COTTONWOOD CREEK TMDL DEVELOPMENT—RESIDUE

FINAL REPORT

June 30, 2005

THE AQUATIC RESTORATION AND RESEARCH INSTITUTE

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Acknowledgements

This project was supported by Alaska Clean Water Actions grant 04-09 and 05-02 funded through Clean Water Act Section 319 and Alaska Clean Water Actions grant 04-02, funded through section 309 of the Coastal Zone Management Act. We would like to acknowledge and thank the volunteer observers living along Cottonwood Creek.

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Summary

Cottonwood Creek, within Wasilla, Alaska, has been listed by the State on their section 303(d) report to the Environmental Protection Agency as a waterbody that does not meet the State's water quality standard for residue due to observations of foam collections and lesions on juvenile fish. Stream surveys of foam accumulations were conducted during the ice-free period from September of 2003 through October of 2004 at sampling locations distributed along the stream system. Stream water pH, turbidity, specific conductance, and discharge (at one location) were determined concomitant with surveys. Dissolved organic carbon (DOC), total fecal coliform, *E. coli* bacteria, total and dissolved reactive phosphorus, and nitrate and ammonia nitrogen were measured once a month from April through September at each survey sampling site. Water temperature was measured continuously (every 3 to 4 hours) at 4 locations. Juvenile salmon were collected at 4 sites on four locations and inspected for lesions or other abnormalities.

Foam accumulations were observed at all sites except for Site 1, located farthest upstream and above the first major tributary input. Foam accumulations increased at discrete times and then slowly diminished in size. Foam abundance increased following rain events, but not all rain events, particularly in the Fall. Foam accumulations and rain events were also correlated with decreases in pH. Reductions in surface water tensions due to the flux of natural surfactants into the stream during spring runoff and storm events is the most probable process resulting in foam accumulations. The natural surfactant likely is a component of the dissolved organic carbon leached from terrestrial and aquatic plants, which are high in organic acids. While the flux of DOC into the stream reduces surface tension, actual foam accumulations also require aeration through flowing over riffles, through culverts, or over logs or other material creating small falls; and a point of accumulation such as emergent aquatic vegetation along an outside bend or a log at the water surface. These physical factors, aeration and accumulation points, are modified by changes in the water surface elevation and aquatic macrophyte beds causing points of foam accumulation to vary. Human influences on foam abundance are not likely to come through the direct release of synthetic surfactants, which are readily biodegradable, but could occur through nutrient releases that increased macrophyte and algal production. However, the affects of eutrophication on dissolved oxygen availability would be more significant. Human activities that reduce the amount of wetlands within the watershed, which are the primary source of DOC, would reduce foam accumulations.

The concentration of fecal coliforms and stream water temperatures exceeded State Water Quality Standards and warrant further investigation.

Introduction

The Alaska Department of Environmental Conservation (DEC) has received numerous complaints about foam in Cottonwood Creek and its tributary Dry Creek. Citizens living along the stream below Wasilla Lake have noticed large accumulations of foam. Upon investigation, DEC staff documented a large foam accumulation. Water samples also revealed fecal coliform concentrations of near 500/100ml near the old Matanuska Road Bridge (July 2002). DEC staff also observed large foam accumulations in Dry Creek, upstream from most human development. The Wasilla Soil and Water Conservation District has observed foam throughout the stream. The Alaska Department of Fish and Game (ADFG) found dead and dying sockeye salmon smolt with eroded fins in the weir at the outlet of Wasilla Lake in May of 2001 (ADFG 2001). The smolt pathological report indicated that the most probable cause of mortality was a ciliated protozoan (*Apiosoma*). The report states that the protozoan is found in freshwater with high organic content. The dead fish may or may not be related to the presence of foam. Due to the sum of all reports and observations, Cottonwood Creek has been Section 303(d) (Federal Clean Water Act) listed by the DEC for non-attainment of the State's residues standard for foam and debris.

Foam can be caused by the human input of surfactants or detergents. These sources generally cause white, sweet-smelling foam that does not persist for long (IDEM 2001). The development of foam in streams also can occur naturally and can be the result of reduced water surface tension caused by organic matter released from decaying algae or other organics. Aeration occurs through physical processes. Foam development in Cottonwood Creek also could be influenced by organic input from septic systems located along the stream. This hypothesis would also provide an explanation for the abundance of the protozoan seen on fish. Private residents living along the creek downstream of Wasilla Lake also have complained about the abundance of mats of growths occurring on the stream substrate. This could be growths of *Sphaerotilus*, also known as "sewage fungus" which is an iron-oxidizing bacteria known to occur at locations of high organic matter.

Changes in the abundance of natural sources of organic material could cause changes in foam and protozoans. Foam development can occur naturally and is often associated with brown water or stained streams. Measurements of stream color (Edmundson et al. 2000) indicate that Cottonwood Creek is lightly stained at most times and occasionally heavily stained. Dry Creek and Cottonwood Creek upstream of Cornelius Lake flow through wide (50 to 100 m) sloped valley wetlands. Stained or brown water streams often occur in locations that drain wetlands and the color is due to organic material that leaches from the buildup of organics within the anaerobic wetland soils. Increases in organics also could be due to increases in primary production within the stream and lakes of Cottonwood Creek and be ultimately caused by increases in macronutrients or other elements that are in concentrations that limit production. Previous studies (Edmundson et al. 2002) indicate that the Cottonweed Creek drainage is mesotrophic. In addition, most of these factors could be interacting, that is an increase in organics could be due to a combination of factors. Interacting factors affecting foam development could include the input of dissolved material from wetlands, human septic systems, natural changes in productivity, and increased productivity due to increases in anthropogenic nutrient sources.

The study objective was to evaluate the chemical and physical factors that could be contributing to the development and persistence of foam residue in Cottonwood Creek and whether those factors could be caused or influenced by human activities. The following tasks were developed to meet this objective.

- Conduct weekly surveys at 8 locations distributed along Cottonwood Creek to record the presence, size, and distribution of foam.
- Collect weekly water samples at 8 locations distributed along Cottonwood Creek and analyze for pH, specific conductance, and turbidity to evaluate potential correlations with foam abundance.
- Collect monthly water samples at 8 locations distributed along Cottonwood Creek and analyze for total fecal coliform and *Escherichia coli* bacteria as an indicator of potential sewage contamination.
- Collect monthly water samples at 8 locations distributed along Cottonwood Creek and analyze for macronutrients (nitrogen and phosphorus) to evaluate potential eutrophication.
- Collect monthly water samples at 8 locations distributed along Cottonwood Creek and analyze for dissolved organic carbon, and total dissolved solids to determine if seasonal or spatial variability in these parameters were related to potential source, or non-point source inputs and foam abundance.
- Measure water temperature at multiple locations to determine whether foam development or other physical, chemical, or biotic measures correlated with water temperature.
- Collect spring and fall samples of the juvenile fish community at multiple locations and look for the presence of lesions or other abnormalities.
- Identify the major macrophyte and algal species distributed along Cottonwood Creek.
- Conduct detailed literature search and report on natural and anthropogenic causes of foam.
- Consolidate available current and historic information on Cottonwood Creek.

Methods

Site Description

Cottonwood Creek is located within Wasilla, Alaska. Cottonwood Creek arises from springs located between the Little Susitna and Wasilla Creek drainages (Figure 1). The Creek is composed of two first order (Strahler 1957) tributaries: Cottonwood Creek which flows into Cornelius Lake to the east and Dry Creek which flows out of Anderson Lake to the west. Both streams flow into Neklason Lake and Cottonwood Creek emerges as a second order stream. The total length of all stream segments is 16.6 miles (Table 1).

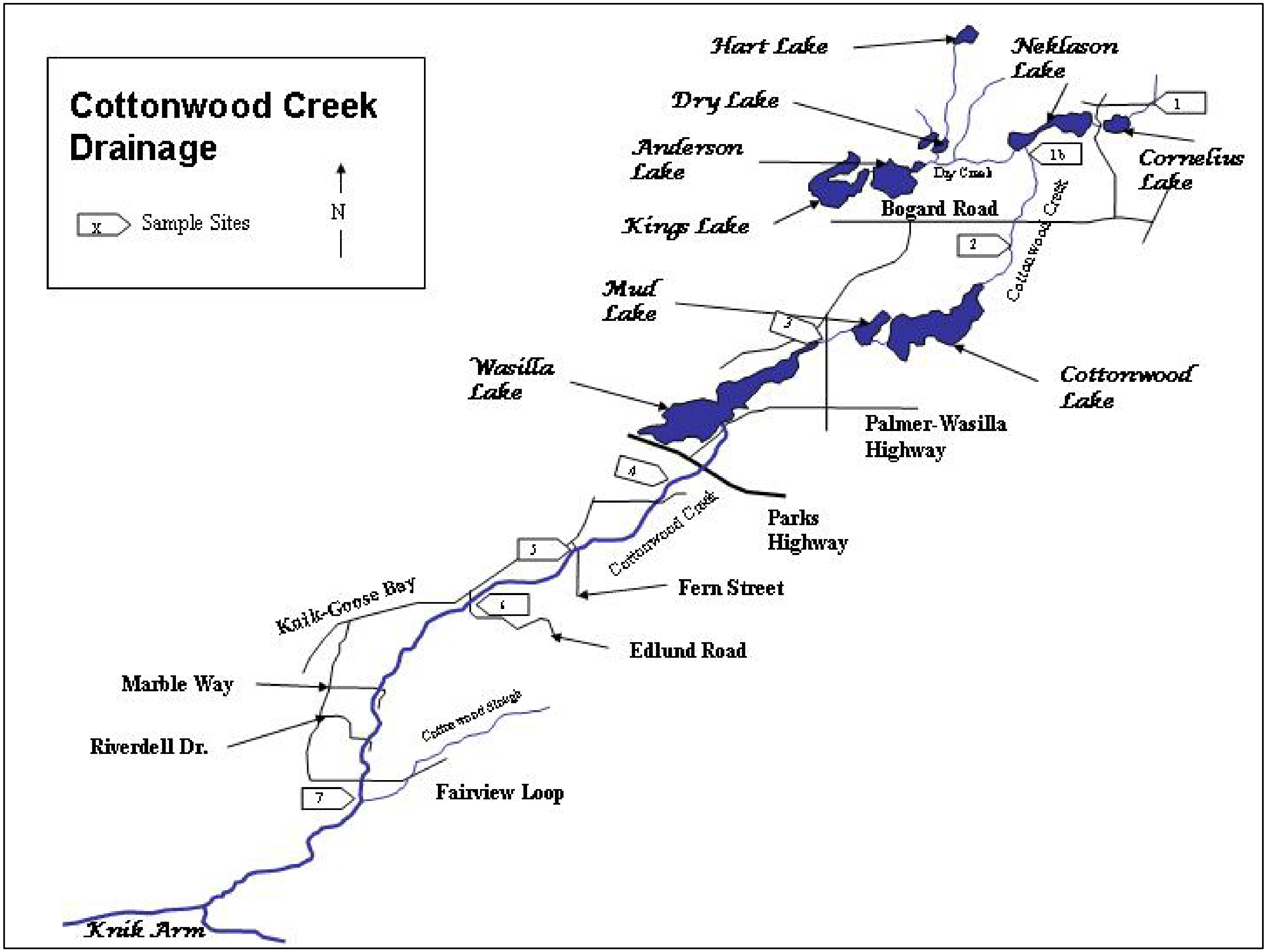

Figure 1. Drawing of Cottonwood Creek Drainage showing sampling locations.

Table 1. Cottonwood Drainage stream and lake measurements. Slopes are between consecutive elevations.

