3	92.8	9.6	5.5	584.1	234.8
4/16/02	6	4.3	276	7.4	126.9	25.1	5.8	422.5	161.0
4/16/02	8								
5/24/02	1	34.5	82	6.7	37.0	154.5	5.6	624.7	246.6
5/24/02	1b	35.5	90	6.8	40.3	136.7	5.8	628.2	239.4
5/24/02	2	38.0	92	6.7	43.2	156.9	3.2	630.6	435.6
5/24/02	2b	36.0	101	6.9	43.9	153.9	4.0	622.4	344.0
5/24/02	3	42.0	101	7.0	46.5	139.5	8.1	560.4	152.9
5/24/02	5	45.5	102	6.8	46.7	136.6	3.3	578.5	387.5
5/24/02	6	47.0	121	7.1	54.2	132.9	9.2	572.6	137.6
5/24/02	8	51.0	122	7.1	56.0	142.2	6.8	431.8	140.4

Date	Station	Turbidity (NTU)	Specific Conductance (µmhos/cm)	pH (Units)	Alkalinity (mg/L-CaCO$_3$)	Total-P (µg/L P)	Dissolved reactive-P (µg/L P)	Nitrate+ nitrite (µg/L N)	Molar N:P (no untis)
6/13/02	1	25.2	91	7.1	45.7	23.0	2.8	314.6	248.4
6/13/02	1b	23.8	111	7.4	58.8	9.3	3.1	243.7	173.8
6/13/02	2	21.8	117	7.3	57.5	9.7	3.2	232.9	160.9
6/13/02	2b	27.0	132	7.4	63.9	10.1	3.8	185.8	108.1
6/13/02	3	25.0	134	7.1	64.0	10.4	3.6	359.9	221.0
6/13/02	5	25.3	135	7.5	64.5	8.4	3.5	347.8	219.7
6/13/02	6	23.6	161	7.4	77.1	14.2	4.8	237.3	109.3
6/13/02	8	22.0	165	7.3	77.7	15.9	4.0	305.8	169.0

Alkalinity was low for all sites and stations, generally less than 100 mg/L-CaCO$_3$. Alkalinity increased with distance downstream.

Dissolved reactive and, to a lesser extent, total phosphorus increased with downstream distance (Figure 22 and Figure 23). Dissolved concentrations increased from July to September 2001, while total concentrations did not follow this trend.

Total phosphorus concentrations were correlated with turbidity and increased sixfold during spring breakup with similar increases in turbidity (Table 8).

Spatial and temporal differences in nitrate nitrogen did not follow the same trends as phosphorus. From July through September 2001 concentrations were highest at stations 2, 3, and 6. Concentrations increased at all stations during spring breakup in May 2002 (Figure 24).

There were differences in the macroinvertebrate community among stations suggesting changes in water quality or habitat. The invertebrate community metric data and ASCI scores are shown in Table 9. The relative abundance of the sediment intolerant caddisfly (Relyea et al. 2000) was determined. The ASCI did not differentiate among the stations, with all stations determined to have a rating of "good".

Differences in the invertebrate community occurred between the upstream station 1 and the remainder of the sites. The portion of the community that were in the Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) (EPT) orders decreased from over 70% of the community at station 1 to less than 50% at and downstream of station 2 (Figure 25). Large differences also were seen in the percent mayflies and caddisflies.

At station 1 the chironomidae (midges) were only a small portion of the community (13%), while at the remaining stations the chironomidae were near 50% and dominated the community. The invertebrate community was more diverse at station 1 (lower Simpson's Diversity Idex) than other stations and the single most dominant organism made up 30% of the community. The dominant organism at station 1 was the sediment intolerant caddisfly, *Ecclisomyi sp.*, which never exceeded 10% of the community at any other station.

