HOMER SOIL AND WATER CONSERVATION DISTRICT
&
COOK INLET KEEPER

Lower Kenai Peninsula's Salmon Streams: Annual Water Quality Assessment

July 2004 - September 2005

COVER PHOTO: ANCHOR RIVER IN FALL COLORS

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&

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July 2004 – September 2005

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TABLE OF CONTENTS

LOWER KENAI PENINSULA'S SALMON STREAMS:
ANNUAL WATER QUALITY ASSESSMENT
July 2004- September 2005

INTRODUCTION

Background

Streams of the lower Kenai Peninsula support healthy sport and commercial fisheries, and provide important subsistence resources for Alaska Natives and other groups. Land use has changed dramatically over the last ten years in these watersheds as logging, road building, gravel extraction and ATV use has increased. The spruce bark beetle infestation has severely altered forested lands and, in 2002, major floods reshaped salmon stream channels and riparian habitat. Monitoring is essential to maintain stream health and to protect these watersheds that support important public resources, particularly in a changing landscape.

Through the Lower Kenai Peninsula Watershed Health Project, the Homer Soil and Water Conservation District (Homer District) and Cook Inlet Keeper (Keeper) have collected baseline water quality data on the Ninilchik River, Deep Creek, Stariski Creek, and Anchor River since 1998 using the project's EPA- and DEC-approved Quality Assurance Project Plan (QAPP). Twelve sites are monitored for discharge, temperature, dissolved oxygen, pH, conductivity, nitrate-nitrogen, ammonia-nitrogen, orthophosphate, total phosphorus, apparent color, turbidity, settleable solids, total suspended solids and bacteria. Keeper monitors four sites on the Anchor River, three on both Ninilchik River and Deep Creek, and two on Stariski Creek (Figure 1). Monitoring goals are to 1) collect baseline data and determine natural variability over time for each parameter, 2) compare data with state water quality standards and federal recommendations, 3) identify water quality patterns within and between watersheds, and 4) educate local citizens about water quality issues.

Previous Water Quality Assessments

In November 2004, the two partners published their sixth annual report that presents water quality data collected from August 1998 through June 2004 (Mauger 2004). This comprehensive report offers a preliminary water quality assessment of the four rivers and is available from Cook Inlet Keeper or online at www.inletkeeper.org. Based on those previous annual assessments, water quality of the four rivers is generally high. However, temperature exceedances are increasing and may pose a risk to migrating salmon as well as egg and fry survival. Some pH measurements fall below Alaska's lower limit to protect aquatic life. Thirty percent of total phosphorus measurements were above EPA's suggested level. Alaska's standards for turbidity and total suspended solids are difficult to use as they require an understanding of natural conditions which is generally lacking in the State. Presently, datasets for turbidity with corresponding stream discharge values are not complete enough to understand the full range of natural variability.

Protecting Kenai Peninsula's Salmon Streams

In 2004, the District redesigned the monitoring program with the assistance of the project's Technical Advisory Committee. The Technical Advisory Committee is composed of representatives from the Natural Resources Conservation Service, Alaska Department of Fish and Game, Kenai Watershed Forum, U.S. Geological Survey, Environmental Protection Agency, Alaska Division of Forestry, Alaska Department of Environmental Conservation, Environment and Natural Resources Institute (University of Alaska Anchorage), and local landowners (see Appendix IV).

Monitoring was redesigned to address the specific actions detailed on the Alaska Clean Water Action (ACWA) Priorities List, with water quality being a primary concern for temperature, turbidity and phosphorus on the Anchor River, Deep Creek and Ninilchik River. Stariski Creek was also considered a priority watershed by the Technical Advisory Committee and is included in the monitoring plan. The objectives in 2004 – 2005 were to:

1) Determine spatial and temporal extent of elevated temperatures; identify tributaries and anthropogenic causes that may be affecting stream temperature.
2) Collect turbidity data to determine if the source of instream sediment is related to human activity or natural processes.
3) Determine if elevated phosphorus levels instream are geologic or anthropogenic.

Post-Flood Habitat Recovery

In Fall 2002, the lower Kenai Peninsula experienced two, 100-year flood events. Major habitat alteration reshaped salmon stream channels and riparian habitat especially in the lower reaches of the Anchor River and Deep Creek. In order to track the biological communities in these streams and to understand flood effects on stream productivity, Keeper expanded its bioassessment program in the summers of 2003 - 2005 to include sampling on all four salmon streams using University of Alaska Anchorage, Environment and Natural Resources Institute's (ENRI) technical-level methods. These data are included in this report and compared with ENRI's bioassessment data collected prior to October 2002.

Watershed-based GIS Analysis

Cook Inlet Keeper has updated its watershed-based GIS coverages to better understand what role land-use activities are having in lower Kenai Peninsula salmon streams and their impacts on fish habitat, water quality and quantity. Each watershed has been delineated into sub-watersheds based on 12-digit Hydrologic Unit Codes (Alaska Geographic Data Committee). Sub-watersheds are 70-15 square mile drainages within a larger watershed. The watershed and sub-watershed analysis are included in this report to determine possible anthropogenic actions causing water quality impairment.

Watershed and sub-watershed characteristics have been updated with information from the Alaska Department of Fish and Game (anadromous streams, 2005), Kenai Peninsula Borough (land ownership, road and harvest data, 2005), Alaska Geographic Data Committee (sub-watershed boundaries, 2005 unpublished), and the Kenai Watershed

Forum (wetland, trail and seismic data, 2005). Based on these current coverages, new calculations have been made for drainage area, miles of anadromous fish streams, miles of paved roads, miles of non-paved roads, number of stream crossings, percentage of land ownership, cumulative area and percent of timber harvest, percentage of recently logged area, percentage of wetland and wetland type.

Figure 1. Lower Kenai Peninsula Watershed Health Project monitoring sites.

STUDY AREA

The Ninilchik River, Deep Creek, Stariski Creek, and Anchor River watersheds lie in the southern part of the Kenai Peninsula. The region is bounded on the west by Cook Inlet and on the east by the Caribou Hills. The topography is gently rolling, with wide river valleys and extensive wetlands. Elevations range from sea level to around 2800 feet.

The climate of the study area is considered to be transitional between continental and maritime (Brabets, 1999). Temperatures in Homer, just south of the study area, range from an average temperature of -5.2 °C/22.7 °F in January to 11.9 °C/53.4 °F in July. Temperatures are generally colder in the central and northern parts of the study area than in the southern portion. Average annual precipitation is 24.84 inches in Homer. Most of the rain falls during August, September, October, and November (National Weather Service, 2003). High stream flows also occur in April and May when air temperatures increase, resulting in snowmelt and ice breakup.

The four watersheds are home to many species of wildlife. A wide variety of seabirds, shorebirds, raptors, waterfowl, and songbirds live in the watersheds. Moose, black and brown bear, fox, lynx, coyote, and many small mammals are found here. Finally, the streams host chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, pink salmon *O. gorbuscha*, Dolly Varden char *Salvelinus malma*, and steelhead (anadromous) and rainbow (resident) trout *O. mykiss*.

Chinook salmon in the Anchor River (7/04)

Mergansers swimming upstream (7/04)

The towns of Anchor Point and Ninilchik, as well as smaller communities of Happy Valley and Nikolaevsk, are located in the study area. The economic base of Anchor Point and Ninilchik is commercial fishing, sport fishing, and tourism. The recreational fishery for Dolly Varden in Anchor River is one of the largest in Alaska (Larson, 1995). The City of Homer has created a reservoir for its drinking water supply on Bridge Creek, a tributary to the Anchor River.

Land use has changed dramatically over the last ten years in the study area with increased road building, logging, and gravel mining. Prior to 1990, much of the study area was relatively undeveloped with access into the backcountry provided only by trails along seismic lines. In 1990, logging began in the four watersheds, and accelerated rapidly. In the Ninilchik River watershed, for example, less than one percent of the watershed was slated for timber sales in 1990. By 1999, 37% of the watershed had been harvested.

Logging activity in Deep Creek watershed (6/04)

Gravel mining in Stariski Creek watershed (6/04)

Forest fire in Anchor River watershed (5/05)

Bank erosion on Deep Creek (6/05)

The increase in logging activity relates to concerns about fire danger due to downed or standing beetle-killed trees. Spruce beetle (*Dendroctonus rufipennis*) infestations during the 1990's have resulted in extensive areas of dead spruce trees in Alaska. On the Kenai Peninsula approximately 1.1 million acres of forested land have been infested by the bark beetle. Increased water yields may result because of reduced transpiration from dead trees (Holsten et al., 1999) or widespread logging activity.

Road building, logging, and gravel mining may affect stream water quality by changing the natural hydrograph of these systems as well as introducing sediments to the stream channel. Off-road vehicle (ORV) trail stream crossings may also be contributing to increasing rates of sedimentation. Sediment pollution, particularly turbidity, is the most prevalent form of pollution in Alaska (Lloyd et al., 1987).

In October and November 2002, the lower Kenai Peninsula experienced flood events not seen in the last 50-100 years. Channel scour, bank erosion and major habitat alteration reshaped salmon stream channels and riparian habitat. Poorly-placed and inadequately-sized culverts on private, Borough and State roads failed resulting in pulses of debris torrents, which caused extensive damage to roads, bridges and property downstream.

A recent USGS report suggests that streams within the Cook Inlet Basin, which includes the Kenai Peninsula, may experience a water temperature change of 3^{o}C in coming years. This is based on a model that uses air temperature to predict water temperature due to climate warming. Ninilchik River was one of the 15 sites predicted to see a 3^{o}C change, a magnitude of change that is considered significant for the incidence of disease in fish populations (Kyle and Brabets, 2001).

WATER QUALITY METHODS

Study Design

In 2004, the salmon stream monitoring project was redesigned to address temperature, turbidity, and phosphorus concerns. Site selection, sampling frequency and analytical methods were fine tuned to improve representation of natural conditions, determine exceedances and possible anthropogenic actions causing impairment. The revised methods are described below.

Sample Site Selection

A total of ten sites were sampled to represent water quality conditions throughout each watershed. Sites were chosen on the upper or middle portion of the watershed, and near the mouth of the river, where the cumulative impacts of human use are expected to be the strongest. Two sites were chosen on Ninilchik River, Deep Creek and Stariski Creek, and four were located in the Anchor River watershed. When determining the exact location of each monitoring station, the following criteria were used: private property access, historical data available from the site, parameters previously measured, representative-ness, and logistical access.

Additional sites were selected to measure temperature variability throughout the watersheds. A total of five temperature loggers were deployed in the Ninilchik River, six in Deep Creek, three in Stariski Creek, and six in the Anchor River. Temperature logger sites were selected at major confluences to provide information about the relative contribution each major tributary makes to overall stream temperature. Landowner permission and road access also influenced site locations.

Parameter Selection

Monitoring was designed to address the specific actions detailed on the Alaska Clean Water Action (ACWA) Priorities List, with water quality being a primary concern for temperature, turbidity and phosphorus. In an effort to continue to collect baseline data and track water quality patterns, additional parameters were monitored also: streamflow, pH, conductivity, total dissolved solids, dissolved oxygen, nitrate-nitrogen, ammonia-nitrogen, color, suspended solids, settleable solids and bacteria.

Monitoring Frequency

Temperature loggers were launched to collect data every 15 minutes from June 2004 – October 2004. Each logger was suspended in PVC pipe that allows stream water to flow through but prevents solar radiation to penetrate. The pipe was attached to a rebar stake sunk into the stream bed. At each site, a habitat assessment using the Alaska Stream Condition Index was performed to quantify habitat parameters that might be affecting temperature. Loggers were retrieved in the fall and a post-sampling habitat assessment was performed. Loggers were redeployed from May - October 2005.

Water quality samples were collected biweekly except in winter months when sampling frequency reduced to bimonthly. Discharge data was collected when the streams were ice free and wadeable.

Measurement and Analysis Techniques

Sampling and analysis methods were chosen so that data could be compared with data from other studies both in Alaska and around the United States. For most parameters, Keeper selected sampling methods from *Standard Methods for the Examination of Water and Wastewater, 19th Edition* (American Public Health Association, 1995), and/or methods that have been approved or accepted by the United States Environmental Protection Agency (EPA). Standard methods, EPA-approved tests and standard operating procedures (SOPs) were used wherever possible so that results could be compared with other studies and accepted by other scientists. A more detailed discussion of both the project design and the sampling and analysis methods can be found in the Quality Assurance Project Plan (Cook Inlet Keeper, 2000).

Data Management

All water quality data are recorded in notebooks and on field data sheets and are entered into Keeper's Microsoft Access database. Data are screened for data entry errors; data that are suspected to be inaccurate due to instrument calibration concerns or that fall outside of the normal expected range for each parameter are not included in data analysis and presentation.

Quality Assurance

Keeper has quality checks on all aspects of the salmon stream monitoring project. First, the monitoring plan was developed under the direction of a Technical Advisory Committee (TAC) of scientists from federal and state agencies as well as industry. The TAC chose sampling sites, determined the sampling frequency, and reviewed the chosen methods. Next, Keeper and the TAC chose standard field and lab methods so that data collected by Keeper could be easily compared with data from other studies. Third, Keeper incorporates quality assurance steps into the data collection process. For example, Keeper splits samples with another professional lab annually to compare results. Keeper also uses a standard solution of known concentration with each laboratory analysis to estimate precision and accuracy. The results of the sample splits are found in Appendix I. Finally, all quality assurance methods are described in detail in Keeper's Lower Kenai Peninsula Watershed Health Project Quality Assurance Project Plan (QAPP). The QAPP in turn was reviewed by the TAC and approved by both Alaska Department of Environmental Conservation and the U.S. Environmental Protection Agency.

The QAPP is available upon request from Cook Inlet Keeper.

WATER QUALITY PARAMETERS

Parameters of Concern

Water Temperature is a crucial aspect of aquatic habitat. Aquatic organisms are adapted to live within a certain temperature range. As the upper and lower limits of the range are approached, organisms become more susceptible to disease. Also, fish that spend extra energy searching for cool areas may be at a disadvantage when competing for food. Stream temperature results from inputs of solar radiation as well as air temperature (EPA, 1991).

Turbidity is an optical property of water that refers to the amount of light scattered or absorbed by the water (American Public Health Association, 1995). In this project, turbidity is measured in nephelometric turbidity units (NTUs). Increasing turbidity is described visually as increasing cloudiness. Silt, clay, organic material, and colored organic compounds can all contribute to turbidity. Although turbidity may be a sign of suspended sediment, it cannot be correlated with a weight concentration of suspended material.

Phosphorus is a nutrient that is important to aquatic life, but at high levels it is considered a contaminant. Keeper measures orthophosphate, dissolved orthophosphate, and total phosphorus. Phosphorus is affected by chemical and biological processes that change its form and transfer it to or from water, soil, biological organisms, and the atmosphere (Mueller and Helsel, 1999). High levels of nutrients can cause increased algal growth beyond what is normal and impact the quality of the water. Decaying algae mats can cause foul odors and tastes and remove dissolved oxygen from the water. In nature, phosphorus comes from underlying geology, soil, decaying plants and animals (Table 1).

Additional Parameters Measured

Streamflow (discharge) is the volume of water moving through a stream at any given point in time. Streamflow is often expressed in cubic feet per second (cfs). The discharge of a stream can vary on a daily basis in response to precipitation, snowmelt, dry periods, and withdrawals of water by people. Streamflow affects water chemistry; thus, water quality measurements should always be looked at in relation to streamflow.

Dissolved Oxygen is needed by fish and other stream organisms to live. In natural small streams, dissolved oxygen levels are usually 100% of the holding capacity of the water. As plant and animal material decays, it consumes dissolved oxygen, particularly in slow-moving areas of the stream. Turbulence, interaction with the air, and photosynthesis replenish oxygen to the water (Table 1). Colder water can hold more dissolved oxygen than warmer water. Dissolved oxygen measurements can be expressed as a concentration in milligrams per liter (mg/L), or as percent saturation: the amount of oxygen the water holds compared to what it could absorb at that temperature.

pH is a measure of the level of activity of hydrogen ions in a solution, resulting in the acidic or basic quality of the solution. The pH range is from 0 (acidic) to 14 (basic), with 7 being neutral (Figure 2). Stream organisms are adapted to certain pH ranges. Humans can impact pH through mining activities (which make water more acidic) and by increasing nutrients, which increase plant growth and pH (Table 1). Most natural rivers range from 6.5 pH units to 8 pH units.

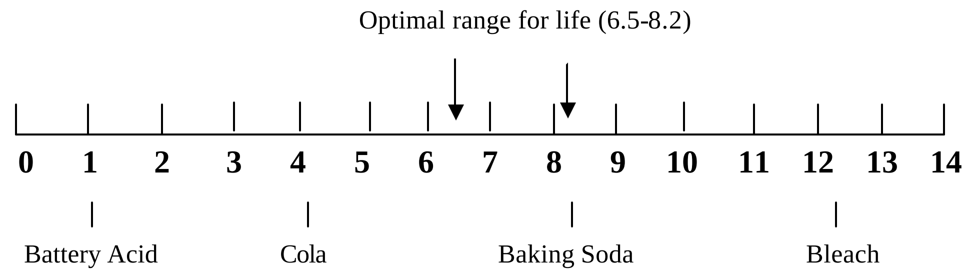


Figure 2. pH levels of some common substances.

Total Dissolved Solids is a measure, in milligrams per liter (mg/L), of the amount of dissolved materials in the stream. Ions such as potassium, sodium, and chloride all contribute to a dissolved solids measurement. Measuring total dissolved solids is a way of estimating the suitability of water for irrigation and drinking water. Groundwater has higher levels of dissolved solids from increased contact with rock and more time to dissolve rock and mineral materials. Thus, when stream flows are high from rain or snow melt, dissolved solids measurements are expected to be low. When stream flow is low, most of the source water is from groundwater and dissolved solids levels are higher (Hem, 1992).

Conductivity is the ability of a substance to conduct an electrical current, measured in microsiemens per centimeter (µS/cm). The presence of ions in a sample of water gives it its ability to conduct electricity; thus conductivity is an indicator of the amount of dissolved solids in the stream. Conductivity is often used to estimate the amounts of dissolved solids rather than measuring each dissolved constituent individually.

Nitrogen is a nutrient that is important to aquatic life, but at high levels it is considered a contaminant. Keeper measures nitrate-nitrogen and ammonia-nitrogen. High levels of nutrients can cause increased growth of algae beyond what is normal and impact the quality of the water by removing dissolved oxygen from the water. In nature, nitrogen comes from the soil and decaying plants and animals.

Settleable Solids are the volume of solids that settles out of a sample of water compared to the total volume of the sample. This is another way of measuring the amount of sediment in a water sample. The State of Alaska uses the amount of settleable solids as the parameter of importance for meeting the state water quality standard for sediment to protect swimming.

Suspended Solids or sediment can reduce visibility, making it hard for fish to find prey. It can clog the gills of fish and suffocate macroinvertebrates. Once suspended sediment is deposited, it can fill the spaces between gravel pieces in the bed of the stream. This reduces the permeability of bed material, meaning that water cannot filter through, bringing dissolved oxygen and nutrients to stream insects, fish eggs and fry.

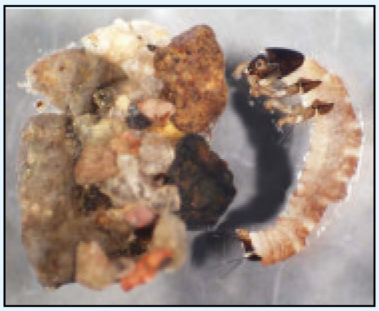
Apparent Color The color of water comes from the leaching of organic debris (dead plants) in wetlands. The color of water is not directly related to any chemical properties of the water. However, it is an important aesthetic quality of drinking water.

Table 1 Water quality parameters and common natural and human impact sources.

Parameter	**Common Natural Contributions**	**Common Human Impact Sources**
Discharge	Precipitation, snowmelt, groundwater	Withdrawals of stream or groundwater, dams, impermeable surfaces
Temperature	Solar radiation, shade, groundwater contributions	Removal of riparian vegetation, inputs from treatment plants
Dissolved Oxygen	Turbulence, interaction with air	Decaying plant and animal material, sewage, effluent
pH	Decaying wetland plants, geology	Mine tailings leaching, agricultural runoff, algae blooms
Total Dissolved Solids	Geology, discharge	Road and fertilizer runoff
Conductivity	Geology, discharge	Pollution, road and fertilizer runoff
Nitrogen: Ammonia and Nitrate	Decaying plant and animal material	Sewage, wastewater treatment plant effluent, fertilizers, logging and lawn debris, deposition from the atmosphere
Phosphorus: Orthophosphate and Total Phosphorus	Decaying plant material, soils, underlying geology	Detergents, fertilizers, sediment
Turbidity	Discharge, natural erosion	Road building and erosion, forest harvest, mining, grazing, wastewater discharges
Suspended Solids	Discharge, natural erosion	Road building and erosion, forest harvest, mining, grazing, wastewater discharges
Settleable Solids	Discharge, natural erosion	Road building and erosion, forest harvest, mining, grazing, wastewater discharges
Color	Chemical compounds from decaying plants	Chemical contaminants

BIOASSESSMENT METHODS

Macroinvertebrates (animals without backbones that are visible to the naked eye) are well suited for monitoring studies because they are abundant and diverse and relatively easy to sample and analyze. In most streams, the macroinvertebrate community is dominated by larval insects (Figure 3). In this stage of development, insects live a completely aquatic existence feeding voraciously on organic matter and other invertebrates. Each insect group has specific requirements for food, substrate, temperature, and dissolved oxygen concentrations. The presence (or absence) of particular insects is, therefore, indicative of certain water quality and habitat conditions.



(Photos by Jeff Adams/
The Xerces Society)

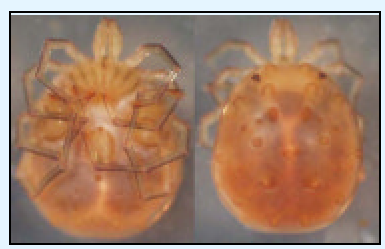
Caddisflies (Order:Trichoptera) often make cases out of rocks or plant material for protection. This saddle-case maker (Family: Glossosomatidae) scrapes algae off rocks.

Stoneflies (Order: Plecoptera) tend to be very sensitive to disturbance. This little brown stonefly (Family: Nemouridae) has gills around its neck and shreds plant material for food.

Mayflies (Order: Ephemeroptera) often have prominent abdominal gills. This flatheaded mayfly (Family: Heptageniidae) lives in swift flowing waters and is moderately sensitive to disturbance.

Chironomids (Order: Diptera, Family: Chironomidae) are diverse and very abundant in Alaska's streams. They can have many generations within a year and are notoriously difficult to identify at the genus and species level.

Black flies (Order: Diptera, Family: Simuliidae) are common in stream samples. They attach themselves to rocks or wood and use the large fans on their heads to filter material out of the water column.



Aquatic mites (Order: Acari) are ubiquitous in freshwater habitats. They are predatory or parasitic on other aquatic organisms. As adults these tiny mites have eight legs and come in a variety of colors.

Figure 3. Common Orders of aquatic macroinvertebrates found in lower Kenai Peninsula streams.

In 1989, EPA published Rapid Bioassessment Protocols or RBPs (Plafkin et al., 1989) in an effort to provide federal and state agencies practical, cost-effective methods for evaluating nonpoint source pollution using macroinvertebrate assemblages. In 2001, these protocols were refined for use in Alaska by the Environment and Natural Resources Institute (ENRI) at University of Alaska Anchorage (Major and Barbour, 2001). In 2003, Keeper expanded its bioassessment program to include sampling on all four salmon streams using ENRI's technical-level methods.

