Technical Report No. 07-03

Aquatic Biomonitoring at Red Dog Mine, 2006
National Pollution Discharge Elimination System
Permit No. AK-003865-2

by Alvin G. Ott and William A. Morris

Slimy Sculpin, Buddy Creek
Photograph by Al Ott 2005

June 2007

Alaska Department of Natural Resources
Office of Habitat Management and Permitting

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Executive Director
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Acknowledgements

We thank Teck Cominco Alaska Inc. (TCAK) for financial and logistical support that enabled us to conduct aquatic biomonitoring work at the Red Dog Mine. We specifically acknowledge the support provided by Mr. Jim Kulas, Mr. Mark Thompson, and Mr. John Martinisko of TCAK.

We thank Ms. Jackie Timothy, Ms. Kerry Howard, Ms. Laura Jacobs, and Mr. Jack Winters with the Office of Habitat Management and Permitting (Alaska Department of Natural Resources) for their help with field and laboratory work. Mr. Fred DeCicco, Alaska Department of Fish and Game, conducted the fall Dolly Varden (*Salvelinus malma*) aerial surveys and collected the fall sample of adult Dolly Varden from the Wulik River. The University of Alaska Fairbanks allowed us to use their equipment for chlorophyll analyses.

We thank Dr. Phyllis Weber Scannell (Scannell Technical Services) for reviewing and updating the long-term water quality data base with 2006 information. Ms. Nora Foster (NRF Taxonomic Services) was responsible for sorting and identification of aquatic invertebrates collected with drift nets.

Executive Summary

●Concentrations of Cd and Zn generally are lower at sample stations located downstream of the Red Dog Mine when compared with pre-mining data. At Station 10 in Mainstem Red Dog Creek the median concentrations of Cd, Pb, and Zn are lower from 1999 through 2006 as compared to baseline data. However, we do see several peak Pb and Al concentrations at Station 10 that exceed baseline data. In Ikalukrok Creek upstream of Mainstem Red Dog Creek (Station 9), both Cd and Zn increased from 1999 through 2001 as compared with baseline data, but have remained stable since 2002 with the exception of some higher concentrations in summer 2006. Water quality changes at Station 9 are most likely related to a very active mineral seep at Cub Creek.

●Chlorophyll-a concentrations are lowest for all sample years at Station 20 in Middle Fork Red Dog Creek. Generally chlorophyll-a concentrations are highest in North Fork Red Dog Creek. At Station 9 (Ikalukrok Creek upstream of Mainstem Red Dog Creek), chlorophyll-a concentrations track very closely with Zn and Cd concentrations measured over similar time frames. Improved water quality in Ikalukrok Creek in recent years has resulted in increased periphyton standing crop at Station 9. Overall, chlorophyll-a concentrations seem to accurately represent the sample sites and serve as a valid indicator of basic biological productivity.

●Aquatic invertebrates from the NPDES sample sites demonstrate a high degree of variability among sites and years. Overall densities of aquatic invertebrates are highest in North Fork Red Dog Creek – the most productive stream currently being sampled for invertebrates under the NPDES permit. Aquatic invertebrate data appear to be representative of productivity at a given site, but variability among site and years is very high.

●Concentrations of total dissolved solids (TDS) at Station 160 (Ikalukrok Creek downstream of Dudd Creek) never exceeded 500 mg/L during summer 2006. TDS concentrations at Station 10, in Mainstem Red Dog Creek, did not exceed 1,500 mg/L during 2006. A TDS site specific criterion (SSC) of 1,500 mg/L during Arctic grayling spawning was made by ADEC and became effective on February 15, 2006. The US Environmental Protection Agency approved the 1,500 mg/L TDS SSC on April 21, 2006. In spring 2006, Arctic grayling spawning in Mainstem Red Dog Creek probably began on May 30 and was judged to be complete by June 15.

●Adult Dolly Varden from the Wulik River have been sampled for metals concentrations in gill, kidney, liver, muscle, and reproductive tissue since 1990. In 1997, Se was added to the analyte list and in 2003, Hg and Ca were added. None of the analytes measured have been found to accumulate in muscle tissue. Various analytes concentrate in specific tissues: Al in gill; Cd in kidney; Cu in liver; Pb in gill; Se in kidney and ovary; and Zn in ovary.