Stream Length From	**To**	**Distance (km)**	**Distance (mi)**	**Cumulative Distance (mi)**	**Elevation (ft)**	**Slope**
Hart Lake	Dry Lake	1.94	1.21	1.21		
Wolf Creek	Dry Creek	1.44	0.89	2.10		
Dry Lake	Dry Creek	0.18	0.11	2.21		
Anderson Lake	Neklason Lake	1.90	1.20	3.41		
Headwaters	Cornelius Lake	1.60	1.00	4.41	450	
Cornelius Lake	Neklason Lake	0.29	0.18	4.59		
Neklason Lake	Bogard Road	1.49	0.92	5.52		
Bogard Road	Cottonwood Lake	1.65	1.03	6.54	350	0.0089
Cottonwood Lake	Mud Lake	0.35	0.22	6.76		
Mud Lake	Wasilla Lake	0.51	0.32	7.08		
Wasilla Lake	Old Matanuska Road	1.39	0.86	7.94		
Old Matanuska Road	Fern Street	2.67	1.66	9.60	309	0.0025
Fern Street	Edlund Road	2.50	1.56	11.15	250	0.0072
Edlund Road	Fairview Loop	4.64	2.88	14.03	125	0.0082
Fairview Loop	Est. Mean High Tide	4.08	2.54	16.57	0	0.0093

Lake Area	Area (m^2)	Area (hectares)	Area (acres)	Perimeter (km)	Perimeter (mi)	Cumulative Acres
Hart Lake	79,029	7.9	19.5	1.174	0.73	19.5
Dry Lake	53,493	5.3	13.2	0.88	0.55	32.7
King Lake	458,795	45.9	113.4	5.226	3.25	146.1
Anderson Lake	387,699	38.8	95.8	3.153	1.96	241.9
Cornelius Lake	147,741	14.8	36.5	1.711	1.06	278.4
Neklason Lake	318,997	31.9	78.8	3.961	2.46	357.2
Cottonwood Lake	1,034,694	103.5	255.7	5.833	3.63	612.9
Mud Lake	196,341	19.6	48.5	2.522	1.57	661.4
Wasilla Lake	1,417,269	141.7	350.2	10.141	6.30	1011.6
Total	4,094,058	409	1,012	35	22	

Watershed Surface Area to Old Mat Road (Site 4) per USGS water quality data is 29 square miles.
Stream Length determined using Arcview with USGS 1:63 Quads.

There are 10 lakes within the drainage (Figure 1) with a total of over 1,000 acres and 22 miles of shoreline. Wolf Lake also is within the watershed; however, because there is no surface water connection to Dry Creek (Ed Weiss, Alaska Department of Natural Resources, personal communication) it is not included.

Sampling design, site selection, and sampling methods were conducted following the procedures for the DEC approved Quality Assurance Project Plan (Appendix A). The QAPP should be referenced for more detail on sampling design and methodology. Eight sampling sites were selected along the stream (Figure 1). The sites were distributed spatially with one site located near the outlet of each lake. Site 1 was the only site above most human impacts. Sampling locations were selected based upon access and previous foam observations. The upstream sites were selected because they would be less likely to obtain inputs from human sources that would affect water quality than downstream sites.

Surveys were conducted weekly during the ice-free period from late September 2003 through June 2005. At each location, observers looked for foam floating on the water surface or for surface accumulations. Foam abundance was classified into four different groups: (1) no foam observed, (2) floating spots of foam, (3) small accumulations of foam (less than 1 square foot), and (4) large foam accumulations. Time of day and recent weather were noted. Photographs were taken upstream and downstream at each sampling station on each date. Water samples were collected during each weekly survey and returned to the laboratory and analyzed for pH (Hanna HI 9023), conductivity (SPER Scientific model 840039) and turbidity (HACH Chemical Co. Model 16800). Weekly surveys were augmented by observations and photographs taken by volunteer observers.

Table 2. Cottonwood Creek observation and water sampling sites.

Site	¼ Sec	Sec	TWSP	Range	Lat	Lon	Description
1	SE	22	18 N	1 E	61.63240	149.24189	Settlement Ave. Road Crossing
1b	NE	28	18 N.	1 E.	61.62433	149.28575	End of Zephyr Drive
2	NW	33	18 N	1 E	61.60872	149.28990	Earl Drive Bridge
3	NE	1	17 N	1 W	61.59615	149.35790	Below Seward-Meridian Crossing
4	SW	11	17 N	1 W	61.57504	149.40783	Old Matanuska Road Bridge
5	SE	16	17 N	1 W	61.56371	149.44823	Fern Street Crossing
6	NE	20	17 N	1 W	61.55485	149.48571	Edlund Road Crossing
7	NW	31	17 N	1 W	61.52537	149.52710	Surrey Road Crossing

A staff gauge was placed at Site 4 and water surface elevation was recorded on each sampling date. Stream discharge was measured after Rantz et al. (1982) using a pygmy meter on multiple occasions and a rating curve developed. Gauge height was recorded during each weekly sampling event.

Water samples were collected at each site in mid April, May, June, July, August, and September. Water samples were analyzed by Analytica Alaska Incorporated for fecal colliforms, *E. coli*, dissolved and total reactive phosphorus, nitrate and nitrite nitrogen, ammonia nitrogen, total dissolved solids, and dissolved organic carbon except for

September phosphorus samples which were sent to AM Test, Inc. in Washington State due to their lower detection limits. The foam was not sampled directly due to the number of different types of chemical surfactants used today and because they can be modified through bacterial decomposition. In addition, other metals and organic compounds can accumulate within the foam.

Water temperature was measured using Optic Stowaway temperature data loggers. One was placed at Site 1 which is at the upper end of the drainage above all lakes and most, if not all, development. The second was at Site 2, downstream of the upper two lakes and upstream of Mud and Wasilla Lake. The third was just downstream of Wasilla Lake near the historic U.S. Geological Survey (USGS) gauging station at Site 4 and the fourth was at the farthest downstream Site 7.

Bioassays of juvenile salmon were conducted on four separate occasions to determine the presence and frequency of lesions using the USGS sampling methodology for DELT anomalies (Moulton et al. 2002). DELT is an acronym for deformities, eroded fins, lesions, and tumors. Juvenile fish were captured in baited minnow traps allowed to soak for 48 (Fall) or 24 (Spring) hours. Traps were placed near stations 1, 1b, 4, and 6. Captured fish were identified by species, except for stickleback, and measured for total length. Each fish was placed in a clear plastic bag and inspected for the presence of any deformities, eroded fins, lesions, or tumors.

Literature describing the development and causes of foam were obtained through Google internet searches, Environmental Protection Agency internet site search, and University of Alaska Anchorage resource bibliographies using the keywords, foam, residue, and surfactants. The results were further reduced, when necessary, by further searches using the key words water, stream(s), lake(s), and quality. Additional references were found by reviewing the citations within documents. All relevant references were copied.

Previous studies conducted on Cottonwood Creek were identified by contacting the Matanuska-Susitna Borough, the Wasilla Soil and Water Conservation District, the Alaska Department’s of Natural Resources, Fish and Game, and Environmental Conservation and searches of these agencies web sites. The CIIMMS database was searched using Cottonwood and Wasilla as keywords.

Results

Site Surveys

Site surveys were conducted during the ice-free period from September of 2003, through October of 2004. Eight sampling sites were surveyed for 34 to 36 weeks resulting in 275 observations (Table 3). Large foam accumulations were observed on at least one occasion at all sites except for Site 1. Among all sites, large foam accumulations were observed from 0 to 47% of the visits. Large foam accumulations were most often observed at Site 1b, just below Neklason Lake, at 38% and at Site 5, below Fern, at 47%.

The persistence of foam at sites 1b and 5 and to a lesser extent sites 4 and 6, were due to rapid increases followed by foam persistence without much change in size. At Site 1b there were small foam accumulations on May 11, immediately after breakup, with no real change until May 26 (see Site 1b photographs in Appendix B).

Table 3. Ranked foam observations from site surveys. Rank 1 = no foam, 2 = floating foam spots, 3 = small accumulations (<1 ft in diameter), and 4 = large foam accumulations. The last column is labeled W for weather observations of, S = sunny, PC = partly cloudy, LR = light rain, and HR = heavy rain over the past 24 hours.

Site	1	1b	2	3	4	5	6	7	W
9/27/2003	1	3	3	2	3	2	4	2	
10/10/2003	1	3	3	2	3	2	2	2	
10/26/2003	2	3	3	2	3	2	3	2	
11/10/2003	1	3	3	2	3	2	2	2	
3/26/2004	1	3	x	1	3	x	x	x	
4/10/2004	1	3	2	1	3	2	x	1	
4/16/2004	1	3	3	3	3	3	1	1	LR
4/21/2004	1	3	2	2	2	3	1	2	
4/23/2004	1	3	3	2	3	3	1	2	S
5/3/2004	1	4	3.5	2.5	3	4	3	2	S
5/7/2004	1	3	3	2	3	3	1	3	S
5/11/2004					4	4	2.5	2.5	HR
5/14/2004	1	3	3	2	4	4	3	3	PC
5/21/2004	1	4	4	2	4	4	3	3	PC
5/26/2004	1	4	4	2	4	4.5	3	3	HR
6/5/2004	1	3	3	2	4	4	3	2	PC
6/11/2004	1	4	3	2	3	4	2	2	PC
6/18/2004	1	4	3	2	3	4	1	2	S
6/25/2004	1	4	3	2	3	4	2	2	S
7/2/2004	1	4	3	2	2	4	3	2	PC
7/9/2004	1	4	3	2	2	4	3	3	PC
7/16/2004	1	4	3	2	3	2	3	3	S
7/23/2004	1	4	3	3	3	3	1	3	S
7/30/2004	1	3	3	2	1	2	1	1	LR
8/6/2004	1	3	3	3	3	3	4	3	S
8/13/2004	1	3	3	2	2	4	2	3	S
8/18/2004	1	3	4	2	3	4	2	4	S
8/28/2004	1	4	4	3	3	4	4	4	LR
9/2/2004	1	3	2	4	3	4	2	2	LR
9/10/2004	1	4	4	2	2	3	3	1	S
9/17/2004	1	3	3	2	2	4	3	3	S
9/23/2004	1	3	3	2	2	3	4	3	S
9/29/2004	x	x	x	2	2	x	x	x	HR
10/7/2004	1	3	3	2	3	3	4	3	LR
10/15/2004	1	3	3	3	3	4	4	3	LR
10/21/2004	1	2	2	2	3	2	3	2	PC
Observations	34	34	34	33	35	36	34	33	275
Percent Rank 4	0.0	38.2	17.7	3.0	14.3	47.2	17.7	6.1	

Table 4. Volunteer survey foam observations. W= weather, S = sunny, PC = partly cloudy, LR = light rain, HR = heavy rain.

	Neklason Lake	Zephyr	Bogard Road	Bogard to Cottonwood Lake	Upstream of Fern	W
5/12/04					1	S
5/14/04					1	S
5/17/04				4		S
5/18/04				4		LR
5/19/04				2	1	PC
5/20/04				2		S
5/21/04				1		PC
5/22/04	2	4	2	1	1	PC
5/23/04				1		LR
5/28/04				1		LR
5/29/04				1	1	PC
5/30/04				1		LR
5/31/04				1		
6/1/04				4		HR
6/2/04				4		HR
6/3/04	2	4	2			HR
6/5/04	2	4	2		1	S
6/6/04	2	4	2			S
6/8/04	2	4	2			LR
6/10/04					1	PC
6/11/04	2	4	2			S
6/16/04					1	S
6/15/04	2	4	2			PC
6/20/04				4		S
6/21/04				4		S
6/22/04	2	4	2	4		S
6/23/04				4	1	S
6/24/04				4		S
6/25/04				4		S
6/27/04				4		S
6/28/04	2	4	2			HR
6/29/04				4	1	HR
7/4/04	2	4	2			HR
7/6/04				4		S
7/7/04				4		S
7/8/04	2	4	2	4		S
7/13/04				4		S
7/14/04	2	4	2	4		S

The amount of foam accumulation at Site 1b increased on June 11, July 2, August 28, and September 10, 2004. The foam accumulations were persistent, rapidly turning brown but slowly diminishing in size so that a small accumulation was present on all but one sampling date. Similarly at Site 5, large foam accumulations were observed on May 3, May 11, May 26, and June 11, with brown persistent smaller accumulations during most other times (see Site 5 photographs in Appendix D). Large accumulations were not seen at Site 5 in July, August, and September as at Site 1; however, this may be the result of reduced aeration because of macrophyte-caused backwater into the upstream culvert rather than the foaming capacity of the water. Foam accumulations also increased at Site 4 on May 11, and May 26, 2004 (see site photographs in Appendix B).