Field and Laboratory Methods

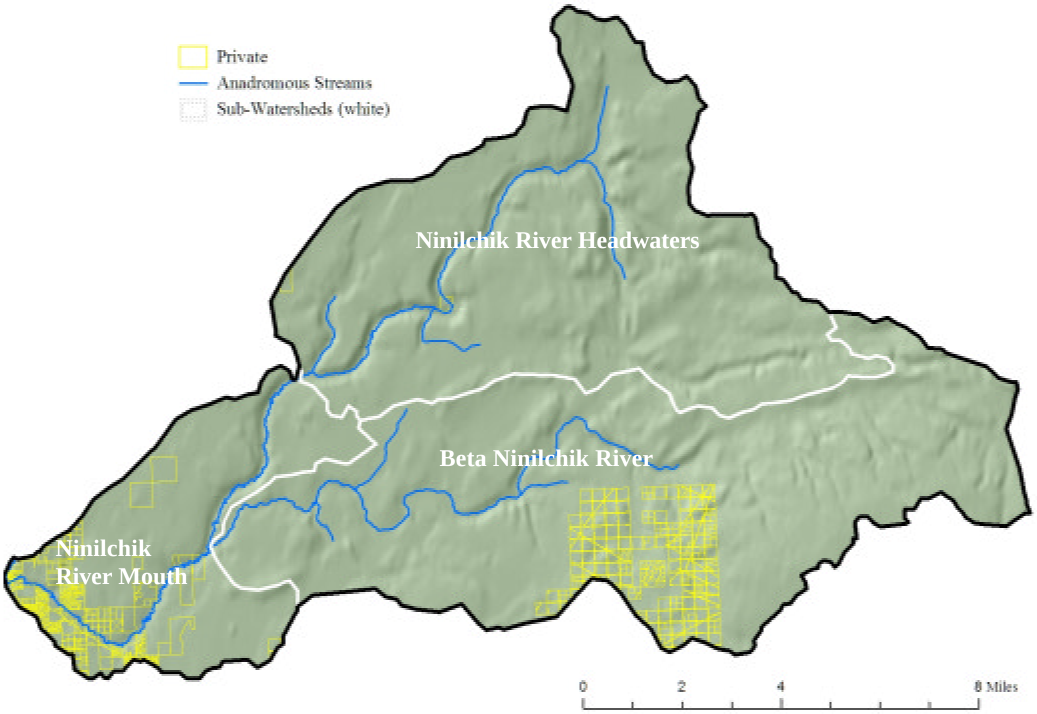
At each site, twenty multi-habitat samples were taken along a 100-meter reach with a 350- micrometer mesh D-frame kicknet. Larger substrate was rubbed carefully by hand in front of the sampler to dislodge any clinging invertebrates. The finer substrate was disturbed to a depth of 10 centimeters with hands or feet. The samples were combined from each site and preserved in ethanol for later sorting in the lab.

In the lab, a 300-count subsample was randomly sorted from an entire sample. The number of subsample grids required to reach 300 organisms (± 20%) was recorded to calculate total sample abundance. The invertebrates were identified to a standard taxonomic effort which is typically to the genus level with some notable exceptions (e.g., Chironomidae, Simuliidae, Lumbriculidae, Hydracarina, Planariidae). A five-minute pick was conducted to find large and rare taxa. These are included in the total taxa count but not added to the 300 count abundance.

Analysis Methods

The data analysis involves examining metrics (attributes of macroinvertebrate assemblages) that have proven to be responsive to ecological change (Fore et al., 1996). These metrics: total taxa richness, EPT taxa richness (Ephemeroptera, Plecoptera, Trichoptera), percent EPT abundance, percent of Chironomidae abundance, each measure a different component of community structure and have a different range of sensitivity to stress. The Fine Sediment Biotic Index (FSBI; Relyea et al., 2000) was calculated from sediment tolerance values assigned to insect taxa (1 = sediment tolerant, 8 = sediment intolerant) and summed for all taxa present. The higher the FSBI the more intolerant the community is to sediment. By comparing these community metrics of pre- and post-flood samples, along with community composition and abundance, we can assess the change and subsequent recovery that has occurred within each watershed.

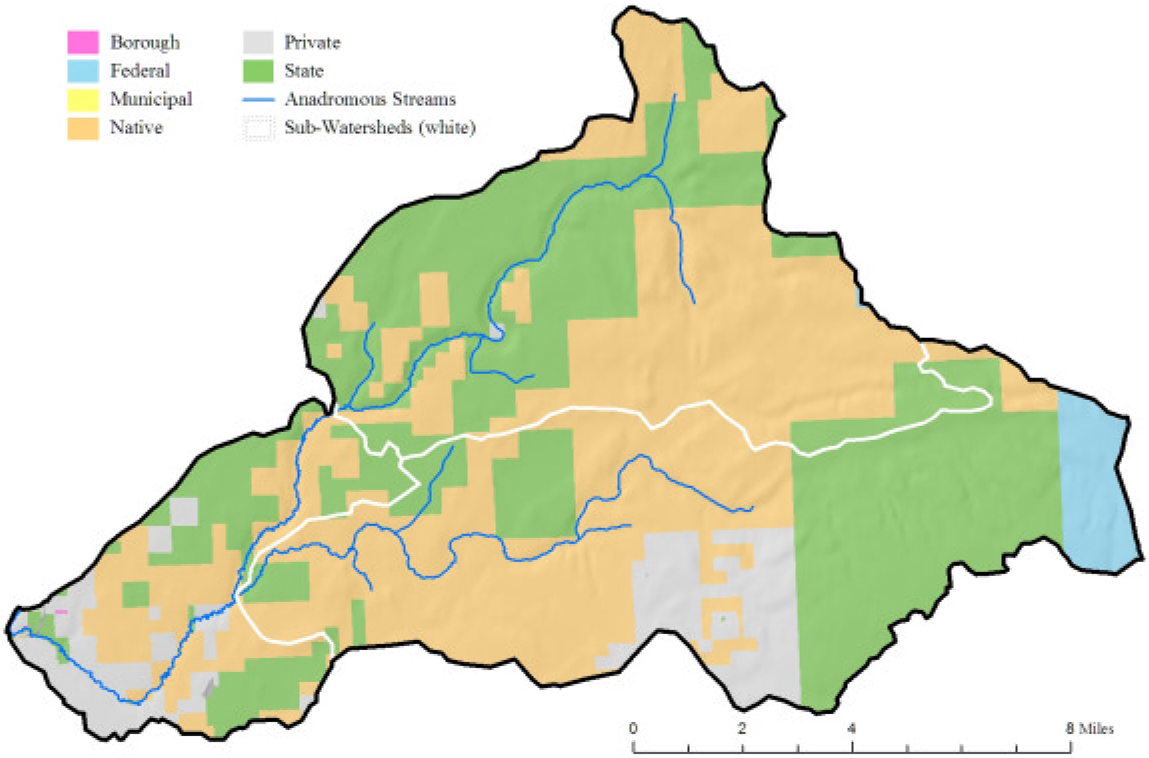
NINILCHIK RIVER WATERSHED



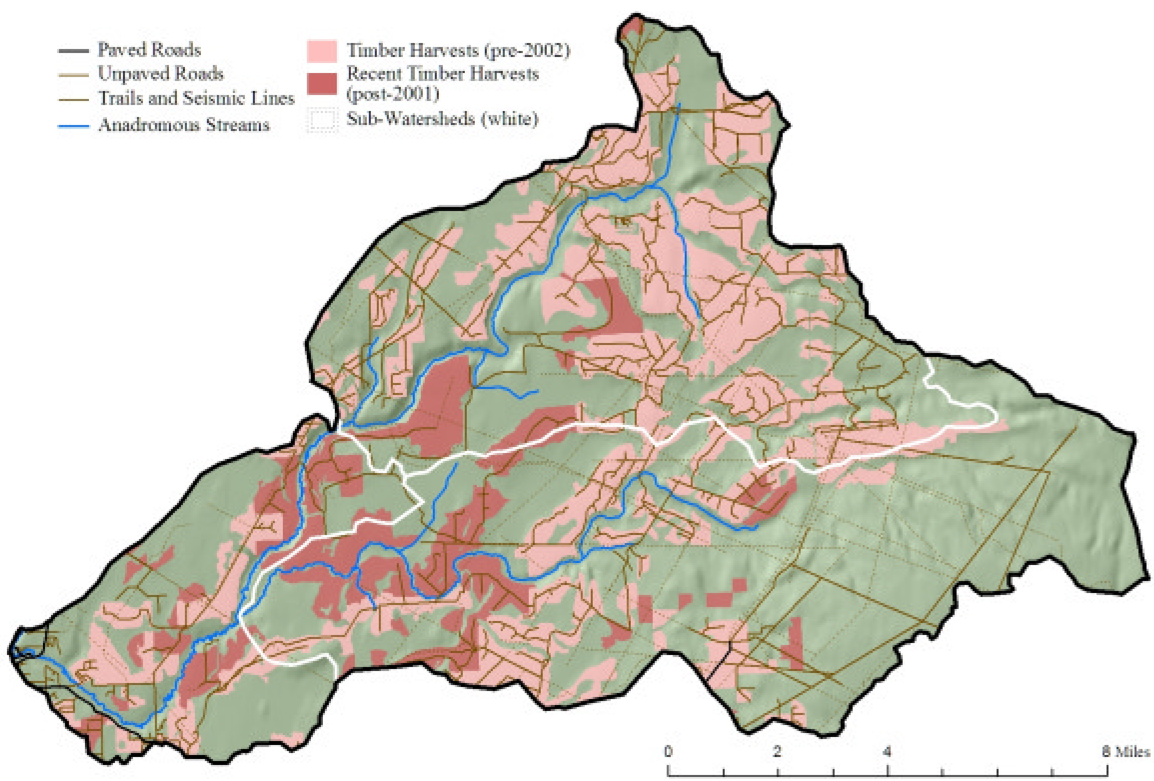
Map 1. Ninilchik River watershed and sub-watershed boundaries.

Table 2. Ninilchik River watershed and sub-watershed characteristics.

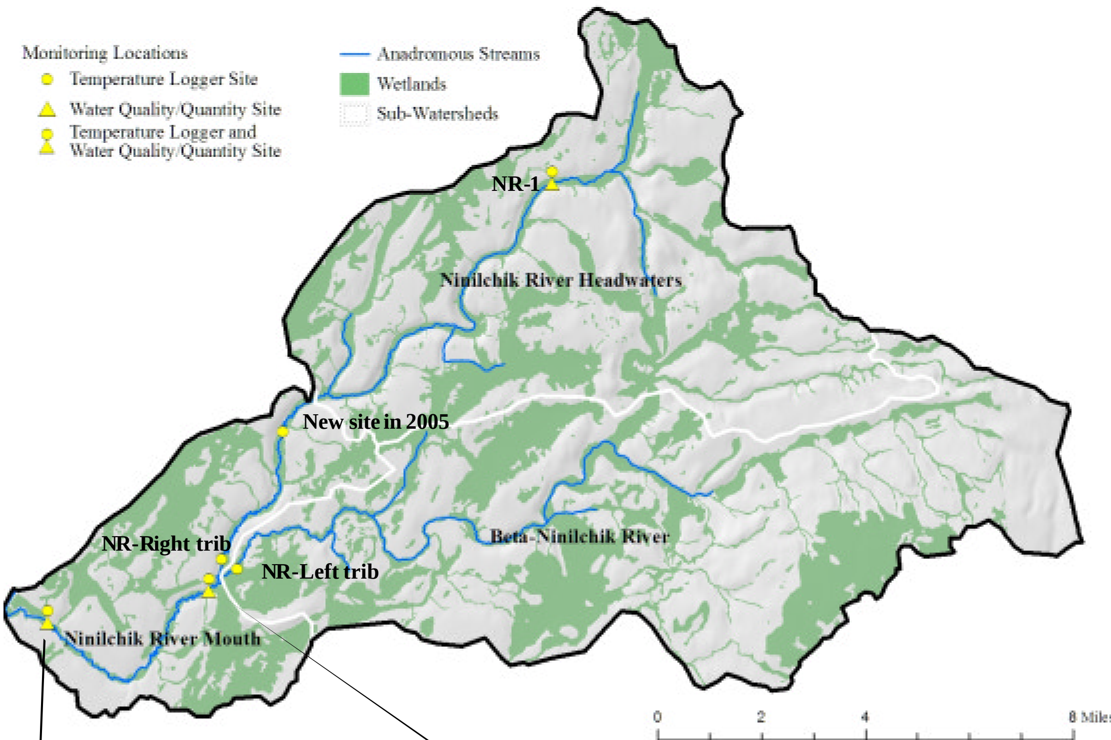
	Ninilchik River Watershed	Ninilchik River Headwaters	Beta Ninilchik River	Ninilchik River Mouth	Notes
Drainage Area (sq. miles)	**137.5**	53.1	62.0	22.5	
Anadromous Streams (miles)	**52.2**	17.6	18.5	16.1	
Total Roads (miles)	**325.9**	167.6	102.6	55.7	See Map 3
paved	**5.7**	0.0	0.9	4.8	
unpaved	**320.2**	167.6	101.7	50.9	
Total Crossings (#)	**18**	6	5	7	Anadromous stream crossings only
paved roads	**2**	0	0	2	
unpaved roads	**16**	6	5	5	
Land Ownership (%)					See Map 2
Borough	**0.0**			0.1	
Federal	**2.9**	0.1	6.3		
Native	**46.7**	50.3	45.5	41.5	
Private	**8.1**	0.3	9.9	21.8	
State	**42.3**	49.3	38.3	36.6	
Total Wetlands (%)	**37.4**	32.6	39.0	44.7	Only 97.2% of watershed mapped See Map 4
Total Timber Harvest (% of area)	**37.0**	45.9	29.3	37.1	See Map 3
Recent Timber Harvest (%, 2001 – 2005)	**10.4**	6.2	11.5	17.0	See Map 3



Map 2. Land ownership in the Ninilchik River watershed.



Map 3. Roads and timber harvest activity in the Ninilchik River watershed.



Map 4. Wetlands and monitoring locations in the Ninilchik River watershed.

Long-term monitoring site: NR-3

Long-term monitoring site: NR-2

Priority Issues

1. Water Temperature

Starting in May 2004, five temperature loggers were deployed in the Ninilchik River to determine how far upstream temperatures are exceeding water quality standards (see Map 4 for locations). The lower site (NR-3) is a fish migration route and thus temperatures above 15°C, Alaska's standard for migration routes, are of concern to salmon health and timing of runs. Four loggers have been placed upstream in spawning areas to record the extent of temperatures above 13°C, Alaska's standard for egg and fry incubation.

Data collected at 15-minute intervals show the frequency of elevated temperatures at each site in 2004 (Figure 4). The NR-Left trib site (yellow) has temperatures consistently higher than at the NR-Right trib site (blue) and the NR-2 site (pink) downstream. Comparison of timber harvest data and roads suggest that the Beta Ninilchik River sub-watershed has had less harvest activity and fewer road miles than the Ninilchik River Headwaters sub-watershed. However, the Beta sub-watershed has had more recent timber harvest than the Headwaters sub-watershed.

Another possible explanation for the higher temperatures recorded at the NR-Left trib site might be related to wetland types in the two sub-watersheds (See Appendix III). Drainageway wetlands, which are mostly groundwater discharge, make up 9.2% of the Headwaters sub-watershed and only 4.9 % of the Beta sub-watershed. This groundwater discharge may help buffer instream temperatures and keep water cooler in the Ninilchik River Headwaters sub-watershed.

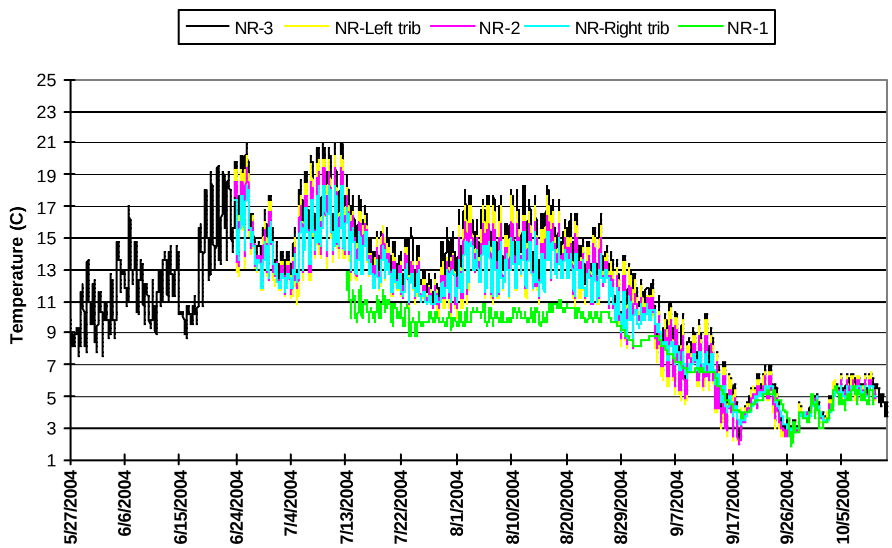


Figure 4. Temperature profiles of five Ninilchik River sites in 2004.

A comparison of data collected at the lower Ninilchik River site (NR-3) in the summers (6/21- 9/11) of 2002 - 2005 show that both the frequency and magnitude of temperature exceedances are generally increasing (Table 3), with the highest values seen in 2004. Six days in 2004 and 4 days in 2005 had temperatures above 20^{o}C which by State Standards "may not be exceeded."

The time period compared in Table 3 suggests temperature exceedances decreased in 2005; however, in 2004 and 2005, loggers were deployed prior to June 21st to document when temperatures first start to rise and to provide more information during May when chinook salmon begin their migration upstream. In 2004, the first high temperatures at the lower site were recorded on May 30th with an additional 13 days with temperatures above 13^{o}C and 4 additional days above 15^{o}C from May 30th – June 20th. In 2005, the first high temperatures were seen on May 23rd with an additional 18 days with temperatures above 13^{o}C and 9 additional days above 15^{o}C from May 23rd – June 20th.

Table 3. Summary of temperature exceedances from the lower Ninilchik River site from 6/21-9/11 in 2002 - 2005.

Water Temp.	Year	# of days	Average # hours/day	# of full days	# of consecutive full days	Maximum temperature
Above 13°C	2002	56	13.6	3	2	
	2003	64	15.9	18	5	
	2004	69	19.1	29	12	
	2005	70	16.8	21	9	
Above 15°C	2002	35	9.7	0	0	19.2
	2003	47	11.8	2	2	
	2004	53	12.6	4	2	
	2005	51	12.0	1	0	
Above 20°C	2002	0	0	0	0	
	2003	2	3.6	0	0	20.7
	2004	6	5.3	0	0	21.0
	2005	4	3.2	0	0	20.4

2. Turbidity

Turbidity data has been collected on the Ninilchik River since 1999; however, there are large gaps in our understanding of natural conditions along the hydrologic gradient. Little information has been collected at flows exceeding 300 cfs when the highest turbidity levels are expected but the river is no longer wadeable. The Homer District has relied on a stream gauge, established and maintained by the U.S. Geological Survey, to understand the relationship between high flow conditions and turbidity. Unfortunately, the gauge is no longer operating due to a lack of funds. One benefit of having continuous discharge information is that turbidity values associated with baseflow and the rising and falling limb of the hydrograph can be identified (Figure 5).

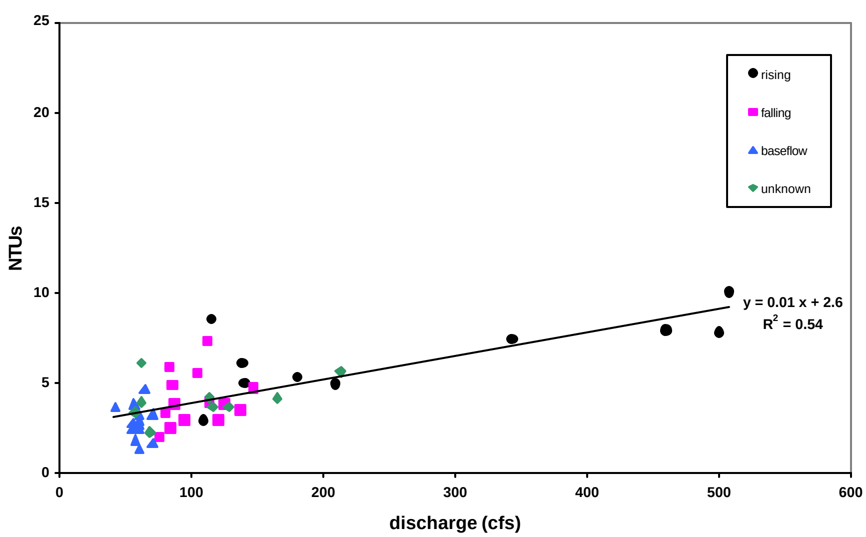


Figure 5. Turbidity data from June 1999 – June 2005 from the lower Ninilchik River with flow data from the USGS gauge (6/99 – 8/03). Unknown points are based on flow data when the relationship to the hydrograph (falling, rising) is not known (9/03 – 6/05).

In 2004 – 2005, the turbidity sampling effort was increased on the middle and lower sites to generate more information during ice free periods. High flows continue to be an obstacle for collecting discharge data in April, May, October and November.

3. Phosphorus

Over the last six years of sampling, total phosphorus measurements on the Ninilchik River have been above EPA's suggested level 47% of the time. Total phosphorus was above this level (0.10 mg/L) 35% of the time from 7/04 – 6/05. These elevated phosphorus levels may be due, in part, to the volcanic origin and sedimentary geology of the region. However, since phosphorus binds easily to sediments, it is possible that land uses that increase sediment inputs may play a role in increased phosphorus levels in salmon streams.

In 2004, water samples were filtered to provide a measure of dissolved orthophosphate, which is the most biologically-available form of phosphorus. By comparing dissolved orthophosphate (filtered), orthophosphate (unfiltered), total phosphorus (unfiltered) data with turbidity values, a relationship between phosphorus and turbidity emerges (Figure 6). During baseflow in the winter, when dissolved orthophosphate values reflect phosphorus contributions from groundwater, there is a consistent level of 0.03 mg/L. From May – October during the growing season, dissolved orthophosphate increases with some response to turbidity. The unfiltered orthophosphate and total phosphorus samples track turbidity levels closely.

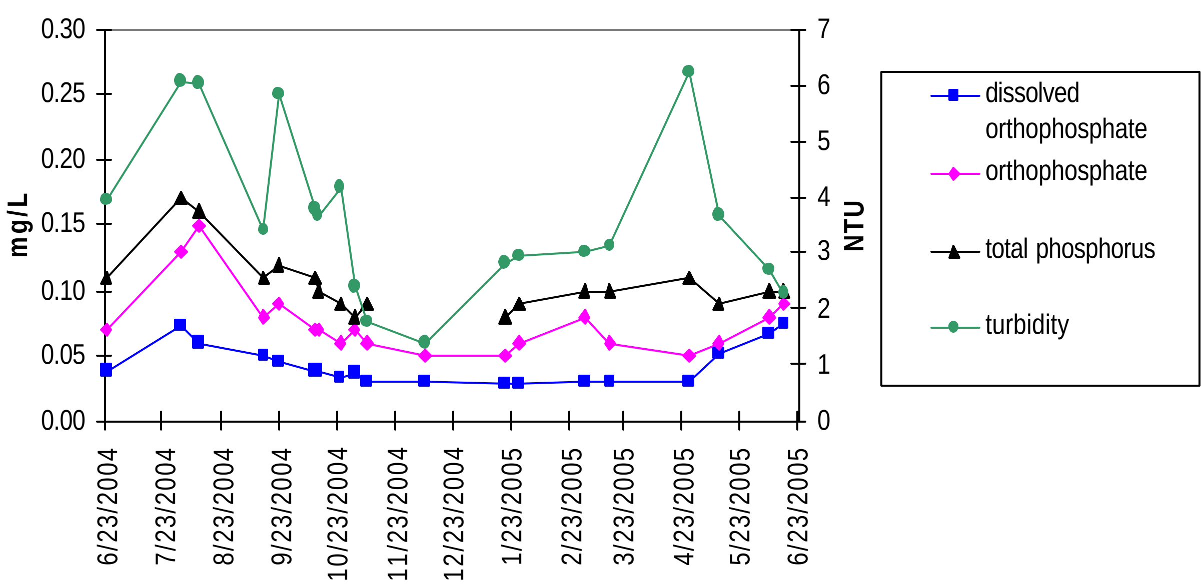


Figure 6. Phosphorus and turbidity values for the lower and middle Ninilchik River sites from 6/23/2004 – 6/16/2005.

