Baseline Water Quality Inventory for the Southwest Alaska Inventory and Monitoring Network, Aniakchak National Monument and Preserve

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Abstract

Water quality was investigated at Aniakchak National Monument and Preserve during June and July of 2003. This project was initiated as part of the National Park Service Inventory and Monitoring Vital Signs program in an effort to collect water quality data in an area where little work had previously been done. The objectives were to collect baseline information on the physical and chemical characteristics of the water resources, and, where possible, relate basic water quality parameters to fish occurrence.

Temperatures at a warm springs tributary to Surprise lake approached 21 -22° C (69.9 – 71.6° F), the temperature range which forms a migration barrier to adult salmonids, and the upper tolerance limits for juvenile salmonids (McCullough 1999). EPA water quality criteria for aquatic life of pH 6.5 to 9.0 and dissolved oxygen lower limits of 4 mg/L (EPA 1986) were not met at this same warm springs complex.

At Turbid Creek, an upper Aniakchak River tributary, temperature was 2.96° C (37.3 °F). Salmon eggs cannot tolerate extended stream temperature below 4° C (39° F) (McCullough 1999). Temperature and pH exceeded limits in an Albert Johnson Creek slough while measured temperatures were also too high at Iris Creek, a coastal stream. Dissolved oxygen was below EPA water quality criteria for aquatic life in a slough off the Meshik River.

Turbid Creek, Section 3 of the Aniakchak River, and Meshik Lake all exceeded both the chronic (87 µg/L) and maximum (740 µg/L) EPA water quality criteria for aquatic life for aluminum. However, there are many instances where the criteria level for aluminum are exceeded under natural conditions (EPA 2002). Meshik Lake also exceeded the water quality criteria for aquatic life for iron of 1000 µg/L (EPA 2002).

Surprise Lake is classified as oligotrophic, or very low in nutrients, while Meshik is eutrophic, or high in nutrients.

Introduction

Aniakchak National Monument and Preserve is located near Port Heiden, approximately 670 km (416 mi) southwest of Anchorage on the Alaska Peninsula (Figure 1). Aniakchak caldera, the defining feature of the park, was formed during a major eruption approximately 3500 years ago (Miller and Smith 1977; Riehle et al. 1987; Beget et al. 1992). Pyroclastic flows reached both the Pacific and Bering Sea coast (Miller and Smith 1977), and attained depths of up to 70 meters (229.7 ft) or more near the caldera (Miller and Smith 1977). Known subsequent eruptions occurred about 500 years ago (McGimsey et al. 1994), and more recently in 1931 (Jagger 1932).

The Southwest Alaska Network (SWAN) includes five park units: Alagnak Wild River (ALAG), Aniakchak National Monument and Preserve (ANIA), Katmai National Park and Preserve (KATM), Kenai Fjords National Park (KEFJ) and Lake Clark National Park and Preserve (LACL).

Little information exists on water quality in these park units, and what data does exist was generally collected a decade or more ago. At Aniakchak, all previous work was conducted at Surprise Lake, and within the Meshik Lake/Meshik River system. In 1984, Wagner and Lanigan (1988) of the U.S. Fish & Wildlife Service studied the fisheries resources of the Meshik River drainage, and collected some water quality information within the Monument boundary, including the Meshik Lake outlet. Mahoney and Sonnevil (1989), also with the U.S. Fish & Wildlife Service collected basic water quality parameters at seven locations within Surprise Lake as part of a fisheries inventory, while Cameron and Larson (1992; 1993) of the Oregon State University National Park Service Cooperative Studies Unit carried out extensive studies in 1988-1989, again at Surprise Lake.

The present study was integrated with an ongoing fish inventory. Water quality data compliments fish distribution information, since poor water quality may explain the absence of fish in an otherwise suitable area. Jointly conducting water quality and fisheries inventories is also cost effective. The objectives of this study were to collect baseline information on the physical and chemical characteristics of the water resources within Aniakchak National Monument and Preserve, and, where possible, relate basic water quality parameters to fish occurrence.

Hydrography

Surprise Lake rests in the northwest corner of the Aniakchak caldera and drains via the 14. 2 km (22 mi) Aniakchak River to the Pacific Ocean at Aniakchak Bay (Figure 2, Figure 3). Numerous warm springs feed the west and southwest sides of the lake; while other tributaries are snow fed, or originate from cold springs (Cameron and Larsen 1992). The lake has a maximum depth of 19.5 m (62 feet) and a surface area of 275.2 hectares (680 acres) (Mahoney and Sonnevil 1991). “Turbid Creek” (not an official name) or T2, as it was identified by Cameron and Larson (1992), drains into the Surprise Lake outlet from an unusually turbid pond in the southeast corner of the caldera.

The Aniakchak River can be divided into four representative segments based on gradient and channel form (Figure 3). Section 1 flows through a bedrock canyon, and exhibits the highest gradient on the river. Section 2 flows through the outwash fan formed 2000 years ago by a catastrophic outburst flood from the caldera (Waythomas et. al, 1996). In Section 3, the river decreases further in gradient, and forms extensive meanders. Below Cape Horn, in Section 4, the river is tidally influenced.

Albert Johnson Creek and North Fork Aniakchak River are the largest tributaries to the Aniakchak River. Albert Johnson Creek joins the river from the south at the lower end of Section 2, while the North Fork Aniakchak River flows into the river in the lower third of Section 3.

Southeast of the caldera, Meshik Lake is a shallow, marshy lake, with a surface area of 26.7 hectares (66 acres). Meshik River drains Meshik Lake, eventually flowing into the Bering Sea.

Along the Aniakchak Pacific coast, “Iris Creek” (unofficial) is the largest stream between the Aniakchak River and Cape Ayutka. “Willow Creek” (unofficial) is a small stream draining into the south side of Amber Bay.

Methods and Materials

During 2003, a water quality technician accompanied the fish inventory project on the three sampling trips to Aniakchak: May 29 – June 13, Surprise Lake, Aniakchak River, and major tributaries; June 16 – June 24; Meshik Lake, Meshik River, and headwaters of Albert Johnson Creek; July 12 – July 21, Coastal streams and lower Aniakchak River. Core water quality parameters including temperature, pH, specific conductance (conductivity compensated for temperature), and dissolved oxygen (Freshwater Workgroup Subcommittee 2002) and turbidity were measured in surface waters with a YSI 6600 multi-parameter sonde unit at fish sampling sites, or other areas of interest in Surprise Lake, the Aniakchak River, Meshik Lake, Meshik River, tributaries to these waterbodies, and selected coastal streams (Figure 3).

Discharge measurements (Rantz 1982) were taken with a Marsh McBirney Flowmate 2000 in most streams where fish and/or water quality were sampled, including flow measurements on the upper and lower Aniakchak River. Lake levels were estimated following NPS Water Resource Division procedures (Freshwater Workgroup Subcommittee 2002).

Water samples for lab analysis were collected at Surprise Lake, Turbid Creek, Albert Johnson Creek, North Fork Aniakchak, Meshik Lake, and in Sections 1-3 in the Aniakchak River (Figure 3). Parameters analyzed included: total suspended solids, total dissolved solids, major ions, nutrients, alkalinity, and trace metals (Tables 2a, 2b). This study attempted to replicate a subset of the Cameron and Larson (1992) sample sites as closely as possible, but their sample locations are only plotted on maps and not georeferenced.

A lake profile was taken near the deepest portion of Surprise Lake, at Cameron and Larson’s ML-1, and Mahoney and Sonnevil’s Site B. Water quality measurements were taken with the YSI at intervals of 1 meter for the first five meters, and thereafter at every five meters. Meshik Lake has a maximum depth of 1.2 m (4 feet), so only surface and bottom measurements were taken.

Coordinates in Lat/Long decimal degrees and WGS84 datum of sampling sites were collected with a Garmin GPS Map 76s (Tables 1a-1f). Data has not been differentially corrected nor was it averaged. Data were transferred into ArcView, and converted to NAD27 datum.

Results

Field Parameters: Temperature, Dissolved Oxygen, Specific Conductance, pH, and Turbidity

In the Aniakchak drainage, temperatures ranged from 20.16 to 20.39° C (68.3 to 68.7° F) at WS-4, a known warm springs tributary to I-11 which flows into Surprise Lake, to 2.96° C (37.3 °F) at Turbid Creek, a tributary that drains the southeast section of the caldera (Table 1a-1f). In June, water temperature in the Aniakchak River rose from 6.55° C (43.8° F) at the lake outlet, to 10.9° C (51.6° F) in the outwash section of the river. After three days of rain, and an influx of colder water from the North Fork, temperatures in the Sections 3 were measured at 8.09° C (46.6 ° F).

The lowest water temperature in the Meshik River drainage (5.48° C, 41.9° F) was found in a backwater area to the river; the highest, at 13.14° C (55.7° F), was in the mainstem river. Meshik lake surface temperatures were 12.12° C (53.8° F) on June 19; five days later and after 30 hours of rain, the temperature had dropped to 9.57° C (49.2° F).

Iris Creek, a moderately sized stream that drains into Amber Bay, had water temperatures below the first tributary ranging from 20.1 to 21.45° C (68.2 to 70.6° F) on July 15, the warmest water temperatures measured in Aniakchak in 2003. Three days later, after a period of rain, water temperature was measured at 10.01° (50.0° F) about 0.5 kilometer (0.3 miles) above the first tributary.