Executive Summary (concluded).

●The number of overwintering Dolly Varden is estimated each fall in the Wulik River. Estimates vary annually. There is no indication, based on surveys conducted before and after mining, that the estimated number of fish overwintering in the Wulik River has exhibited a trend of increasing or decreasing numbers. Aerial surveys before mine development found that 90% of the Dolly Varden in the Wulik River are located below the mouth of Ikalukrok Creek. Surveys, post mining, have continued to find that 90% of the Dolly Varden counted during the fall survey are found below the mouth of Ikalukrok Creek.

●Annual aerial surveys are made to assess the distribution of chum salmon in Ikalukrok Creek from its mouth (i.e., confluence with Wulik River) upstream to Dudd Creek. Counts of adult chum salmon after mine development in 1990 and 1991 were lower than reported in baseline studies. Surveys began in 1995, with the highest return of chum salmon seen in fall 2006. The highest number of chinook salmon seen was in the fall of 2004. Large returns of chum salmon in recent years (2001, 2002, and 2006) are indicators that the population has recovered from the low counts made in the early 1990s.

●Juvenile Dolly Varden were not caught in all sample reaches in fall 2006. Catches in 2006 were the lowest recorded since 1997. Presence of resident Dolly Varden using North Fork Red Dog Creek in spring continued to be confirmed by fyke net catches.

●Arctic grayling spawn in North Fork Red Dog and Mainstem Red Dog creeks each spring. We estimated the Arctic grayling population in North Fork Red Dog and Mainstem Red Dog creeks at 870 fish in spring 2001. Relative abundance of fry varies annually and recruitment to the population does not occur each year. The last year where recruitment may have occurred is 1999. In spring 2006, we observed a post-spawning outmigration of large mature Arctic grayling during our spring sample period – we have not seen this occur during previous spring sampling events. The cold temperatures in North Fork Red Dog Creek continued well beyond the normal time frame for Arctic grayling spawning. We believe that Arctic grayling entered North Fork Red Dog Creek in late May and due to cold water temperatures, abandoned spawning.

•Premining slimy sculpin abundance is not known, but baseline data reports indicate that this species was numerous in the Ikalukrok Creek drainage. Catches of slimy sculpin in the Ikalukrok Creek drainage NPDES sample sites indicate an increasing trend from 2000 through 2005, but not in 2006. Lower numbers of slimy sculpin in 2006 were due, in part, to a reduced sample effort (i.e., July sample did not occur due to high water). Increasing numbers of slimy sculpin through 2005 appeared to reflect general improvement in water quality due to mine operations and water treatment and natural decreases in the Cub Creek seep located in the upper Ikalukrok Creek drainage.

Introduction

The Red Dog zinc (Zn) and lead (Pb) deposit is located in northwestern Alaska, about 130 km north of Kotzebue and 75 km inland from the Chukchi Sea coast (Figure 1). Mine operations and facilities and surrounding vegetation and wildlife are described in Weber Scannell and Ott (1998). A chronology of development and operations at the Red Dog Mine is presented in Appendix 1. Aquatic resources in the Wulik River drainage are described in Weber Scannell et al. 2000.

In July 1998, the US Environmental Protection Agency (EPA) issued a draft National Pollution Discharge Elimination System Permit No. AK-003865-2 (NPDES Permit) to Teck Cominco Alaska Inc. (TCAK) to allow discharge of up to 2.418 billion gallons of treated effluent per year. The Alaska Department of Environmental Conservation (ADEC) issued a Certificate of Reasonable Assurance and the NPDES became effective August 28, 1998. The NPDES Permit was modified effective August 23, 2003, to include ADEC's authorization of two mixing zones for total dissolved solids in Mainstem Red Dog and Ikalukrok creeks.

The NPDES Permit requires biomonitoring of fish, aquatic invertebrates, and periphyton in streams downstream of and adjacent to the Red Dog Mine. Although the NPDES Permit expired August 28, 2003, it was administratively extended until such time as a new permit is issued. Aquatic biomonitoring has continued annually as required by the NPDES Permit. Our report contains results of studies undertaken by the Alaska Department of Natural Resources (ADNR) in 2006 and comparisons of the 2006 data with previous years.