Additional Water Quality Parameters

Additional water quality data collected during July 2004 - June 2005 can be found in Appendix II. No exceedances of Alaska's standards for dissolved oxygen, pH, total dissolved solids, or nitrate-nitrogen were observed.

Post-Flood Habitat Recovery

Macroinvertebrates were collected on 6/11/03 and 6/16/05 at the lower Ninilchik River site (NR-3). Results are compared with ENRI's samples collected at the same site on 6/6/97 and 6/2/99 (Table 4). Pie charts (Figure 7) show the community composition of different invertebrate groups. Caddisflies and non-insects make a greater contribution in 2005 than in 1997.

Table 4. Taxonomic names and abundances for organisms identified in the 300-count subsample. An asterisk (*) denotes a taxa that was found during the search for large and rare taxa.

Order	Family	Genus/Final ID	6/6/97	6/2/99	6/11/03	6/16/05
		Oligochaeta	1	1	2	7
Acari		Hydracarina	5	19	12	37
Coleoptera					3	
Diptera	Ceratopogonidae	Ceratopogon			1	
Diptera	Ceratopogonidae	Probezzia		*	2	2
Diptera	Chironomidae	Chironomidae	86	50	223	123
Diptera	Empididae	Chelifera		1		
Diptera	Simuliidae	Simuliidae	139	95	13	33
Diptera	Tipulidae	Dicranota		*		
Ephemeroptera	Baetidae	Baetidae	19	58	2	4
Ephemeroptera	Ephemerellidae	Ephemerella		1	1	
Ephemeroptera	Heptageniidae	Cinygmula	2	8		
Ephemeroptera	Heptageniidae	Rhithrogena				19
Plecoptera	Chloroperlidae	Chloroperlidae			1	2
Plecoptera	Chloroperlidae	Neaviperla		1		
Plecoptera	Chloroperlidae	Suwallia	2		1	2
Plecoptera	Nemouridae	Zapada		1		
Plecoptera	Perlodidae	Isoperla		4		
Plecoptera	Pteronarcyidae	Pteronarcella	1	1		
Trichoptera	Brachycentridae	Brachycentrus	2			
Trichoptera	Hydroptilidae	Ochrotrichia			3	48
Trichoptera	Hydroptilidae	Stactobiella	1			
Trichoptera	Lepidostomatidae	Lepidostoma	1			
Trichoptera	Limnephilidae	Ecclisomyia			3	*
Trichoptera	Limnephilidae	Limnephilus		2		
Trichoptera	Rhyacophilidae	Rhyacophila	3		1	
Veneroida	Sphaeriidae	Sphaeriidae		2		

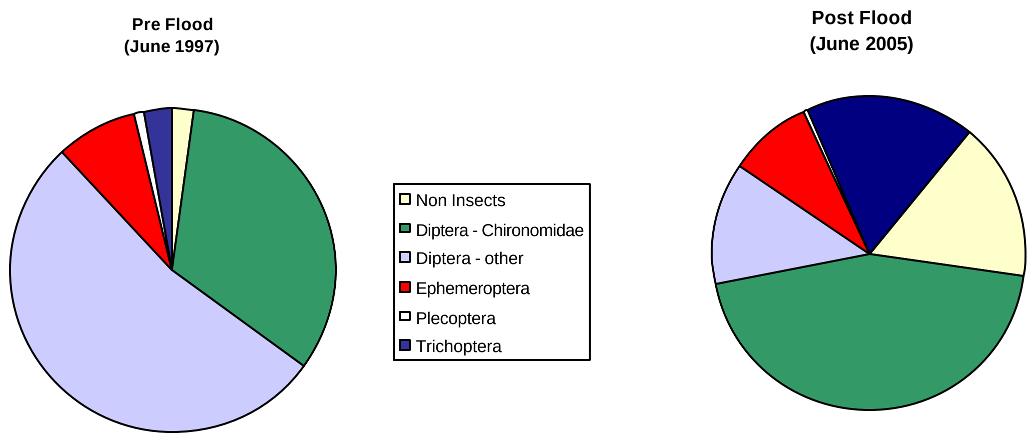


Figure 7. Pie charts based on macroinvertebrate community composition from June 1997 and June 2005.

The overall taxa number for samples collected on the Ninilchik River is relatively low and likely reflects the sandy, unstable habitat available for macroinvertebrate settlement(Table 5). Water levels were higher during the sampling event in June 2003 than in June 2005 making more stream bank and emergent vegetation habitat available. The twenty kicknet samples in June 2003 included a greater diversity of habitat types which likely accounts for the higher diversity seen in 2003 than in 2005. Midge abundance increased after the flood to 83.2% of the sample but decreases again by 2005. The FSBI does show a decreasing trend towards more sediment tolerant taxa. Total sample abundance fluctuates with the lowest numbers in June 2003 (Figure 8). By June 2005, abundance was higher but still not at pre-flood levels.

Table 5. Metric values for samples collected at the lower Ninilchik River.

Metrics	**6/6/97**	**6/2/99**	**6/11/03**	**6/16/05**
Total taxa number	12	16	14	11
% EPT taxa	67	50	50	55
% EPT abundance	11.8	31.1	4.5	27.1
% Chironomidae (midge) abundance	32.8	20.5	83.2	44.4
Fine Sediment Biotic Index (FSBI)	29	27	24	21

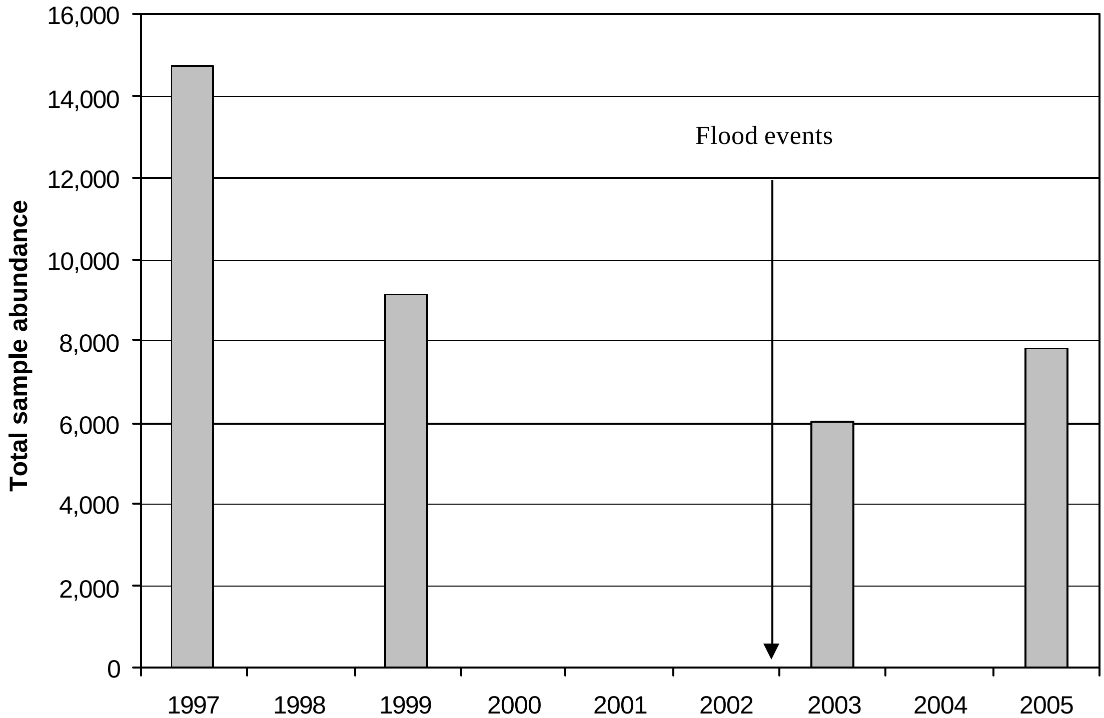
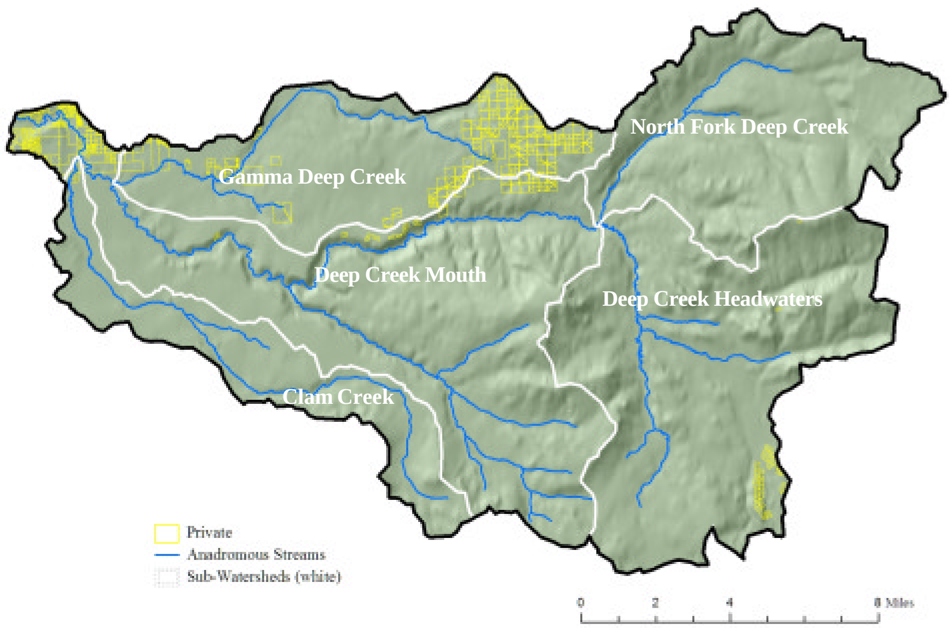


Figure 8. Total sample abundance for samples collected on the lower Ninilchik River.

Jeff Adams/The Xerces Society

Microcaddis (Order: Trichoptera, Family: Hydroptilidae) are tolerant caddisflies that were found in post-flood samples on the lower Ninilchik River.

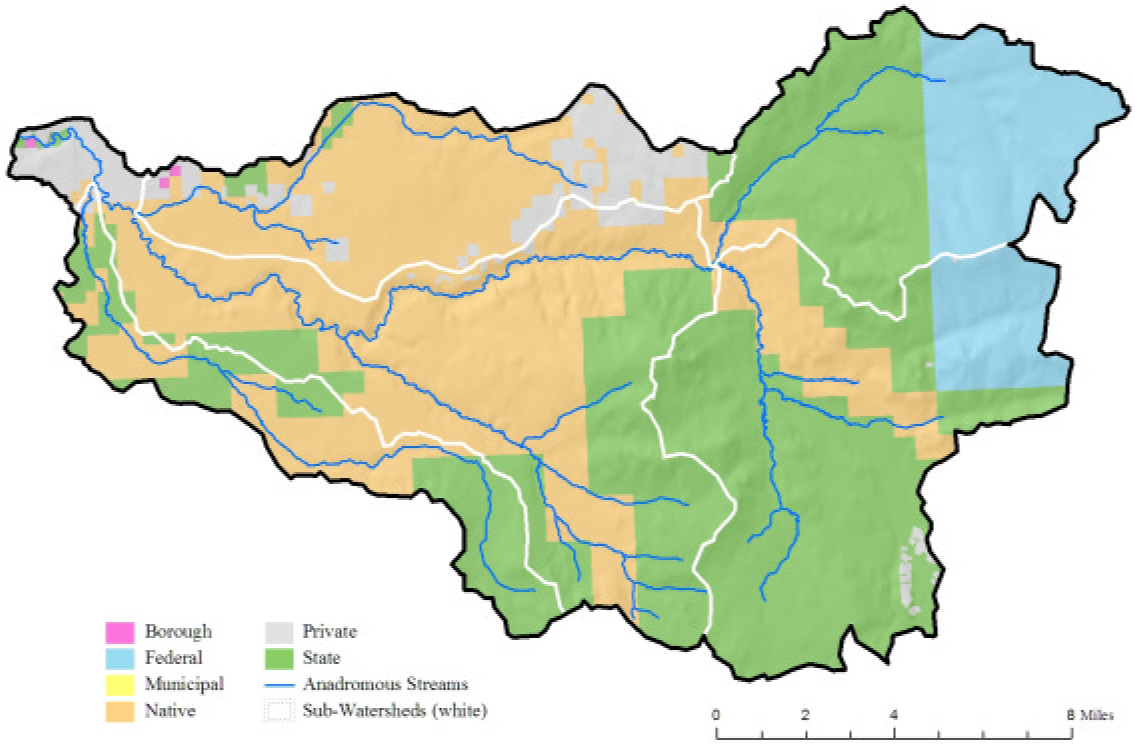
DEEP CREEK WATERSHED



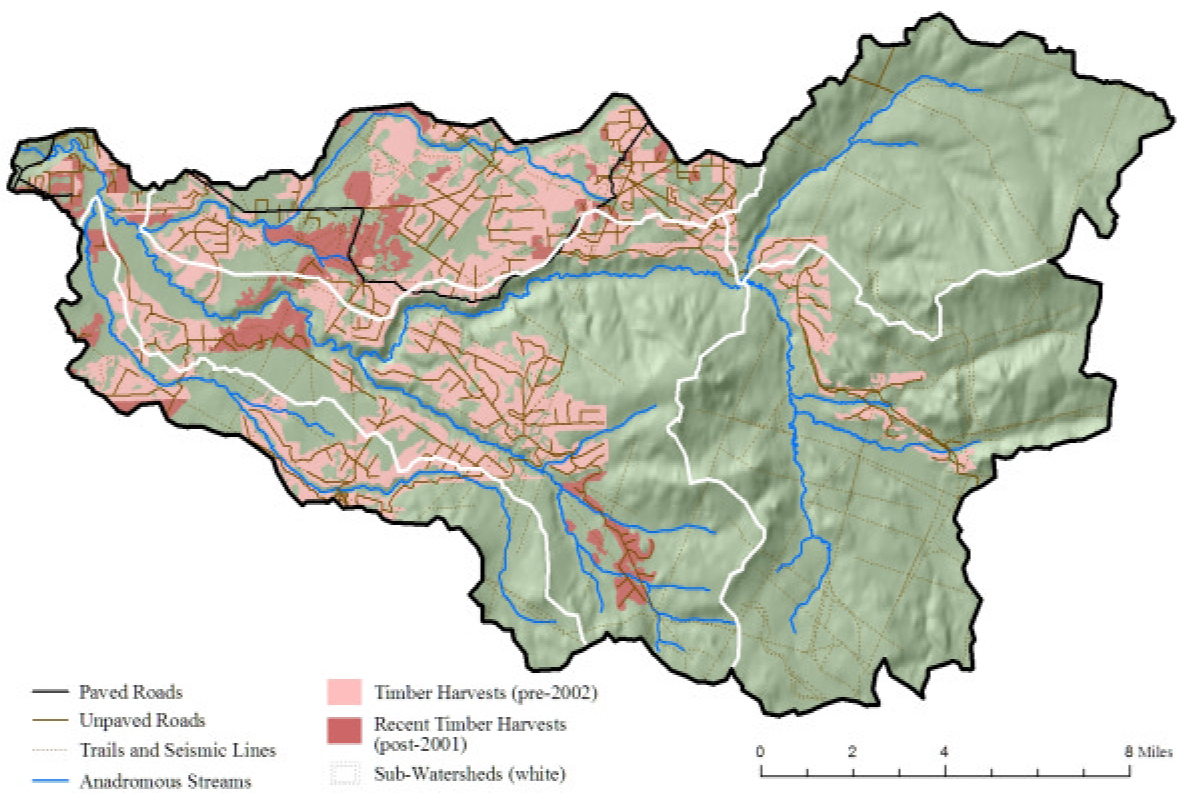
Map 5. Deep Creek watershed and sub-watershed boundaries.

Table 6. Deep Creek watershed and sub-watershed characteristics.

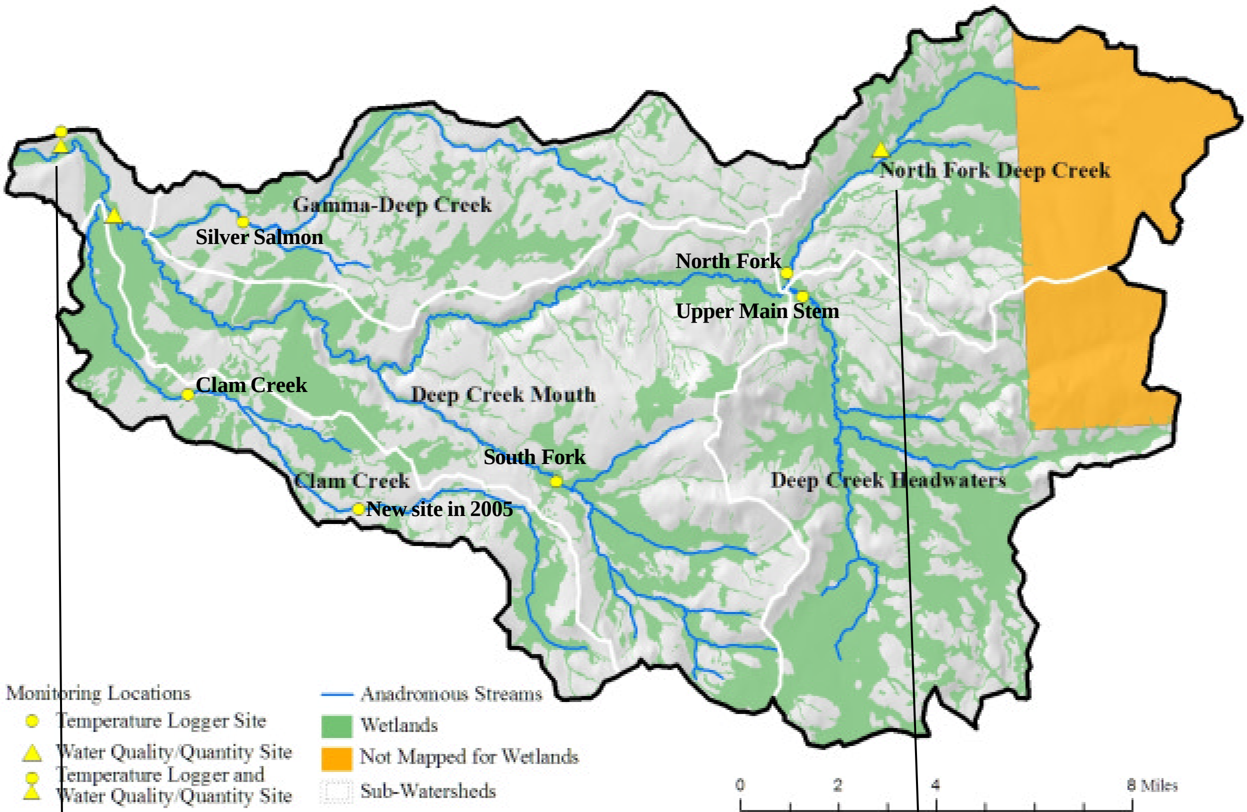
	Deep Creek Watershed	Deep Creek Headwaters	North Fork Deep Creek	Gamma Deep Creek	Clam Creek	Deep Creek Mouth	Notes
Drainage Area (sq. miles)	**218.3**	57.9	38.0	33.5	21.4	67.4	
Anadromous Streams (miles)	**119.7**	20.8	10.2	16.6	21.9	50.2	
Total Roads (miles)	**254.8**	24.1	4.6	92.2	23.0	110.9	See Map 7
paved	**17.7**	0.0	0.0	10.4	0.0	7.3	
unpaved	**237.1**	24.1	4.6	81.8	23.0	103.6	
Total Crossings (#)	**23**	4	1	8	3	7	Anadromous stream crossings only
paved roads	**3**	0	0	2	0	1	
unpaved roads	**20**	4	1	6	3	6	
Land Ownership (%)							See Map 6
Borough	**0.1**	0.0	0.0	0.4	0.0	0.1	
Federal	**11.2**	14.3	41.9	0.0	0.0	0.0	
Native	**38.5**	15.0	3.5	74.3	41.9	60.6	
Private	**5.3**	0.9	0.1	20.8	.5	6.2	
State	**44.9**	69.8	54.5	4.5	57.6	33.1	
Total Wetlands (%)	**43.7**	52.2	49.1	32.1	50.4	39.4	Only 88.9 % of watershed mapped See Map 8
Total Timber Harvest (% of area)	**22.1**	4.7	2.0	56.9	28.7	28.9	See Map 7
Recent Timber Harvest (%, 2001 – 2005)	**4.2**	0.0	0.0	12.2	3.8	6.3	See Map 7



Map 6. Land ownership in the Deep Creek watershed.



Map 7. Roads and timber harvest activity in the Deep Creek watershed.



Map 8. Wetlands and monitoring locations in the Deep Creek watershed.

Long-term monitoring site: DC-3

Long-term monitoring site: DC-1

Priority Issues

1. Temperature

In 2004, six temperature loggers were deployed in Deep Creek to determine how far upstream temperatures are exceeding water quality standards (see Map 8 for locations). The lower site (DC-3) is a fish migration route and thus temperatures above 15°C, Alaska's standard for migration routes, are of concern to salmon health and timing of runs. Five loggers have been placed upstream in spawning areas to record the extent of temperatures exceeding 13°C, Alaska's standard for egg and fry incubation.

Data collected at 15-minute intervals show the frequency of elevated temperatures at sites in the lower portion of the watershed in 2004 (Figure 9). Sites in the upper portion of the watershed show some differences which may be related to drainage size (Figure 10). The Upper Main Stem site drains a 58-square mile area while the North and South Fork sites drain less than 40 square miles.

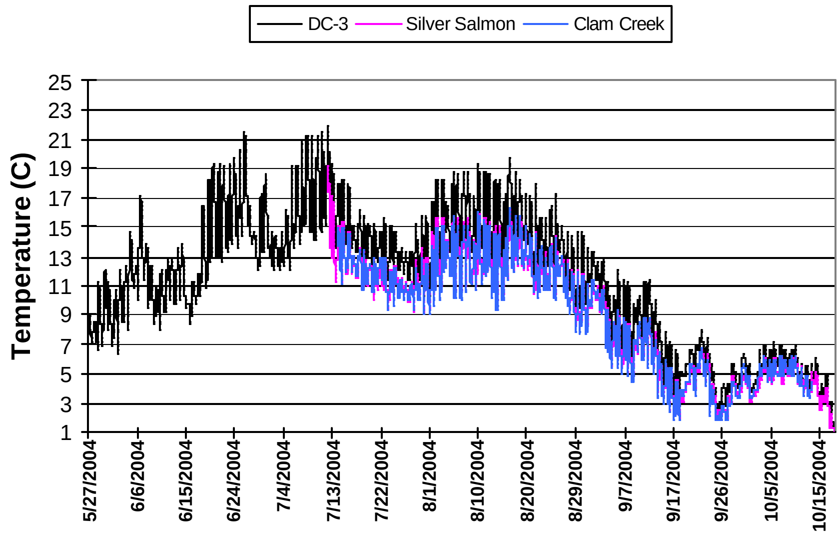


Figure 9. Temperature profiles of sites in the lower portion of Deep Creek watershed.