Volunteer observations occurred at Neklason Lake, Zephyr Road (Site 1b), Bogard to Cottonwood Lake (bracketing Site 2), and upstream of Fern (above Site 5) (Table 4). There was little variation in foam accumulations observed by volunteers. Spots of foam were observed consistently at the outlet of the culvert dividing Upper and Lower Neklason Lake. Large accumulations were observed consistently at the end of Zephyr, (Site 1b). Spots of foam were observed consistently at the Bogard Road culvert outlet. Volunteer observations between Bogard and Cottonwood initially observed only near Bogard Road and documented either foam spots or no foam consistent with other observations. The survey area was expanded downstream to Cottonwood Lake where large foam accumulations were observed consistently. Volunteer observations upstream of Fern recorded no foam, which is inconsistent with the project's foam observations below the Fern Road culvert (Site 5) where large accumulations were common. Volunteers noted that the number of foam spots increased during rain events and tended to build foam accumulations; however, during some rain events rising water levels would wash the foam away.

Water Chemistry

pH

There were no consistent trends in pH among sites. pH was generally between 7.5 and 8.5 with high values of 9.06 and 9.34 recorded at Sites 1 and 2, respectively. There were 13 measures (5% of all samples) that exceeded State water quality standards (18 AAC 70.020(6)(c)) (8.5 for Fresh Water) and 7 of these occurred in September of 2003. pH values tended to be quite similar among sites in May and into June with variability increasing in July and August (Figure 2). High values for most sites occurred in late September of 2003 except for Site 1b, where the high value was in April of 2004 and Site 1 where the high value was on July 16 of 2004. Water samples were not taken at Site 1b in September of 2003 (See Appendix E).

Low pH values coincided with increase in foam accumulation. The low pH points shown in Figure 2 occurred on May 14, May 26, June 11, July 2, August 28, and September 10. Foam accumulations were observed at Site 1b on all of these dates, Site 5 in May and June, and Site 4 on these same dates in May.

Specific Conductance/TDS

Specific conductance ranged from 128 to 205 µS/cm among all sites and all sampling dates, although most measurements fell between 150 to 200 µS/cm. There were no apparent seasonal trends although the lowest value occurred at Site 1b in early April and specific conductance tended to be higher in May and June compared to August and September (Appendix E and Figure 3). There were no trends among sites and no apparent relationship with foam accumulations.

The mass of total dissolved solids (TDS) ranged from 80 to 140 mg/L among all sites and all sampling dates. Seasonal trends in dissolved substances were similar among sites with concentrations decreasing during the summer months. For most sites, the lowest monthly values were on July 20, with the exception of Sites 2 and 3 where the lowest monthly values were on June 18, 2004 (Figure 4).

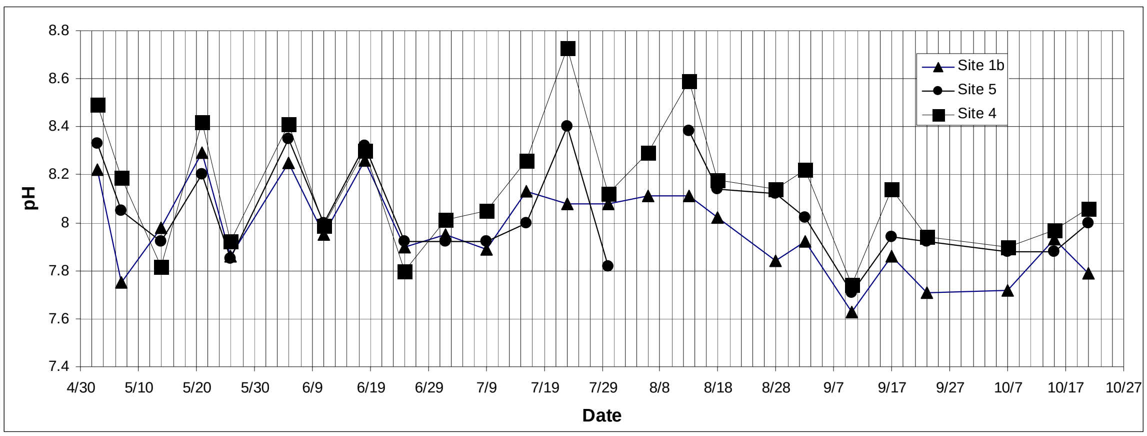

Figure 2. pH for three representative Cottonwood Creek sites in 2004.

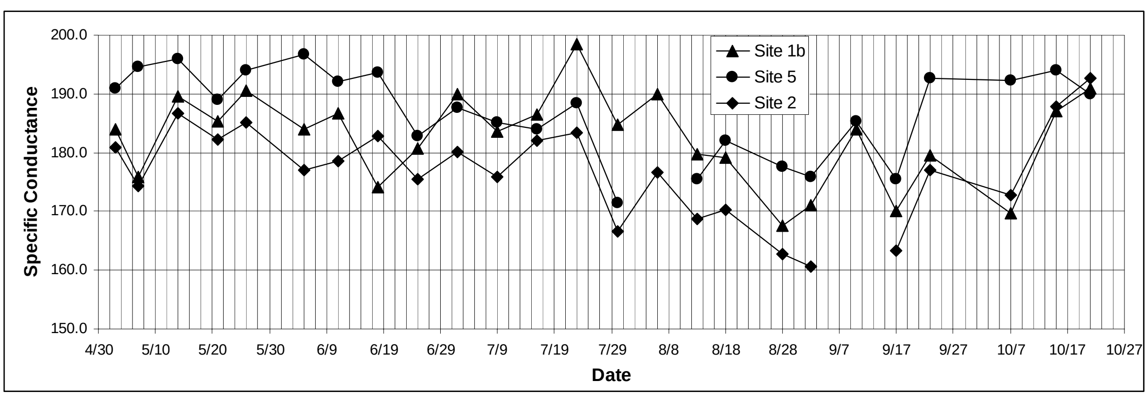

Figure 3. Specific conductance for three representative Cottonwood Creek sites for 2004.

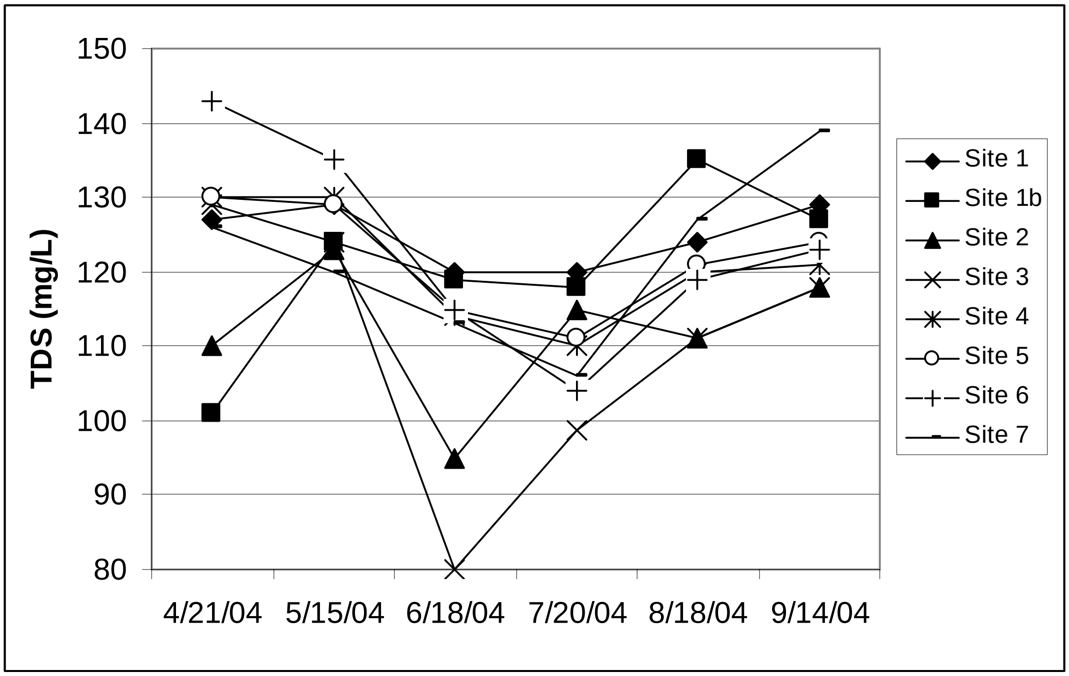

Figure 4. Total dissolved solids for all sites on all sampling dates showing decrease in concentration during the growing season.

Turbidity

Turbidity in Cottonwood Creek was quite low at all times throughout the year. Turbidity (NTU) ranged from 0.4 to 3.4 with no differences among sites or through time (Appendix E). Cottonwood Creek does not become more turbid during spring runoff or storm events as is observed in most streams. Cottonwood Creek was observed turbid with values above 100 NTU on one occasion at Site 4 as storm runoff transported sediment from the Park's Highway road construction.

Dissolved Organic Carbon

Dissolved organic carbon (DOC), is that portion of total organic carbon that passes through a 0.45µm filter and is measured by conversion to carbon dioxide. Concentrations of DOC in Cottonwood Creek ranged from 1.5 to 4.0 mg/L at sites 1b through 7. The concentrations of DOC in the reference Site 1, distinguished it from the remainder of the creek (Figure 5). Concentrations at the spring-fed Site 1 were near 1.0 in April and September, but below detection limits (1.0 mg/L) during the summer months. DOC concentrations at the 5 upstream sites increased from April to May. Concentrations at Sites 6 and 7 were stable from April to May, peaked in July, and then decreased to near April concentrations. Similarly, concentrations in most of the upstream sites decreased and remained fairly constant following the May peak. Site 3 was an exception where concentrations continued to increase until July and then decreased in August and September. Monthly sampling events did not coincide well with increases in foam accumulations. The high values in May preceded the large foam accumulations observed on May 26th.

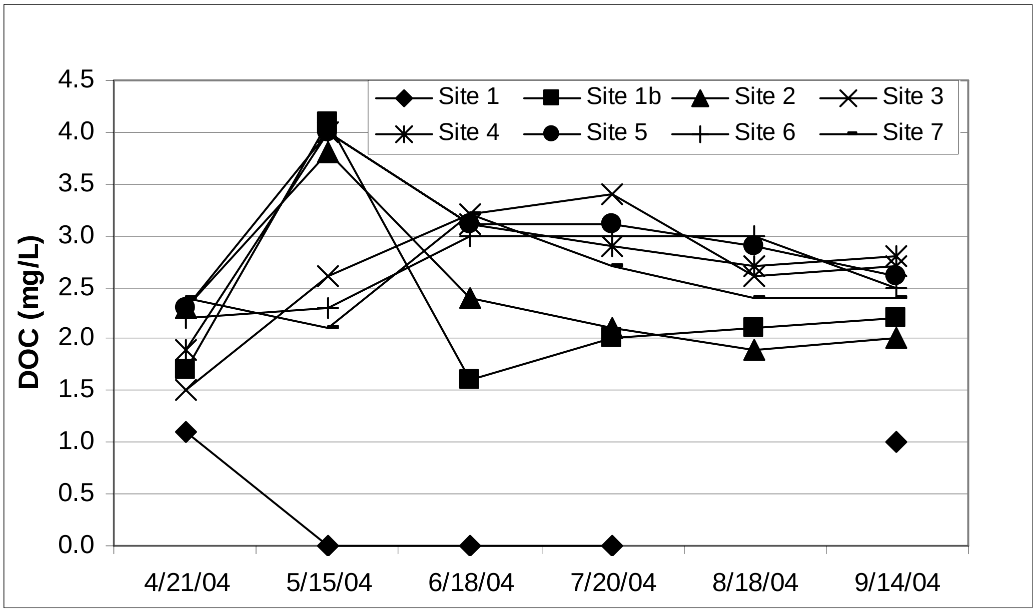

Figure 5. Concentrations of dissolved organic carbon in Cottonwood Creek from monthly sampling.