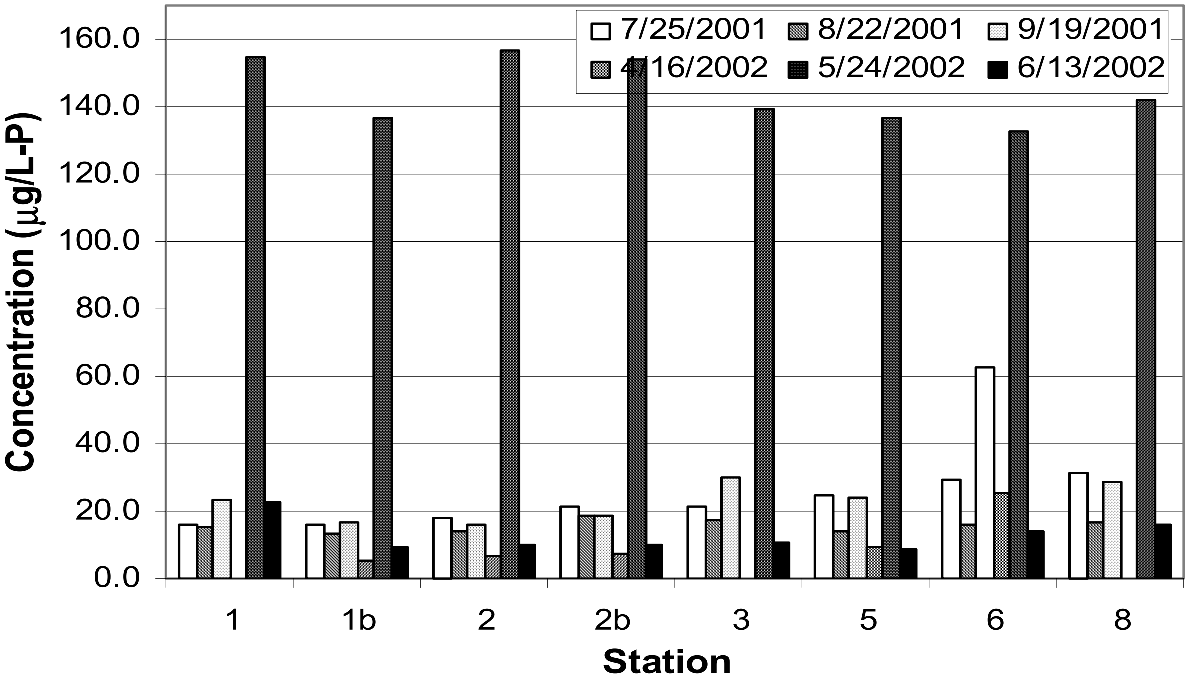


Figure 22. Total phosphorus concentrations for all sampling stations showing high concentration during breakup in May.