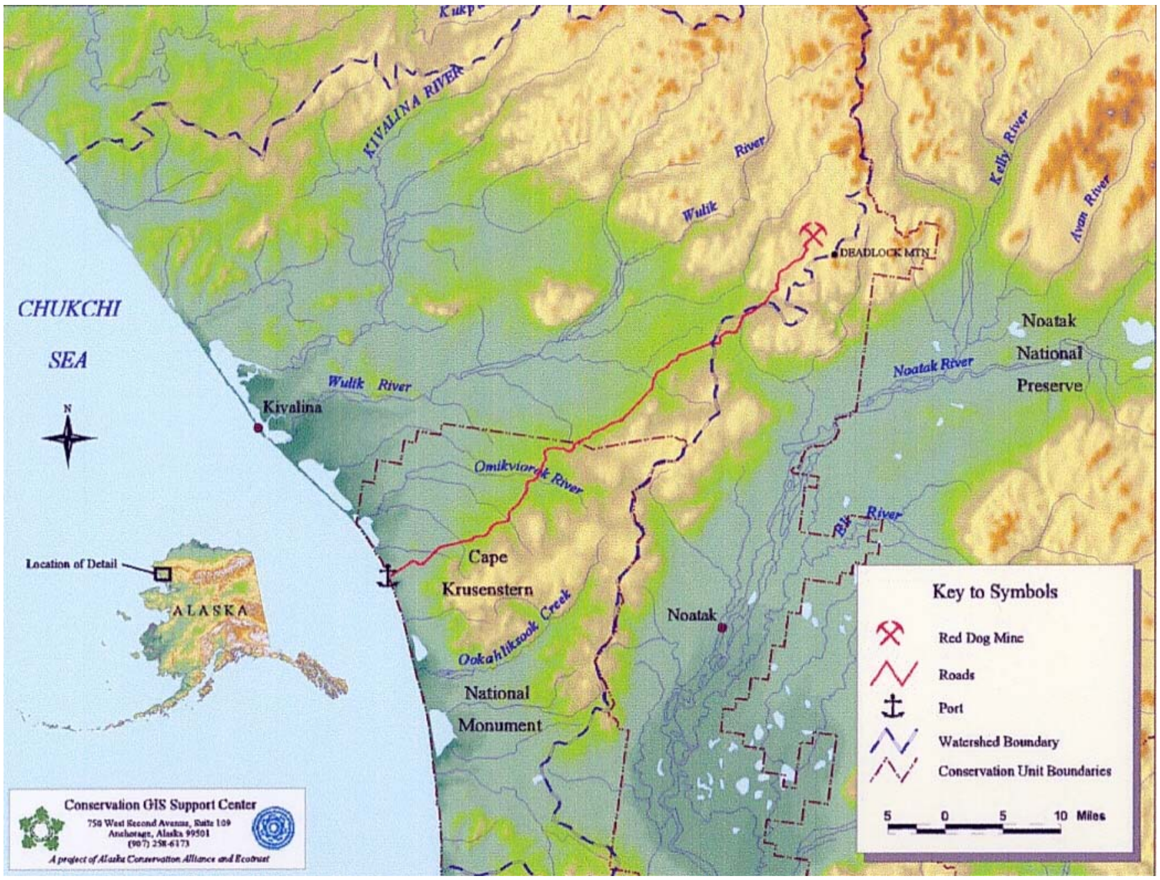

Figure 1. Location of the Red Dog Mine in northwestern Alaska. Map used with permission of Conservation GIS Support Center, Anchorage, Alaska.

Structure of Report

Results of water quality monitoring, estimates of periphyton standing crop, and aquatic invertebrate sampling are given for each site for the years sampled (1999 to 2006). Following presentation of these results by individual site is a table summarizing changes in biotic communities and water quality conditions. Metals concentration data for adult Dolly Varden (*Salvelinus malma*) collected from the Wulik River are then presented. Aerial survey estimates of overwintering Dolly Varden in the Wulik River and chum salmon (*Oncorhynchus keta*) spawners in Ikalukrok Creek are covered next. Finally, biological monitoring data for Dolly Varden juveniles, Arctic grayling (*Thymallus arcticus*), and slimy sculpin (*Cottus cognatus*) are discussed.