Dissolved oxygen approached or exceeded 100% saturation throughout all sampled watersheds, with only a few exceptions (Table 1a-1f). Two warm springs influenced tributaries to Surprise Lake, WS-4/I-11, and I-9.5, had levels of 0.86 mg/l (9.6%) and 6 mg/l (55%) respectively. Low dissolved oxygen of 2.77 mg/l (22%) was also found in a Meshik River backwater. Dissolved oxygen in coastal streams ranged from 10.15 mg/l (87.4 %) to 11.55 mg/l (130.7%).

In the Aniakchak River drainage, specific conductance was highest at the WS-4 warm springs, (734 - 998 µs/cm), lower in Surprise Lake (387 surface, 398 µs/cm bottom), than dropped downriver, as tributaries with lower specific conductance emptied into the mainstem (121 µs/cm at the lowest measurement before tidal influence) (Table 1a-1f). The highest specific conductance measured was 1258 µs/cm at a small, spring fed tributary to the lower, tidally influenced section of the river.

Other tributaries had much lower conductivities. Albert Johnson Creek ranged from 63µs/cm in the headwaters to 95 µs/cm near the confluence with the Aniakchak River, while the North Fork measured 53 µs/cm. Specific conductance in the Meshik River drainage ranged from 89 µs/cm at Meshik lake to 64-91 µs/cm in the river and tributaries. The highest reading in the Meshik drainage was 226 µs/cm, taken in a backwater (Tables 1a-1f). Despite some measurements in tidally influenced areas, all coastal streams were less than 100 µs/cm.

pH was neutral to alkaline (basic) in the majority of waters through out the sampling area (Table 1a-1f). Warm spring tributaries to Surprise Lake were the exception, with a pH of 5.83 to 6.69, while Surprise Lake offshore of the warm springs area showed a surface pH of 5.91.

The Aniakchak River ranged from a pH of 7.59 at the outlet to 8.44 in the outwash section, than dropped to 7.8 below the North Fork. Again, this final measurement was taken after three days of rain. Albert Johnson creek was the most alkaline of all the tributaries, with pH measuring 8.64 in the lower reaches, but 7.48 to 7.81 in the headwaters. An Albert Johnson Creek slough had the highest recorded pH of 9.68.

Meshik Lake, Meshik River and their tributaries had a generally alkaline pH, with a range from 7.61 to 8.36. Coastal streams showed a similar variation in pH, with ranges from 6.87 at “Willow Creek” to 8.11 at “Iris Creek” (Tables 1a-1f).

Turbidity was generally less than 20 NTU, and frequently at or near 0 NTU throughout the Aniakchak River drainage (Table 1a-1f). Turbidity in Surprise Lake and tributaries ranged from 0 to 12 NTU; higher readings were taken (242 NTU in I-10, 1280.5 NTU at the bottom of Surprise Lake) but were assumed to be from inadvertent physical disturbance of the substrate by the water quality probe. The Aniakchak River measured 13.2 NTU near the lake outlet, dropped to 2.7 in the outwash section, but rose from 14 near the North Fork to 18.7 in the tidally influenced area.

Meshik Lake had varying turbidities (12.1 to 46.7), but was generally around 40 NTU, while the river and tributaries ranged from 0.4 to 5.9 NTU. Coastal drainages showed the effects of rain, with Iris Creek measuring 0.8 to 2.6 NTU before (although in the lower river) and 39 NTU in the upper river after sustained rain. Willow Creek was only measured after significant precipitation; turbidity ranged from 11.4 to 24.9 NTU.

Surprise Lake Profiles

Surprise Lake was not stratified, with surface temperature, Do, specific conductance, pH and turbidity showing little significant change with depth at station ML-1, the deepest part of the lake (Table 1b). Offshore of the warm

springs area, temperature and specific conductance showed a slight increase with depth (6.49 to 7.00° C; 328 to 388 µs/cm) while dissolved oxygen and pH slightly increased until reaching depths of 6 to 9 ft, and than decreased. (dissolved oxygen: 10.55 to 12.09 to 11.31; pH: 5.9 to 7.14 to 6.81).

Alkalinity

Alkalinity is a measure of the buffering capacity of water, or its ability to resist changes in pH. In this study, it ranged from 15 to 152 mg/L with values dropping from Surprise Lake down the Aniakchak River (Table 2). Measurements were lower in the tributaries; Albert Johnson Creek had the highest tributary value (33.8 mg/l), while the North Fork Aniakchak River had the lowest (15 mg/l). Meshik Lake alkalinity was measured at 31 mg/l (Table 1).

Nutrients

Total nitrate/nitrite was below the detection level of 0.095 mg/L in all sampled locations (Table 2). Kjeldahl nitrogen (organic) ranged from 1.1 to 1.9 mg/L in the Aniakchak River and Meshik Lake, and was below the minimum detection level of 0.33 mg/L in Surprise Lake and the three Aniakchak River tributaries. Total phosphorous ranged from 0.08 to 0.22 mg/l while potassium ranged from 0.442 to 3.9 mg/l. Kjeldahl nitrogen and phosphorous levels were highest in Meshik Lake.

Chlorophyll-*a* was only analyzed at Surprise (0.534 mg/l) and Meshik Lakes (16 mg/l) due to misplacement of the filtering device on the Aniakchak River float trip. High chlorophyll-a levels in Meshik Lake and a brown/green color to the water suggest a plankton bloom was occurring. Water color was still very turbid and green during an unrelated visit July 24 - 27. Dissolved organic carbon was below detection levels of 1 mg/L at five sampling sites and 1.4 mg/l at Meshik Lake. One sample was not collected in the field and a second was lost in the lab (Table 2).

Major Ions and Trace Elements

The highest major ion concentrations (Table 2) were found in Surprise Lake, and than dropped at each subsequent downstream location on the Aniakchak River (Table 2). The North Fork Aniakchak River had the lowest concentrations of calcium and magnesium. Trace elements were generally low with cadmium, copper and lead not detected in all eight, four of eight, and five of eight sampling locations (Table 2). Meshik Lake, the North Fork Aniakchak River, and the main Aniakchak River below the North Fork had elevated aluminum and iron concentrations. Surprise Lake also had high iron concentrations, but less than Meshik Lake.

Discharge and Lake Levels

Surprise Lake was considered to be at mean seasonal level, based on the relationship of the waterline to moss on adjacent rocks. Meshik Lake was initially at mean level, based on beach exposures, but than rose during two days of rain.

Discharge of the Aniakchak River increased from 222 cfs at the lake, to 1223 below the North Fork. Turbid Creek, at 23.8 cfs, accounted for 1.9% of the mainstem flow, Albert Johnson Creek (75.2 cfs) was 6.1%, and the North Fork (231.1 cfs) was 18.9%. These discharges were taken over a four day span, with a period of rain preceding the North Fork and lower river discharge measurements, so correlations between streams, and between streams and the mainstem are poor.

Meshik River discharge at the lake outlet was measured at 10.0 cfs on June 18. Two days later, a large tributary was measured at 21.9 cfs, and the river just below this tributary was measured at 23.9 cfs.

Discussion

Field Parameters: Temperature, Dissolved Oxygen, Conductivtiy, pH, and Turbidity

Water temperature at I-11, a warm springs tributary to Surprise Lake which corresponds to the WS-4 warm springs complex of Cameron and Larson (1992), were too high to support salmonids. On May 31, water temperature ranged from 20.16 to 20.39° C (68.3-68.7° F). These temperatures exceeded the point (15.6° C or 60.0° F) at which spawning salmon show an increased incidence of disease for sustained temperatures, and approached 21 -22° C (69.9 – 71.6° F), the temperature range which forms a migration barrier for salmonids, and the upper tolerance limit for juveniles (McCullough 1999). These temperatures also surpassed the disease threshold of 17° C (62.6°F) for juveniles (McCullough 1999). Other studies (Hamon 2001, Mahoney and Sonnevil 1991), as well as the fish inventory accompanying this study (Miller and Markis 2004), found no indications of use by sockeye or chum salmon or Dolly Varden, the only salmonids known to use the Surprise Lake area.

Other studies found similar temperatures in these warm springs. During July 26-28, 1987, Mahoney and Sonnevil (1991) measured stream temperature at 19.4 ° C at the lower end of the stream draining this warm springs complex. Cameron and Larson (1992, 1993), on August 18, 1988, measured temperatures of 23.9, 20.6, and 19.9° C at springs in the WS-4 complex, and took an additional reading of 21.3 in lower I-11, the Surprise Lake tributary to which WS-4 contributes.

Additional sites with water temperatures that fell outside the guidelines for aquatic life include an Albert Johnson Creek slough with a temperature of 17.53° C (63.6° F) on June 6, and Turbid Creek, with a June water temperature of 2.96°

C (37.3 °F). McCullough (1999) states salmonids eggs cannot tolerate extended temperatures of less than 4° C (39° F). Eighty-three juvenile silver salmon were caught near the water quality sampling site in the Albert Johnson Creek slough; Turbid Creek was not sampled for fish.

Temperatures within the Meshik River drainage were well within guidelines for salmonids during this study. However, Wagner and Lanigan (1988) recorded a water temperature of 18° C (64.4° F) with a handheld thermometer on June 5, 1984, which could indicate that at times water temperatures approach stressful levels for salmonids.

On July 15, water temperatures of 20.1 to 21.45° C in lower Iris Creek approached the upper tolerance limit for juveniles (McCullough 1999). However, 38 juvenile silver salmon were caught in the vicinity of these readings, and rainbow/steelheads were identified in other reaches of Iris Creek (Miller and Markis 2004). Thus, either these water temperatures are quite uncommon and attained for only short periods of time, temperature refugia are found nearby, or these populations of salmonids have adapted to a greater temperature range than that measured by McCullough (1999) for Columbia River salmonids.