Macronutrients

The results of the analyses of monthly water samples for macronutrients are shown in Appendix E. Concentrations of nitrate-N were different at Site 1 than the remaining stations but similar for ammonia-N. Nitrate-N concentrations were near 0.4 mg/L at Site 1 and remained stable throughout the sampling period. At sites 1b through 7, April concentrations were near 0.2 mg/L, then decreased to near (Site 7) or below the 0.10 mg/L detection limit. Ammonia-N concentrations were close to or below detection limits (0.025 mg/L) in April and then in August and September, but were near 0.05 mg/L through the growing season (Figure 6).

Total and dissolved reactive phosphorus concentrations were below detection limits (0.025 mg/L-P) at all sites from April through July. August samples were not analyzed for phosphorus. In September samples were analyzed at a different laboratory with detection limits of 0.005 mg/L for total phosphorus and 0.001 mg/L for dissolved phosphorus. Concentrations remained low but exceeded detection limits at sites 1, 3, 5 and 7 (Figure 7).

Fecal Coliforms/E. Coli

Fecal coliform bacteria and *E. coli* bacteria results are shown in Tables 5 and 6. Fecal coliform bacteria are made up of many different bacteria species. Fecal coliform bacteria are capable of surviving in a lactose medium and are a subset of all coliform bacteria. E. coli bacteria are one of the fecal coliform species; however, E. coli counts include organisms of the species that are not of fecal origin. For contact recreation in fresh water the water quality standards are as follows. “In a 30-day period, the geometric mean of samples may not exceed 100 FC/100 ml, and not more than one sample, or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100 ml" (18 AAC 70.020(b)(1)(B)(i)).

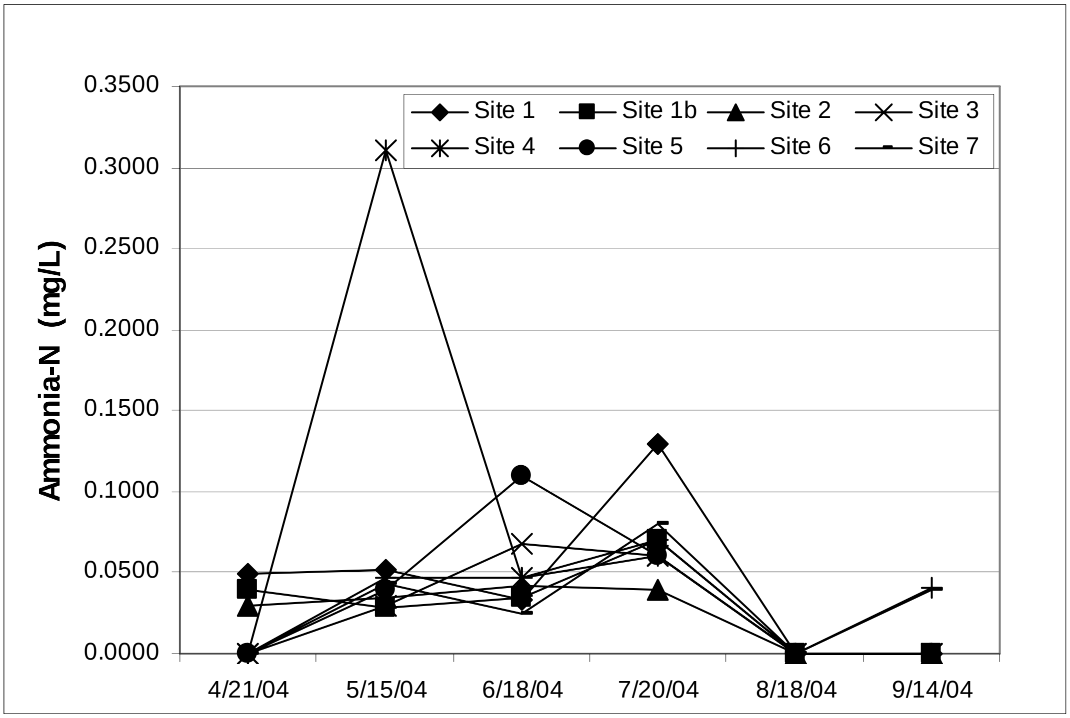

Figure 6. Concentrations of nitrogen as ammonia from monthly water samples at the Cottonwood Creek sampling sites.

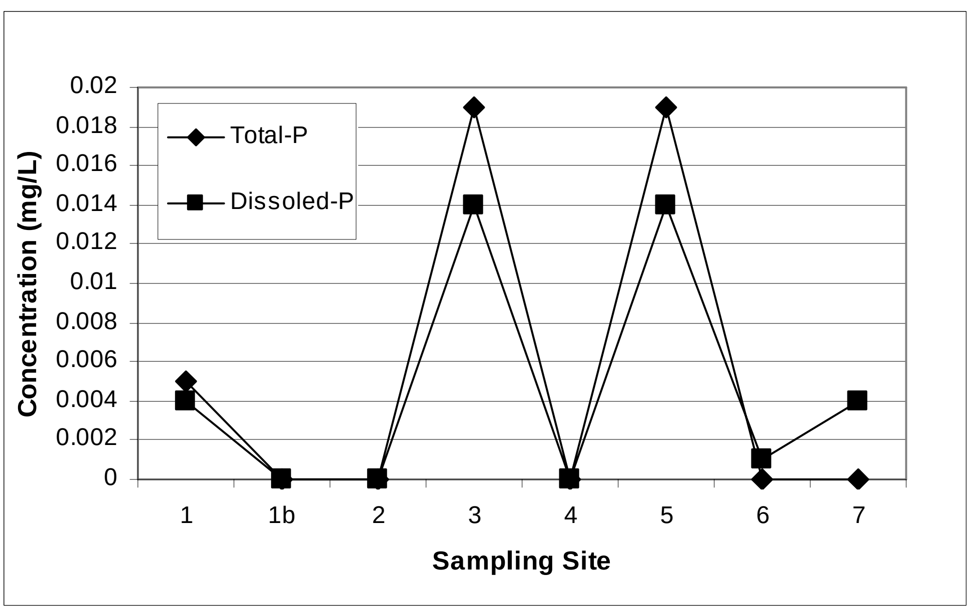

Figure 7. Total and dissolved phosphorus concentrations on September 14, 2004.

For this use, water quality standards were exceeded at Site 1in July and August, Site 6 in September, and Site 7 in June and July by exceeding 200 FC/100 ml. The averages of two consecutive samples less than 30 days apart exceed 100 cfu/100ml at Site 1, Site 4, Site 6 and Site 7.

State water quality standards for fecal coliforms in fresh water for aquaculture use are that, “For products normally cooked, the geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml. For products not normally cooked, the criteria for drinking water supply, (2)(A)(i), apply.” (18 AAC 70.020(b)(1)(A)(iii)). It is not clear how many samples must be taken in a 39-day period to calculate the mean or if the 10% applies only to the samples taken within the 30-day period. However, calculating the average of any two consecutive samples within a 30-day period, water quality standards were exceeded twice at Site 1 and once at Site 6. Water samples collected on July 20 and August 18 were within a 30-day period and the average of these two samples is 930 cfu/100 ml. The average between August and September Site 1 samples is 815 cfu/100 ml. The average of June and July Site 7 fecal coliform samples is 245; however, the two sampling dates are more than 30 days apart. The average fecal coliform count between August and September at Site 6 is 205 cfu/100 ml.

Table 5. Total fecal coliform bacteria (cfu/100 ml) at Cottonwood Creek sampling sites.

Site	4/21/04	5/15/04	6/18/04	7/20/04	8/18/04	9/14/04
1	<2.9	3	80	260	1600	30
1b	<2.9	<2.9	8	50	11	4
2	<2.9	3	11	78	8	8
3	94	6	14	16	21	8
4	58	30	80	110	130	50
5	130	10	70	120	50	130
6	100	20	110	130	170	240
7	93	57	240	250	80	80

Table 6. E. coli bacteria (cfu/100 ml) at Cottonwood Creek sampling sites.

Site	4/21/04	5/15/04	6/18/04	7/20/04	8/18/04	9/14/04
1	0	2	14	40	2400	37
1b	0	1	33	96	13	2
2	0	5.2	24	81	9.7	12
3	1	5.1	22	16	9.8	1
4	0	20	49	180	70	70
5	1	11	34	250	61	76
6	1	12	55	120	89	200
7	1	170	490	500	63	48

Discharge

A staff gauge was placed under the foot bridge at Site 4 on April 23, 2004. Discharge was measured on 6 different dates and ranged from 5.5 to 16.1 cfs. A discharge rating curve was developed based upon these six measurements. The equation for discharge calculation is,

$$D = 40.654 Ln(h) + 16.524$$

where *D* is discharge (cfs) and *h* is gauge height (ft). The R^2 for the regression was 0.98 and accuracy between measured and estimated values ranged from 94 to 108%. Using this equation, discharge was estimated for each sampling date (Figure 8). Annual lows of 5.5 cfs were recorded on July 23rd and August 18th. High flow of 20.3 cfs occurred on October 21st. Discharge was 22.8 cfs on January 4, 2005, calculated from gauge height read during mid-winter thaw and rain event.

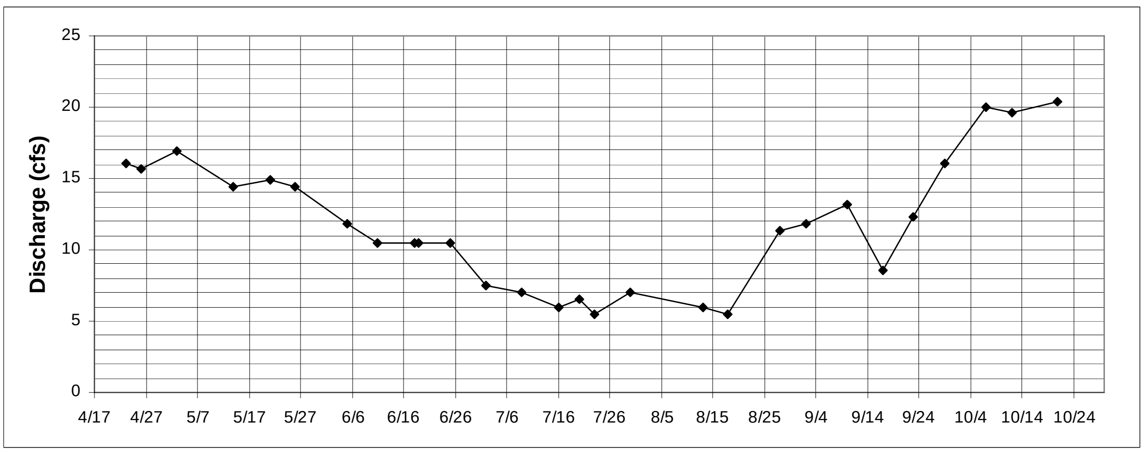

Figure 8. Cottonwood Creek discharge in 2004 at Site 4 (Old Matanuska Road).

The gradual decline in stream flow from April to August is delayed on May 14 through May 26, June 11 and July 2. Stream flow increase rapidly on August 28 and again on September 10, and October 7, which, with the exception of October 7, correlates with increasing foam accumulations.