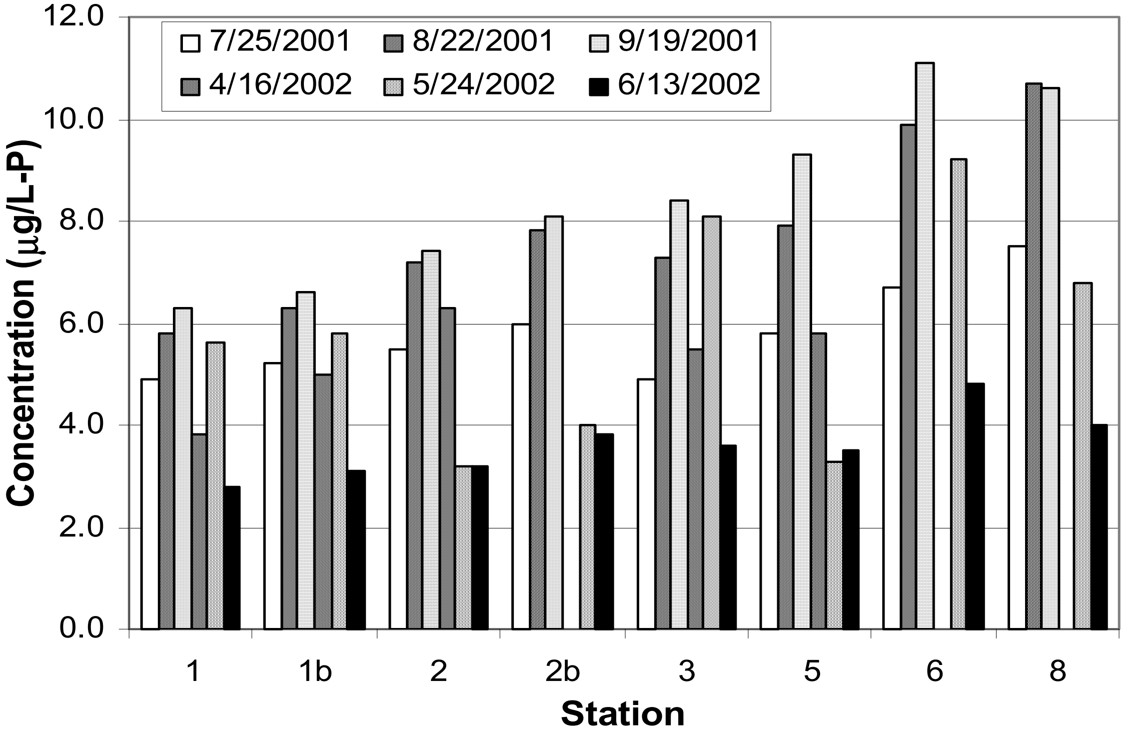


Figure 23. Dissolved reactive phosphorus concentrations for all stations showing downstream increases.

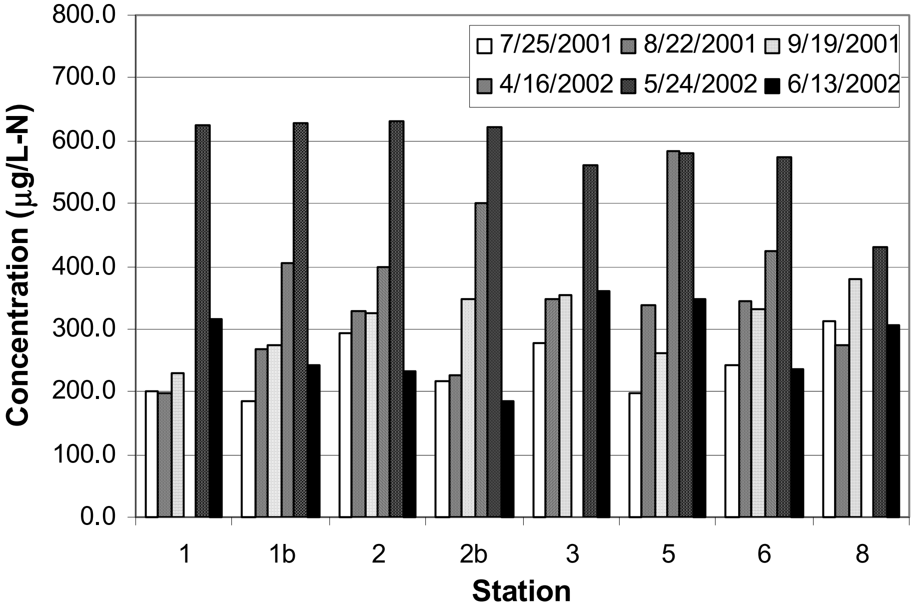


Figure 24. Wasilla Creek nitrate-nitrogen concentrations for all stations and sampling dates.

Table 9. Community metrics from Wasilla Creek invertebrate data. EPT is Ephemeroptera, Plecoptera, and Trichoptera. O/E is observed taxa to expected taxa. HBI is Hilsenhoff's Biotic Index.