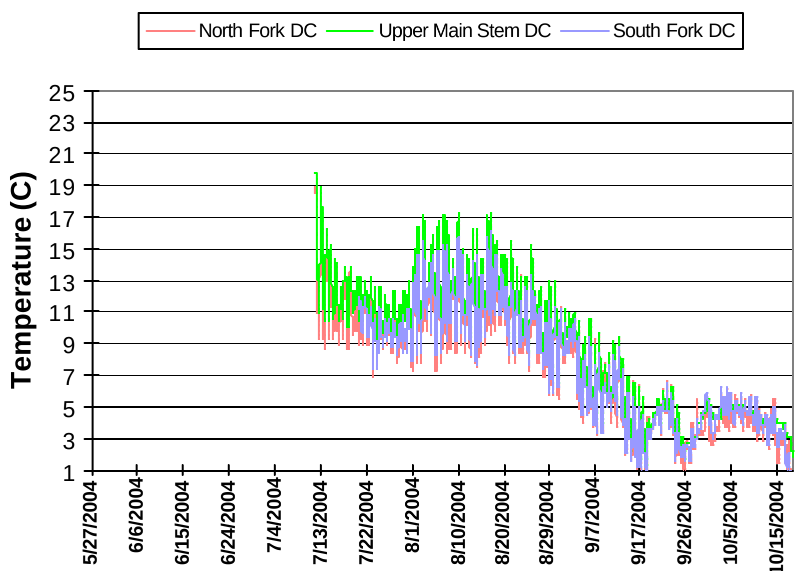


Figure 10. Temperature profiles of sites in the upper portion of Deep Creek watershed.

A comparison of data collected at the lower Deep Creek site (DC-3) in the summers (6/21-9/11) of 2002 - 2005 show that both the frequency and the magnitude of the temperature exceedances are generally increasing (Table 7), with the highest values seen in 2004. Eight days in 2004 and one day in 2005 had temperatures above 20°C which by State Standards "may not be exceeded."

The time period compared in Table 7 suggests that temperature exceedances decreased in 2005; however, in 2004 and 2005, loggers were deployed prior to June 21st to document when temperatures first start to rise and to provide more information during May when chinook salmon begin their migration upstream. In 2004, the first high temperatures were recorded on June 4th with an additional 8 days with temperatures above 13°C and 4 additional days above 15°C from June 4th – June 20th. In 2005, the first high temperatures were seen on May 25th with an additional 14 days with temperatures above 13°C and 7 additional days above 15°C from May 25th – June 20th.

Table 7: Summary of elevated water temperatures from the lower Deep Creek site from 6/21 – 9/11 in 2002 – 2005.

Water Temp.	**Year**	**# of days**	**Average # hours/day**	**# of full days**	**# of consecutive full days**	**Maximum temperature**
Above 13°C	2002	50	11.4	0	0	
	2003	56	17.0	17	5	
	2004	73	18.6	31	13	
	2005	69	16.9	19	5	
Above 15°C	2002	28	7.7	0	0	18.5
	2003	42	12.1	0	0	
	2004	56	12.7	0	0	
	2005	51	11.0	1	0	
Above 20°C	2002	0	0	0	0	
	2003	5	4.3	0	0	21.2
	2004	8	5.5	0	0	21.9
	2005	1	4.8	0	0	20.7

2. Turbidity

Turbidity in 2004 – 2005 fell within the range of variability seen since 1999 on the lower and upper Deep Creek sites (Figure 11). Discharge values in 2004 are some of the lowest recorded at both sites. No continuous discharge data exists for Deep Creek so it is not possible to associate the rising, falling and baseflow conditions of the hydrograph with turbidity data.

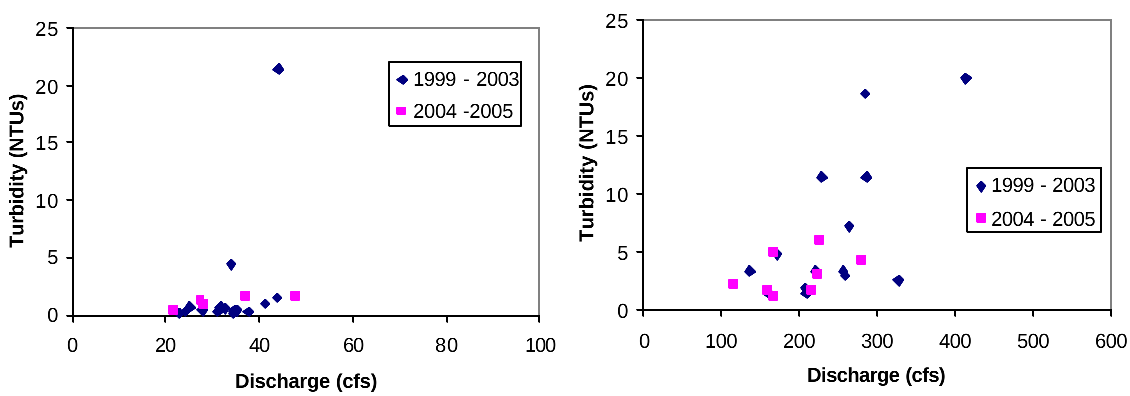


Figure 11. Turbidity data (June 1999 – June 2005) from the upper Deep Creek site (DC-1, left chart) and lower Deep Creek site (DC-3, right chart).

3. Phosphorus

Over the last six years of sampling, total phosphorus measurements on Deep Creek have been above EPA's suggested level 16% of the time. Total phosphorus was above this level (0.10 mg/L) only once from 7/04 – 6/05. A relationship between phosphorus and turbidity can be seen by comparing dissolved orthophosphate (filtered), orthophosphate (unfiltered), total phosphorus (unfiltered) data with turbidity values (Figure 12). During baseflow in the winter, when dissolved orthophosphate values reflect phosphorus contributions from groundwater, there is a consistent level of 0.02 mg/L. From May – October during the growing season, dissolved orthophosphate increases only slightly. Total phosphorus samples track turbidity levels closely.

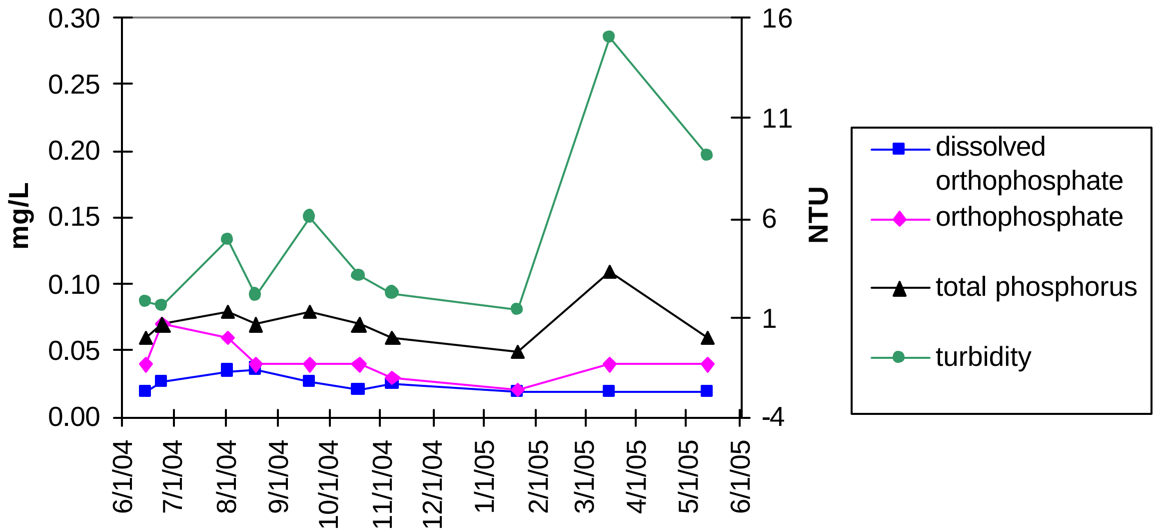


Figure 12. Phosphorus and turbidity values for the lower Deep Creek site from 6/04 – 6/05.

Additional Water Quality Parameters

Additional water quality data collected during July 2004 – June 2005 can be found in Appendix II. No exceedances of Alaska's standards for dissolved oxygen, pH, total dissolved solids, or nitrate-nitrogen were observed.

Post-Flood Habitat Recovery

Macroinvertebrates were collected on 6/16/03, 8/20/03, 6/24/04, 8/18/04, 6/23/05, and 8/12/05 at the lower Deep Creek site (DC-3). Results are compared with ENRI's sample collected at the same site on 6/6/97 (Table 8). Pie charts (Figure 13) show only a slight shift in the number of stoneflies and non-insect taxa. Chironomids (midges) were abundant in June 2003 but, by 2005, these numbers had dropped to below pre-flood levels (Table 9). The total taxa number decreased initially after the floods and stayed low until August 2005 when it returned to pre-flood levels. Similarly, the Fine Sediment Biotic Index decreased after the flood and only returned to the pre-flood value in August

2005. The most notable change is that the total sample abundance has not returned to pre-flood levels (Figure 14). Following the expected low numbers in June 2003, the abundance data shows a quick upturn in August 2003 but the subsequent two years of data suggest a clear downward trend in both June and August samples.

Table 8. Taxonomic names and abundances for organisms identified in the 300-count subsample. An asterisk (*) denotes a taxa that was found during the search for large and rare taxa.

Order	Family	Genus/Final ID	6/6/97	6/16/03	8/20/03	6/24/04	8/18/04	6/23/05	8/12/05
		Oligochaeta		2	44		1	1	10
Acari		Hydracarina	4	2	10	3	19	12	40
Diptera	Chironomidae	Chironomidae	139	218	248	114	199	147	101
Diptera	Empididae	Chelifera						1	
Diptera	Empididae	Empididae	*						
Diptera	Muscidiae	Limnophora					*		1
Diptera	Psychodidae	Pericoma			1				1
Diptera	Simuliidae	Simuliidae	52	19	5	125	5	74	62
Diptera	Tipulidae	Dicranota			1	*	6		7
Diptera	Tipulidae	Tipulidae	1						
Ephemeroptera	Baetidae	Baetidae	10	16	12	28	23	36	15
Ephemeroptera	Ephemerellidae	Drunella	*	2	2	*		4	4
Ephemeroptera	Ephemerellidae	Serratella					1		1
Ephemeroptera	Ephemerellidae	Ephemerella	*			3			
Ephemeroptera	Heptageniidae	Cinygmula	11	7		*			
Ephemeroptera	Heptageniidae	Epeorus	1						
Ephemeroptera	Heptageniidae	Heptageniidae				9			
Ephemeroptera	Heptageniidae	Rhithrogena					*	33	6
Plecoptera	Chloroperlidae	Alloperla	*						
Plecoptera	Chloroperlidae	Chloroperlidae			30		7		
Plecoptera	Chloroperlidae	Suwallia	7	3	*	3		7	5
Plecoptera	Nemouridae	Zapada			2	4	17		10
Plecoptera	Perlodidae	Isoperla	1	*	3		15	1	8
Plecoptera	Pteronarcyidae	Pteronarcella	*	1					1
Trichoptera	Brachycentridae	Brachycentrus	9			*	1	*	1
Trichoptera	Glossosomatidae	Glossosoma	3						5
Trichoptera	Hydroptilidae	Ochrotrichia	2	3				1	
Trichoptera	Hydrosychidae	Hydropsyche					*		1
Trichoptera	Lepidostomatidae	Lepidostoma	1						
Trichoptera	Limnephilidae	Ecclisomyia	1	15	*	9			1
Trichoptera	Limnephilidae	Limnephilidae		1					
Trichoptera	Limnephilidae	Onocosmoecus	2						

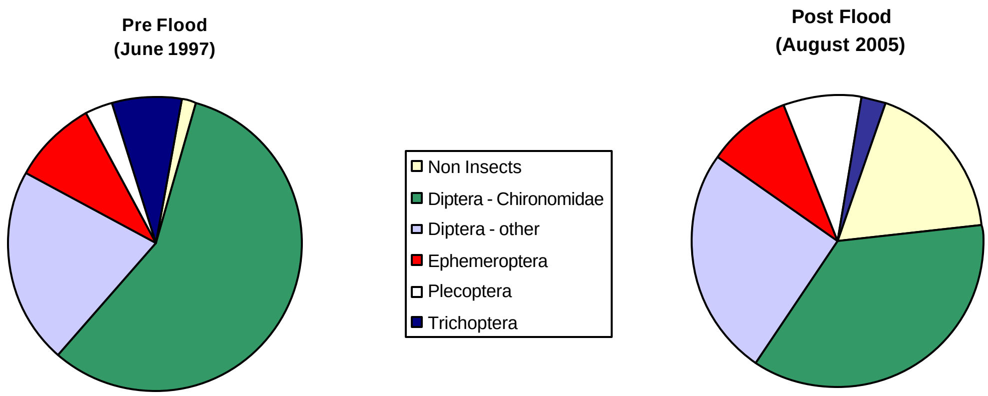


Figure 13. Pie charts based on macroinvertebrate community composition from June 1997 and August 2005.

Table 9. Metric values for samples collected on lower Deep Creek.

Metrics	6/6/97	6/16/03	8/20/03	6/24/04	8/18/04	6/23/05	8/12/05
Total taxa number	20	13	12	12	14	12	19
% EPT taxa	75	69	58	75	57	58	63
% EPT abundance	19.7	17.0	13.7	18.8	21.8	25.9	20.7
% Chironomidae abundance	57.0	75.0	69.3	48.3	67.7	46.4	36.1
Fine Sediment Biotic Index	59	30	35	44	37	30	58

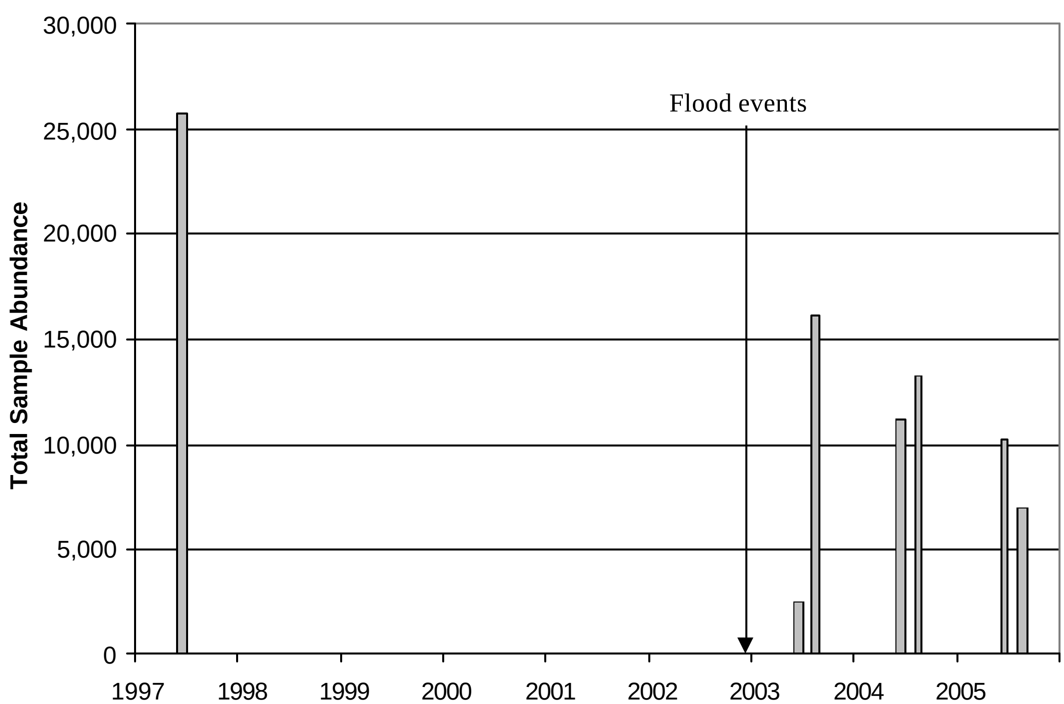
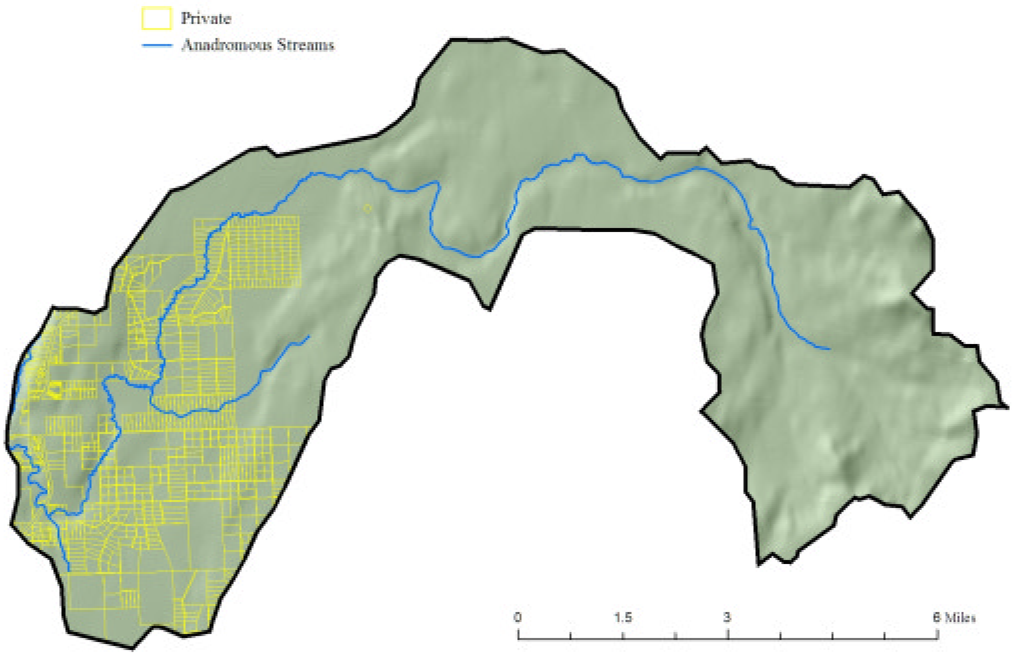


Figure 14. Total sample abundance for samples collected on lower Deep Creek.

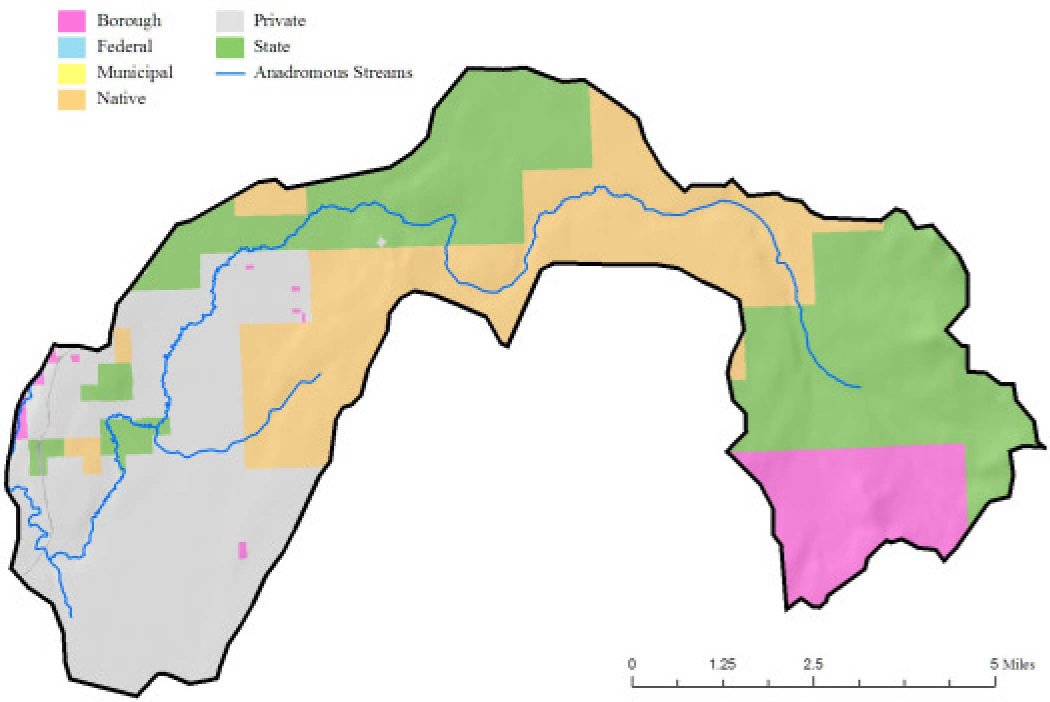
STARISKI CREEK WATERSHED



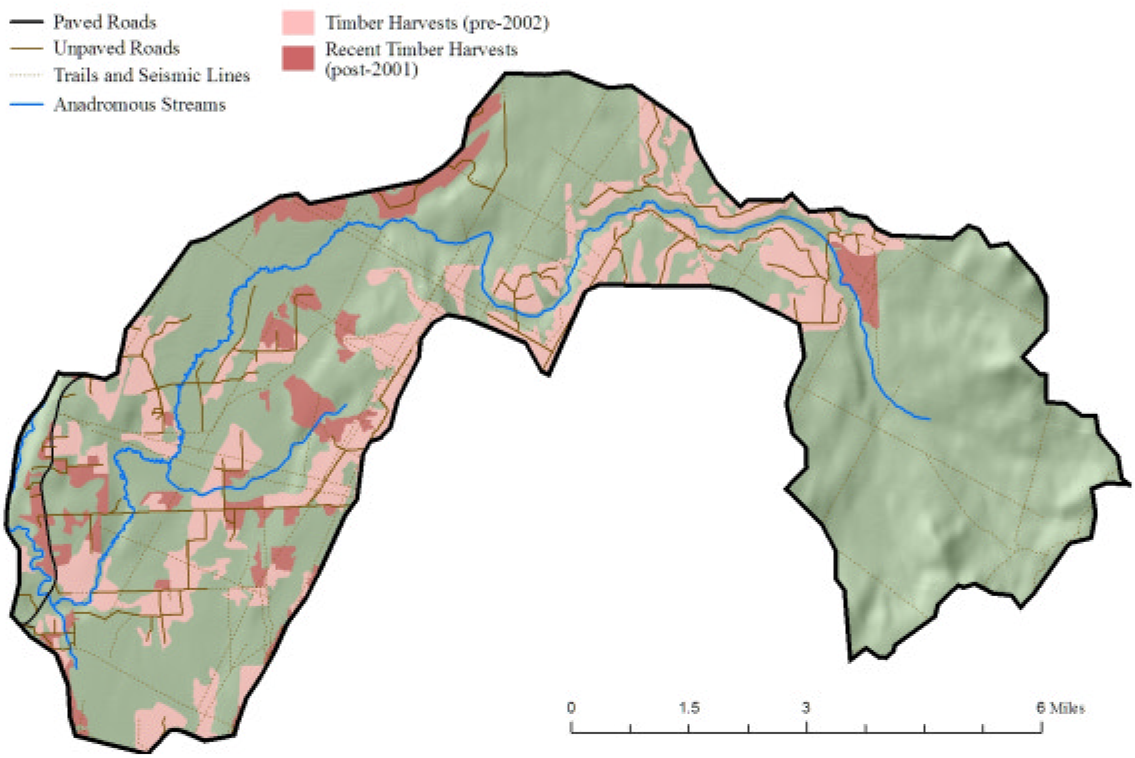
Map 9. Stariski Creek watershed boundaries (no sub-watersheds).