Dissolved oxygen levels at two sampling sites in this study were less than the EPA minimum regulatory limits of 4 mg/L for coldwater aquatic life (EPA 1986), and one site did not meet the minimum limit of 8 mg/L for embryonic life stages of coldwater aquatic life. All three readings at WS-4, the same group of warm springs with temperature limitations, were less than 2 mg/L, ranging from 9.6 to 16.1%. Dissolved oxygen levels at or below 3 mg/l are generally lethal for salmonids (EPA 1986, Flora et al. 1984). Cameron and Larson (1992) measured dissolved oxygen with a Hydrolab model 4041-110 sonde probe at WS-4 in August at 13.0 %. Cameron and Larson (1992) also attempted to determine dissolved oxygen at WS-4 with the Winkler titrametric method on six additional occasions but levels were too low for analysis. In 1987, Mahoney and Sonnevil recorded dissolved oxygen in this stream at 2.5 mg/L using a Hydrolab.

The fish inventory associated with this study seined Dolly Varden from I-9.5, a nearby slough with dissolved oxygen readings of 6 mg/L (55 %) (Miller and Markis 2004). Neither Cameron and Larson (1992, 1993) nor Mahoney and Sonnevil (1991) sampled this location.

A slough off the Meshik River also did not meet minimum EPA regulatory dissolved oxygen limits. Although one blackfish was captured at this location, dissolved oxygen only recorded at 2.7 mg/L (22 %). This sampling location had normal pH (7.69), but lower temperatures (5.48° C, 41.9° F), and, for this drainage, elevated specific conductance (226 µs/cm). Blackfish are known for their tolerance of low dissolved oxygen.

Specific conductance measurements from this study correlate reasonably well with previous work at Surprise Lake, despite differences in instrumentation. Cameron and Larson measured specific conductance at Surprise Lake tributaries with a Hydrolab, and samples were collected at the same locations for analysis at the Alaska Department of Fish and Game limnology lab. Their Hydrolab readings were consistently higher than the lab samples. Results from this study are comparable with their lab analysis. Water samples taken by Cameron and Larson at I-10 for specific conductance were measured at 275 µs/cm, and at I-11 at 774 µs/cm in June of 1988, whereas this study found specific conductance to vary from 246 to 270 µs/cm for three measurements at I-10. One sample site for this study in I-11 ("at lower warm springs") recorded at 734 µs/cm, while the "upper warm springs" measured 936-989 µs/cm. Mahoney and Sonnevil (1987) reported specific conductivity for I-11 at 901 µs/cm. Two additional readings at I-11 during this study, presumably in a non warm springs influenced tributary, recorded at 89. Cameron and Larson found little change in specific conductance readings in I-10 throughout the season (275-292 µs/cm), with greater variability in I-11 (774-903 µs/cm). Variability was associated with rainfall and snowmelt (Cameron and Larson 1992).

Mahoney and Sonnevil (1987) in late July of 1987 found that specific conductance at ML-1 increased from 387 at the surface to 394 µs/cm at 19 m, with a measurement of 392 µs/cm at 13 and 15 m. In June of 1988, Cameron and Larson (1992) found specific conductance at ML-1 varying from 383 µs/cm at the surface to 387 µs/cm at 3 m to 383 µs/cm at their last sample at 14 m. This study measured specific conductance at 387 µs/cm at the surface down to 14 m, than rising to 398 at the bottom.

pH is influenced by many factors, including temperature, dissolved oxygen, and various anions and cations, but a range of 6.5 to 9.0 is the regulatory criteria for freshwater aquatic life (EPA 1986). The majority of pH readings in Aniakchak National Monument and Preserve fell within this range (Table 1a-1f). The Surprise Lake tributary and warm spring complex I-11/WS-4 had low pH readings ranging from 5.76 to 6.39, and a Surprise Lake profile near the outlet of this warm springs complex had a pH of 5.9. The upper pH limit was only exceeded once, with a reading of 9.68 at an Albert Johnson Creek slough. Despite the high pH, 83 silver salmon were captured in this slough (Miller and Markis 2004).

Cameron and Larson (1992) and Mahoney and Sonnevil (1987) also found pH at I-11 to be less than the regulatory criteria, with eleven measurements by the former ranging from 5.6 to 6.2, and the later reporting a reading of 5.25. This study measured pH at I-10 at 6.51-6.55, or just above the lower regulatory limit of 6.5. Cameron and Larson reported a range of 6.3 to 6.8 over 12 readings but only 4 were less than 6.5. Mahoney and Sonnevil recorded pH at 1-10 as 6.15.

Alkalinity

All alkalinity samples for Aniakchak were above 10 mg/L, the generally accepted level for vulnerability to changes in pH from natural and human caused sources (Table 1a-1f). Schindler (1988) states that average ratios of alkalinity to calcium plus magnesium (in millequivalents) in lakes of pristine areas usually range from 0.6 to 1.1. In 2003, Surprise Lake had a ratio of 1.4, while Meshik had a ratio of 1.1, indicating that there is little anthropogenic acid deposition. Although Schindler (1988) does not address streams, ratios for streams ranged from 0.8 to 1.4.

Nutrients

Surprise Lake is oligotrophic, or having low biologic productivity. Meshik Lake would be considered eutrophic due to high chlorophyll-*a* readings, although nitrogen and phosphorous readings were in the range of other oligotrophic lakes. Meshik Lake is very shallow and surrounded by wetlands, which may contribute to its high productivity.

Major Ions and Trace Elements

In a comparison of the proportion of major cations, the upper Aniakchak watershed (Surprise Lake and the Aniakchak River, Section 1) was dominated by sodium, followed by magnesium, calcium and potassium. The lower Aniakchak River (Section 2, Section 3), as well as Albert Johnson Creek, were similarly dominated by sodium, but calcium and magnesium were reversed. Calcium was the foremost ion in Turbid Creek, North Fork Aniakchak River, and Meshik Lake, followed by sodium, magnesium and potassium. Calcium and magnesium in Surprise Lake and all three samples sites on the Aniakchak River were always within four percentage points of each other, whereas calcium and magnesium for Meshik Lake and Aniakchak River tributaries had a spread of from 12 to 35 percentage points. For anions, Meshik was strongly sulfate controlled, Turbid was somewhat higher in sulphate than chloride, and the remainder were dominated by chloride, with Albert Johnson Creek strongly so. High sodium and chloride levels are likely due to the close proximity to the ocean. These results should be viewed with caution, since they are based on one sample point for each water body.

LaPerriere (1996) found the eleven lakes that she studied in Katmai to be dominated by calcium followed by sodium. Magnesium was only slightly less than sodium but like this study, potassium levels were considerably less**.**

Aluminum concentrations in Turbid Creek, the main Aniakchak River below the North Fork, and Meshik Lake appear to be elevated, and probably exceed both the EPA chronic (CCC or criteria continuous concentration) and maximum (CMC or criteria maximum concentration) concentrations of 87 and 740 µg/L, respectively (EPA 2002). Although these aluminum levels are from filtered samples, whereas the EPA criteria are based on unfiltered samples, filtered

samples should have lower levels. Aluminum toxicity has been shown to decrease with higher pH and hardness, and there are many instances where the criteria levels of aluminum are exceeded under natural conditions (EPA 2002). LaPerriere (1996) found repeated high aluminum concentrations in the Savonoski and Ukak Rivers and in Up-a-Tree and Headwaters Creek, both tributaries to Brooks Lake. Aluminum was also high in additional streams where, like this study, only one measurement was made.

The Meshik Lake sample (3320 µg/L) also exceeded the EPA chronic criteria for iron but all other locations were less than the 1000 µg/L criteria (EPA 1999). Concentrations of arsenic, cadmium, copper, lead, and zinc at all sample locations met EPA aquatic life criteria (EPA 2002).

Discharge and Lake Levels

Cameron and Larson (1992) found that the three tributaries to Surprise Lake (I-9, I-10, I-11), contributed 14.4%, 65.6%, 14.9%, and of all surface flow to Surprise Lake, whereas this study found that they contributed only 5.7%, 22%, and 6.8%. However, Cameron and Larson measured all the major tributaries to the lake and computed a percentage of their total, whereas this study took a percentage of the discharge at the lake outlet. Cameron and Larson did not measure discharge at the lake outlet, and they suggest that groundwater may directly enter the lake floor at some locations.

The Meshik River and tributary measurements are contradictory and cannot be explained.