Temperature

Stream water temperatures in Cottonwood Creek were above 0°C from early April through October of 2004. Highest temperatures were recoded at Site 4, below Wasilla Lake, where over 2500 degree days (sum of average daily temperatures above 0) accumulated (Figure 9 through 13). A computer error resulted in the loss of July 1 through July 17 temperature data. It is estimated that with these data total degree days would be increased by 400 to 500. Stream water temperatures were lower at Sites 2 and 7 where cumulative degree days exceeded 2000. Stream water cumulative degree days were considerably different in the spring-fed Site 1 and did not exceed 1000.

State standards for the growth and propagation of fish, shellfish, or other aquatic life, and wildlife are13°C for spawning and incubation and 15°C for rearing and migration. Average daily temperatures at Site 1 were well below State Water Quality Standards. Stream water temperature exceeded State standards at the remaining sites from mid-June through mid-September. Maximum stream temperatures were 9.6, 25, 26.7, and 21.6 for sites 1 through 7, respectively. Maximum stream water temperatures exceeded 20°C 52 days at Site 4 and 51 days at Site 2. Water temperature decreased from the outlet of Wasilla Lake to Site 7 where maximum temperatures exceeded 20°C only 4 days.

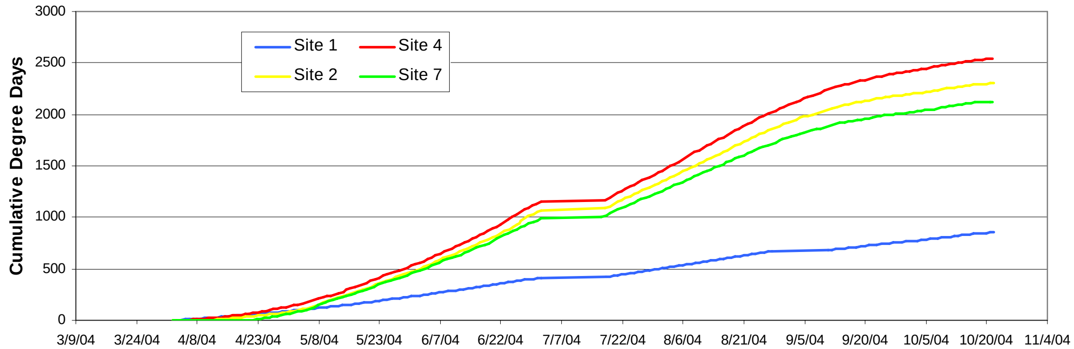

Figure 9. Annual (2004) cumulative degree days showing the differences among sampling sites along Cottonwood Creek. Temperature data from July 1 through July 17 was lost.

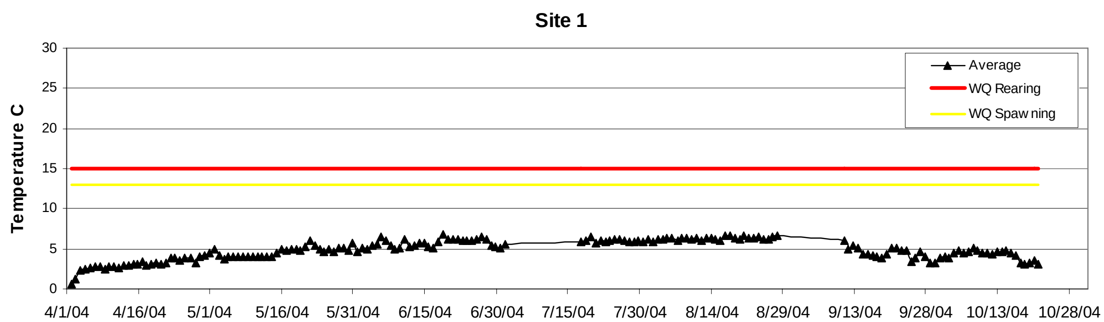

Figure 10. Daily average water temperature at Site 1 (upstream of Cornelius Lake) from April 1 through October 21, 2004. WQ = State water quality standard for rearing and migration (red line) and spawning and incubation (yellow line).

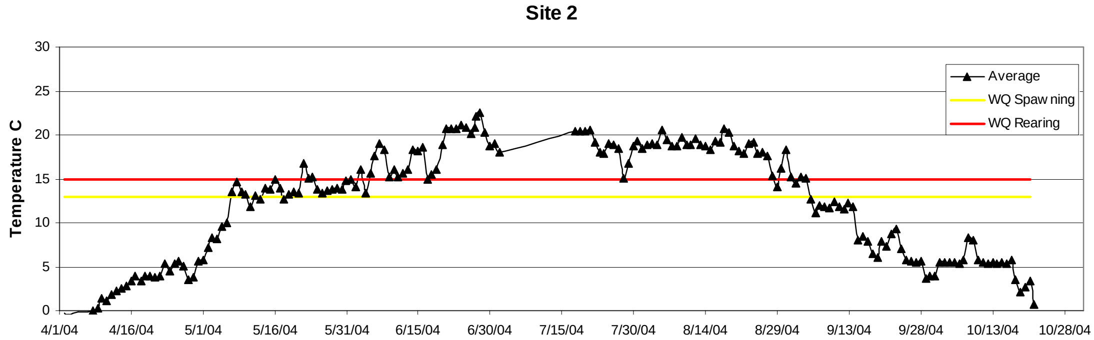

Figure 11. Daily average water temperature at Site 2 (downstream from Bogard Road).

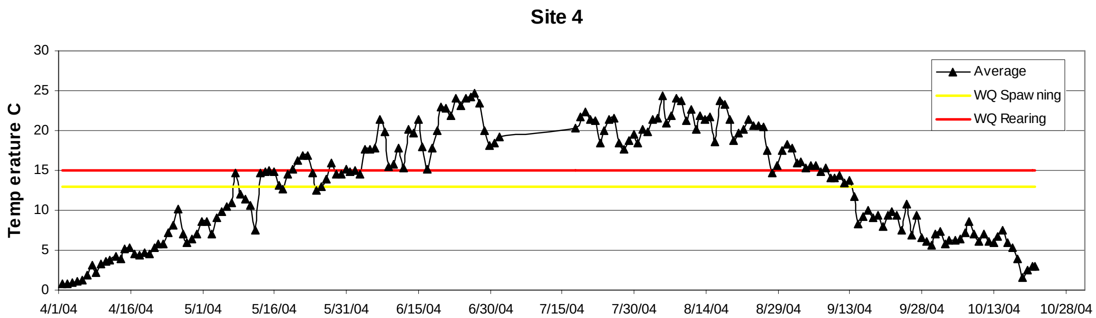

Figure 12. Daily average water temperature at Site 4 (Old Matanuska Road). Water quality standards were exceeded from mid-May through mid September at this coho salmon and rainbow trout spawning location.

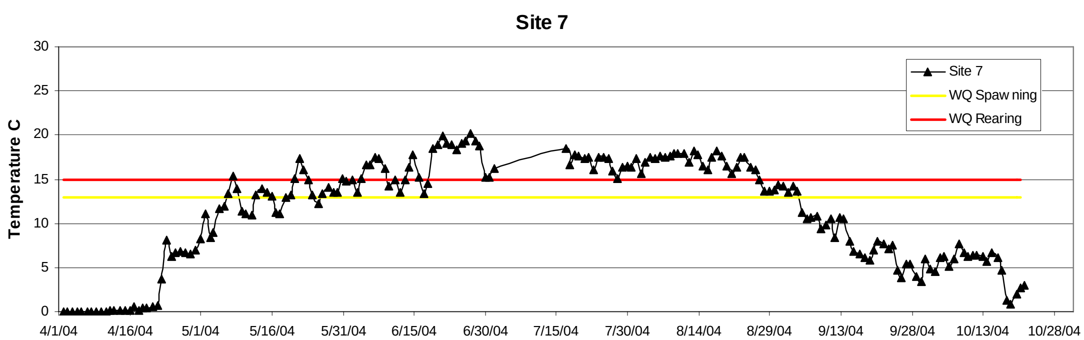

Figure 13. Average daily water temperature at Site 7 (Surrey Road below Fairview Loop).

Fish

In October of 2003, single baited fish traps were set at Sites 1, 2, 4, and 6 and retrieved after 48 hours. Coho salmon juveniles dominated the catch. More coho were caught at the lower, slow velocity Sites 6 and 4 (approximately 116) than at Site 1 (14 coho salmon). One Dolly Varden was captured at Site 2 (Table 7). Of these fish, one coho salmon captured at Site 4 had an eroded dorsal fin. Two of the fish (one coho salmon and one Dolly Varden) had abrasions on their sides that may have been caused by the fish trap. Coho salmon measured from 60 to 100 mm and the size distribution suggested that two age-classes were present (Figure 8).

In June of 2004, baited fish traps were set at Sites 1, 4, 5, and 6 and retrieved after 24 hours. Approximately 50 coho, 25 rainbow trout, and 4 Dolly Varden were captured along with approximately 30 stickleback. All of the Dolly Varden were captured at Site 1. Two coho salmon were observed to have eroded dorsal fins. One was at Site 6 and one at Site 5. Two of the five coho salmon captured at Site 1 had lesions. The size distribution of coho salmon was dominated with larger fish when compared with the September 2003 sample and appeared to be composed of primarily one age class (Figure 15).

In September of 2004, single baited fish traps were set at sites 1, 1b, 4, and 6 and retrieved after 24 hours. Considerably fewer salmon were captured in comparison to October of 2003. Only on coho salmon was captured at sites 4 and 6 combined compared with 133 the previous year. Dolly Varden, rare in 2003, dominated the fish community at Site 1. No DELT anomalies were observed. Although considerably fewer fish were captured, the size distribution was similar to 2003 coho salmon catches (Figure 16).

Very few fish were captured in June of 2005 (Figure 17) at sites 1, 1b, 4, and 6. A total of 9 salmonids, 8 coho and 1 rainbow trout were captured. The size distribution, unlike the June 2004 sample, was composed of smaller fish representative of the younger age class. Sticklebacks made up the remainder of the catch and no anomalies were observed.

Table 7. Number of fish captured in traps by site and common names. Coho = coho salmon, RT = rainbow trout, DV = Dolly Varden, SB = sticklebacks.

Oct 03						**June 04**					
Site	Coho	RT	DV	SB	Sculpin	Site	Coho	RT	DV	SB	Sculpin
1	14	0	0	0	1	1	5	0	4	0	0
2	3	1	1	0	1	4	30	4	0	4	0
4	32	3	0	0	1	5	16	11	0	23	0
6	84	6	0	7	0	6	3	11	0	2	0
Total	133	10	1	7	3		54	26	4	29	0
Sept 04						**June 05**					
Site	Coho	RT	DV	SB	Sculpin	Site	Coho	RT	DV	SB	Sculpin
1	5	1	21	0	0	1	1	0	0	0	0
1b	11	7	1	2	0	1b	2	0	0	5	0
4	0	1	0	0	0	4	4	0	0	26	0
6	1	0	0	0	0	6	1	1	0	26	0
Total	17	9	22	2	0		8	1	0	57	0

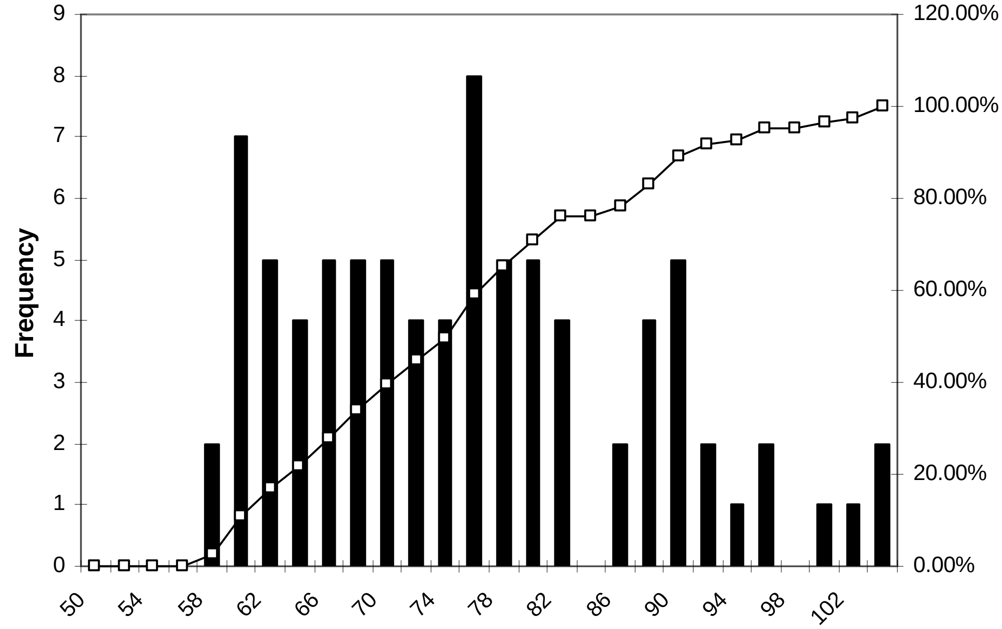

Figure 14. Size distribution (mm) of juvenile coho salmon captured on October 26, 2003 (n=83).