Location of Sample Sites

Biomonitoring is conducted in streams adjacent to and downstream of the Red Dog Mine as required under the EPA NPDES Permit No. AK-003865-2 (Table 1, Figure 2). A description of the site location and the Station Number identification, where one exists, are presented in Table 1.

Table 1. Location of sample sites for NPDES biomonitoring.

Stream of Site Name	Station Number
Ikalukrok Creek downstream of Dudd Creek	Station 7
Ikalukrok Creek upstream of Dudd Creek	no station #
Ikalukrok Creek downstream of Mainstem Red Dog Creek	Station 8
Ikalukrok Creek upstream of Mainstem Red Dog Creek	Station 9
Mainstem Red Dog Creek	Station 10
North Fork Red Dog Creek	Station 12
Middle Fork Red Dog Creek	Station 20

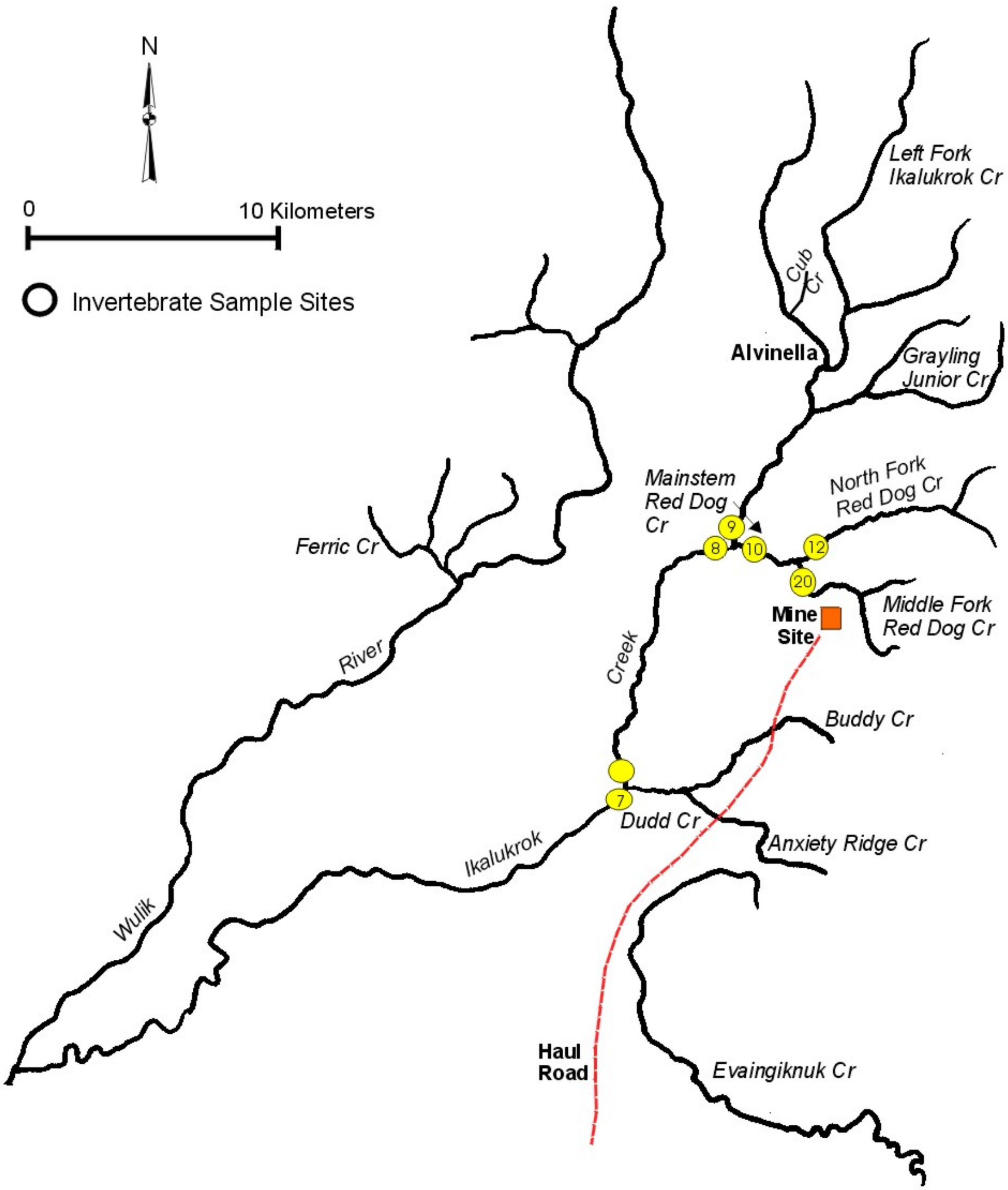

Figure 2. Location of sample sites in the Ikalukrok Creek drainage for aquatic invertebrate and periphyton sampling. The Ikalukrok Creek site upstream of Dudd Creek does not have a numerical description.