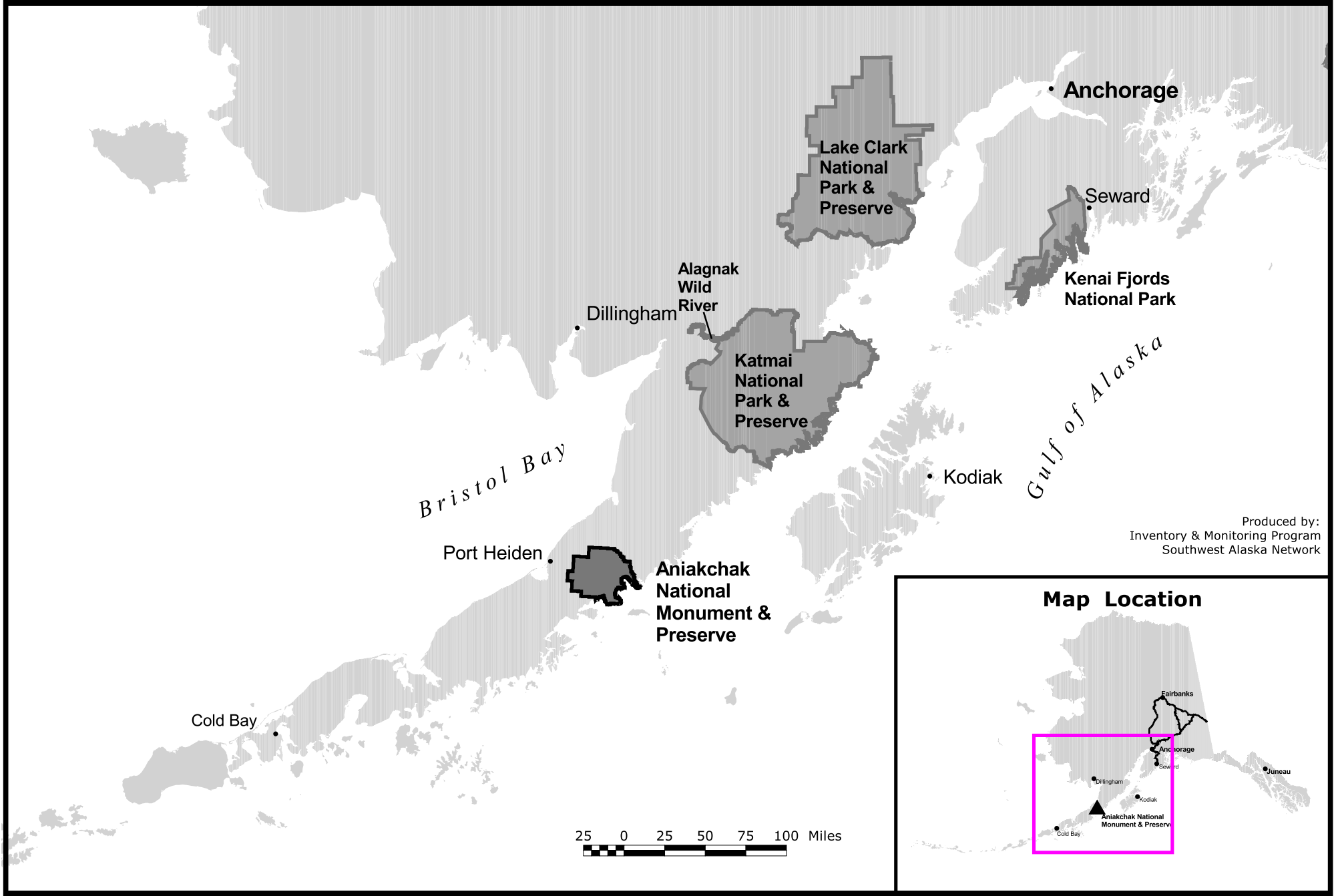
Plans for Coming Year

The water quality inventory will be continued in Kenai Fjords in 2004.

Figure 1. Southwest Alaska Network

Location of Aniakchak National Monument & Preserve

National Park Service
U.S. Department of the Interior



April 1, 2003

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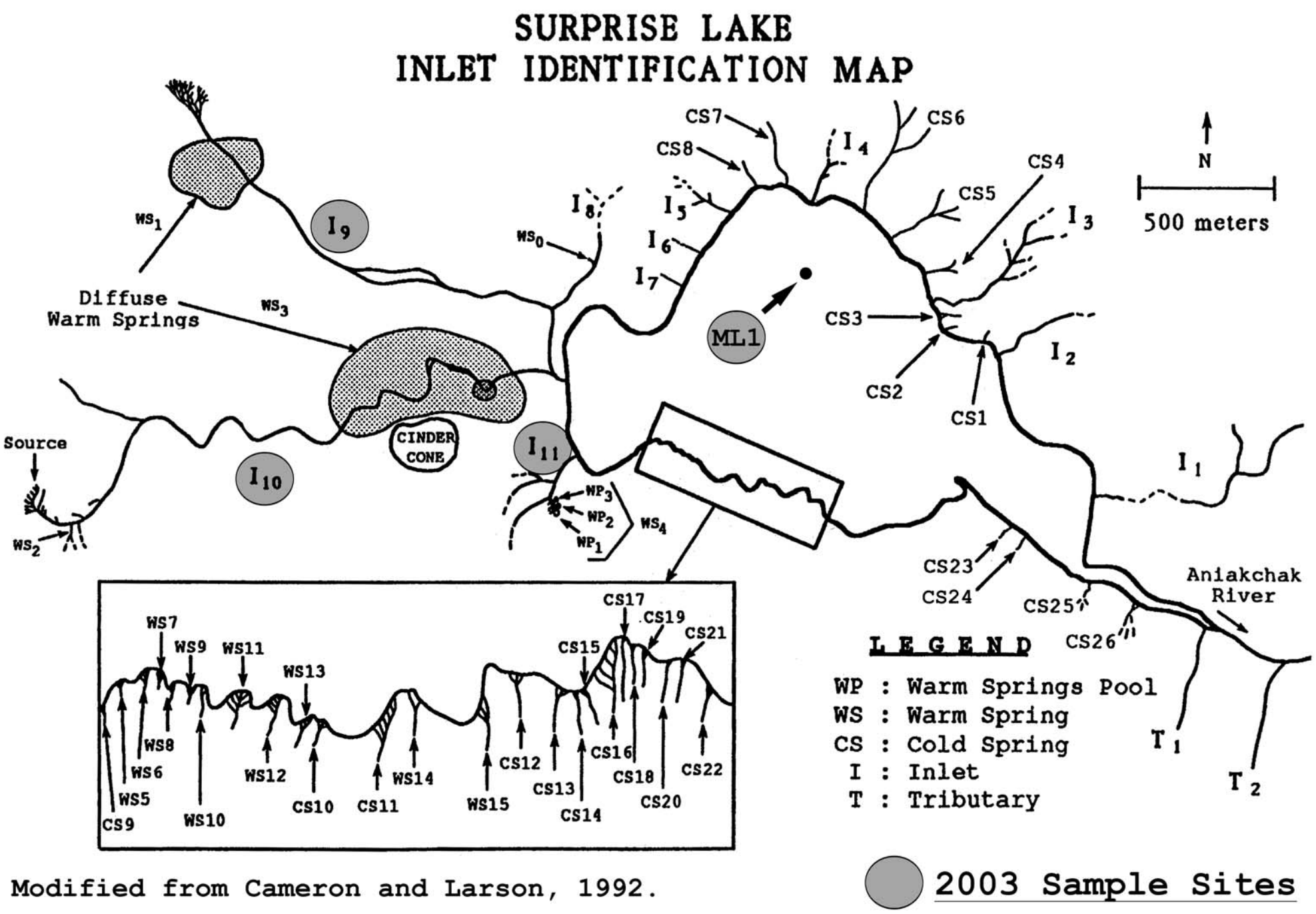
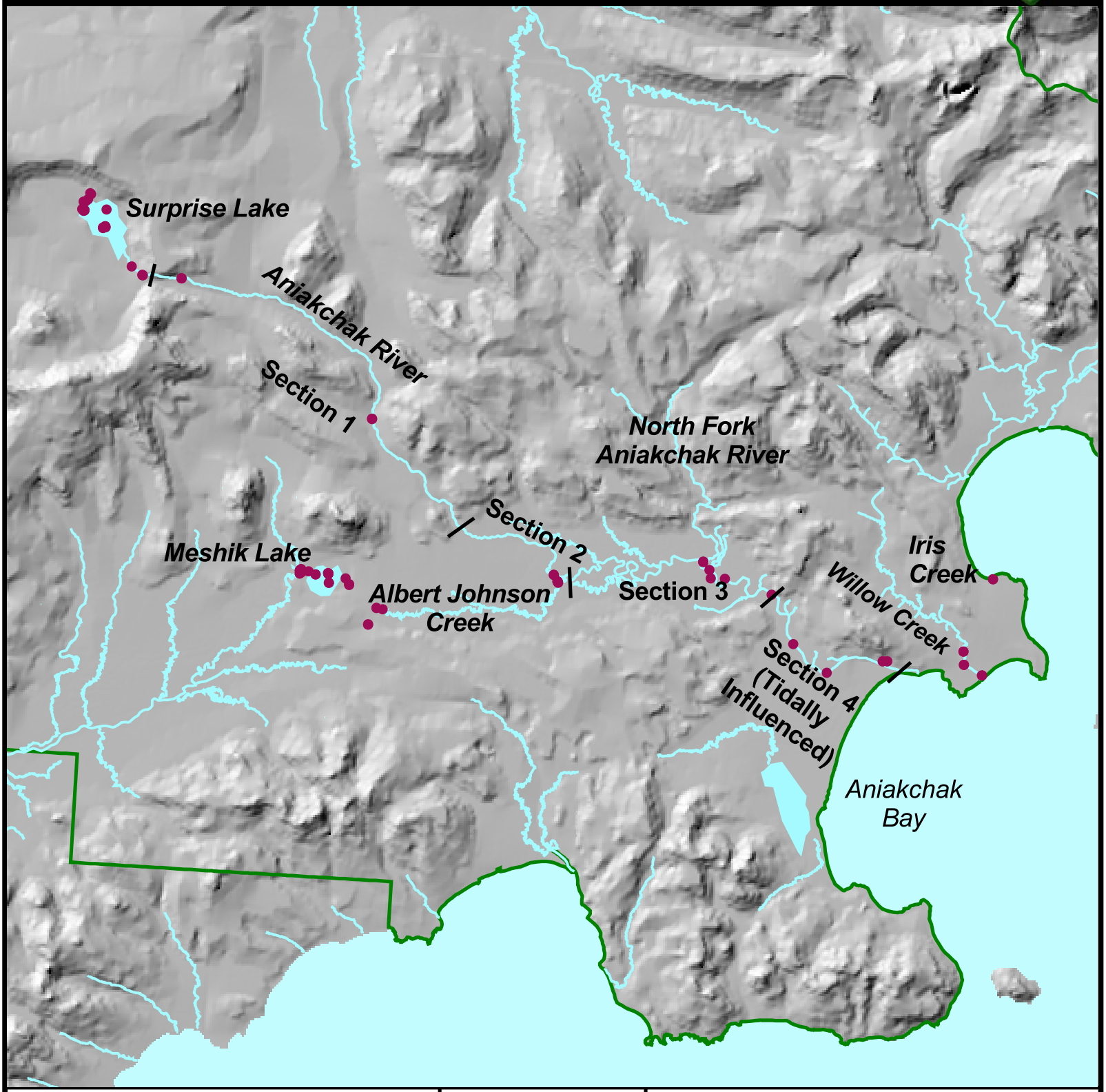
Figure 2. Aniakchak National Monument & Preserve
Water Quality Inventory, Surprise Lake Sample Sites, 2003



Modified from Cameron and Larson, 1992.