Metrics	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Number of Taxa	14	15	15	14	15	18	16	18
Number of Ephemeroptera Taxa	4	4	2	3	2	5	3	3
Number of Plecoptera	2	2	3	3	3	4	5	4
Number of Trichoptera	4	5	5	5	5	5	5	6
%EPT	71.9	47.0	32.7	40.7	41.9	50.9	24.3	48.2
% Chironomidae	13.0	41.7	55.2	57.5	49.1	45.1	57.6	49.8
% Dominant Taxa	29.6	41.7	55.2	57.5	49.1	45.1	57.6	49.8
% Ephemeroptera	17.4	15.9	2.5	6.5	2.8	16.7	3.9	13.0
% Plecoptera	10.3	14.5	6.0	10.6	5.0	23.9	6.5	16.4
% Trichoptera	44.3	16.6	24.2	23.6	34.2	10.2	13.9	18.7
% Ephemeroptera (no baetidae)	8.30	3.89	2.14	3.73	1.24	3.75	1.62	4.01
Baetidae/Ephemeroptera	0.52	0.76	0.14	0.43	0.56	0.78	0.58	0.69
% non-insects	0	0	0	0	0	0	0	0
O/E (family 75%)	0.8	0.7	0.8	0.6	0.6	0.8	0.7	0.8
% Scrapers	6.72	7.07	5.69	4.66	10.87	1.37	6.15	4.01
HBI	3.36	4.15	4.36	4.07	3.99	4.12	4.54	3.97
Simpsons Diversity	0.151	0.230	0.337	0.358	0.278	0.259	0.374	0.285
EPT/Chironomidae	5.52	1.13	0.59	0.71	0.85	1.13	0.42	0.97

Metrics	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
% Shredders	5.14	14.13	5.34	4.35	4.04	21.50	4.85	12.37
% Predators	6.32	2.12	6.05	8.39	5.59	4.44	2.59	8.03

ASCI Metric Scores	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Number of Ephemeroptera Taxa	72.73	72.73	36.36	54.55	36.36	90.91	54.55	54.55
% Plecoptera	73.40	100.00	43.21	75.42	35.49	100.00	46.23	100.00
% Ephemeroptera (no baetidae)	41.50	19.43	10.68	18.63	6.21	18.77	8.09	20.07
Baetidae/Ephemeroptera	47.73	24.44	85.71	57.14	44.44	22.45	41.67	30.77
% Non-insects	100	100	100	100	100	100	100	100
O/E (family 75%)	80	70	80	60	60	80	70	80
% Scrapers	44.80	47.11	37.96	31.06	72.46	9.10	40.99	26.76
HBI	100.00	100.00	100.00	100.00	100.00	100.00	97.82	100.00
ASCI Score	70.02	66.72	61.74	62.10	56.87	65.15	57.42	64.02
ASCI Rank	Good	Good	Good	Good	Good	Good	Good	Good

Insects Intolerant to Fine Sediment (0 to 30% fines)

Order	Genus	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Limnephilidae	*Ecclisomyia*	0.30	0.09	0.05	0.01	0.09	0.03	0.01	0.02