Table 10. Stariski Creek watershed characteristics.

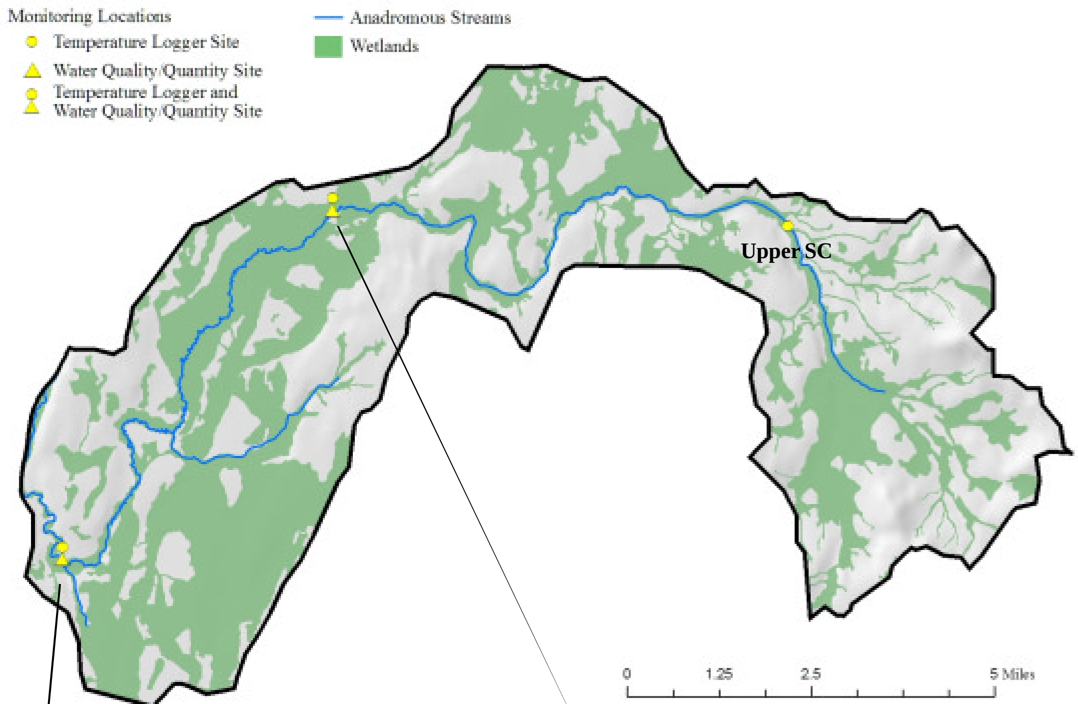
	Stariski Creek Watershed	Notes
Drainage Area (sq. miles)	**52.1**	
Anadromous Streams (miles)	**29.9**	
Total Roads (miles)	**60.4**	See Map 11
paved	**3.8**	
unpaved	**56.5**	
Total Crossings (#)	**8**	Anadromous stream crossings only
paved roads	**1**	
unpaved roads	**7**	
Land Ownership (%)		See Map 10
Borough	**9.5**	
Federal	**0.0**	
Native	**25.9**	
Private	**29.6**	
State	**35.1**	
Total Wetlands (%)	**48.6**	100% of watershed mapped See Map 12
Total Timber Harvest (% of area)	**24.5**	See Map 11
Recent Timber Harvest (%, 2001 – 2005)	**6.4**	See Map 11



Map 10. Land ownership in the Stariski Creek watershed.



Map 11. Roads and timber harvest activity in the Stariski Creek watershed.



Map 12. Wetlands and monitoring locations in the Stariski Creek watershed.

Long-term monitoring site: SC-2

Long-term monitoring site: SC-1

Priority Issues

1. Temperature

In 2004, three temperature loggers were deployed in Stariski Creek to determine how far upstream temperatures are exceeding water quality standards (see Map 12 for locations). The lower site (SC-2) is a fish migration route and spawning area thus temperatures above 15°C, Alaska's standard for migration routes, and 13°C, Alaska's standard for egg and fry incubation, are of concern to salmon health and timing of runs. Two loggers have been placed higher up in the watershed in spawning areas to record the extent of temperatures exceeding 13°C. Data collected at 15-minute intervals show the frequency of elevated temperatures at each site in 2004 (Figure 15).

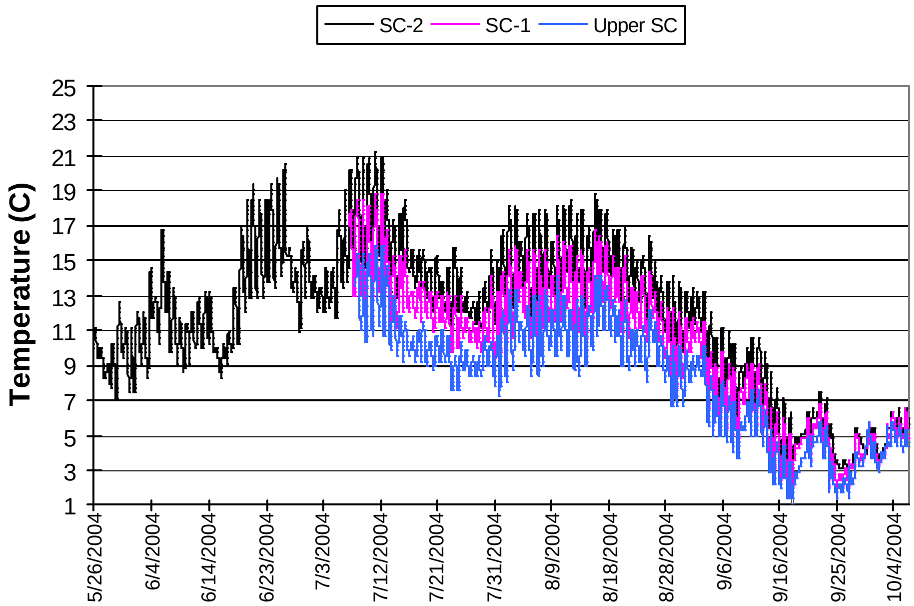


Figure 15. Temperature profiles for sites on Stariski Creek.

A comparison of data collected at the lower Stariski Creek site (SC-2) in the summers (6/21-9/11) of 2003 - 2005 show that both the frequency and magnitude of the temperature exceedances are generally increasing (Table 11), with the highest values seen in 2004. Seven days in 2004 and two days in 2005 had temperatures above 20°C which by State Standards "may not be exceeded."

The time period compared in Table 11 suggests that temperature exceedances decreased in 2005; however, in 2004 and 2005, loggers were deployed prior to June 21st to document when temperatures first start to rise and to provide more information during May when chinook salmon begin their migration upstream. In 2004, the first high temperatures were recorded on June 4th with an additional 19 days with temperatures above 13°C and 3 additional days above 15°C from June 4th – June 20th. In 2005, the first high temperatures were seen on May 23rd with an additional 18 days with temperatures above 13°C and 7 additional days above 15°C from May 23rd – June 20th.

Table 11. Summary of elevated water temperatures on the lower Stariski Creek site from 6/21 – 9/11 in 2003 - 2005.

Water Temp.	Year	# of days	Average # hours/day	# of full days	# of consecutive full days	Maximum temperature
Above 13°C	2003	51	18.8	21	6	
	2004	74	18.1	28	9	
	2005	68	18.3	27	11	
Above 15°C	2003	39	11.9	1	0	
	2004	51	13.3	1	0	
	2005	50	12.4	2	0	
Above 20°C	2003	0	0	0	0	20.0
	2004	7	5.2	0	0	21.2
	2005	2	2.8	0	0	20.6

2. Turbidity

Turbidity in 2004 – 2005 fell within the range of variability seen since 1999 on the middle and lower Stariski Creek sites (Figure 16). Discharge values in 2004 are some of the lowest measured at both sites. Turbidity rises quickly with increased flows at the lower site compared to the middle site.

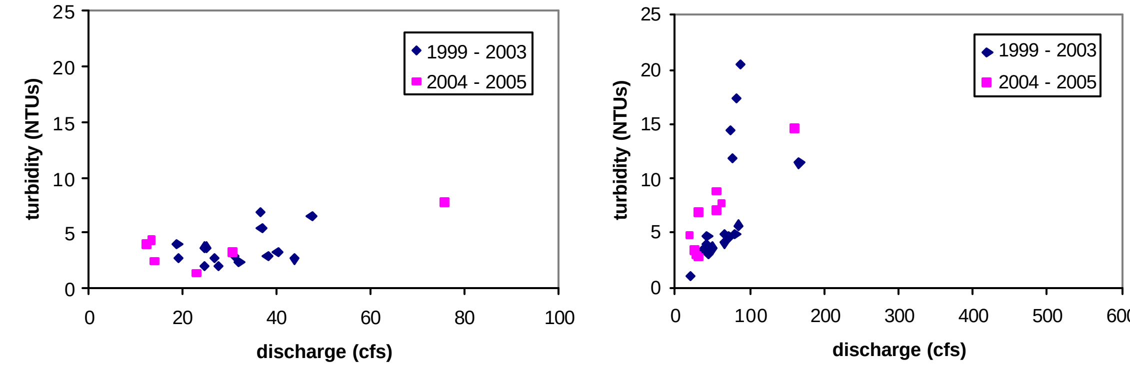


Figure 16. Turbidity data (June 1999 – June 2005) from the middle Stariski Creek site (SC-1, left chart) and lower Stariski Creek site (SC-2, right chart).

3. Phosphorus

Over the last six years of sampling, total phosphorus measurements on Stariski Creek have been above EPA's suggested level 40% of the time. Total phosphorus was above this level (0.10 mg/L) 44% of the time from 7/04 – 6/05. A relationship between phosphorus and turbidity can be seen by comparing dissolved orthophosphate (filtered), orthophosphate (unfiltered), total phosphorus (unfiltered) data with turbidity values (Figure 17). During baseflow in the winter, when dissolved orthophosphate values reflect phosphorus contributions from groundwater, there is a consistent level of 0.02 mg/L. From May – October during the growing season, dissolved orthophosphate increases only slightly. Total phosphorus does not track turbidity levels closely.

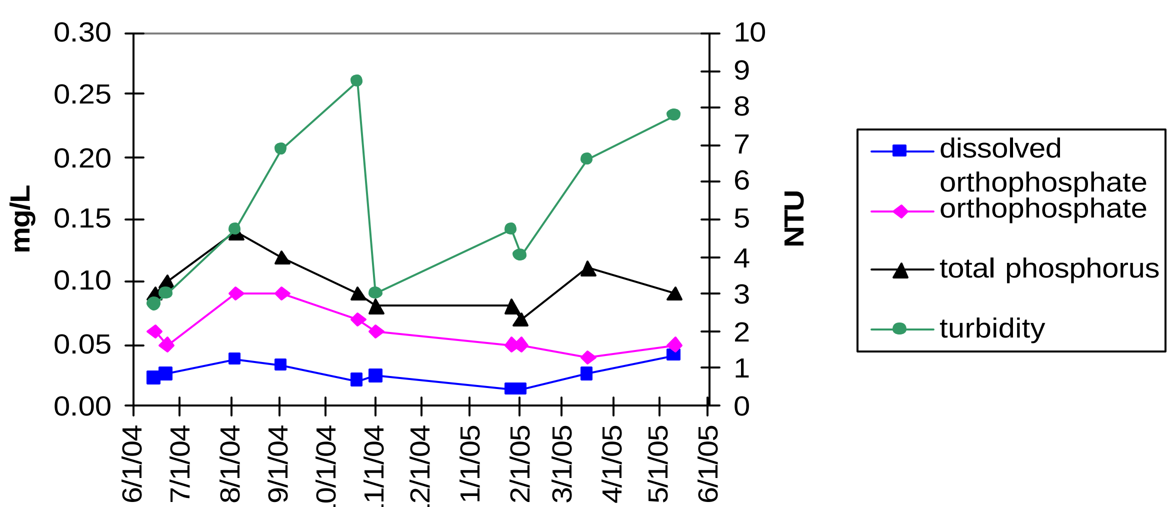


Figure 17. Phosphorus and turbidity values for lower Stariski Creek site (6/04 – 6/05).

Additional Parameters

Additional water quality data collected during July 2004 – June 2005 can be found in Appendix II. No exceedances of Alaska's standards for dissolved oxygen, pH, total dissolved solids, or nitrate-nitrogen were observed.

Post-Flood Habitat Recovery

Macroinvertebrates were collected on 6/27/03 and 6/21/04 at the lower Stariski Creek site (SC-2). Results are compared with ENRI's sample collected at the same site on 6/6/97 (Table 12). Pie charts (Figure 18) show a shift to fewer EPT taxa (mayflies, stoneflies and caddisflies) with a greater contribution from other Diptera (black flies) from 1997 to 2004. Based on the Fine Sediment Biotic Index, the community is composed of more sediment tolerant taxa than before the floods. The total number of taxa has not returned to pre-flood levels as of June 2004 (Table 13); however, total sample abundance has increased notably since 2002 (Figure 19).

Table 12. Taxonomic names and abundances for organisms identified in the 300-count subsample. An asterisk (*) denotes a taxa that was found during the search for large and rare taxa.

Order	Family	Genus/Final ID	6/6/97	6/27/03	6/21/04
		Oligochaeta			1
Acari		Hydracarina	2	8	20
Diptera	Chironomidae	Chironomidae	128	90	60
Diptera	Simuliidae	Simuliidae	126	154	162
Ephemeroptera	Baetidae	Baetidae	24	20	15
Ephemeroptera	Ephemerellidae	Drunella		3	1
Ephemeroptera	Ephemerellidae	Ephemerella	4		
Ephemeroptera	Heptageniidae	Cinygmula	5	*	
Ephemeroptera	Heptageniidae	Rhithrogena		16	
Plecoptera	Chloroperlidae	Chloroperlidae		1	
Plecoptera	Chloroperlidae	Plumiperla	1		
Plecoptera	Chloroperlidae	Suwallia		2	
Plecoptera	Nemouridae	Nemoura	1		
Plecoptera	Nemouridae	Zapada	4		
Plecoptera	Perlodidae	Isoperla	1		4
Plecoptera	Pteronarcyidae	Pteronarcella	1		
Trichoptera	Brachycentridae	Amiocentrus	2		
Trichoptera	Brachycentridae	Brachycentrus	32	3	*
Trichoptera	Glossosomatidae	Glossosoma	1		
Trichoptera	Hydroptilidae	Ochrotrichia		6	5
Trichoptera	Lepidostomatidae	Lepidostoma	5		
Trichoptera	Limnephilidae	Ecclisomyia			2
Trichoptera	Limnephilidae	Onocosmoecus	4	*	*

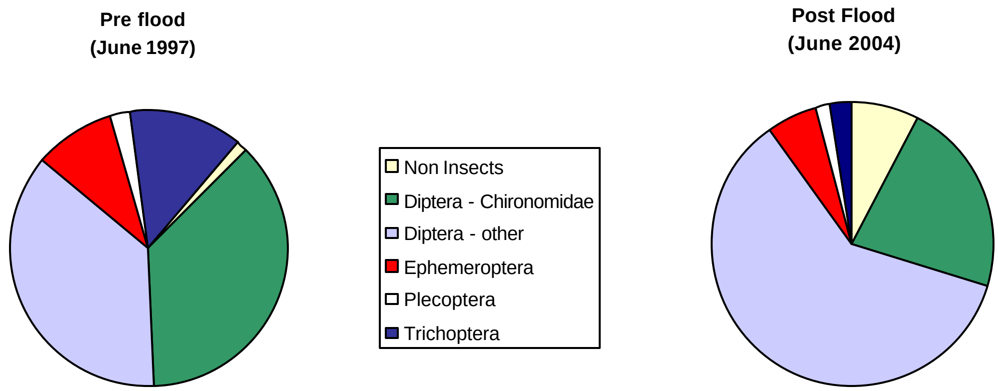


Figure 18. Pie charts based on macroinvertebrate community composition from June 1997 and June 2004.

Table 13. Metric values for samples collected on lower Stariski Creek.

Metrics	**6/6/97**	**6/27/03**	**6/21/04**
Taxa number	16	11	11
% EPT taxa	81.3	81.8	63.6
% EPT abundance	24.9	16.8	10.0
% Chironomidae abundance	37.5	29.7	22.2
Fine Sediment Biotic Index	40	32	30

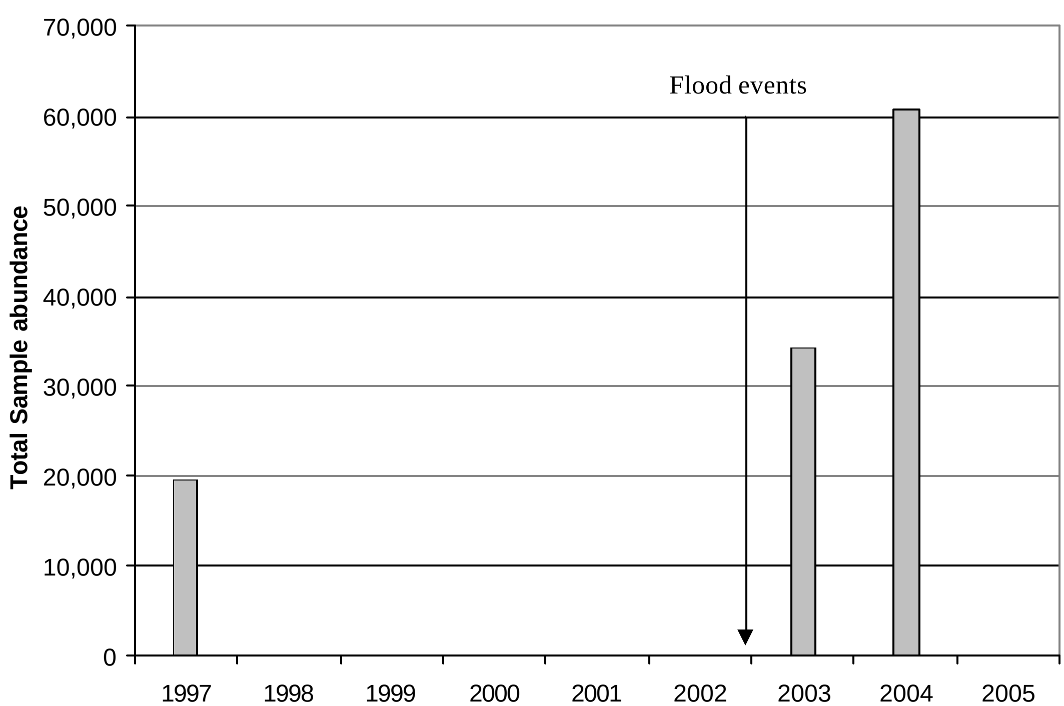
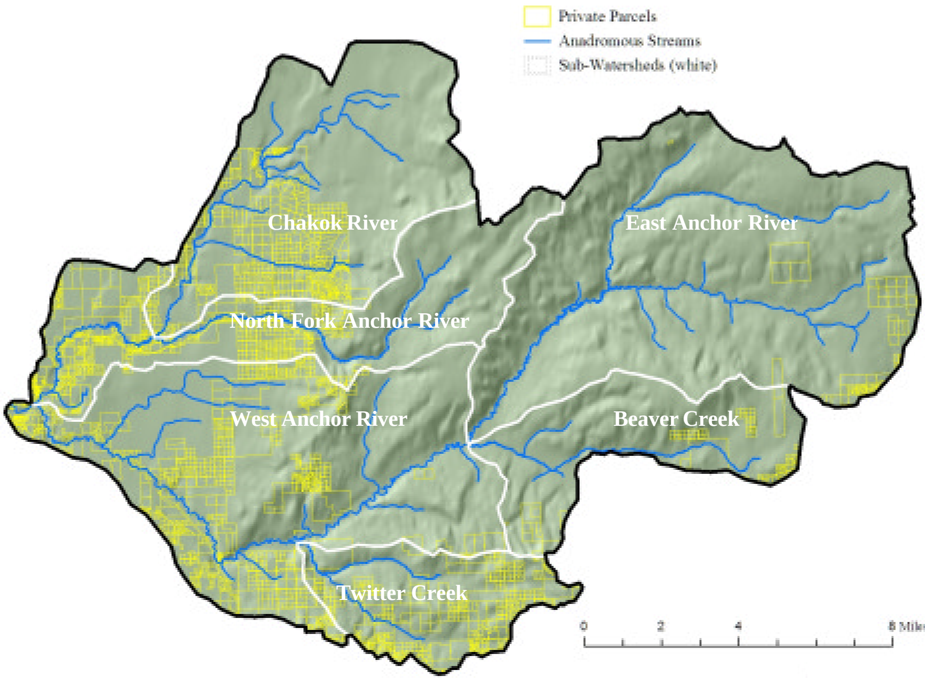


Figure 19. Total sample abundance for samples collected on lower Stariski Creek.