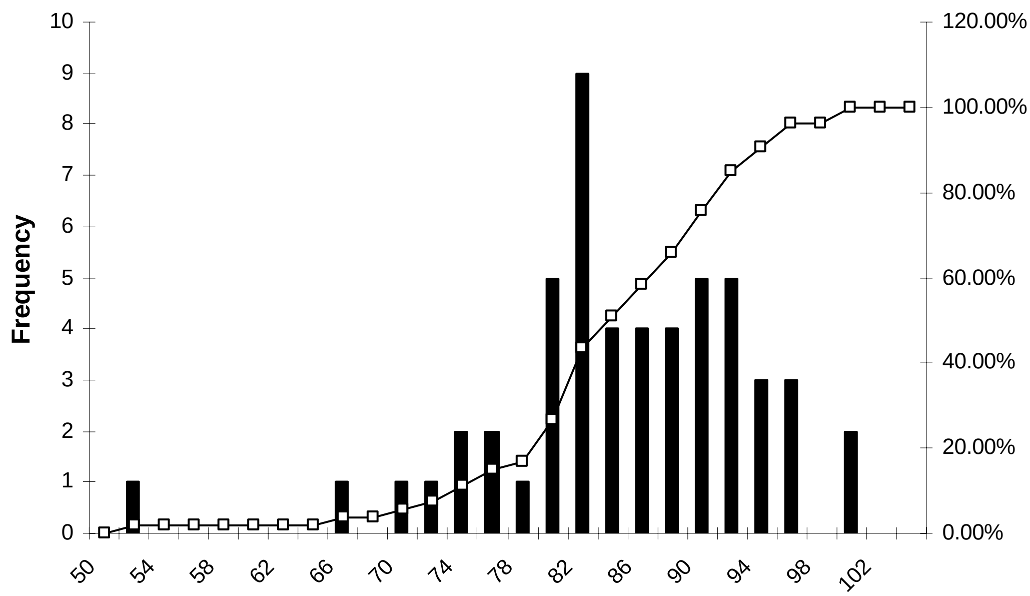

Figure 15. Size distribution (mm) of juvenile coho salmon captured in Cottonwood Creek on June 19, 2004 (n=53).

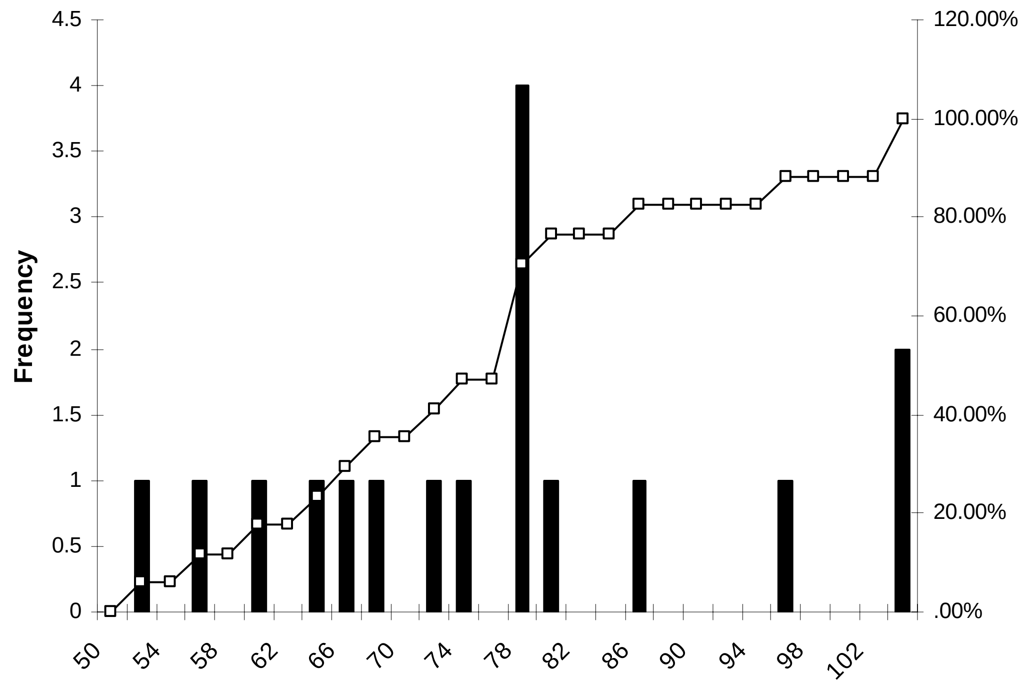

Figure 16. Size distribution (mm) of coho salmon juveniles captured in Cottonwood Creek on 23 September 2004 (n=17).

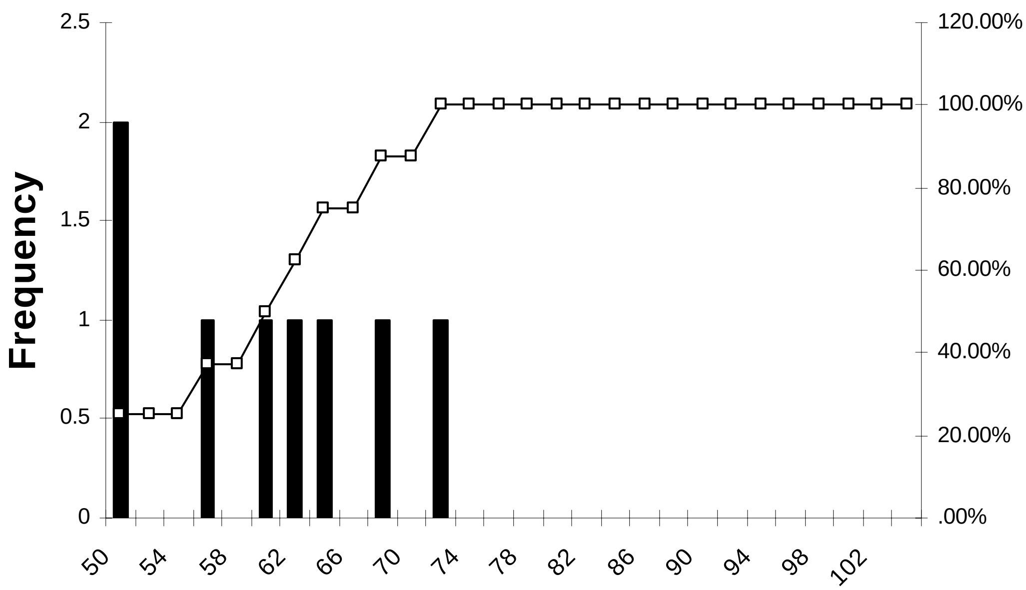

Figure 17. Size distribution (mm) of coho salmon juveniles captured in Cottonwood Creek on 13 June 2005 (n=8).

Macrophytes

Large macrophyte beds occur throughout the Cottonwood Creek drainage, particularly from Cottonwood Lake to below Edlund road. Common macrophytes were identified using Prescott (196x) and Hulten (1968). At locations of slow water velocity, macrophytes could dominate the channel cross-section but were restricted to the stream margins in areas of higher velocity. *Calla palustris* was observed most often, followed by *Menyanthes trifoliata*, *Potentilla palustris* and *Nuphar* species (Figures 18 through 22).

Figure 18. Calla Palustris.

Figure 19. Menyanthes trifoliata.

Figure 20. Nuphar, Water Lilly

Figure 20. Potentilla palustris.

Figure 19. Potamogeton natans.

Previous Cottonwood Watershed Studies

Previous Cottonwood Creek publications and reports are shown in Table 8, and are summarized below.

Table 8. List of previous investigations of Cottonwood Creek.

Date	Investigators	Title or Description
1949-1954, 1998-2000	USGS	Discharge data
1948-1952, 1981-1983	USGS	Water quality data from the gauge site on Old Matanuska Road.
1953-1959	USFWS	USFWS Federal Aid to Fish Restoration Reports—Rainbow Trout
1998-2000	ENRI	Macroinvertebrate and habitat assessment at two locations.
2000-2005	WSWCD	Citizen sampling of water chemistry at 3 or 4 stream sites.
2000	ADFG-Habitat	Survey of culverts for fish passage.
2000	Edmundson et al. 2000, ADFG	An assessment of the trophic status of 25 lakes in the Matanuska-Susitna Borough, Alaska.
2002	Edmundson 2002, ADFG	Limnological information supporting the development of regional nutrient criteria for Alaskan Lakes.
2005	ADFG	Coho salmon smolt and adult surveys.

US Geological Survey

The USGS collected discharge data at the Old Matanuska Road Bridge from 1949 to 1954 and from 1998 to 2000. Annual peak flows are shown in Figure 18.

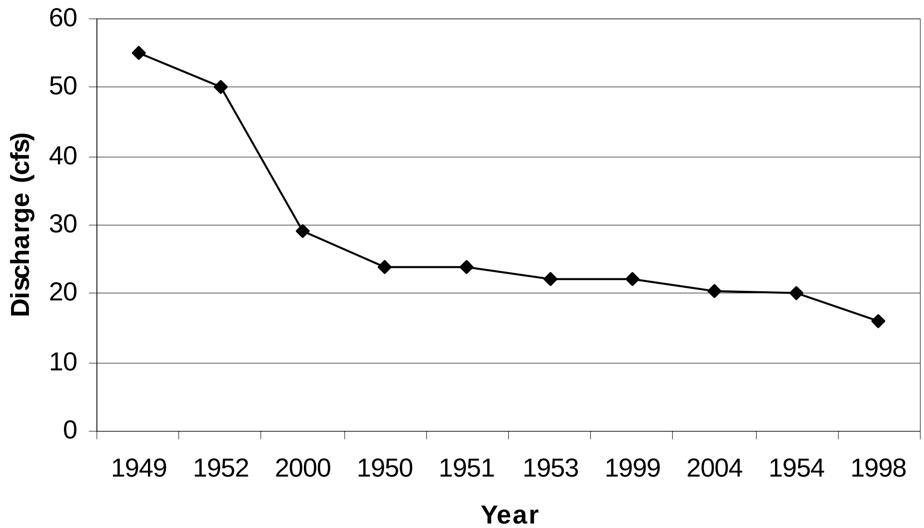

Figure 21. Cottonwood Creek annual peak flows from USGS gauge data (2004 data point from this study).

Table 9. Select Cottonwood Creek USGS water quality data collected from the gauge site at the Old Matnuska Road Crossing.