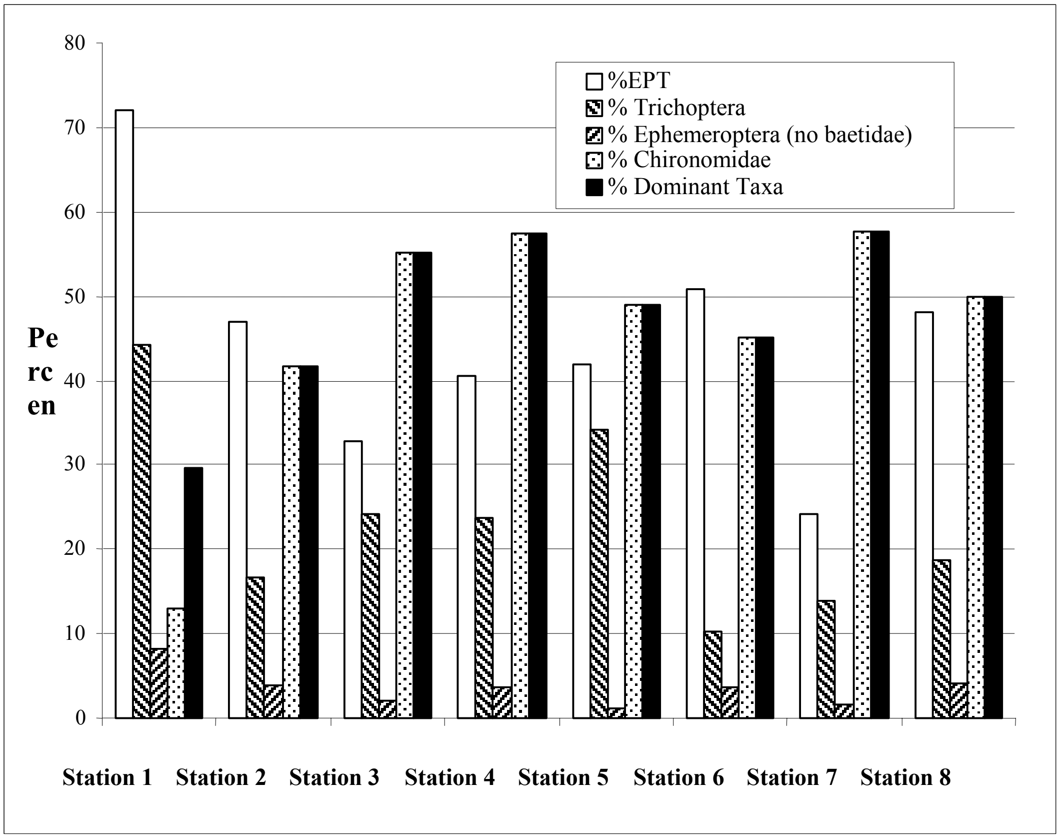


Figure 25. Comparison among stations for select metrics showing the change in the invertebrate community downstream from station 1.

DISCUSSION

This study was conducted to look at the potential impacts of agricultural practices, primarily livestock grazing, on water quality and fish habitat. Secondary objectives were to evaluate other potential land-use impacts such as urban development. Comparisons between grazed and ungrazed locations revealed alterations in the natural stream components. Livestock-grazing affects on Wasilla Creek were different than those observed on streams in the western United States. Livestock grazing on western streams is often concentrated in riparian areas where vegetation is more abundant and succulent. Relatively intense grazing can result in the loss of riparian vegetation, decrease undercut banks and reduce bank angles, increase stream width to depth ratios, temperatures, and the amount of fine sediment (Platts 1991).

The riparian vegetation at unmodified locations along Wasilla Creek was open mixed birch spruce forest. Although willows and alders were common along the streambanks, there was not a distinct shift in the plant community adjacent to the stream. For this reason, livestock grazing at stations 2 through 4 did not appear to be concentrated along the streambanks. At stations 2 and 4 the streambanks remained vegetated except at locations where the cattle crossed or watered and bank erosion appeared to be limited to these areas. Alternatively, the riparian vegetation at the heavily grazed station 3 was completely removed along most of the site and erosion was evident. Differences in channel geometry were not consistent among grazed sites. Stream width depth ratios at stations 2 and 4 were higher than non-grazed locations consistent with observations in the western U.S.; however, the ratio of width to depth decreased at the heavily grazed station 3.

At stations 2 and 4 it appeared that grazing had resulted in some aggradation and channel widening. At station 3 previous grazing and land clearing had caused a change in the riparian vegetation to a closed alder shrub community. Subsequent bank erosion resulted in large increases in fine sediment, near 40% of the substrate at the time of this study. This deposition of fine material caused the channel to meander. The increase in sinuosity explains the low slope at this station relative to other sites. The meandering channel has undercut the banks causing the remaining riparian alders to enter the stream resulting in the high amount of debris dams seen at this site. These debris dams further reduce stream energy and the ability of the stream to transport the sediment load. Woody debris can also redirect flow, causing additional bank scouring (Thorne 1990). This process of erosion, followed by deposition leading to more erosion has been observed by others (Beeson and Doyle 1995).