Description of Streams

All streams in this study are in the Wulik River drainage, except for Evaingiknuk Creek, which is in the Noatak River drainage. Station numbers correspond either to those used by Dames and Moore (1983) during baseline studies or to the current water quality program being conducted by TCAK. Water quality and fish data collected during baseline studies (1979 to 1982) represent pre-mining conditions. Each component and location listed in Table 2 is required by NPDES Permit No. AK-003865-2. ADNR and ADEC conduct additional sampling that is supplemental to the requirements under the NPDES Permit to further our understanding of the aquatic communities (Table 3).

Table 2. Study sites and components required by NPDES Permit.

Ikalukrok Creek Stations 7, 8, 9, and upstream of Dudd Creek Creek	periphyton (as chlorophyll-a, mg/m^2) aquatic invertebrates (taxa richness, density) fish presence and use
Mainstem Red Dog (10), North Fork Red Dog (12) and Middle Fork Red Dog (20) Creeks	periphyton (as chlorophyll-a, mg/m^2) aquatic invertebrates (taxa richness, density) fish presence and use
Ikalukrok Creek	chum salmon aerial survey
Wulik River	Dolly Varden fall aerial survey
Anxiety Ridge, Evaingiknuk, and Buddy Creeks	fish presence and use

Table 3. Study sites and components of supplemental biomonitoring in 2006.[1]

Ikalukrok Creek, upstream of Mainstem Red Dog Creek	aerial Arctic grayling surveys
Mainstem Red Dog Creek	juvenile Dolly Varden, whole body metal analyses fish presence and use downstream of North Fork spawning condition of Arctic grayling (spent, ripe) mark-recapture of Arctic grayling
North Fork Red Dog Creek	spawning condition of Arctic grayling (spent, ripe) mark-recapture of Arctic grayling
Buddy Creek, below waterfalls	periphyton (as chlorophyll-a, mg/m^2) aquatic invertebrates (taxa richness, density) juvenile Dolly Varden, whole body metal analyses
Buddy Creek, above Haul Road	periphyton (as chlorophyll-a, mg/m^2) aquatic invertebrates (taxa richness, density) fish presence and use
Bons Creek, below Bons Pond	periphyton (as chlorophyll-a, mg/m^2) aquatic invertebrates (taxa richness, density) fish presence and use
Bons Pond	fish presence and use mark-recapture of Arctic grayling Arctic grayling population estimate
Bons Creek, above Bons Pond	periphyton (as chlorophyll-a, mg/m^2) aquatic invertebrates (taxa richness, density) fish presence and use spawning condition of Arctic grayling (spent, ripe) mark-recapture of Arctic grayling

[1]draft technical report in preparation summarizing aquatic biomonitoring in Bons and Buddy creeks and Bons Pond covering data collected in 2004, 2005, and 2006.

Methods Used for NPDES Biomonitoring

All methods used for the NPDES biomonitoring study were described by ADF&G (1998) and submitted to EPA for their approval and comment. Only minor modifications, as described by Ott and Weber Scannell (2003) have been made.

The method detection limit (MDL) in 2000 for copper (Cu), Pb, and selenium (Se) were 50, 20, and 50 *u*g/L, respectively, for some of the samples early in the ice-free season. MDL's were changed part way through summer 2000 for Cu, Pb, and Se to 1, 2, and 1 *u*g/L. Because of the high MDLs used in early 2000, water quality data for these analytes are not presented.

Water quality data presented in our report are for "total recoverable." Water quality data are provided by TCAK. The number of water quality samples taken each year varies with the permit condition requirements, but for most analytes samples are collected twice each month with a sample size of 9 to 13 for each ice-free season.