Figure 3. Aniakchak Water Quality Inventory, 2003

National Park Service
U.S. Department of the Interior



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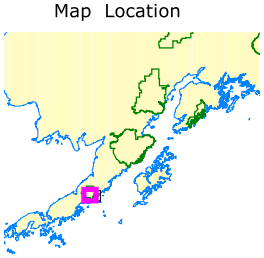
Map Location



Southwest Alaska Network
Aniakchak National Monument and Preserve

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W E
S

2.5 0 2.5 5 7.5 10 12.5 Kilometers

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August 9, 2004

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Table 1a. Core Water Quality Parameters, Surprise Lake Tributaries, Aniakchak Water Quality Inventory 2003										
Sample	Site ID	Fish Sample Site No.	Cameron Larson ID	Date	Time	Latitude	Longitude	Temp (C)	Discharge (cfs)	Specific Conductance (µS/cm)
I11_99	I-11 stream	I11	I-11	5/31/2003	13:40:00	56.928593	-158.125657		15.2	
I11_0	I-11 stream		I-11	5/31/2003	13:42:50	56.928540	-158.125700	20.39		936
I11_1	I-11 stream @ upper warm spring		I-11	5/31/2003	13:47:10	56.928427	-158.126025	20.38		998
I11_2	I-11 stream @ lower warm spring		I-11	5/31/2003	13:51:14	56.928255	-158.1263183	20.16		734
I11_3	I-11 trib		I-11	5/31/2003	13:59:37	56.928907	-158.1272467	7.44		89
I11_4	I-11 trib		I-11	5/31/2003	14:00:46	56.928898	-158.1272133	7.86		89
I10_0	I-10 stream		I-10	5/31/2003	14:36:13	56.932202	-158.1250483	8.58	49	270
I10_1	I-10 stream		I-10	5/31/2003	14:38:55	56.932113	-158.1255867	8.54		246
I10_2	I-10 stream		I-10	5/31/2003	14:41:39	56.931998	-158.1266283	8.44		265
I9-5_0	I-9.5	SURP 032	NA	5/31/2003	14:52:14	56.932918	-158.1234217	11.41		135
I9_0	I-9 stream	SURP 033	I-9	5/31/2003	15:06:41	56.935132	-158.1216467	9.27	12.6	132
I9_1	I-9 stream	SURP 034	I-9	5/31/2003	15:11:52	56.935482	-158.12225	8.34		122

Sample	BP (psi)	DO (%)	DO (mg/L)	Depth (ft)	pH	Turbidity YSI (NTU)	Total Dissolved Solids YSI (g/L)
I11_99							
I11_0	13.9	16.1	1.45	-0.161	5.83	0	0.609
I11_1	13.92	9.6	0.86	-0.148	5.83	2.1	0.649
I11_2	13.92	10.6	0.96	-0.136	5.76	-0.9	0.477
I11_3	13.93	88.5	10.63	-0.145	6.38	-1.1	0.058
I11_4	13.93	88.8	10.55	-0.142	6.39	-1.2	0.058
I10_0	13.93	97	11.32	0.211	6.55	242.6	0.176
I10_1	13.92	98.5	11.51	-0.183	6.51	0	0.16
I10_2	13.91	97	11.36	-0.17	6.53	0.6	0.172
I9-5_0	13.91	55	6	-0.108	6.69	-1	0.088
I9_0	13.94	105.8	12.15	-0.147	7.31	-1	0.086
I9_1	13.92	103.3	12.13	0.058	7.25	-1.1	0.079

Table 1b. Core Water Quality Parameters, Surprise Lake, Aniakchak Water Quality Inventory 2003												
Sample	Site ID	Fish Sample Site No.	Cameron Larson ID	Date	Time	Latitude	Longitude	Temp (C)	Comment	Specific Conductance (µS/cm)	Barometric Pressure (psi)	Dissolved Oxygen (%)
SURPRISE_0	Surprise Lake spring profile 1	SURP 001		5/29/2003	18:33:09	56.9219233	-158.111312	6.49	water level normal: moss, beach exposure	328	14.04	85.9
SURPRISE_1	Surprise Lake spring profile 1	SURP 002		5/29/2003	18:43:18	56.9220783	-158.111247	8.27		390	14.03	102.1
SURPRISE_2	Surprise Lake spring profile 1	SURP 002		5/29/2003	18:46:09	56.9220217	-158.11128	7.87		377	14.04	96.1
SURPRISE_3	Surprise Lake spring profile 2	Loc A		5/29/2003	18:50:11	56.92255	-158.109863	7.56		373	14.04	101.1
SURPRISE_4	Surprise Lake spring profile 2	Loc A		5/29/2003	18:51:02	56.9225833	-158.109782	7.54		374	14.04	100.9
SURPRISE_5	Surprise Lake spring profile 2	Loc A		5/29/2003	18:52:56	56.9226	-158.109587	7.5		376	14.04	100.9
SURPRISE_6	Surprise Lake spring profile 2	Loc A		5/29/2003	18:54:04	56.9225917	-158.10957	7.44		376	14.04	100.3
SURPRISE_7	Surprise Lake spring profile 2	Loc A		5/29/2003	18:56:22	56.922485	-158.109538	7.35		378	14.03	99.6
SURPRISE_8	Surprise Lake spring profile 2	Loc A		5/29/2003	18:57:59	56.9223717	-158.109375	7.26		377	14.03	97.8
SURPRISE_9	Surprise Lake spring profile 2	Loc A		5/29/2003	19:02:45	56.9223067	-158.109603	7.00		388	14.03	93.3

Sample	Dissolved Oxygen (mg/L)	Depth (ft)	pH	Turbidity YSI (NTU)	Total Dissolved Solids YSI (g/L)
SURPRISE_0	10.55	0.078	5.9	4	0.213
SURPRISE_1	12	0.593	6.88	11.3	0.254
SURPRISE_2	11.4	3.329	6.6	11.9	0.245
SURPRISE_3	12.09	1.126	7.11	7.8	0.243
SURPRISE_4	12.07	3.361	7.1	7.7	0.243
SURPRISE_5	12.08	6.437	7.14	7.7	0.244
SURPRISE_6	12.03	9.068	7.09	7.8	0.245
SURPRISE_7	11.98	12.02	7.07	8	0.246
SURPRISE_8	11.78	15.7	6.84	7.5	0.245
SURPRISE_9	11.31	22.79	6.81	17.2	0.252