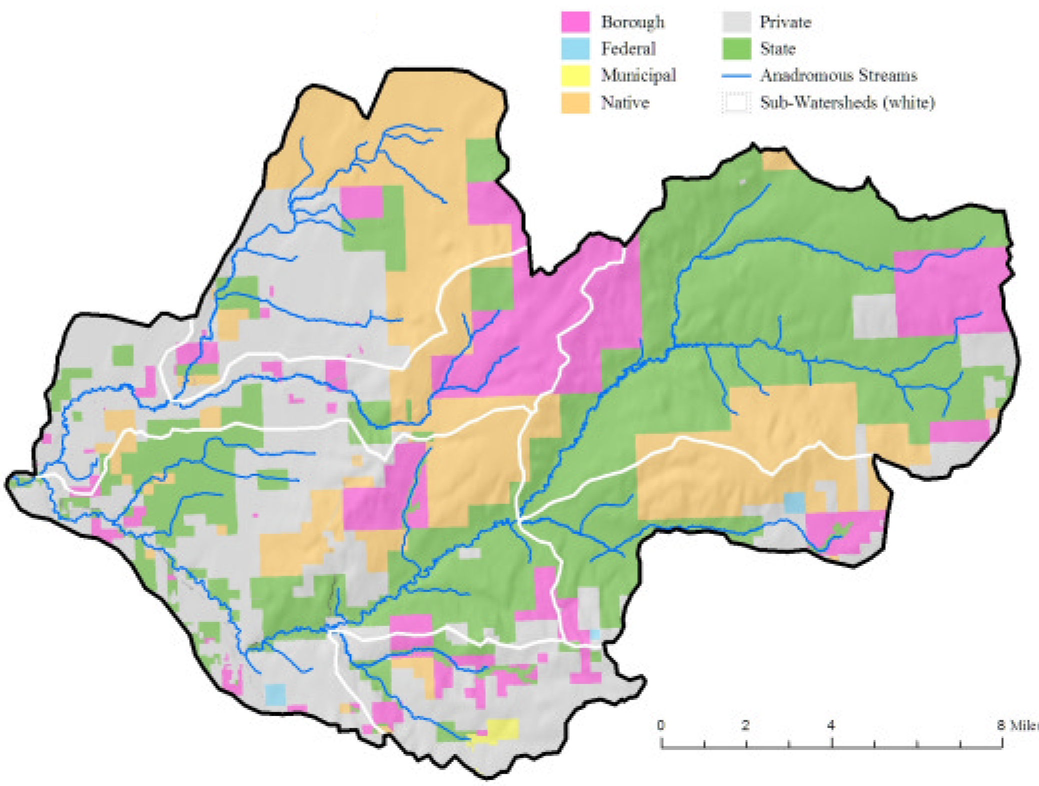
ANCHOR RIVER WATERSHED



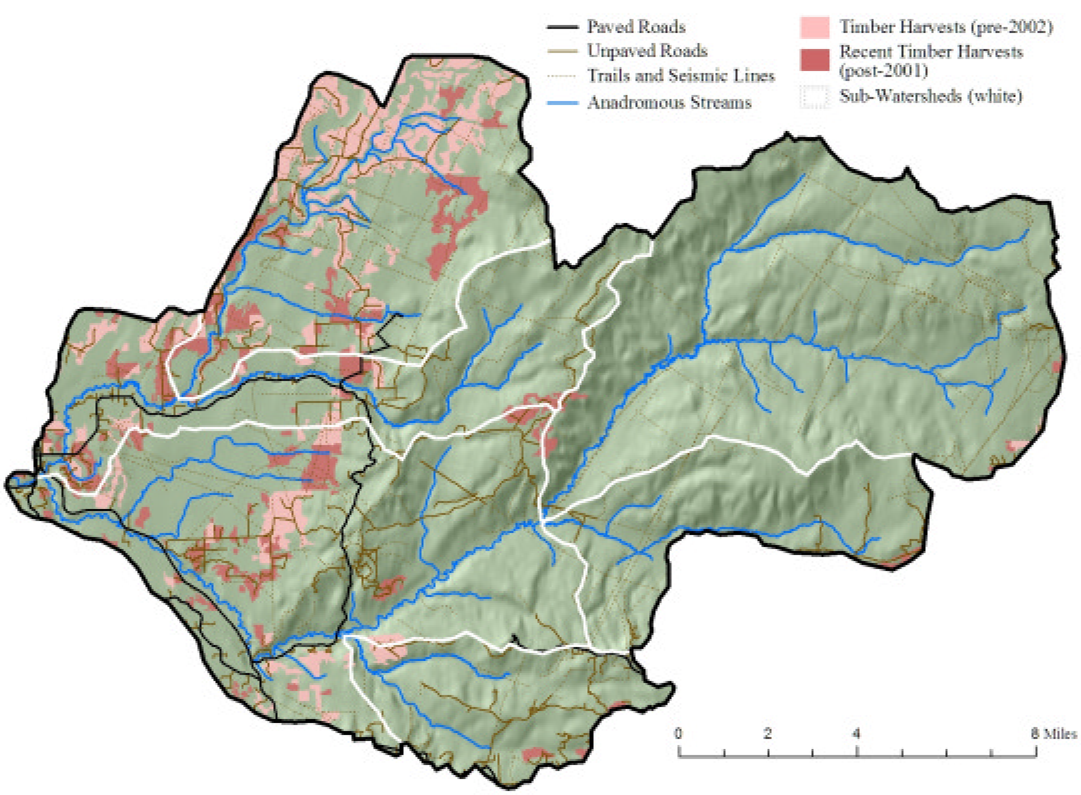
Map13. Anchor River watershed and sub-watershed boundaries.

Table 14. Anchor River watershed and sub-watershed characteristics.

	Anchor River	East Anchor River	Beaver Creek	Twitter Creek	Chakok River	North Fork Anchor	West Anchor River	Notes
Drainage Area (sq. miles)	**224.9**	65.2	20.0	15.7	38.1	30.9	55.0	
Anadromous Streams (miles)	**164.1**	43.5	12.5	9.4	30.0	25.9	42.8	
Total Roads (miles)	**231.3**	5.7	11.4	31.6	41.3	49.5	91.8	See Map 15
paved	**40.7**	0.0	0.0	3.6	1.9	11.8	23.6	
unpaved	**190.6**	5.7	11.4	28.0	39.4	37.7	68.2	
Total Crossings (#)	**42**	1	3	0	10	11	17	Anadromous stream crossings only
paved roads	**12**	0	0	0	0	3	9	
unpaved roads	**30**	1	3	0	10	8	8	
Land Ownership (%)								See Map 14
Borough	**14.1**	15.4	9.9	16.1	7.3	30.3	9.2	
Federal	**0.3**	0.0	1.6	0.0	0.0	0.0	0.5	
Native	**22.0**	12.7	37.2	3.6	48.9	17.8	16.5	
Private	**26.6**	5.2	14.1	63.0	34.0	38.5	35.1	
State	**36.8**	66.7	37.3	13.8	9.8	13.4	38.7	
Municipal	**0.2**			3.5				
Total Wetlands (%)	**48.2**	46.4	34.7	32.9	53.3	51.9	54.03	100 % mapped See Map 16
Total Timber Harvest (% of area)	**10.3**	0.7	0.7	3.6	30.8	13.5	11.1	See Map 15
Recent Timber Harvest (%, 2001 – 2005)	**4.5**	0.5	0.7	1.5	10.2	7.1	6.0	See Map 15



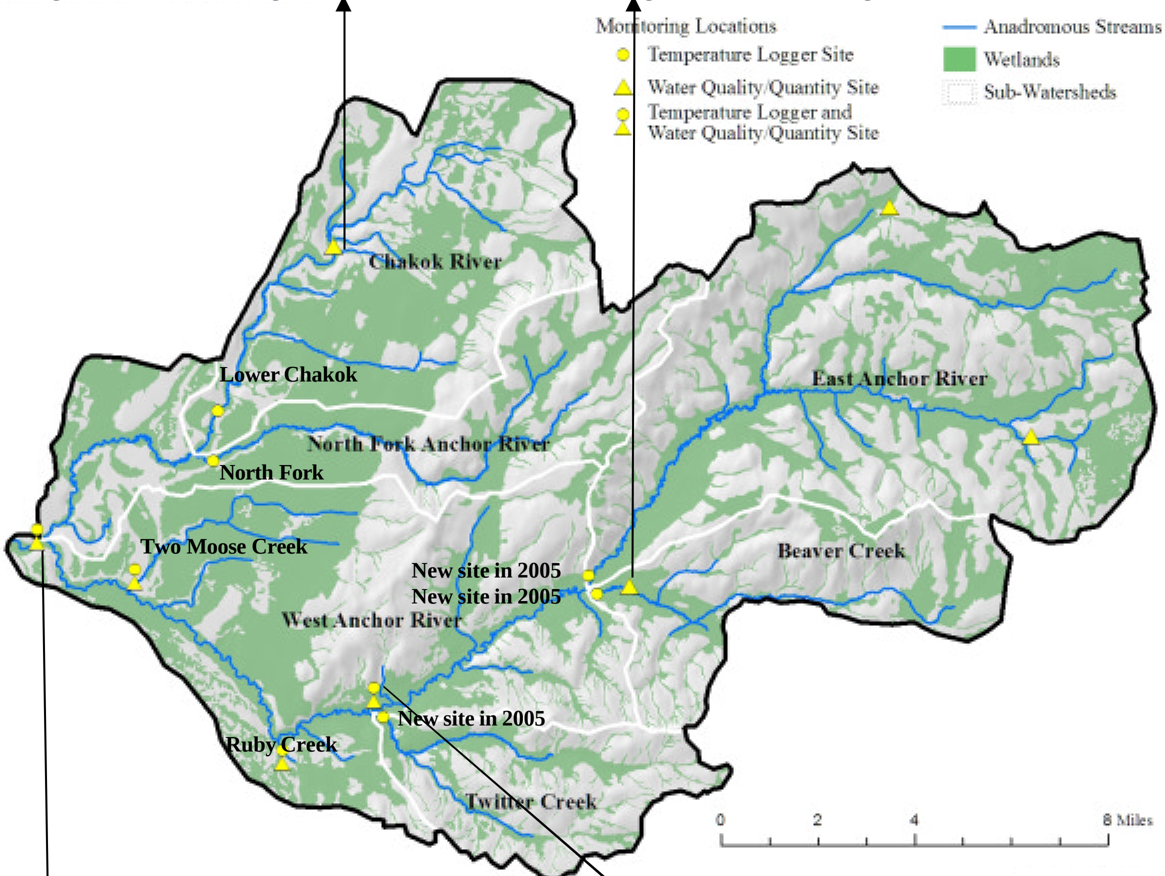
Map 14. Land ownership in the Anchor River watershed.



Map 15. Roads and timber harvest activity in the Anchor River watershed.

Long-term monitoring site: AR-4

Long-term monitoring site: AR-5



Map 16. Wetlands and monitoring locations in the Anchor River watershed.

Long-term monitoring site: AR-3

Long-term monitoring site: AR-2

Priority Issues

1. Temperature

In 2004, six temperature loggers were deployed in the Anchor River to determine how far upstream temperatures are exceeding water quality standards (see Map 16). The lower site (AR-3) is a fish migration route and thus temperatures above 15°C, Alaska's standard for migration routes, are of concern to salmon health and timing of runs. Five loggers have been placed higher upstream in spawning areas to record the extent of temperatures exceeding 13°C, Alaska's standard for egg and fry incubation.

Data collected at 15-minute intervals show the frequency of elevated temperatures at sites in the northern portion of the watershed in 2004 (Figure 20). The Lower Chakok site drains a larger sub-watershed than the North Fork site, which may explain the higher temperature profile at the Chakok site. Chakok River sub-watershed has also seen the greatest timber harvest activity over time.

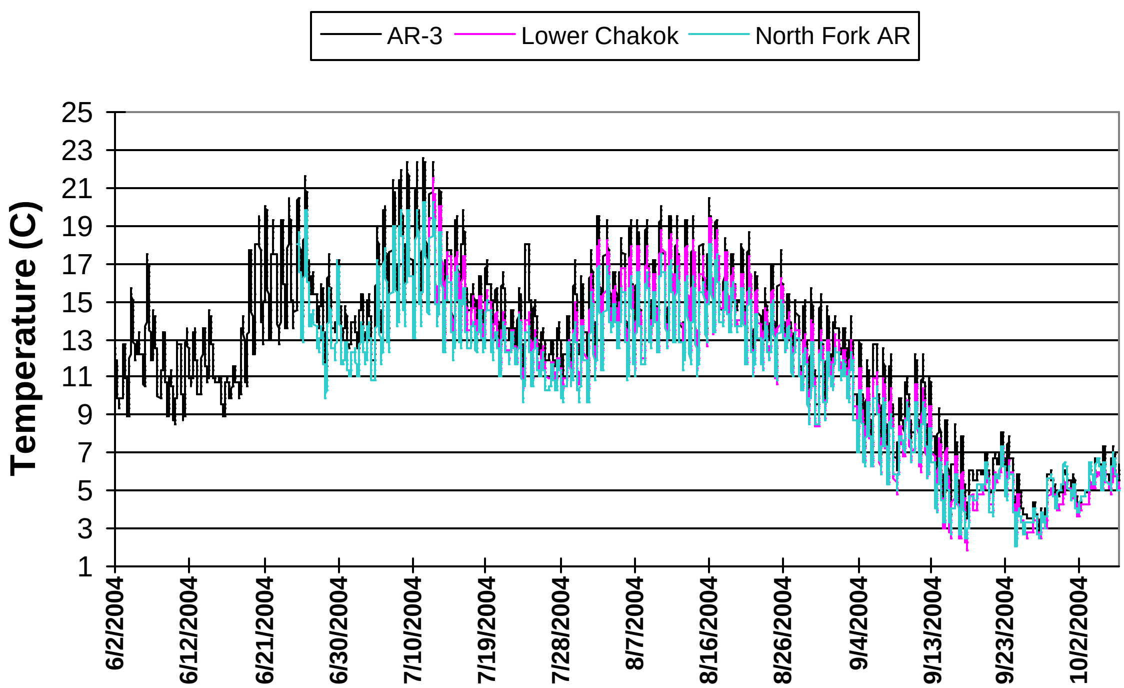


Figure 20. Temperature profiles of sites in the northern portion of the Anchor River watershed.

Two Moose Creek in the southern portion of the watershed has high temperatures in relation to its drainage size (Figure 21). Gravel pit operations occur upstream and may be related to higher stream temperatures.

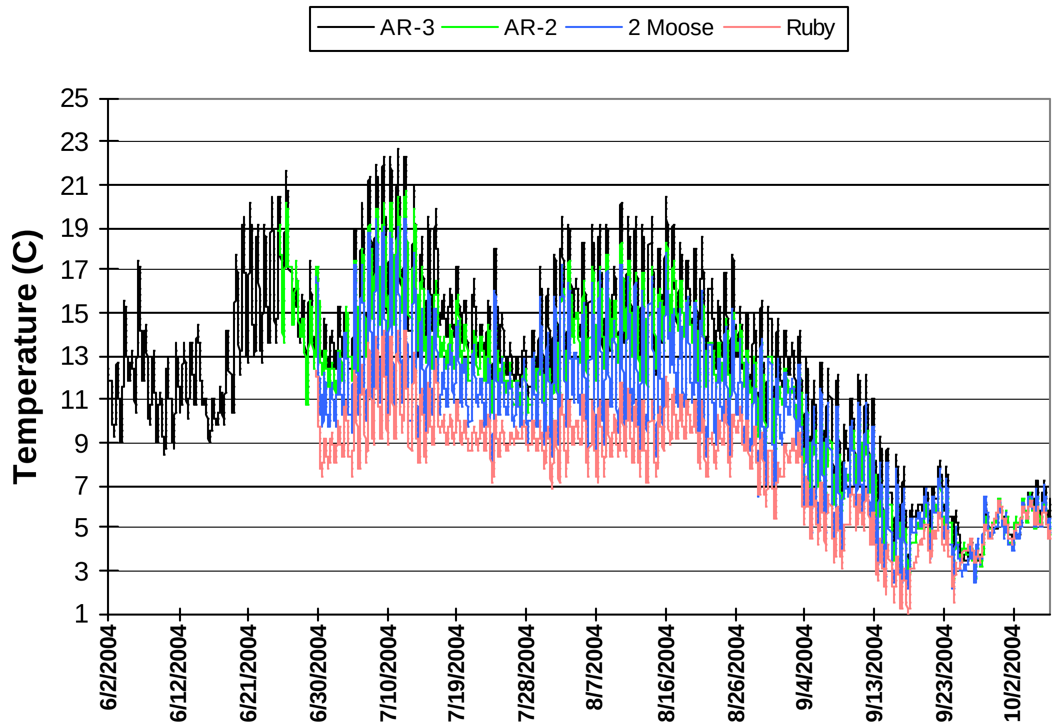


Figure 21. Temperature profiles of sites in the southern portion of the Anchor River watershed.

A comparison of data collected at the lower Anchor River site (AR-3) in the summers (6/21-9/11) of 2002 - 2005 show that both the frequency and the magnitude of the temperature exceedances are increasing (Table 15), with the highest values seen in 2004. Ten days in 2004 and six days in 2005 had temperatures above 20°C which by State Standards "may not be exceeded."

Table 15. Summary of elevated water temperatures on the lower Anchor River site from 6/21 - 9/11 in 2002 - 2005.

Water Temp.	Year	# of days	Average # hours/day	# of full days	# of consecutive full days	Maximum temperature
Above 13°C	2002	54	11.0	0	0	
	2003	60	17.7	24	11	
	2004	74	19.2	30	8	
	2005	68	18.5	24	9	
Above 15°C	2002	32	8.4	0	0	19.2
	2003	50	12.3	4	3	
	2004	65	12.9	3	0	
	2005	55	11.7	0	0	
Above 20°C	2002	0	0	0	0	
	2003	7	2.3	0	0	20.7
	2004	10	5.4	0	0	22.6
	2005	6	2.9	0	0	21.1

The time period compared in Table 15 suggests that temperature exceedances decreased in 2005; however, in 2004 and 2005, loggers were deployed prior to June 21st to document when temperatures first start to rise and to provide more information during May when chinook salmon begin their migration upstream. In 2004, the first high temperatures at the lower site were recorded on June 4th with an additional 12 days with temperatures above 13°C and 4 additional days above 15°C from June 4th – June 20th. In 2005, the first high temperatures were seen on May 23rd with an additional 20 days with temperatures above 13°C and 10 additional days above 15°C from May 23rd – June 20th.

2. Turbidity

Turbidity in 2004 – 2005 fell within the range of variability seen since 1999 on the upper Chakok River and Beaver Creek sites (Figure 22). Discharge values in 2004 are some of the lowest measured at both sites. Beaver Creek turbidity rises more quickly than on the Chakok River. Turbidity on the lower site (AR-3) shows more variability than the other sites which may be due to its location down stream of a major confluence (Figure 23). The north fork of the Anchor River generally is less turbid than the south fork. This lower site may reflect the variability in mixing or in the location of the sample taken on the transect. One sampling event on 9/2/04 contributed more turbidity than expected on the middle site (AR-2).

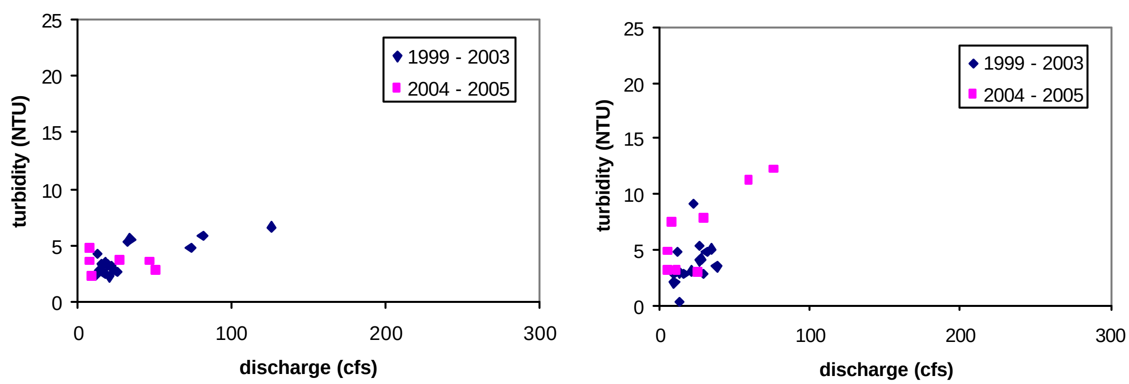


Figure 22. Turbidity data (June 1999 – June 2005) from the upper Chakok River site (AR-4, left chart) and Beaver Creek site (AR-5, right chart).

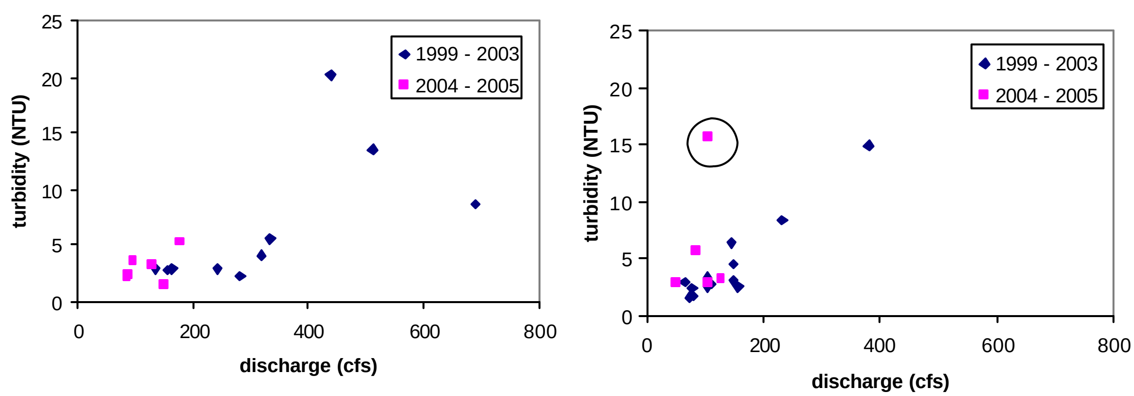


Figure 23. Turbidity data (June 1999 – June 2005) from the lower Anchor River site (AR-3, left chart) and middle Anchor River site (AR-2, right chart).

3. Phosphorus

Over the last six years of sampling, total phosphorus measurements on Anchor River have been above EPA's suggested level 22% of the time. Total phosphorus was above this level (0.10 mg/L) 38% of the time from 7/04 – 6/05. A relationship between phosphorus and turbidity can be seen by comparing dissolved orthophosphate (filtered), orthophosphate (unfiltered), total phosphorus (unfiltered) data with turbidity values (Figure 24). During baseflow in the winter, when dissolved orthophosphate values reflect phosphorus contributions from groundwater, there is a consistent level of 0.02 mg/L. From May – October during the growing season, dissolved orthophosphate increases slightly. Total phosphorus samples track turbidity levels closely.

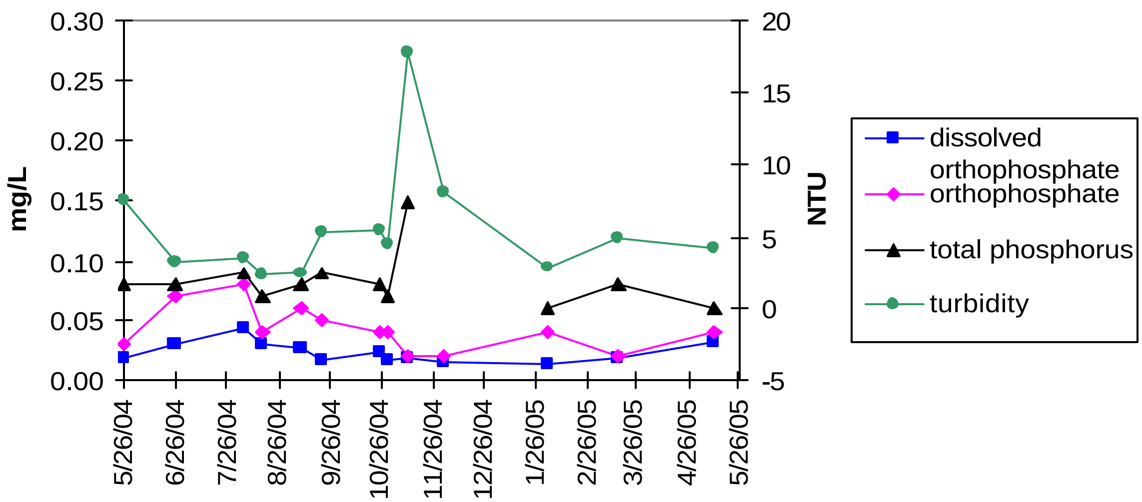


Figure 24. Phosphorus and turbidity values for the lower Anchor River from 5/04-5/05.

<u>Additional Parameters</u>

Additional water quality data collected during July 2004 – June 2005 can be found in Appendix II. No exceedances of Alaska's standards for dissolved oxygen, pH, total dissolved solids, or nitrate-nitrogen were observed.

<u>Post-Flood Habitat Recovery</u>

Macroinvertebrates were collected at two sites on the Anchor River: the lower site (AR-3) and Beaver Creek (AR-5). Samples were collected at the lower site on 6/19/03, 8/21/03, 6/25/04, 8/16/04, 6/24/05, and 8/12/05. Results are compared with ENRI's samples collected at the same site on 6/5/97 and 7/9/99 (Table 16). Pie charts (Figure 25) show a greater contribution of non-insect taxa and fewer from non-chironomid dipterans (i.e. black flies) from 1997 to 2005 (Figure 25). Post-flood samples show a strong seasonal pattern in metric values. June samples have a higher percentage of EPT taxa and abundance and lower percent of Chironomidae abundance (Table 17). The total number of taxa decreased initially after the floods and, by August 2005, had not returned fully to pre-flood levels. Another notable change is that total sample abundance suggests a clear downward trend from pre-flood abundance levels (Figure 26).