Two culverts were located in a road just downstream of station 3 and may be further compounding this process by reducing stream cross-sectional area, water slopes, and sediment transport capacity. While not measured directly, the erosion and sediment deposition appeared to be continuing for a kilometer or more downstream of the sampling station.

We did not observe the loss of undercut banks or increases in water temperature as reported by Platts (1991). At stations 2 and 4 undercut banks remained because of the intact riparian vegetation. At station 3 the shifting channel appeared to create undercutting below the remaining alder. At the altered sites investigated in this study we would not expect temperatures to increase, because the plant community was not removed but changed to alder shrub, which appeared to absorb more solar energy than the open birch forests.

In addition to riparian and physical habitat changes at livestock-grazed sites, there were peaks in NO_3-N at stations 2 and 3. These increases may be due to runoff from pastures. Additional work should be conducted to address this hypothesis. Ratios of nitrate to dissolved phosphate-P indicate phosphorus limitation. Phosphate-P has been found to limit primary production at concentrations below 6 μg/L (Mulholland et al. 1990; Bothwell 1989) and concentrations in Wasilla Creek are near this value. However, chlorophyll-a and dissolved phosphate-P concentrations are not correlated. Light also may become limiting at some times and some locations.

Longitudinal differences in invertebrate community metrics suggest a decline in water quality that did not coincide with the livestock grazed sites. The change in the invertebrate metrics; decline in EPT orders, non-baetid Ephemeroptera, *Ecclisomyia*, and an increase in chironomidae all suggest impaired water quality downstream of station 1. Similarly, the salmonid portion of the fish community decreased and the sculpin portion increased downstream of station 2. The differences in the biotic community are not correlated with any of the other parameters measured in this study.

Land clearing and livestock grazing on Wasilla Creek leads to a shift in the riparian plant community from open forest, mixed birch and spruce or cottonwood, to closed alder shrub. This change likely reduces solar radiation, which may alter instream productivity. We attempted to quantify solar radiation with point measurements; however, there was too much diel variation to make these data useful. Continuous measure of solar radiation at multiple locations and seasons should be conducted to further evaluate the changes in riparian vegetation on light and water temperatures.

Complete removal of the riparian vegetation results in deposits of fine sediment, which cause the channel to meander, reduce slope, increase wood input (where present), and further accelerate erosion. The branches of alders tend to droop into the channel and collect material causing debris dams, which further reduce sediment transport capacity. The species of LWD as pieces and dams should be determined in future work, as well as whether live vegetation is a component of the debris dams. Additional factors such as culverted roads or other cross-channel structures may influence these processes as well.

The downstream increase in conductivity and nutrients reported here also was observed in previous studies conducted on Chester Creek within the Municipality of Anchorage, Alaska (Davis and Muhlberg 2001). Reference data are required to determine if this is related to development.

Most of the changes in Wasilla Creek stream parameters are due to the alteration of the riparian plant community. Based upon qualitative observations, the naturally occurring riparian zone vegetation of much of Wasilla Creek appears to have been removed or converted to closed alder shrub. This is presumably due to current and historic land clearing activities associated with agriculture. Future restoration projects need to focus on preventing further damage to the natural riparian forest and returning the riparian zone to open spruce and birch forests. Fences could be used to prevent livestock access to streams or limit access to a few watering points. Where stream banks are intact, limited clearing of alders and the introduction of birch through seeding or transplants or both could facilitate the conversion back to the natural riparian plant community. Where banks are actively eroding, stream bank restoration projects should be implemented to stabilize the banks until vegetation can be reestablished (see Muhlberg and Moore 1998). Sediment transport capacity needs to be considered when constructing cross-channel structures such as culverted roads and bridges.

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