Sample	Site ID	Fish Sample Site No.	Cameron Larson ID	Date	Time	Latitude	Longitude	Temp (C)	Comment	Specific Conductance (µS/cm)	Barometric Pressure (psi)	Dissolved Oxygen (%)
SURPRISE_10	Lake Profile	Surprise M1	ML1	6/2/2003	9:17:28	56.930437	-158.105403	7.44	Secchi depth: 1.5 m	387	14.15	97.5
SURPRISE_11	Lake Profile	Surprise M1	ML1	6/2/2003	9:17:58	56.930485	-158.105403	7.44		387	14.16	97.6
SURPRISE_12	Lake Profile	Surprise M1	ML1	6/2/2003	9:19:36	56.930705	-158.105730	7.43		387	14.15	97.6
SURPRISE_13	Lake Profile	Surprise M1	ML1	6/2/2003	9:21:56	56.930843	-158.106348	7.43		387	14.16	97.2
SURPRISE_14	Lake Profile	Surprise M1	ML1	6/2/2003	9:23:15	56.930843	-158.106592	7.43		387	14.15	97.1
SURPRISE_15	Lake Profile	Surprise M1	ML1	6/2/2003	9:25:50	56.930770	-158.107227	7.44		387	14.15	97.1
SURPRISE_16	Lake Profile	Surprise M1	ML1	6/2/2003	9:26:37	56.930778	-158.107128	7.45		387	14.15	97.2
SURPRISE_17	Lake Profile	Surprise M1	ML1	6/2/2003	9:27:35	56.930810	-158.107210	7.44		387	14.15	97.1
SURPRISE_18	Lake Profile	Surprise M1	ML1	6/2/2003	9:29:38	56.930550	-158.107617	7.38		387	14.15	97.2
SURPRISE_19	Lake Profile	Surprise M1	ML1	6/2/2003	9:30:19	56.930477	-158.107780	7.45		387	14.15	97
SURPRISE_20	Lake Profile	Surprise M1	ML1	6/2/2003	9:33:14	56.930192	-158.108528	7.43		387	14.15	96
SURPRISE_21	Lake Profile	Surprise M1	ML1	6/2/2003	9:33:55	56.930110	-158.108562	6.96		389	14.16	94.9
SURPRISE_22	Lake Profile	Surprise M1	ML1	6/2/2003	9:34:46	56.930037	-158.108643	6.87		388	14.16	94.7
SURPRISE_23	Lake Profile	Surprise M1	ML1	6/2/2003	9:35:10	56.930013	-158.108675	6.8		388	14.16	94.3
SURPRISE_24	Lake Profile	Surprise M1	ML1	6/2/2003	9:38:10	56.929615	-158.108562	6.7		389	14.16	94
SURPRISE_25	Lake Profile	Surprise M1	ML1	6/2/2003	9:40:21	56.929362	-158.108757	6.58		391	14.16	92.2
SURPRISE_26	Lake Profile	Surprise M1	ML1	6/2/2003	9:41:12	56.929387	-158.108838	6.58		391	14.16	90
SURPRISE_27	Lake Profile	Surprise M1	ML1	6/2/2003	9:42:22			6.63		390	14.16	91.5
SURPRISE_28	Lake Profile	Surprise M1	ML1	6/2/2003	9:42:38	56.929435	-158.109050	6.58		398	14.16	91.7
SURPRISE_29	Lake Profile	Surprise M1	ML1	6/2/2003	9:42:42	56.929443	-158.109050	6.58		397	14.16	91.6
SURPRISE_30	Lake Profile	Surprise M1	ML1	6/2/2003	9:43:16	56.929492	-158.108935	6.69		389	14.16	90.2
SURPRISE_31	Lake Profile	Surprise M1	ML1	6/2/2003	9:43:19	56.929427	-158.109065	6.7		389	14.16	90.5
SURPRISE_32	Lake Profile	Surprise M1	ML1	6/2/2003	9:43:45	56.929427	-158.109147	6.75		387	14.16	91.9
SURPRISE_33	Lake Profile	Surprise M1	ML1	6/2/2003	9:44:09	56.929435	-158.109197	6.87		388	14.16	93
SURPRISE_34	Lake Profile	Surprise M1	ML1	6/2/2003	9:44:27	56.929395	-158.109310	7.28		389	14.16	93.7
SURPRISE_35	Lake Profile	Surprise M1	ML1	6/2/2003	9:45:09	56.929330	-158.109358	7.45		387	14.16	95.8
SURPRISE_36	Lake Profile	Surprise M1	ML1	6/2/2003	9:45:28	56.929345	-158.109375	7.45		386	14.16	96.3
SURPRISE_37	Lake Profile	Surprise M1	ML1	6/2/2003	9:45:49	56.929353	-158.109408	7.47		386	14.16	96.7
SURPRISE_38	Lake Profile	Surprise M1	ML1	6/2/2003	9:46:20	56.929345	-158.109375	7.48		386	14.16	96.9
SURPRISE_39	Lake Profile	Surprise M1	ML1	6/2/2003	9:46:24	56.929338	-158.109358	7.48		386	14.16	97
SURPRISE_40	Lake Profile	Surprise M1	ML1	6/2/2003	9:47:02	56.929313	-158.109342	7.45		387	14.16	97.2
SURPRISE_41	Lake Profile	Surprise M1	ML1	6/2/2003	9:47:40	56.929297	-158.109375	7.45		386	14.16	97.1
SURPRISE_42	Lake Profile	Surprise M1	ML1	6/2/2003	9:48:14	56.929297	-158.109408	7.5		386	14.16	97.1
SURPRISE_43	Lake Profile	Surprise M1	ML1	6/2/2003	9:48:51	56.929313	-158.109473	7.49		386	14.16	97.2
SURPRISE_44	Lake Profile	Surprise M1	ML1	6/2/2003	9:49:20	56.929313	-158.109488	7.49		386	14.16	97.2
SURPRISE_45	Lake Profile	Surprise M1	ML1	6/2/2003	9:49:59	56.929338	-158.109440	7.47		386	14.16	97.3

Sample	Dissolved Oxygen (mg/L)	Depth (ft)	pH	Turbidity YSI (NTU)	Total Dissolved Solids YSI (g/L)
SURPRISE_10	11.7	6.396	7.32	8.3	0.251
SURPRISE_11	11.71	3.221	7.32	8.3	0.251
SURPRISE_12	11.71	9.137	7.31	8.4	0.251
SURPRISE_13	11.67	13.21	7.31	8.3	0.251
SURPRISE_14	11.65	14.87	7.31	8.4	0.252
SURPRISE_15	11.65	21.3	7.32	8.2	0.252
SURPRISE_16	11.65	25.46	7.31	8.2	0.252
SURPRISE_17	11.64	29.08	7.31	8.4	0.252
SURPRISE_18	11.67	34.87	7.32	8.1	0.252
SURPRISE_19	11.63	32.25	7.32	8.1	0.252
SURPRISE_20	11.52	41.83	7.29	8	0.252
SURPRISE_21	11.52	45.25	7.17	7.8	0.253
SURPRISE_22	11.52	46.93	7.2	7.7	0.252
SURPRISE_23	11.49	50.85	7.19	7.5	0.252
SURPRISE_24	11.49	55.18	7.23	7.6	0.253
SURPRISE_25	11.29	60.59	7.23	25.4	0.254
SURPRISE_26	11.02	60.38	7.2	774.9	0.254
SURPRISE_27	11.2	56.65	7.23	10.1	0.253
SURPRISE_28	11.24	61.48	7.2	1280.5	0.259
SURPRISE_29	11.23	61.54	7.16	1122.3	0.258
SURPRISE_30	11.02	54.52	7.21	8.6	0.253
SURPRISE_31	11.06	54.22	7.22	8.3	0.253
SURPRISE_32	11.21	49.12	7.26	7.4	0.251
SURPRISE_33	11.32	44.9	7.23	7.3	0.252
SURPRISE_34	11.28	40.12	7.21	8	0.253
SURPRISE_35	11.48	35.08	7.33	7.8	0.251
SURPRISE_36	11.55	30.37	7.34	7.7	0.251
SURPRISE_37	11.59	25.32	7.35	7.7	0.251
SURPRISE_38	11.62	20.32	7.36	7.7	0.251
SURPRISE_39	11.62	20.08	7.36	7.8	0.251
SURPRISE_40	11.65	14.62	7.36	7.7	0.251
SURPRISE_41	11.64	12.74	7.36	7.7	0.251
SURPRISE_42	11.64	9.146	7.35	7.8	0.251
SURPRISE_43	11.64	6.016	7.36	7.9	0.251
SURPRISE_44	11.65	3.087	7.36	7.9	0.251
SURPRISE_45	11.66	0.612	7.37	7.7	0.251

Table 1c. Core Water Quality Parameters, Aniakchak River, Aniakchak Water Quality Inventory 2003								
Sample	Site ID	Fish Sample Site No.	Date	Time	Latitude	Longitude	Temp (C)	Discharge (cfs)
ANIA_DC_	Aniakchak river (main stem)	SURP 070-073	6/5/2003	14:01:00	56.907309	-158.088310		222
ania-rv_0	Aniakchak mainstem		6/5/2003	14:32:18	56.9042317	-158.080208	6.55	
ANIA_TUR	Aniakchak mainstem below Turbid Creek		6/5/2003	19:50:00	56.903728	-158.051361		
ania-rv_1	Aniakchak mainstem below Turbid Creek		6/5/2003	20:00:47	56.9037683	-158.051352	6.98	
ania-rv_2	Aniakchak mainstem below Turbid Creek		6/5/2003	20:02:57	56.9037683	-158.051335	6.99	
ania-rv_3	Aniakchak mainstem		6/6/2003	12:13:14	56.8521233	-157.905420	7.71	
ania-rv_4	Aniakchak outwash area	ANIA 003	6/6/2003	20:25:41	56.7938883	-157.765642	10.9	
ania-rv_5		ANIA 003	6/6/2003	20:26:51	56.7938883	-157.765625	10.88	
ania-rv_6	Aniakchak mainstem below second mouth, North Fork		6/9/2003	13:09:03	56.7961183	-157.650618	8.09	1225.38
ania-rv_7	Aniakchak mainstem below second mouth, North Fork		6/9/2003	14:34:38	56.790958	-157.605372	9.07	
ania-rv_8	Aniakchak mainstem below second mouth, North Fork		6/9/2003	15:07:15	56.771517	-157.587533	9.26	
ania-rv_9	Aniakchak mainstem below second mouth, North Fork		6/9/2003	15:26:58	56.760880	-157.561882	9.36	
ania_rv_97	Aniakchak Main Stem Near Mouth	Near LANI4	7/20/03	19:27:48	56.766530	-157.521610	10.70	
ania_rv_98	Aniakchak Main Stem Near Mouth		7/20/03	19:32:00	56.766530	-157.521610	10.71	