Date	Time	Temp	Discharge (cfs)	DO (mg/L)	DO % Sat	Sp Cond. µS/cm)	pH	Alkalinity (mg/L CaCO3)	Nitrate-N (mg/L)	Hardness (mg/L CaCO3)	Fecal Coliforms (cfu/100 ml)	TDS (mg/L)
10/19/48						172		90	0.07	86		
5/19/49		12	14			151	7.7	74	0.14	72		
10/31/50						192	7.5	103	0.14	100		
3/21/51		2	10			225	8	112	0.36	110		
5/24/51			14			201	8.5	99	0.07	100		
11/26/51		0	16			218	7.5	100	0.09	110		131
2/12/52			13			224	7.6	115	0.09	120		141
3/12/52		1	12			230	7.3	116	0.09	120		141
4/15/52		0	15			210	7.5	105	0.07	100		126
5/7/52		3.5	17			179	7.7	91	0.02	92		
6/11/52		14.5	10			190	7.7	97	0.14	83		
7/16/52			15			182	7.6	92	0.11	90		
8/29/52		13.5	8			169	7.4	84	0.29	85	15	
6/25/81		18	21	8.8	92	189	7.8	92				
3/9/82		1.5	17	13.6	100		7.9					
8/6/82		18	23	9.9	104	175	8.3				8	
3/1/83		0	16	12	82	195	7.9				1	
7/27/83	9:50	15.5	15	8.5		167	7.7					
7/27/83	16:00	22	13	9.2		168	8.1					

Water quality data were collected by the USGS as the gauge site in 1948 to 1952, and 1981 to 1983 (Table 9).

U.S. Fish and Wildlife Service Federal Aid to Fish Restoration Reports

The first work in this series, Allin 1953, provides background biological and water chemistry data. The physical characteristics, perimeter, depths, and volumes of Wasilla and Cottonwood Lakes are provided. There were two resorts on the lake and nineteen private homes or cabins around Wasilla Lake. Bogard Road and the Palmer-Wasilla

Highway touched the lake on the north and south. The type and relative abundance of aquatic plants are listed, with *Potamogeton,* and *Nuphar* (water Lilly) being the most common. Both *Calla palustris*, and *Menyanthes trifoliata* were present at that time. Water chemistry data included temperature, dissolved oxygen, pH, and alkalinity. Planktonic algae collected in March of 1953 are listed. The lake substrate of Wasilla Lake is described for various locations. Clam beds are described as present in the northeastern end of the lake and aquatic snails at several locations. Variable sized gill nets were used to sample the fish population. Rainbow trout and fine-scaled suckers dominated the catch.

A second publication believed to be produced in 1954 (Allin 1954), reports on a study to determine the number of gill-net sets necessary to obtain a valid population estimate. There were an estimated 3,800 rainbow trout, and 8,800 fine-scaled suckers within Wasilla Lake. The catch of suckers increased in shallow near-shore areas and in large shoals. Growth rates as length/weight relationships are compared with the previous year (1953) and show an increase in the condition of rainbow trout. Also in 1954 (USFWS 1954) a report of rainbow trout scale analyses is released for a number of Lakes on the Kenai Peninsula and Anchorage area including the Cottonwood Creek drainage.

Studies through the summer of 1956, 1957, and 1958 focused on the run timing of adult and juvenile rainbow trout in Cottonwood Creek downstream from Wasilla Lake. The 1956 study investigated the downstream migration of fish, primarily rainbow trout, through a weir near the Old Matanuska Road, spawning habitat and behavior, egg development and growth rates, upstream migration, feeding preferences, and angling pressure. Water temperature, discharge and pH were monitored at the weir.

In 1956 (Whitesel et al. 1957), rainbow trout migrated downstream from Wasilla Lake until the end of July. Approximately 13% of the run were fish over 10.0 inches in length and fish from 3.0 to 4.9 inches constituted 69% of the run. Upstream migration began on May 7 and extended through September. Ninety five percent of the run were fish less than 10.0 inches. There was an early June migration peak of returning downstream migrants and a late July peak of age 1 and 2 fish migrating to Wasilla Lake for the first time. Run timing is discussed relative to water temperatures, cloud cover, and discharge, return per spawners are estimated. Adult rainbow trout moved up to 5 ½ miles downstream and spawned at the lower edge of riffles in 5 to 10 inches of water where velocities ranged from 1 to 3.5 feet/second. Females from 14 to 17 inches carry 1200 to 1700 eggs. Eggs taken in the last week of April hatched by mid June. Approximately 1100 heat units (degrees Fahrenheit) were required to bring the eggs to buttoned-up fry. Sticklebacks made up 75 % of the rainbow trout diet by weight and 17% insects. Stream fish used a slightly higher percentage of insects that lake fish.

In 1957, a weir at the inlet was added in addition to the outlet weir. Migration timing was similar as in 1956. Smaller number of fish moved upstream to spawn; however, there was more spawning habitat per fish downstream relative to upstream. Spawning mortality for fish over 7 inches in length was estimated at 43% of the run, excluding tagging mortalities. Angler harvest was investigated in more detail and initial studies were conducted to evaluate competition between sculpin and rainbow trout. Rainbow trout stomach analyses revealed a large use of stickleback as in 1956.

The 1958 study focused on downstream spawning locations and juvenile rearing and migration. Cottonwood Creek was divided into ¼ mile segments starting at the outlet of Wasilla Lake. The sectors are described as follows.

"Sector 1 immediately below Wasilla Lake is characteristically a wide straight channel flowing over silt. In Sector 2 and 3 a beaver dam has formed a pool. Sectors 4-7 are typically shallow, gravel-boulder areas with good pool-riffle development and a moderate quantity of aquatic vegetation bordering the channels. Sector 8 is characterized by a braided area where a thin film of water flows over gravel and around numerous small gravel and vegetative islands. Sectors 9-16 are typically pool-riffle development, highly meandered, with heavy quantities of aquatic vegetation along the stream edges, and the bottoms predominantly composed of rubble. Sectors 17-21 have steeper gradient with excellent pool-riffle development, lesser vegetation and bottoms of gravel-rock. Sectors 22 and 23 are composed of beaver dams with the major dam holding a f foot head and backing up water approximately one-third mile. Sectors 24-27 have moderate to high gradients flowing over gravel, boulders and rock. They are slightly meandered and the stream is restricted by high, close, heavily timbered banks. Some riffle development occurs in this area. Sectors 28-34 are high gradient areas with high velocity water tumbling down over boulders and rock. But for a large beaver dam in Sector 28, flow is constricted by narrow banks with a dense timber canopy, Sector 35 is open with little gradient, typically meadow, subject to tidal influence."

Most spawning rainbow trout were observed in sectors 18 to 24 (4.5 to 6 miles below Wasilla Lake), sectors 14 to 15 (3.5 to 3.75 miles), and 4 to 5 (1 to 1.25 miles). Migration began in early April. The spring migration of juveniles upstream to Wasilla Lake was composed of both returning post-spawning adults and age 0 and age 1 recruitment. The fall migration of approximately 2,200 fish was entirely recruitment. The highest numbers of juvenile fish were observed in sectors 3 and 16 (0.75 and 4 miles below Wasilla Lake). This coincides with the areas near the Old Matanuska Road and Edlund Road. There were strong correlations between trout and juvenile silver salmon and trout fry and trichoptera abundance.

ENRI Invertebrates

The Environment and Natural Resources Institute (ENRI) presents macroinvertebrate metric data in Appendix B of the 2001 report (Major et al. 2001). Invertebrates were collected at two locations and used to develop regional criteria for biotic water quality assessment. Metrics are provided for invertebrate collections in 1998 and 2000. The exact sampling locations are not listed. The sites were selected as potentially water quality impaired and ranked Good/Fair based upon the invertebrate community composition metrics used in the Alaska Stream Condition Index methodology.

ADFG Limnology Reports

The 2000 ADFG limnology report (Edmunds et al. 2000) summarizes historic nutrient data for 25 lakes within the Matanuska-Susitna Borough. The report was conducted to assist in the development of regional nutrient criteria as part of an Environmental Protection Agency national program. The physical characteristics and water mean seasonal water chemistry data are provided for Anderson, Cornelius, Neklason, Cottonwood, Mud, and Wasilla Lakes. The trophic status of each lake is determined based upon measures of Secchi depth, total phosphorus, and chlorophyll-*a* concentrations. Select water chemistry data are provided in Appendix J. Lakes within the Cottonwood Creek drainage had higher specific conductance (198 µS/cm) and alkalinity (93 mg/L $CaCO_3$) concentrations when among the lakes evaluated. Lake productivity was predicted to be limited by concentrations of phosphorus based upon molar ratios of total phosphorus to total nitrogen greater than 15. Average N:P ratio was 65. Based upon color values greater than 20 most lakes within the Cottonwood Creek drainage were considered stained except for Anderson Lake. Total phosphorus concentrations were within the range (10 to 20 µg/L) often associated with mesotrophic conditions, while chlorophyll-*a* concentrations were indicative of oligotrophy.

The 2002 ADFG limnology report (Edmunds 2002) focuses on 7 lakes within the Matanuska-Susitna Borough including two lakes within the Cottonwood Creek drainage: Cottonwood and Wasilla Lakes. Monthly water samples were collected and analyzed for physical and chemical characteristics. Measures included solar radiation, temperature, and dissolved oxygen at depths and the calculation of light extinction coefficients; particulate organic carbon, and phytoplankton species identification. Algal production among the lakes was determined to be limited by phosphorus and there was a strong correlation between total phosphorus and algal biomass as chlorophyll-a. Total nitrogen increased the correlation only slightly. Light availability was not determined limiting. Cottonwood and Wasilla Lakes were determined to be mesotrophic based on trophic indices using total phosphorus, chlorophyll-a, and Secchi depth.

Total phosphorus concentrations in Cottonwood and Wasilla Lakes were similar between the two data presented in 2000 (1983-1999) and 2002 (2001), with an average of over 12 µg/L. Similarly, total dissolved and dissolved reactive phosphorus were at concentrations of 3 to 5 µg/L. Ammonia nitrogen decreased from an average of 25 to 8 µg/L and nitrate nitrogen decreased from 25 to 11 µg/L. Algal biomass as chlorophyll-*a* increased considerably from the previously reported average of 1.2 to over 5 µg/L in 2001 (Appendix J).

ADFG Culvert Survey (2000)

The ADFG surveyed culverts within the Cottonwood Creek drainage in 2000 (Albert and Weiss, In Review). The culvert survey was conducted to evaluate the ability for salmon to migrate through the culverts. The survey was conducted with funding from the U.S. Fish and Wildlife Service. At this time the results have not been published. The USFWS currently is funding an additional study to consolidate and evaluate the field data (B. Rice personal communication). ARRI obtained the project culvert data from the USFWS.

A total of 22 stream crossings were surveyed, 14 of which were on the mainstem of Cottonwood Creek (Table 10). The two culverts at the Surrey Road crossing were not included in the database.

We used these culvert data to evaluate fish passage using the Fish X-ing software version 2.2. Channel cross-sections at the outlet control downstream of the culvert were not measured so the constant tailwater method was used. We used the outlet invert elevation for pool bottom and outlet invert elevation plus outlet water depth for pool surface elevation. The program was run at flows of 5, 12, and 20 cfs, bracketing common discharge measures. The design fish was a 55-mm long coho salmon juvenile. The program results are shown in Appendix H.

Juvenile fish movement appears to be severely restricted within Cottonwood Creek due to road culverts. At the design flow (12 cfs) passage was calculated to occur at only two locations: Fairview Loop and Private Drive. Both of these crossings were relatively wide (7 and 10 ft) and the slopes within the pipes were very low at 0.01 and 0.04 for Fairview Loop and Private Drive, respectively. Juvenile coho salmon were estimated to be able to make it 95% of the way through the Palmer-Wasilla Highway culvert at 12 cfs and approximately 50% of the way through the Seward-Meridian culvert. Passage was possible at these two sites as well as Riverdell, Marble Way, and Fern at 5 cfs.

Table 10. Summary of culverts along the mainstem of Cottonwood Creek. Discharge is the flow at which uniform flow within the culvert exceeds 1.0 ft/s as calculated by Fish X-ing.