Results and Discussion

Ikalukrok Creek, Station 7

Site Description

Ikalukrok Creek, downstream of Dudd Creek (Station 7, Figure 3) is about 10 to 40 m wide with depths from 0.3 to 1.2 m. The substrate consists of small to medium gravel with prevalent gravel bars at low flows. Ikalukrok and Dudd creeks are not completely mixed at Station 7; complete mixing of the two creeks under various flow conditions occurs about 8 km downstream of their confluence.

Figure 3. Ikalukrok Creek downstream of Dudd Creek, Station 7.

Water Quality

In May 1999, the stream gauge and monitoring station near Dudd Creek (Station 7) was moved about 8 km downstream on Ikalukrok Creek (Station 160). Station 160 is located below complete mixing of Dudd and Ikalukrok creeks. Baseline water quality data are from Station 7, but water quality data are from Station 160 for 1999 through 2006.

Concentrations of total dissolved solids (TDS) at Station 160 are shown in Figure 4. During summer 2006, TDS concentrations did not exceed 500 mg/L. The highest TDS concentration was 486 mg/L on October 1, 2006. The wastewater discharge is regulated to ensure that TDS does not exceed 500 mg/L at Station 160 from July 25 through the end of the discharge season. Dolly Varden and chinook (*Oncorhynchus tshawytscha*) and chum salmon spawn in Ikalukrok Creek downstream of Station 160.

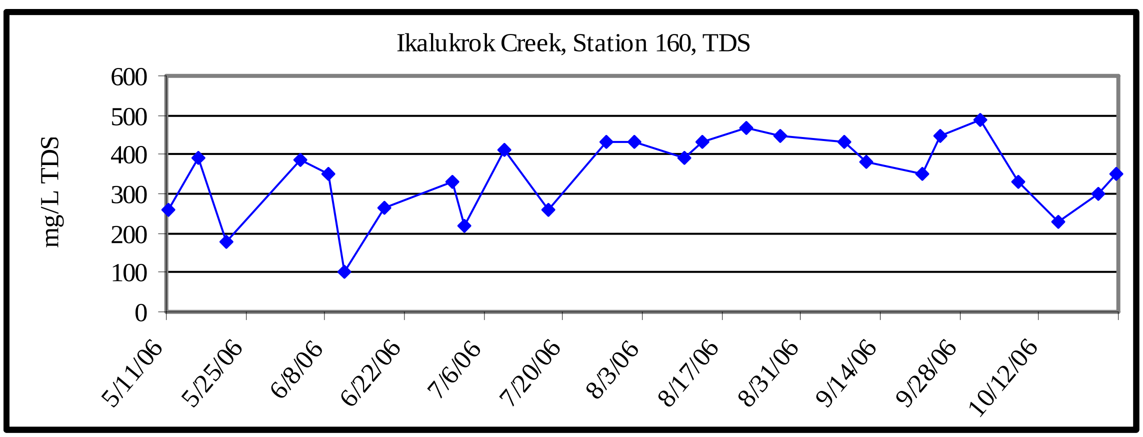

Figure 4. TDS concentrations in Ikalukrok Creek at Station 160.

Concentrations of aluminum (Al), cadmium (Cd), Cu, Pb, Se, and Zn are presented in Figures 5 through 10. Baseline data are only available for Cd, Pb, and Zn. Median Cd and Zn concentrations are lower than baseline data. Median Pb concentrations vary with respect to baseline data, but maximum concentrations are higher than pre-mining.

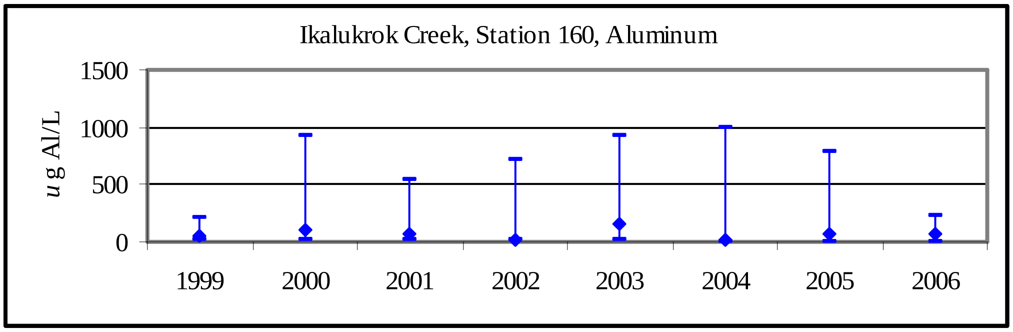

Figure 5. Median, maximum, and minimum concentrations of Al at Station 160.