Sample	Comment	Specific Conductance (µS/cm)	Barometric Pressure (psi)	Dissolved Oxygen (%)	Dissolved Oxygen Concentration (mg/L)	Depth (ft)	pH	Turbidity YSI (NTU)	Total Dissolved Solids YSI (g/L)
ANIA_DC_	At lake outlet, water level low: T. Hamon, exposed rocks								
ania-rv_0		301	14.02	100.2	12.29	0.467	7.59	13.2	0.196
ANIA_TUR		0							
ania-rv_1	Duplicate YSI reading, by cut bank.	329	14.1	99	12.01	0.607	7.89	6	0.214
ania-rv_2	Duplicate YSI reading, away from cut bank	329	14.1	98.3	11.93	0.498	7.91	5	0.214
ania-rv_3	By Garden Creek	282	14.49	104.6	12.46	2.556	8.38	4.5	0.183
ania-rv_4	Duplicate YSI	262	14.72	107	11.82	1.81	8.38	2.7	0.17
ania-rv_5	Duplicate YSI	246	14.72	106.1	11.72	1.603	8.44	2.7	0.16
ania-rv_6	Taken between second and third mouth of NF	155	14.67	109.8	12.97	1.592	7.9	13.3	0.101
ania-rv_7		100	14.7	123.5	14.24	2.008	7.68	16.8	0.065
ania-rv_8		129	14.69	117.2	13.46	1.868	7.8	14.9	0.084
ania-rv_9		124	14.72	118	13.52	1.908	7.81	16.3	0.081
ania_rv_97	Not logged in YSI, bank reading	121		105.5	11.71	1.394	7.62	18.0	0.079
ania_rv_98	Not logged in YSI, bank reading	121		106.1	11.78	0.091	7.62	18.7	0.079

Table 1d. Core Water Quality Parameters, Aniakchak River Tributaries, Aniakchak Water Quality Inventory 2003									
Sample	Site ID	Fish Sample Site No.	Cameron Larson ID	Date	Time	Latitude	Longitude	Temp (C)	Discharge (cfs)
Tur_0	Turbid creek		T2	6/5/2003	14:24:33	56.90398833	-158.080045	2.98	23.768
Tur_1	Turbid creek		T2	6/5/2003	14:26:09	56.90396333	-158.0800617	2.96	
gardn-cr	Garden creek (small trib to Aniakchak)		NA	6/6/2003	12:11:30	56.85208333	-157.9054367	3.59	
abjcreek_0	Albert Johnson creek (dup reading)	ABJC 001	NA	6/6/2003	19:08:17	56.79135667	-157.762565	11.53	75.2
abjcreek_1	Albert Johnson creek (dup reading)		NA	6/6/2003	19:09:13	56.79134167	-157.7627433	11.46	
abjcreek_2	Albert Johnson creek(dup reading)		NA	6/6/2003	19:10:13	56.79134167	-157.7626633	11.51	
abjcreek_3	Albert Johnson creek slough	ABJC 002	NA	6/6/2003	19:16:04	56.79094167	-157.76219	17.53	
abjcreek_4	Albert Johnson creek headwaters (Dup reading w/ abjcreek_5)	MESH 500	NA	6/21/2003	15:16:45	56.76984833	-157.8993167	8.64	3.022
abjcreek_5	Albert Johnson creek headwaters (dup reading w/ abjcreek_4)	MESH 500	NA	6/21/2003	15:17:28	56.769825	-157.8993	8.64	
abjcreek_6	Albert Johnson creek headwaters lake system	MESH 502-505	NA	6/21/2003	17:17:40	56.77621333	-157.8893883	10.09	4.378
abjcreek_7	Albert Johnson creek headwaters lake system	MESH 502-505	NA	6/21/2003	17:20:04			10.07	
POND1_0	Pond that flows into Albert Johnson Creek	MESH 501	NA	6/21/2003	16:18:47	56.77670167	-157.89414	13.93	
POND1_1	Pond that flows into Albert Johnson Creek	MESH 501	NA	6/21/2003	16:19:37	56.77669333	-157.8941083	13.94	

Sample	Comment	Specific Conductance (µS/cm)	Barometric Pressure (psi)	Dissolved Oxygen (%)	Dissolved Oxygen Concentration (mg/L)	Depth (ft)	pH	Turbidity YSI (NTU)	Total Dissolved Solids YSI (g/L)
Tur_0	Discharge low & not turbid: T. Hamon	66	14.02	101.3	13.64	0.311	7.83	1.9	0.043
Tur_1		67	14.03	98	13.21	0.333	7.78	1.5	0.044
gardn-cr		66	14.48	101.8	13.49	1.334	7.81	-0.7	0.043
abjcreek_0		93	14.71	118	12.85	1.891	8.64	33.6	0.06
abjcreek_1		95	14.71	117.6	12.83	3.504	8.64	0.5	0.062
abjcreek_2		95	14.71	117.5	12.8	3.121	8.66	2.3	0.061
abjcreek_3		151	14.72	186	17.78	1.58	9.68	0.3	0.098
abjcreek_4	Normal flow, glide and cascade over boulder	63	14.54	107.5	12.54	0.681	7.67	-0.2	0.041
abjcreek_5		63	14.54	107.4	12.52	0.681	7.67	0	0.041
abjcreek_6		60	14.59	112.3	12.64	2.7	7.48	-0.2	0.039
abjcreek_7		60	14.59	111.3	12.54	2.701	7.47	-0.2	0.039
POND1_0		56	14.59	124.9	12.89	0.922	7.81	17	0.036
POND1_1		56	14.59	124.6	12.86	0.923	7.81	11.9	0.036

Sample	Site ID	Fish Sample Site No.	Cameron Larson ID	Date	Time	Latitude	Longitude	Temp (C)	Discharge (cfs)
	North Fork Aniakchak river: lab results		NA						
DC_ANIA_NF	North Fork Aniakchak River GPS reading			6/9/2003	12:02:00	56.802609	-157.656669		
ania-nf_0	North Fork Aniakchak river (Channel B, upstream fork)		NA	6/9/2003	12:04:09	56.8024167	-157.6567050	7.35	23.09
ania-nf_1	North Fork Aniakchak river (Channel A, downstream fork)		NA	6/9/2003	12:06:27	56.8024250	-157.6566900	7.25	202.69
ania-nf_2	First trib, downstream of North Fork Aniakchak		NA	6/9/2003	12:48:11	56.7993817	-157.6520017	8.06	194.48
ania-bnf	Below North Fork (second trib below NF)		NA	6/9/2003	13:50:13	56.7962317	-157.6403150	8.43	207.37
LANI_0	Lower Aniakchak river trib	Near LANI 003		7/20/2003	14:44:35	56.766660	-157.518224	8.64	<10 cfs
LANI_1	Lower Aniakchak river trib			7/20/2003	14:48:18	56.766660	-157.518224	8.65	

Sample	Comment	Specific Conductance (µS/cm)	Barometric Pressure (psi)	Dissolved Oxygen (%)	Dissolved Oxygen Concentration (mg/L)	Depth (ft)	pH	Turbidity YSI (NTU)	Total Dissolved Solids YSI (g/L)
		0							
DC_ANIA_NF		0							
ania-nf_0		53	14.7	109.3	13.15	1.886	7.45	21.8	0.034
ania-nf_1	Total NF discharge is 225.78	53	14.69	107.4	12.96	1.624	7.42	15.9	0.034
ania-nf_2		53	14.68	116	13.71	1.571	7.43	17.2	0.035
ania-bnf		54	14.74	113.4	13.29	1.819	7.36	18.7	0.035
LANI_0	Spring fed, no detectable flow	1252	14.64	87.4	10.15	0.728	6.83	-0.4	0.814
LANI_1		1258	14.65	88.2	10.24	0.729	6.81	-0.5	0.818

Table 1e. Core Water Quality Parameters, Meshik Drainage, Aniakchak Water Quality Inventory 2003									
Sample	Site ID	Fish Sample Site No.	Date	Time	Latitude	Longitude	Temp (C)	Discharge (cfs)	Comment
mestr1_0	Small Meshik Lake tributary	MESH 100	6/18/2003	9:09:27	56.785507	-157.915185	5.69	<10	
mestr1_1	Small Meshik Lake tributary	MESH 100	6/18/2003	9:10:38	56.785188	-157.915170	5.74		
meshlk_0	Meshik Lake	MESH 103	6/18/2003	9:59:55	56.787793	-157.917952	12.1		Lake level: low normal/normal
meshlk_99	Meshik Lake		6/19/2003	9:21:00	56.789416	-157.930981			
meshlk_1	Meshik Lake Profile (Surface)		6/19/2003	9:22:37	56.789307	-157.930778	12.11		
meshlk_2	Meshik Lake Profile (bottom)		6/19/2003	9:25:19	56.789273	-157.930583	12.24		
meshlk_3	Meshik Lake Profile (Surface)		6/19/2003	9:26:42	56.789250	-157.930583	12.12		
meshlk_4	Meshik Lake Profile (Surface)		6/19/2003	9:27:29	56.789193	-157.930533	12.12		
meshlk_5	Meshik Lake Profile (bottom)		6/19/2003	9:28:28	56.789152	-157.930533	12.12		
meshlk_6	Meshik Lake		6/24/2003	10:27:31	56.785507	-157.929980	9.58		
meshlk_7	Meshik Lake		6/24/2003	10:27:57	56.785507	-157.929980	9.57		Lab sample taken following ~ 30 hrs of rain
meshrv_0	Meshik River	MESH 209	6/18/2003	13:33:12	56.788542	-157.939942	13.12		
meshrv_1	Meshik River	MESH 209	6/18/2003	13:33:44	56.788533	-157.939942	13.14	10.096	
meshrv_2	Meshik River Backwater	MESH 213	6/20/2003	9:44:17	56.789608	-157.945427	5.48		side slough/backwater
meshrv_3	Meshik River (Duplicate location with YSI 4)		6/20/2003	12:56:15	56.788663	-157.951773	7.69		Discharge taken after confluence with Trib 1
meshrv_4	Meshik River (Duplicate location with YSI 3)	MESH 403	6/20/2003	12:58:02	56.788663	-157.951773	7.38	23.057	
mesrvtr1_0	Meshik River tribuary		6/20/2003	10:20:37	56.790348	-157.950993	6.38		
mesrvtr1_1	Meshik River tribuary		6/20/2003	10:24:47	56.790388	-157.950960	6.38		
mestr1_2	Meshik River tribuary	MESH 404	6/20/2003	13:48:46	56.789117	-157.950553	6.85	21.283	
mestr1_3	Meshik River tribuary	MESH 406	6/20/2003	14:22:10	56.789883	-157.951823	7.73		Slough/Oxbow; standing water off Meshik Trib 1