Table 16. Taxonomic names and abundances for organisms identified in the 300-count subsample of lower Anchor River (AR-3) samples. An asterisk (*) denotes a taxa that was found during the search for large and rare taxa.

Order	Family	Genus/Final ID	6/5/97	7/9/99	6/19/03	8/21/03	6/25/04	8/16/04	6/24/05	8/12/05
		Oligochaeta		*	9	22		26	4	21
		Turbellaria				1				
Acari		Hydracarina	2	2	35	35	35	44	72	81
Diptera	Ceratopogonidae	Probezzia			2			1	3	1
Diptera	Chironomidae	Chironomidae	202	27	103	229	142	179	105	185
Diptera	Empididae	Chelifera	*	1	2		2		3	
Diptera	Empididae	Empididae	3							
Diptera	Muscidiae	Limnophora				1		*		*
Diptera	Psychodidae	Pericoma				2		1		5
Diptera	Simuliidae	Simulium	74	190	88	2	48	2	8	3
Diptera	Tipulidae	Dicranota				3		3		4
Diptera	Tipulidae	Hexatoma	*							
Diptera	Tipulidae	Tipulidae	1							
Ephemeroptera	Baetidae	Baetidae	20	61	13	7	31	7	7	1
Ephemeroptera	Ephemerellidae	Drunella	*	*	2	3	1	2	*	
Ephemeroptera	Ephemerellidae	Ephemerella	*	1	1					
Ephemeroptera	Heptageniidae	Cinygmula		*						
Ephemeroptera	Heptageniidae	Heptageniidae	*	3			17			
Ephemeroptera	Heptageniidae	Rhithrogena			14	2		1	8	1
Plecoptera	Chloroperlidae	Alloperla	*							
Plecoptera	Chloroperlidae	Chloroperlidae		1		1	8	2		2
Plecoptera	Chloroperlidae	Neaviperla	*	1						
Plecoptera	Chloroperlidae	Plumiperla		*						
Plecoptera	Chloroperlidae	Suwallia	11		2		*		7	
Plecoptera	Nemouridae	Zapada				11	6	7	3	19
Plecoptera	Perlodidae	Isoperla	*	*	*				*	
Plecoptera	Pteronarcyidae	Pteronarcella	*	*		1		1		*
Trichoptera	Brachycentridae	Brachycentrus	5	2	4	1	*	1	1	1
Trichoptera	Glossosomatidae	Glossosoma				1		5		3
Trichoptera	Hydroptilidae	Ochrotrichia			10		22		51	
Trichoptera	Hydroptilidae	Stactobiella	1							
Trichoptera	Lepidostomatidae	Lepidostoma	1							
Trichoptera	Limnephilidae	Ecclisomyia			1		1			1
Trichoptera	Limnephilidae	Grensia	1							
Trichoptera	Limnephilidae	Lenarchus		*						
Trichoptera	Limnephilidae	Onocosmoecus	*				*		*	
Trichoptera	Limnephilidae	Psychoglypha		2						
		Nematoda								1

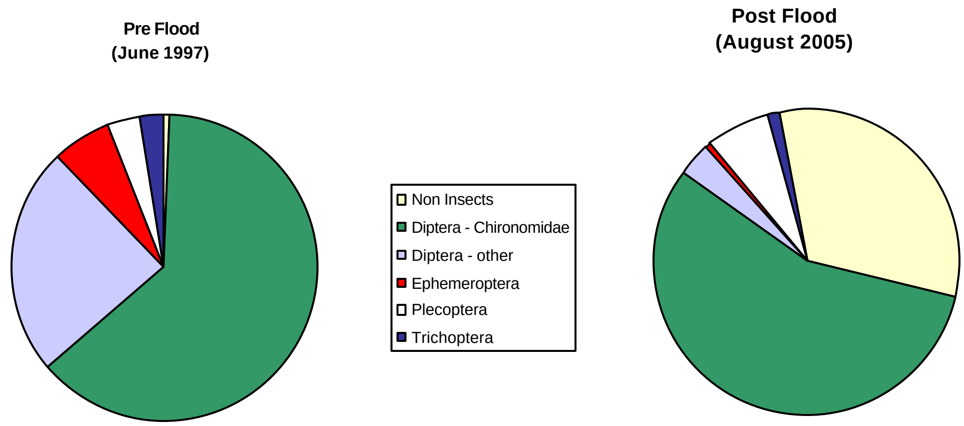


Figure 25. Pie charts based on macroinvertebrate community composition at the lower Anchor River site from June 1997 and August 2005.

Table 17. Metric values for samples collected at the lower Anchor River.

Metric	6/5/97	7/9/99	6/19/03	8/21/03	6/25/04	8/16/04	6/24/05	8/12/05
Total taxa number	21	18	15	16	14	16	15	17
% EPT taxa	66.7	72.2	60	50	71.4	50	60	47.1
% EPT abundance	12.1	24.4	16.4	8.4	27.5	9.2	28.3	8.5
% Chironomidae abundance	62.9	9.3	36	71.1	45.4	63.5	38.6	56.2
Fine Sediment Biotic Index	36	37	42	43	34	46	32	44

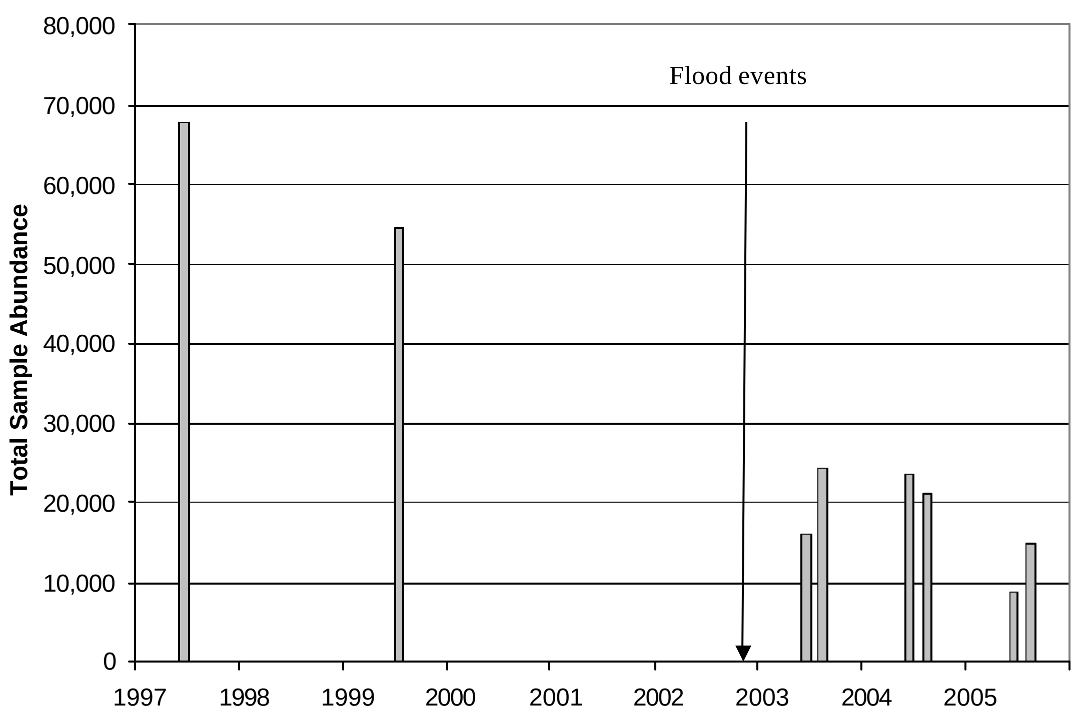


Figure 26. Total sample abundance for samples collected on the lower Anchor River site.

Samples were collected at Beaver Creek on 6/12/03 and 8/19/04. Results are compared with ENRI's sample collected at the same site on 6/4/97. Pie charts (Figure 27) show an increase in EPT abundance and decrease in diptera abundance. The Fine Sediment Biotic Index decreased initially after the flood but, by August 2004, the score suggests a greater presence of sediment intolerant taxa than before the floods (Table 18). Total sample abundance decreased after the flood in 2003 and increased again in 2004 (Figure 28).

Table 18. Taxonomic names and abundances for organisms identified in the 300-count subsample of Beaver Creek (AR-5) samples. An asterisk (*) denotes a taxa that was found during the search for large and rare taxa.

Order	Family	Genus/Final ID	6/4/97	6/12/03	8/19/04
		Oligochaeta		7	
		Turbellaria		1	1
Acari		Hydracarina	3	18	38
Diptera	Ceratopogonidae	Ceratopogonidae	*		
Diptera	Ceratopogonidae	Probezzia		2	2
Diptera	Chironomidae	Chironomidae	173	94	148
Diptera	Psychodidae	Pericoma			13
Diptera	Simuliidae	Simuliidae	151	34	3
Diptera	Tipulidae	Dicranota			3
Ephemeroptera	Baetidae	Baetidae	20	38	28
Ephemeroptera	Ephemerellidae	Drunella	3	2	2
Ephemeroptera	Ephemerellidae	Ephemerella	1		5
Ephemeroptera	Heptageniidae	Cinygmula	9	30	3
Plecoptera	Chloroperlidae	Alloperla	*		
Plecoptera	Chloroperlidae	Plumiperla	*		
Plecoptera	Chloroperlidae	Suwallia	3	3	
Plecoptera	Nemouridae	Zapada	2	3	34
Plecoptera	Perlodidae	Isoperla	2	2	2
Trichoptera	Brachycentridae	Brachycentrus	6	35	70
Trichoptera	Glossosomatidae	Glossosoma			16
Trichoptera	Lepidostomatidae	Lepidostoma	2		
Trichoptera	Limnephilidae	Onocosmoecus	*	1	
Trichoptera	Rhyacophilidae	Rhyacophila		2	1
Veneroida	Sphaeriidae	Sphaeriidae			*

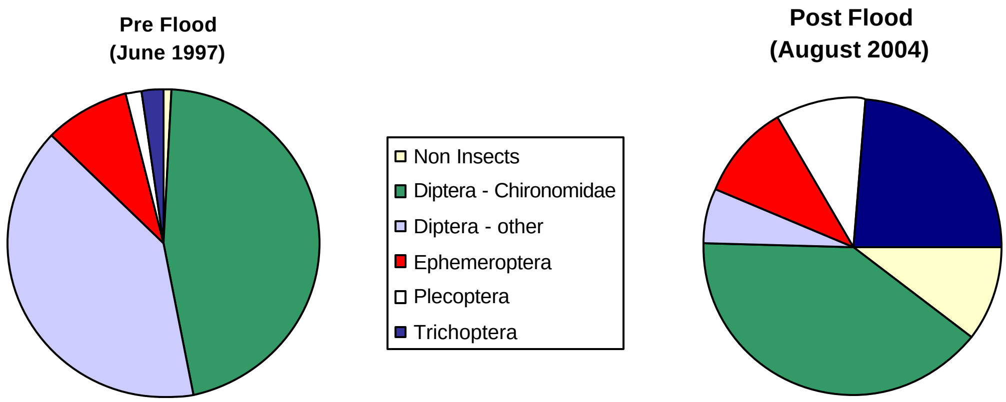


Figure 27. Pie charts based on macroinvertebrate community composition at the Beaver Creek site from June 1997 and August 2004.

Table 19. Metric values for samples collected at Beaver Creek.

Metrics	6/4/97	6/12/03	8/19/04
Total taxa number	16	15	17
% EPT taxa	75	60	53
% EPT abundance	12.8	42.6	43.6
% Chironomidae abundance	46.1	34.6	40.1
Fine Sediment Biotic Index	41	37	54

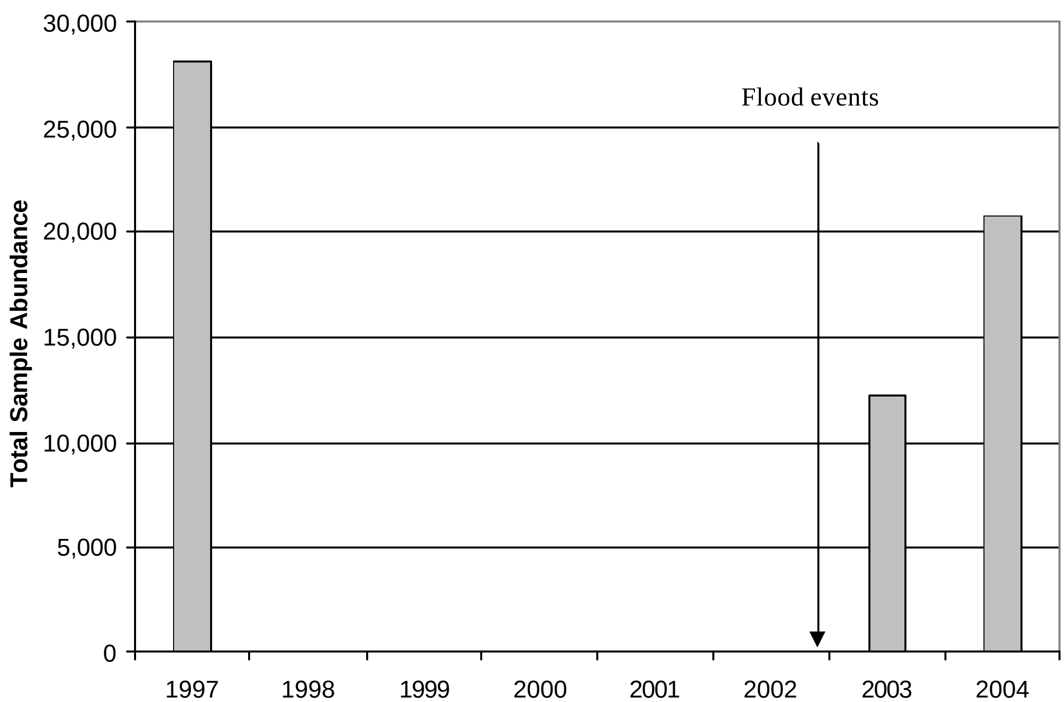


Figure 28. Total sample abundance for samples collected on Beaver Creek.

DATA SUMMARY
JULY 2004 - SEPTEMBER 2005

Water Quality

The Homer Soil and Water Conservation District and Cook Inlet Keeper have been monitoring water quality on lower Kenai Peninsula streams since August 1998 to document current water quality conditions and compare current conditions with the water quality standards that the State of Alaska has developed. Based on these data, temperature, turbidity, and phosphorus have been identified as water quality parameters of concern. Monitoring during July 2004 – September 2005 reveal the following:

On the Ninilchik River:

- In 2004, temperatures exceeded 13°C on 82 days, 15°C on 57 days, and 20°C on 6 days with a high of 21.0°C. The earliest exceedance was on May 30th.
- In 2005, temperatures exceeded 13°C on 88 days, 15°C on 60 days, and 20°C on 4 days with a high of 20.4°C. The earliest exceedance was on May 23rd.
- 35% of the total phosphorus measurements were above EPA's suggested level.

On Deep Creek:

- In 2004, temperatures exceeded 13°C on 81 days, 15°C on 60 days, and 20°C on 8 days with a high of 21.9°C. The earliest exceedance was on June 4th.
- In 2005, temperatures exceeded 13°C on 83 days, 15°C on 58 days, and 20°C on 1 day with a high of 20.7°C. The earliest exceedance was on May 25th.
- 7% of the total phosphorus measurements were above EPA's suggested level.

On Stariski Creek:

- In 2004, temperatures exceeded 13°C on 83 days, 15°C on 54 days, and 20°C on 7 days with a high of 21.2°C. The earliest exceedance was on June 4th.
- In 2005, temperatures exceeded 13°C on 86 days, 15°C on 57 days, and 20°C on 2 days with a high of 20.6°C. The earliest exceedance was on May 23rd.
- 44% of the total phosphorus measurements were above EPA's suggested level.

On the Anchor River:

- In 2004, temperatures exceeded 13°C on 86 days, 15°C on 69 days, and 20°C on 10 days with a high of 22.6°C. The earliest exceedance was on June 4th.
- In 2005, temperatures exceeded 13°C on 88 days, 15°C on 65 days, and 20°C on six days with a high of 21.1°C. The earliest exceedance was on May 23rd.
- 38% of the total phosphorus measurements were above EPA's suggested level.

Data for turbidity are difficult to relate to state standards because they are described in relation to natural conditions rather than as a specific value. The data in this report should be valuable in determining what the natural conditions are for these streams, although some land-use changes may have already occurred that affect turbidity and discharge patterns. Of note is that discharge values in 2004 are some of the lowest measured since monitoring began on Deep Creek, Stariski Creek and the Anchor River.

Bioassessment

Macroinvertebrate monitoring was implemented in 2003 to understand the effects from two major flood events in 2002 on stream productivity and to track the biological communities within the Ninilchik River, Deep Creek, Stariski Creek, and Anchor River. Biological monitoring revealed the following:

On the lower Ninilchik River:
- Diversity and abundance is low in both pre- and post-flood samples reflecting the sandy, unstable habitat available in this river.
- After the floods, the Fine Sediment Biotic Index shows a trend to more sediment tolerant taxa.
- By 2005, diversity remains low and total sample abundance is increasing towards pre-flood levels.

On lower Deep Creek:
- In August 2005, diversity values and the Fine Sediment Biotic Index suggest a recovery to pre-flood levels.
- Abundance numbers suggest a notable downward trend.

On lower Stariski Creek:
- After the floods, the Fine Sediment Biotic Index shows a trend to more sediment tolerant taxa.
- By 2004, diversity remains low and total sample abundance has increased above pre-flood numbers.
- Black flies make up a large proportion (>50%) of the post-flood invertebrate community.

On the lower Anchor River:
- Post-flood samples show a strong seasonal pattern in metric values.
- By August 2005, diversity has not returned to pre-flood levels.
- Abundance numbers suggest a notable downward trend.

On Beaver Creek (in Anchor River watershed):
- Fine Sediment Biotic Index suggests a greater presence of sediment intolerant taxa than before the floods.
- Sample abundance in 2004 is increasing to pre-flood levels.

DISCUSSION

Temperature Concerns

Temperature monitoring in 2004 and 2005 reveal that summer water temperatures continue to rise in the salmon streams of the lower Kenai Peninsula. Extensive historical data are not available so there is no way to be certain if elevated temperatures are typical in these streams or if they are responding to climate change. However, a USGS report (Kyle and Brabets, 2001) suggests that the Ninilchik River is likely to see a 3°C increase in coming years. This conclusion is based on a model that uses air temperature to predict water temperature. In response to this report, the Homer District and Keeper collected air temperature data in 2005 at each water temperature logger site to develop a regression model to see how much variance in stream temperature can be explained by air temperature. In sub-watersheds where this air-water temperature relationship is weak, the updated GIS information will help identify landscape characteristics and land-use activities that may be contributing to higher water temperatures.

Housings for air temperature loggers were designed to prevent direct solar radiation.

In 2005, twenty-four water temperature loggers were deployed across the four watersheds. Data from the lower site in each watershed are included in this report. The additional 2005 water temperature data will be analyzed and included in next year's report. Data collected at the Ninilchik River site: NR-Left trib, and on the Anchor River site: Two Moose Creek will continue to be tracked to determine if their elevated temperature profiles are evident again in 2005.

Elevated Phosphorus Levels

Monitoring from July 2004 – June 2005 shows that total phosphorus measurements continue to exceed 0.1 mg/L (100 µg/L), the level recommended by EPA for streams and rivers that do not drain into lakes and reservoirs (EPA, 1986). Since phosphorus binds easily to sediments, data analysis in 2005 focused on the relationship between phosphorus values and turbidity levels. Dissolved orthophosphate is the most biologically available form of phosphorus; it was found to have only a slight response to turbidity. Total phosphorus (unfiltered samples), on the other hand, increased consistently with higher turbidity levels. In 2005, both filtered and unfiltered total phosphorus samples were collected. These data will be analyzed in the winter of 05/06 to see if the dissolved component of total phosphorus exceeds EPA's recommended level.

Intensive phosphorus and discharge sampling took place in September 2005 from headwaters to river mouth in the Anchor and Ninilchik Rivers when turbidity levels were low. Sampling will be repeated in spring of 2006 during a rain event, when precipitation delivers more sediment into stream channels. Data will be analyzed to determine if there are sampling locations that suggest a major tributary is contributing a disproportionate amount of phosphorus and turbidity.

Increasing Sedimentation

To describe background levels of turbidity across the hydrologic gradient, stage gauges were established on Deep Creek and Ninilchik River in September 2005. Gauges were taken out in November due to ice cover and will be re-established in April/May of 2006. A discharge - stage relationship will be created by collecting discharge data when streams are wadeable at each gauge station to create a continuous discharge dataset for these rivers. Weekly turbidity samples will be collected and compared with the discharge dataset to develop a relationship between turbidity and stream discharge; only with this complete discharge dataset can turbidity exceedances be determined.

Post-Flood Habitat Recovery

The high mobility of most stream insects contributes to a high rate of recovery after major disturbances. Generally colonization processes lead to a rapid return to pre-flood abundance levels with a slower, smoother trajectory of diversity recovery (Lake, 2000). This was not the pattern seen in lower Kenai Peninsula salmon streams following the floods of 2002, particularity on the lower Anchor River and lower Deep Creek sites.

The rate of recovery of macroinvertebrate communities after a flood event may depend on the severity of flooding, availability of refugia, and the seasonal timing. The two, 100-year flood events in October and November of 2002 were both severe and late in the season for quick recovery. The extensive bank sloughing and channel widening on the Anchor River and Deep Creek may have limited the availability of refugia. On Beaver Creek, much higher up in the Anchor River watershed, the recovery pattern is more typical and, with an increase in Fine Sediment Biotic Index scores, suggests a positive flood effect of moving sediment out of the stream bottom.

Stariski Creek and the Ninilchik River samples show a trend to more sediment tolerant taxa after the floods. This loss of sensitive taxa is a sign of habitat degradation caused by increased sediment pollution. The Fine Sediment Biotic Index has not been tested extensively in Alaska, although a study on the Kenai Peninsula concluded that the FSBI may be useful for detecting sedimentation impacts during summer base-flow conditions (Rinella and Bogan, 2003).

The downward trend in abundance values on the Anchor River and Deep Creek suggests a poor recovery pattern in stream productivity. Kicknets samples are considered semi-quantitative so the abundance values can not be expressed as a measure of density. The trend is very consistent in both watersheds and the degree of change so great that the pattern is unlikely to be a sampling anomaly or a measure of natural variation, especially when different patterns were evident in other watersheds.

DIRECTIONS FOR FUTURE MONITORING

Monitoring stream temperatures, turbidity, discharge and macroinvertebrate communities will continue to be a priority for these watersheds. In 2006, temperature loggers will be deployed at the lower site in each watershed to see if the trend towards earlier temperature exceedances in May continues. Also, temperature monitoring sites will be included to target specific types of land-use activities (logging, urban development, gravel mining) and types of wetlands (discharge slope, drainageway, headwater fen) to determine if they play a role in temperature regulation that can be measured beyond the affect of rising air temperature. We will place loggers in locations along the Ninilchik River which will help tease out whether the drainageway wetlands are important sources of cooler water.

Macroinvertebrate monitoring will continue in 2006 to assess if the recovery patterns seen thus far persist. The Homer District and Keeper will work with the Technical Advisory Committee to develop a strategy to: 1) flush out the seasonal patterns seen in the Anchor River, 2) provide a better density measure of macroinvertebrates, 3) determine the need to improve the taxonomic level of identification, and 4) incorporate other measures of stream productivity. Discussions with local researchers and resource managers will continue in early 2006 to consider if 1) recovery to pre-flood levels may be an unrealistic expectation in watersheds that are undergoing large-scale changes such as climate change and forest death, 2) salmon productivity would be expected to respond to decreasing macroinvertebrate densities, 3) ocean productivity patterns will damped out those seen in coastal watersheds for anadromous species, and 4) resident fish populations are being monitored closely enough to track freshwater productivity trends.