Road	Culvert Length (ft)	Culvert Type	Culvert Diameter (ft)	Slope %	Discharge
Settlement Ave.*	60.7	Metal Pipe*	4.0	0.02	>10.21
Engstrom Rd	50	Metal Pipe	3.0	0.94	0.75
Private Dr.	48	Pipe Arch	10.0	0.04	14.15
Bogard Rd Right	126	Metal Pipe	6.5	0.65	0.92
Bogard Rd Left	126	Metal Pipe	6.0	0.26	1.07
Elks Trail Right*	20	Metal Pipe	3.0	0.39	0.46
Elks Trail Left*	23	Metal Pipe	3.0	0.57	0.23
Seward-Meridian	90	Pipe Arch	9.0	1.37	2.64
Palmer-Wasilla	82	Pipe Arch	7.5	1.46	0.82
Parks Hwy	109	Metal Pipe	5.5	0.45	0.69
Glenwood	63	Pipe Arch	9.5	1.01	2.68
Fern Left	48	Pipe Arch	8.0	1.25	0.81
Fern Middle	40.3	Pipe Arch	5.0	0.99	1.37
Fern Right	40.3	Pipe Arch	5.0	0.62	1.24
Edlund	50	Pipe Arch	9.0	1.74	1.08
Marble Way	30.5	Pipe Arch	9.5	3.05	1.51
Riverdell Rt.	50	Metal Pipe	3.0	1.54	0.33
Riverdell Lt.	51	Pipe Arch	5.0	0.02	18.12
Fairview Loop	67	Metal Pipe	7.0	0.01	24.94

* Culvert replaced or modified since survey.

Wasilla Soil and Water Conservation District Citizen Monitoring

The Wasilla Soil and Water Conservation District has overseen a citizen volunteer water quality monitoring program (Eldred 2001). Water quality data have been collected on Wasilla Creek since April of 2000 (Appendix I). Sampling sites are located at the outlet of Neklason Lake, at the Earl Drive Bridge, at the Old Matanuska Road Crossing, and at the Edlund Road Crossing. Samples were collected monthly or twice a month. Analyses included pH, conductivity, turbidity, dissolved oxygen, nitrate nitrogen, total phosphorus, fecal coliforms and *E. coli* bacteria. Data collection has been intermittent with the most complete data sets at the outlet of Neklason Lake and the Old Matanuska Road.

Discussion

For foam accumulations to appear at a given location, the water surface tension must be reduced by the presence or increase in surfactants, the water must be aerated, and there must be something at the water surface to retain the bubbles of foam. Therefore, foam may not accumulate at a certain location even when water surface tension is reduced by the introduction of surfactants. Aeration of the water occurs at any location where the water surface is disrupted. This often is where water flows over logs or other obstructions, or as a riffle or rapid. Flow through stream culverts also can cause aeration through disruption of the water surface. Within Cottonwood Creek, aeration occurred as the water flowed through constrictions and riffles at bridges and culverts. The effects of stream features that cause aeration change with stream flow. That is, as the stream water surface elevation increases logs that once caused a small fall may become totally submerged. Similarly, cobbles that approached the water surface and caused a riffle, when further submerged may not result in disruption of the water surface. The large macrophyte beds within Cottonwood Creek reduced the flow of water and increased water levels upstream.

Foam accumulations occurred in backwaters or eddies along the stream or on lake margins, against logs or other woody debris like alder branches bent to the water surface, and within macrophyte beds. Accumulation points also changed with changes in water surface elevations as flow increased or decreased logs or other debris were either overtopped or did not reach the water surface. Increasing flow also reduced or eliminated eddies or slow water areas along the stream margins. It is for these reasons that citizens living along Cottonwood Creek reported consistent foam accumulations for years (outlet of Neklason Lake), having never seen foam, even when there were large accumulations just downstream (upstream of Fern), or the new onset of intermittent seasonal accumulations (downstream of Old Matanuska Road).

The presence of foam spots or the accumulations of foam were observed throughout Cottonwood Creek. Foam accumulations increased at discrete times and were initially white and then turned brown and diminished slowly. The largest foam accumulations occurred in May following snowmelt and spring runoff. Subsequent accumulations followed rain events; however, not all rain events caused an increase in foam. Concomitant with increases in foam was a decrease in pH. Therefore, the transport of an acidic surfactant in surface runoff is either systemic or occurs in the upper reaches and is recalcitrant with the effects transported downstream.

We did not find any publications or reports describing foam buildup in streams from human-derived synthetic surfactants. However, there were anecdotal references to the buildup of foam following the initial development of surfactants associated with the non-biodegradable chemical structure (Courtemanch 2004, Fendinger et al. 1994). Current synthetic surfactants degrade rapidly in the environment (Fendinger et al. 1994). Because surfactants degrade rapidly, in order for the foam in Cottonwood Creek to be human caused there would need to be a source of surfactants throughout the drainage. Surfactants are common in most household cleaning products. Although detergents are commonly used outside to wash cars, most use undoubtedly occurs inside where the surfactants must pass through the septic system prior to entering the environment. It is unlikely that these biodegradable molecules are passing through the septic systems and groundwater in sufficient quantity to cause foam accumulations in Cottonwood Creek. If surfactants were delivered through the groundwater, then concentrations would be expected to decrease during storm events as groundwater became diluted by surface runoff, which is not consistent with foam development following storms.

The production of foam within Cottonwood Creek is best explained by changes in the concentration of plant-derived surfactants composed of dissolved organic acids from terrestrial sources. There are a number of reports and studies describing the development of foam in freshwater and marine environments (Maryland Department of Natural Resources 2004, Fuller 2003, Wegner and Hamburger 2002, Bätje and Michaelis 1986, Velimirov 1982, Velimirov 1980) due to dissolved organic plant material. Foam is often seen in streams draining peatlands and water high in organic compounds (Michigan Department of Environmental Quality 2004). Foam was observed in a number of regional brown-water streams (Chijik Creek, Caswell Creek, Trapper Creek, Little Willow Creek and Willow Creek), following spring runoff and storm events (Davis and Davis 2004). Dissolved organic carbon acts as a surfactant and is released from terrestrial and aquatic plants and algae as they decompose. The concentrations of DOC often increase following snowmelt as decomposing organic matter from the upper soil horizons is flushed into streams (Boyer et al. 2000, Brooks et al. 1999, Boyer et al. 1997). This spring flush of DOC is accompanied by a decrease in pH (Leenheer 1994, Campbell et al. 1992). Concentrations of DOC have been shown to increase during rain storms (Hinton et al. 1997; Kaplan and Newbold 1993). There is a fraction of this DOC that is highly labile and taken up quickly by soil microbes and microbes at the soil/water interface (Kaplan and Newbold 1993); however, a large portion is highly recalcitrant (Kaplan and Newbold 1993) and is the cause of stained or brown appearance of northern peatland streams.

The concentration of DOC in stream is affected by the surrounding terrestrial vegetation. Stream DOC increases with the portion of the drainage composed of wetlands (Dillon and Molot 1997). There is a particularly strong association between DOC and the portion of wetlands immediately adjacent to streams (Dosskey and Bertsch 1994, Eckhardt and Moore 1990, Gergel et al. 1999). The positive relationship between catchment wetlands and stream DOC is due to the relatively slow decomposition rate within saturated and often anoxic wetland soils. DOC concentrations are inversely related to the portion of the drainage composed of lakes where DOC is either lost as particulate carbon on the lake bottom or respired to carbon dioxide and released to the atmosphere. Cottonwood Creek has a brown appearance and has been classified as stained based upon color (Edmundson et al. 2000). Wetlands border the two upper stream channels above Neklason Lake. The concentrations of DOC in Cottonwood Creek ranged from 1.5 to 4.0 mg/L with the exception of Site 1 (upstream of Cornelius Lake) where concentrations were less than 1.0 mg/L. DOC concentrations in streams where wetlands made up 1% of the drainage ranged from 3.5 to 7.2 mg/L (Eckhardt and Moore 1990). Cottonwood Creek DOC concentrations are at the lower end of the range observed in northern wetland lakes (Quinby 2000).

The causes of large foam accumulations in freshwater and marine environments has been linked to aquatic macrophytes (Wegner and Hamburger 2002) and, more often, algal blooms (Wyatt 1998, Velimirov 1980, Bätje and Michaelis 1986). Foam accumulation below falls on the Rhine River were determined to be due to DOC leached from macrophytes particularly following disturbance by changes in flow (Wegner and Hamburger 2002). The establishment of the macrophyte beds was believed to be due to nutrient enrichment in the 1960s and the stabilization of flow by the construction of dams. Extensive macrophyte beds are common in Cottonwood Creek, particularly in the slower meandering portion of the creek from Wasilla Lake to Edlund Road. However, macrophyte beds were present in the late 1950s prior to most human development and are common in stable spring fed systems like Cottonwood Creek.

Foam development in marine and estuary waters often follows the die-off of algal blooms (Wyatt 1998). Algal blooms can occur naturally but often are associated with nutrient enrichment. Large algal growths were observed at the inlet to Wasilla Lake in 2004; however, excessive algal blooms have not been reported for any of the drainage lakes. Based upon algal biomass, lakes within the Cottonwood Creek drainage have been classified as oligotrophic or mesotrophic. The most recent measures of algal biomass show an increase from previous measures but it is unknown whether this represents a trend. Algal blooms of 10,000 cells/ml were reported in association with algal blooms in the Potomac River (Maryland Department of Natural Resources 2004), certainly in excess of densities observed within Cottonwood Creek. The presence of foam in the spring prior to peak autochthonus production, foam production upstream macrophyte beds and most lakes, and increases in foam following snowmelt and storm events points toward a terrestrial rather than aquatic sources of DOC.

Cottonwood Creek is spring fed stream with relatively minor variations in discharge. Maximum peak flows have ranged from 15 to 55 cfs. Inorganic turbidity is low (< 3.0) and does not increase during spring runoff or storm events. The relatively constant stream flows provide conditions that allow for the proliferation of macrophytes. Macrophyte beds of *Calla* and *Menyanthes* are common particularly below Wasilla Lake. Instream organic biomass appears to be dominated by macrophytes; however, large growths of filamentous algae were observed at the inlet to Wasilla Lake in 2004.

Cottonwood Creek nutrient concentrations were within the range of previous lake measurements. Stream total phosphorus concentrations were less than detection limits of 25µg/L (5 µg/L in September), comparable with the average lake values of 12 µg/L (Edmundson 2002). Similarly total dissolved lake and stream phosphorus concentrations were at or below 5 µg/L. These concentrations are near those previously found to limit algal production (6 µg/L) (Mulholand et al. 1990, Bothwell 1989). Nitrogen has been found to limit algal production and concentrations below 0.10 to 0.55 mg/L (Grimm and Fisher 1986, Lohman et al. 1991). The concentration of nitrate and nitrite nitrogen was below 0.10 mg/L at all sites except for Site 1 and; therefore, also may be in growth limiting concentrations. Edmundson (2002) predicted phosphorus limitation based upon ratios of nitrogen to phosphorus above 15; however, the organically bound nitrogen (Kjeldahl-N) included in these ratios may not be readily available to primary producers.

Stream water temperatures and chemical composition was distinct in the tributary to Cornelius Lake (upper Cottonwood Creek) compared to samples below input from Dry Creek. Nitrate nitrogen concentrations are higher and DOC and water temperatures lower upstream of Cornelius Lake compared with downstream of the tributary input at Neklason Lake. Specific conductance is near 200 µS/cm, pH is generally in the range from 7.5 to 8.0. DOC concentrations range from 1.5 to 4 mg/L. Water temperature above Cornelius Lake were generally below 10°C, while water temperatures exceeded State water quality standards from Bogard Road to Surrey Road. Water temperatures were highest below Wasilla Lake at the Old Matanuska Road Crossing where average values exceeded 25°C in 2005. Fecal coliform bacteria counts also exceeded State standards on at least one occasion in the lower reaches and upstream of Cornelius Lake.

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