Sample	Specific Conductance (µS/cm)	Barometric Pressure (psi)	Dissolved Oxygen (%)	Dissolved Oxygen Concentration (mg/L)	Depth (ft)	pH	Turbidity YSI (NTU)	Total Dissolved Solids YSI (g/L)
mestr1_0	72	14.4	73	9.16	0.817	7.31	1.1	0.047
mestr1_1	72	14.4	66.8	8.36	1.07	6.84	0.8	0.047
meshlk_0	89	14.4	106.6	11.46	0.087	7.87	5.6	0.058
meshlk_99	0							
meshlk_1	89	14.53	100.6	10.81	0.49	7.72	12.1	0.058
meshlk_2	89	14.52	100.6	10.78	2.547	7.45	2.1	0.058
meshlk_3	89	14.52	100.4	10.78	0.726	7.61	46.7	0.058
meshlk_4	89	14.52	100.5	10.8	0.724	7.7	30.2	0.058
meshlk_5	89	14.53	100.2	10.77	2.345	7.72	2589.1	0.058
meshlk_6	81	14.36	109.8	12.51	1.039	7.69	41.8	0.053
meshlk_7	81	14.36	109.7	12.51	0.809	7.69	46.5	0.053
meshrv_0	90	14.43	112.2	11.79	0.169	8.03	4.3	0.059
meshrv_1	91	14.43	111.8	11.75	-0.07	7.99	5.9	0.059
meshrv_2	226	14.51	22	2.77	2.371	7.69	1083	0.147
meshrv_3	69	14.5	109.4	13.05	0.315	7.68	0.9	0.045
meshrv_4	67	14.5	109.3	13.14	1.802	7.69	1.4	0.044
mesrvtr1_0	65	14.5	109.4	13.49	0.14	7.61	0.4	0.042
mesrvtr1_1	65	14.5	107.4	13.24	0.193	7.62	0.4	0.042
mestr1_2	64	14.5	109.1	13.29	0.098	7.73	0.4	0.042
mestr1_3	63	14.5	113.7	13.56	0.093	8.36	658.1	0.041

Table 1f. Core Water Quality Parameters, Coastal Streams, Aniakchak Water Quality Inventory 2003									
Sample	Site ID	Fish Sample Site No.	Date	Time	Latitude	Longitude	Temp (C)	Discharge (cfs)	Comment
IRIS-CRK_0	Iris creek		7/15/2003	16:12:36	56.766919	-157.462005	20.1		
IRIS-CRK_1	Iris creek		7/15/2003	16:13:41	56.766919	-157.462005	20.12		GPS not recorded on YSI
IRIS-CRK_2	Iris creek	Betweeen IRIS 015 & 016	7/15/2003	17:47:29	56.763080	-157.448410	21.45		tidally influenced (jelly fish on bank.)
IRIS-CRK_3	Iris creek	Betweeen IRIS 015 & 016	7/15/2003	17:49:21	56.763080	-157.448410	21.14		
IRIS-CRK_4	Iris creek	Between IRIS 002 & 003	7/18/2003	13:03:42	56.772130	-157.462830	10.01	GPS reading from field notes	overbank flow, fast and turbid
IRIS-CRK_5	Iris creek	Between IRIS 002 & 003	7/18/2003	13:05:19	56.772130	-157.462830	10.01	GPS reading from field notes	
IRIS-CRK_6	Willow creek	Near Willow 001	7/18/2003	15:04:04	56.801680	-157.443837	13.12	est. 10-15 cfs; GPS reading from field notes	clear, brown water, over bank flow
IRIS-CRK_7	Willow creek		7/18/2003	15:07:16	56.801680	-157.443837	13.15	est: 40 cfs; GPS not recorded on YSI	
PACK-CRK_0	Packer's cabin creek		7/20/2003	16:52:51			7.02	<1 cfs	cabin drinking water supply
PACK-CRK_1	Packer's cabin creek		7/20/2003	16:53:48			7.01		

Table									
Site ID	Specific Conductance µS/cm	Conductivity µS/cm	Barometric Pressure (psi)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Depth (ft)	pH	Turbidity YSI (NTU)	Total Dissolved Solids YSI (g/L)
Iris creek	83	76	14.76	123.9	11.24	0.362	8.03	0.8	0.054
Iris creek	83	76	14.76	124.5	11.29	0.37	8.04	0.7	0.054
Iris creek	91	85	14.73	130.7	11.55	-0.13	8.03	2.6	0.059
Iris creek	87	81	14.72	126.1	11.21	0.972	8.11	0.8	0.057
Iris creek	65	46	14.67	223.8	25.26	0.13	7.47	39	0.042
Iris creek	65	46	14.68	228.8	25.82	0.612	7.39	39.9	0.042
Willow creek	76	58	14.73	772.9	81.21	0.479	6.94	11.4	0.049
Willow creek	76	59	14.73	776	81.48	0.106	6.87	24.9	0.049
Packer's cabin creek	119	78	14.61	101.4	12.3	0.557	7.6	5.5	0.077
Packer's cabin creek	119	78	14.62	102.1	12.39	0.108	7.56	3.9	0.077

Table 1c. Core Water Quality Parameters, Aniakchak River, Aniakchak Water Quality Inventory 2003								
Sample	Site ID	Fish Sample Site No.	Date	Time	Latitude	Longitude	Temp (C)	Discharge (cfs)
ANIA_DC_	Aniakchak river (main stem)	SURP 070-073	6/5/2003	14:01:00	56.907309	-158.088310		222
ania-rv_0	Aniakchak mainstem		6/5/2003	14:32:18	56.9042317	-158.080208	6.55	
ANIA_TUR	Aniakchak mainstem below Turbid Creek		6/5/2003	19:50:00	56.903728	-158.051361		
ania-rv_1	Aniakchak mainstem below Turbid Creek		6/5/2003	20:00:47	56.9037683	-158.051352	6.98	
ania-rv_2	Aniakchak mainstem below Turbid Creek		6/5/2003	20:02:57	56.9037683	-158.051335	6.99	
ania-rv_3	Aniakchak mainstem		6/6/2003	12:13:14	56.8521233	-157.905420	7.71	
ania-rv_4	Aniakchak outwash area	ANIA 003	6/6/2003	20:25:41	56.7938883	-157.765642	10.9	
ania-rv_5		ANIA 003	6/6/2003	20:26:51	56.7938883	-157.765625	10.88	
ania-rv_6	Aniakchak mainstem below second mouth, North Fork		6/9/2003	13:09:03	56.7961183	-157.650618	8.09	1225.38
ania-rv_7	Aniakchak mainstem below second mouth, North Fork		6/9/2003	14:34:38	56.790958	-157.605372	9.07	
ania-rv_8	Aniakchak mainstem below second mouth, North Fork		6/9/2003	15:07:15	56.771517	-157.587533	9.26	
ania-rv_9	Aniakchak mainstem below second mouth, North Fork		6/9/2003	15:26:58	56.760880	-157.561882	9.36	
ania_rv_97	Aniakchak Main Stem Near Mouth	Near LANI4	7/20/03	19:27:48	56.766530	-157.521610	10.70	
ania_rv_98	Aniakchak Main Stem Near Mouth		7/20/03	19:32:00	56.766530	-157.521610	10.71	

Sample	Comment	Specific Conductance (µS/cm)	Barometric Pressure (psi)	Dissolved Oxygen (%)	Dissolved Oxygen Concentration (mg/L)	Depth (ft)	pH	Turbidity YSI (NTU)	Total Dissolved Solids YSI (g/L)
ANIA_DC_	At lake outlet, water level low: T. Hamon, exposed rocks								
ania-rv_0		301	14.02	100.2	12.29	0.467	7.59	13.2	0.196
ANIA_TUR		0							
ania-rv_1	Duplicate YSI reading, by cut bank.	329	14.1	99	12.01	0.607	7.89	6	0.214
ania-rv_2	Duplicate YSI reading, away from cut bank	329	14.1	98.3	11.93	0.498	7.91	5	0.214
ania-rv_3	By Garden Creek	282	14.49	104.6	12.46	2.556	8.38	4.5	0.183
ania-rv_4	Duplicate YSI	262	14.72	107	11.82	1.81	8.38	2.7	0.17
ania-rv_5	Duplicate YSI	246	14.72	106.1	11.72	1.603	8.44	2.7	0.16
ania-rv_6	Taken between second and third mouth of NF	155	14.67	109.8	12.97	1.592	7.9	13.3	0.101
ania-rv_7		100	14.7	123.5	14.24	2.008	7.68	16.8	0.065
ania-rv_8		129	14.69	117.2	13.46	1.868	7.8	14.9	0.084
ania-rv_9		124	14.72	118	13.52	1.908	7.81	16.3	0.081
ania_rv_97	Not logged in YSI, bank reading	121		105.5	11.71	1.394	7.62	18.0	0.079
ania_rv_98	Not logged in YSI, bank reading	121		106.1	11.78	0.091	7.62	18.7	0.079

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