The relationship between water quality and water quantity is likely to change in the coming years as global climate change alters Kenai Peninsula watersheds by affecting flooding frequencies, stream temperature, precipitation levels, surface and ground water volumes, soil nutrient dynamics, and other hydrologic characteristics. In addition, climate change may impact geographic distribution of wetlands. The forest recovery from the Spruce Bark Beetle infestation on the lower Kenai Peninsula may also result in significant changes in hydrologic patterns. Stage gauges will continue to be an important tool to understand how in-stream flows are changing and how turbidity is changing in relation to discharge patterns. Stage gauges will be re-established on the Ninilchik River and Deep Creek in May 2006, and funding for a new gauge station on Stariski Creek will be sought.

At the same time that climate and landscape-level changes are occurring, urban development is expanding rapidly on the lower Kenai Peninsula increasing impervious surfaces. In 2006, Cook Inlet Keeper will create a series of comprehensive GIS maps and tools to quantify the extent of impervious surfaces in the watersheds of the lower Kenai Peninsula salmon streams. By correlating impervious cover with in-stream flow and water quality data, resource managers will have better tools to make informed decisions about salmon resources.

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APPENDIX I.

Results of Quality Assurance Checks

Keeper estimates the precision and accuracy of its laboratory analysis in four ways:

- Splitting samples annually with another professional lab, using the same procedures.
- Splitting samples quarterly with the Project's QA Officer during Keeper's laboratory analysis.
- Analyzing a known standard solution for each parameter during each laboratory analysis session.
- Participating in USGS Standard Reference Sample Program.

In March 2005, Keeper split five samples with Analytica International, Inc. Samples were analyzed for nitrate-nitrogen, orthophosphate, total phosphorus, total suspended solids, conductance, and turbidity. Nitrate results showed the greatest difference between labs.

In 2003, Keeper's lab: *Cook Inlet Community-based Water Quality Laboratory*, enrolled in the USGS Standard Reference Sample Program. Participating labs are evaluated by using performance evaluation samples, called Standard Reference Samples (SRSs). SRSs are submitted to laboratories semi-annually for round-robin laboratory performance comparison purposes. Currently, approximately 100 laboratories are evaluated for their analytical performance. Keeper participated in the Spring 2005 round robin study and analyzed SRSs for nitrate, orthophosphate, total phosphorus, conductivity, and pH.

Keeper also split samples during laboratory quality assurance sessions to test how results can differ between two people using the same methods at the Keeper lab. The results of the sample split showed negligible differences between people using the same method.

Results of quality assurance checks. The table shows the average difference between the sample splits and project data.

	Nitrate-Nitrogen	**Orthophosphate**	**Total Phosphorus**	**Suspended Solids**	**Conductivity**	**Turbidity**	**pH**
Analytica March 2005	0.06 mg/L	0.01 mg/L	-0.02 mg/L	-1.8-mg/L	7.3 µS/cm	-0.4 NTUs	
Standard Reference Sample (USGS) Spring 2005	0.00 mg/L	0.00 mg/L	-0.01 mg/L		4.0 µS/cm		0.05

APPENDIX II.

All Water Quality Data Collected by Cook Inlet Keeper, 7/04-6/05.
Values that exceed federal recommendations or state standards are in **bold**.

Site ID	Date	Water Temp °C	DO mg/L	DO % sat	pH	Cond. uS/cm	TDS mg/L	Turb. NTU	Color PtCo units	Dis. Ortho Phos	Ortho Phos. mg/L	Total Phos. mg/L	Ammonia Nitrogen mg/L	Nitrate N mg/L	TSS mg/L	Dis-charge cfs
AR-2	7/29/2004	11.60	10.37	100	7.38	85.60	40	5.69	55.00	0.07	0.12	**0.13**	0.16	0.14	9.00	87.4
AR-2	8/11/2004	**16.70**	8.85	96	7.70	91.70	43	2.90	39.00	0.07	0.10	**0.11**	0.09	0.09	3.00	48.96
AR-2	9/2/2004	11.70	10.44	102	6.67	91.90	43	15.70	70.00	0.04	0.08	**0.18**	0.11	0.00	24.00	108
AR-2	10/22/2004	1.50	12.64	96	7.32	73.10	32	2.91	53.00	0.03	0.06	**0.11**	0.21	0.13	4.00	106.6
AR-2	11/10/2004	0.20	13.40	92		62.00	26	20.20	118.00	0.02	0.05	**0.19**	0.21	0.10	43.00	
AR-2	12/1/2004	1.20	13.20	94	6.96	59.10	26	10.93	118.00	0.03	0.05		0.15	0.20	21.00	
AR-2	1/26/2005	0.20	12.87	89	7.26	72.20	34	3.95	32.00	0.03	0.05	0.08	0.12	0.29	6.00	
AR-2	3/15/2005	0.30	13.10	91		60.40	30.2	4.35	62.00	0.03	0.06	0.10	0.15	0.10	7.00	
AR-2	4/27/2005	4.70	11.20	91	7.25	35.80	18	31.10	173.00	0.02	0.04	**0.16**	0.33	0.16	58.00	
AR-2	6/1/2005	9.60	11.18	103	6.90	62.40	31.2	3.21	48.00	0.04	0.05	0.08	0.01	0.02	4.00	129
AR-3	8/4/2004	**16.40**	9.84	106	8.23	91.20	43	3.55	48.00	0.04	0.08	0.09	0.04	0.06	4.00	96.4
AR-3	8/16/2004	**19.10**	8.90	102	7.64	99.60	47	2.30	37.00	0.03	0.04	0.07	0.09	0.00	3.00	86.7
AR-3	9/8/2004	10.70	10.92	105	8.16	101.70	48	2.46	32.00	0.03	0.06	0.08	0.01	0.00	3.00	88
AR-3	9/20/2004	6.60				92.00	42	5.34	84.00	0.02	0.05	0.09	0.19	0.00	9.00	177
AR-3	10/25/2004	1.90	13.42	104	7.34	58.00	25	5.44	94.00	0.02	0.04	0.08	0.32	0.02	9.00	
AR-3	10/29/2004	2.20	13.41	104	7.10	57.20	25	4.51	88.00	0.02	0.04	0.07	0.27	0.03	7.00	
AR-3	11/10/2004	0.20	13.60	94	7.32	65.60	28	17.80	133.00	0.02	0.02	**0.15**	0.28	0.11	32.00	
AR-3	12/2/2004	0.50	13.40	93	7.38	44.70	19	8.19	121.00	0.02	0.02		0.25	0.07	21.00	
AR-3	2/2/2005	0.20	13.10	90	6.93	77.70	37	2.94	45.00	0.01	0.04	0.06	0.12	0.04	4.00	
AR-3	3/15/2005	0.30	12.90	89	7.27	50.10	25	4.98	107.00	0.02	0.03	0.08	0.29	0.03	9.00	
AR-3	5/11/2005	11.90			7.18	55.10	27.6	4.22	60.00	0.03	0.04	0.06	0.13	0.19	6.00	
AR-3	6/24/2005	**14.30**	10.13	105	7.28	78.10	39.1	1.48	45.00		0.06	0.07	0.09	0.00	4.00	143

Site ID	Date	Water Temp °C	DO mg/L	DO % sat	pH	Cond. uS/cm	TDS mg/L	Turb. NTU	Color PtCo units	Dis. Ortho Phos	Ortho Phos. mg/L	Total Phos. mg/L	Ammonia Nitrogen mg/L	Nitrate N mg/L	TSS mg/L	Dis-charge cfs
AR-4	7/21/2004	12.40	9.89	98	7.71	87.20	41	4.78	77.00	0.04	0.08	**0.12**	0.21	0.16	5.00	7.95
AR-4	8/5/2004	**14.40**	8.92	92		88.10	42	4.67	74.00	0.05	0.10	**0.13**	0.16	0.18	4.00	7.47
AR-4	9/9/2004	5.70	12.79	108	7.19	94.50	43	3.54	56.00	0.03	0.08	**0.13**	0.07	0.16	2.00	7.74
AR-4	10/19/2004	3.10	13.03	103	7.09	63.20	28	3.67	71.00	0.02	0.05	0.08	0.22	0.13	5.00	27.3
AR-4	12/16/2004	0.20	12.20	84		63.70	27	1.68	48.00	0.02	0.03		0.09	0.20	4.00	
AR-4	1/27/2005	0.30	12.80	88	7.48	66.30	31	2.77	52.00	0.02	0.05	0.07	0.11	0.29	3.00	
AR-4	3/9/2005	0.30	13.30	92				4.28	65.00	0.02	0.06	0.10	0.15	0.18	5.00	
AR-4	5/4/2005	5.10	11.34	94		43.80	21.9	3.59	66.00	0.02	0.03	0.06	0.18	0.36	7.00	47.4
AR-4	6/30/2005	**14.60**	9.81	102	6.98	73.80	36.9	2.27	67.00		0.07	0.09	0.22	0.12	3.00	10.1
AR-5	7/26/2004	9.70	10.78	100		78.10	36	7.48	58.00	0.05	0.08	**0.13**	0.21	0.25	12.00	9.3
AR-5	8/10/2004	**13.60**	8.78	88	7.26	80.00	38	4.84	55.00			**0.11**	0.16	0.22	6.00	6.18
AR-5	8/19/2004	13.00	10.19	101	7.57	84.70	40	3.03	53.00	0.04	0.06	0.09	0.07	0.11	5.00	6.27
AR-5	9/23/2004	5.30	12.08	101	7.16	78.70	36	3.05	50.00	0.03	0.07	0.08	0.14	0.10	3.00	11.4
AR-5	10/26/2004	1.90	12.47	96	7.20	55.90	24	2.95	77.00	0.02	0.03	0.07	0.24	0.16	5.00	25.9
AR-5	12/8/2004	0.20	13.00	90	7.05	61.10	26	2.66		0.02	0.03		0.06		1.00	
AR-5	2/7/2005	0.20	12.30	85	7.04			2.69	37.00	0.02	0.03	0.07	0.10		3.00	
AR-5	3/10/2005	0.20	12.70	88	7.35			8.33	63.00	0.03	0.07	**0.14**	0.14	0.25	15.00	
AR-5	5/5/2005	3.00	12.57	99	7.06	36.80	18.4	12.30	93.00	0.02	0.03	0.09	0.17	0.29	22.00	76
AR-5	6/29/2005	**14.20**	8.96	92	6.96	49.40	24.7	7.82	114.00	0.02	0.06	**0.12**	0.37	0.04	14.00	29.9
AR-sp	9/8/2004	3.30	7.75	62	6.77	107.40	48	0.49	2.00	0.02	0.03	0.09	0.28	0.05	3.00	
DC-1	7/28/2004	10.10	11.12	102	7.51	71.30	33	1.20	18.00	0.02	0.03	0.04	0.18	0.00	2.00	27.47
DC-1	8/12/2004	11.50	10.27	99	7.32	75.90	36	0.37	12.00	0.02	0.03	0.04	0.08	0.00	1.00	21.7
DC-1	10/28/2004	1.80			7.42	56.40	25	1.56	23.00	0.02	0.02	0.04	0.06	0.00	4.00	37.24
DC-1	3/2/2005	0.40	13.00	90	7.51			9.55	73.00	0.02	0.02	0.05	0.07	0.02	17.00	
DC-1	4/28/2005	3.70	11.99	95	7.24	28.00	14	24.50	130.00		0.00	0.10	0.24	0.00	48.00	
DC-1	6/27/2005	12.90	9.71	97	6.72	60.80	30.4	0.97	11.00		0.05	0.04	0.00	0.00	1.00	28
DC-3	8/2/2004	**17.90**			7.30	75.70	36	4.93	53.00	0.03	0.06	0.08	0.03	0.00	10.00	169
DC-3	8/18/2004	**16.70**	9.02	98	7.41	88.10	42	2.10	29.00	0.04	0.04	0.07	0.06	0.00	3.00	115

Site ID	Date	Water Temp °C	DO mg/L	DO % sat	pH	Cond. uS/cm	TDS mg/L	Turb. NTU	Color PtCo units	Dis. Ortho Phos	Ortho Phos. mg/L	Total Phos. mg/L	Ammonia Nitrogen mg/L	Nitrate N mg/L	TSS mg/L	Dis-charge cfs
DC-3	9/20/2004	6.20	11.99	101	7.46	79.70	36	6.04	67.00	0.03	0.04	0.08	0.13	0.00	11.00	227
DC-3	10/18/2004	0.70	14.26	105	7.42	68.70	29	3.06	44.00	0.02	0.04	0.07	0.14	0.02	6.00	223
DC-3	10/25/2004	0.90	13.02	94	7.42	60.90	26	4.21	57.00	0.02	0.03			0.01	8.00	281.1
DC-3	11/8/2004	0.20	14.00	96	7.32	75.80	32	2.20	28.00	0.03	0.03	0.06	0.06	0.09	3.00	
DC-3	12/2/2004	0.20	13.60	94	7.14	54.00	23	9.45	96.00	0.02	0.03		0.15	0.05	15.00	
DC-3	12/22/2004	0.20	13.50	93	7.16	66.40	30	1.90	28.00	0.02	0.03		0.02	0.10	2.00	
DC-3	1/20/2005	0.20	12.60	87	7.34			1.43	21.00	0.02	0.02	0.05	0.03	0.13	3.00	
DC-3	3/16/2005	0.20	13.10	90		67.20	33.6	15.10	84.00	0.02	0.04	**0.11**	0.19	0.08	26.00	
DC-3	5/12/2005	9.70			7.41	42.20	21.1	9.07	75.00	0.02	0.04	0.06	0.14	0.01	17.00	
DC-3	6/23/2005	**16.00**	9.34	99	7.01	70.80	35.4	1.14	28.00	0.04	0.04	0.06	0.12	0.00	3.00	169
NR-2	8/11/2004	**13.80**	9.45	96	7.36	115.90	55	6.02	69.00	0.06	0.15	**0.16**	0.25	0.05	6.00	42.4
NR-2	9/22/2004	6.20	11.34	96	6.97	96.40	44	5.85	64.00	0.05	0.08	**0.12**	0.19	0.00	8.00	112
NR-2	10/11/2004	5.30	11.42	95	7.08	80.40	36	3.78	68.00	0.04	0.07	**0.11**	0.23	0.00	7.00	107
NR-2	11/1/2004	0.20			7.32	78.40	33	2.40	63.00	0.04	0.07	0.08	0.25	0.02	5.00	74.8
NR-2	12/9/2004	0.20	11.10	76	7.11	86.50	37	2.60	42.00	0.03	0.05		0.14	0.05	2.00	
NR-2	1/20/2005	0.20	11.20	77				2.81	45.00	0.03	0.06	0.08	0.14	0.08	5.00	
NR-2	3/3/2005	0.20	11.40	79	7.20			3.03	48.00	0.03	0.08	0.10	0.13	0.09	3.00	
NR-2	4/27/2005	4.80	9.85	81	7.03	39.80	19.9	6.21	110.00	0.03	0.05	0.11	0.29	0.00	14.00	
NR-2	6/8/2005	9.90	10.35	96	7.05	83.50	41.7	2.71	62.00	0.07	0.08	0.10	0.09	0.00	4.00	77.7
NR-3	8/2/2004	**16.00**			7.32	104.40	49	6.09	75.00	0.07	0.13	**0.17**	0.16	0.06	9.00	61.4
NR-3	9/15/2004	5.90	13.24	112	7.11	105.20	48	3.39	53.00	0.05	0.08	**0.11**	0.11	0.01	3.00	56.5
NR-3	10/13/2004	4.70	12.61	103	7.43	80.00	36	3.68	70.00	0.04	0.07	0.10	0.23	0.01	6.00	116
NR-3	10/25/2004	0.50	12.75	95	7.27	68.30	29	4.17	83.00	0.03	0.06	0.09	0.32	0.00	8.00	165
NR-3	11/8/2004	0.20	12.40	85	7.24	90.50	39	1.76	46.00	0.03	0.06	0.09	0.18	0.07	3.00	
NR-3	12/9/2004	0.20	11.70	81	7.21	82.80	35	1.40	49.00	0.03	0.06		0.23	0.06	1.00	
NR-3	1/27/2005	0.20	11.10	77	7.16	85.60	40	2.92	46.00	0.03	0.06	0.09	0.11	0.09	4.00	
NR-3	3/16/2005	0.30	11.80	81		82.70	41.4	3.14	71.00	0.03	0.07	0.10	0.21	0.03	5.00	
NR-3	5/12/2005	10.00	10.32	96	7.29	63.60	31.8	3.68	65.00	0.05	0.06	0.09	0.17	0.03	6.00	128

Site ID	Date	Water Temp ^{o}C	DO mg/L	DO % sat	pH	Cond. uS/cm	TDS mg/L	Turb. NTU	Color PtCo units	Dis. Ortho Phos	Ortho Phos. mg/L	Total Phos. mg/L	Ammonia Nitrogen mg/L	Nitrate N mg/L	TSS mg/L	Dis-charge cfs
NR-3	6/16/2005	**18.10**	9.51	107	7.76	97.10	48.5	2.28	53.00	0.07	0.08	0.10	0.05	0.00	4.00	68.2
SC-1	7/7/2004	**17.30**	8.44	93	7.30	80.00	38	2.41	50.00	0.04	0.09	**0.11**	0.20	0.05	4.00	14.16
SC-1	8/5/2004	**13.70**	8.98	91	7.56	83.10	39	4.27	51.00	0.06	0.12	**0.13**	0.12	0.11	6.00	13.6
SC-1	9/15/2004	6.00	12.16	103	7.49	85.60	39	3.97	39.00	0.04	0.08	0.10	0.17	0.02	2.00	12.7
SC-1	10/20/2004	0.90	12.93	97	6.99	67.20	29	3.14	60.00	0.03	0.06	0.09	0.23		7.00	30.7
SC-1	12/21/2004	0.20	13.20	91	7.12	69.90	30	1.77	39.00	0.03	0.04		0.11	0.19	4.00	
SC-1	3/9/2005	0.20	12.80	88	7.34			5.64	46.00	0.03	0.08	**0.11**	0.13	0.24	8.00	
SC-1	5/4/2005	3.90	11.95	95	7.47	39.80	19.9	7.67	75.00	0.02	0.03	0.08	0.18	0.16	15.00	75.9
SC-1	6/9/2005	9.70	10.80	100		60.30	30.1	1.34	46.00	0.04	0.06	0.07	0.01	0.00	2.00	22.9
SC-2	8/4/2004	**15.80**	9.84	105	7.45	84.30	40	4.74	84.00	0.04	0.09	**0.14**	0.09	0.04	5.00	20.1
SC-2	9/2/2004	12.20	10.40	102	7.27	93.40	44	6.90	72.00	0.03	0.09	**0.12**	0.10	0.00	8.00	31.2
SC-2	10/20/2004	1.90	12.74	98		68.70	30	8.72	80.00	0.02	0.07	0.09	0.24		7.00	57.4
SC-2	11/1/2004	0.10			7.35	66.90	28	3.03	75.00	0.02	0.05	0.08	0.21	0.05	4.00	
SC-2	12/1/2004	0.40	12.80	89	7.11	45.80	19	14.50	146.00	0.01	0.02		0.29	0.00	27.00	161
SC-2	1/26/2005	0.20	12.40	85	6.92	71.70	34	4.72	52.00	0.01	0.05	0.08	0.09	0.15	7.00	
SC-2	2/2/2005	0.20	11.00	76		76.30	36	4.01	56.00	0.01	0.05	0.07	0.09	0.16	5.00	
SC-2	3/16/2005	0.30	12.80	89		53.30	26.7	6.61	99.00	0.03	0.04	**0.11**	0.26	0.04	13.00	
SC-2	5/11/2005	10.60	9.81	93	6.61	53.50	26.8	7.77	70.00	0.04	0.05	0.09	0.18	0.14	14.00	63.1
SC-2	6/30/2005	**16.00**	9.03	97	7.33	75.10	37.5	3.44	72.00		0.07	**0.12**	0.18	0.00	4.00	27.4

Note: Water temperature data recorded here are from site visits. Temperature logger datasets are available upon request from Cook Inlet Keeper.

APPENDIX III.

Wetland Types based on Kenai Watershed Forum's Wetlands of the Kenai Lowlands Project

	Wetlands Mapped	Total Wetlands	Depression	Discharge Slope	Drainage-way	Head-water Fen	Kettle	Lakebed	Riparian	Tidal	Wetland / Upland Complex	Late Snow
	%	%	%	%	%	%	%	%	%	%	%	%
Ninilchik River Watershed	**97.2**	**37.42**	**1.06**	**7.96**	**6.29**	**0.37**	**4.93**	**7.90**	**6.29**	**0.03**	**2.57**	**0.00**
Ninilchik River Headwaters	99.9	32.62	1.11	4.96	9.19	0.04	5.56	6.05	5.55	0.00	0.15	0.00
Beta-Ninilchik River	93.9	38.99	1.15	11.39	4.90	0.81	5.55	2.81	6.71	0.00	5.64	0.00
Ninilchik River Mouth	100.0	44.67	0.71	6.19	3.05	0.00	1.86	25.45	6.92	0.19	0.30	0.00
Deep Creek Watershed	**88.9**	**43.73**	**0.84**	**15.36**	**2.73**	**0.49**	**4.09**	**4.74**	**9.24**	**0.04**	**4.36**	**1.84**
Deep Creek Headwaters	85.6	52.20	0.15	25.65	3.25	0.56	5.08	4.23	8.30	0.00	3.21	1.77
North Fork Deep Creek	58.2	49.06	1.41	18.51	0.81	1.17	3.01	0.00	9.23	0.00	7.56	7.35
Gamma -Deep Creek	100.0	32.07	2.07	6.61	3.33	0.24	7.57	2.09	6.50	0.00	3.63	0.00
Clam Creek	100.0	50.35	0.44	13.85	3.22	0.69	1.15	18.58	7.57	0.00	4.50	0.35
Deep Creek Mouth	100.0	39.46	0.66	11.59	2.52	0.29	2.91	3.58	11.81	0.12	4.48	1.48
Anchor River Watershed	**100.0**	**48.22**	**0.25**	**16.81**	**5.27**	**0.90**	**2.27**	**8.52**	**9.73**	**0.00**	**2.69**	**1.59**
East Anchor River	100.0	46.43	0.46	18.67	6.82	1.79	1.58	1.29	8.56	0.00	2.65	4.60
Beaver Creek	100.0	34.70	0.01	10.59	5.55	1.18	2.94	1.42	8.35	0.00	1.78	2.87
Twitter Creek	100.0	32.94	0.11	15.94	0.00	0.49	1.49	0.00	10.59	0.00	4.30	0.00
Chakok River	100.0	53.33	0.33	15.51	7.51	0.56	0.19	17.40	8.43	0.00	3.32	0.00
North Fork Anchor River	100.0	51.86	0.21	14.52	5.02	0.90	0.88	17.96	9.07	0.00	2.73	0.04
West Anchor River	100.0	54.03	0.08	19.30	3.40	0.08	5.31	10.66	12.64	0.00	2.13	0.00
Stariski Creek Watershed	**100.0**	**48.58**	**0.27**	**12.83**	**7.04**	**0.45**	**1.15**	**19.55**	**6.72**	**0.28**	**0.28**	**0.02**

APPENDIX IV.

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