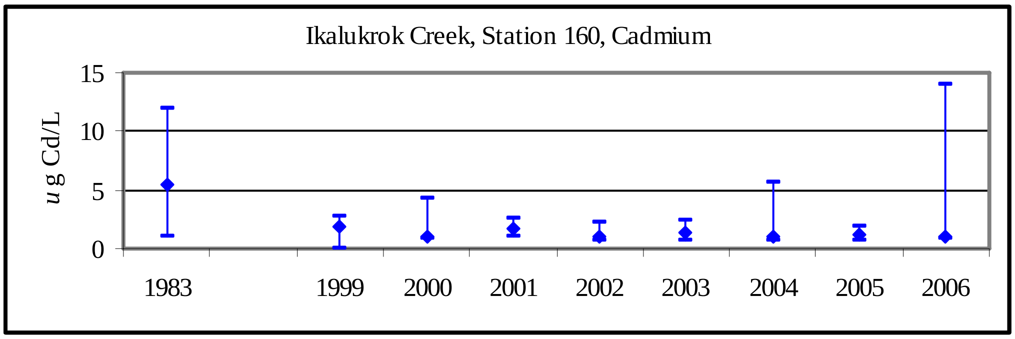

Figure 6. Median, maximum, and minimum concentrations of Cd at Station 160.

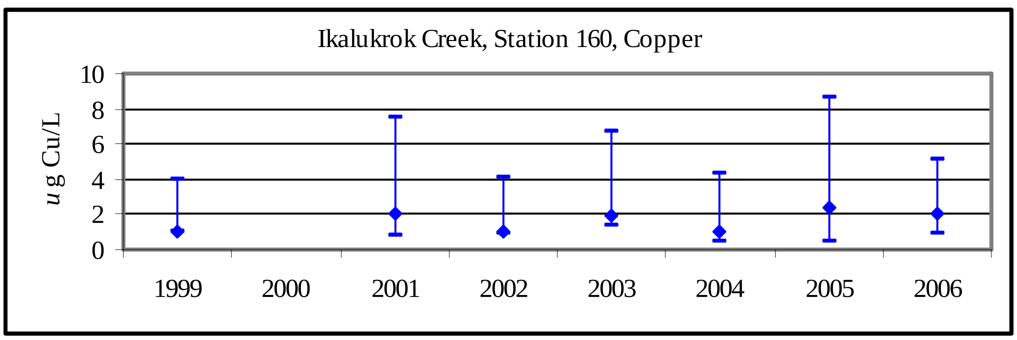

Figure 7. Median, maximum, and minimum concentrations of Cu at Station 160.

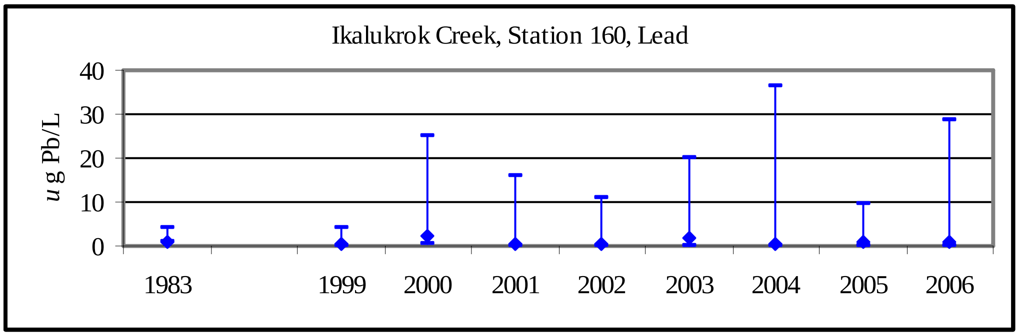

Figure 8. Median, maximum, and minimum concentrations of Pb at Station 160.

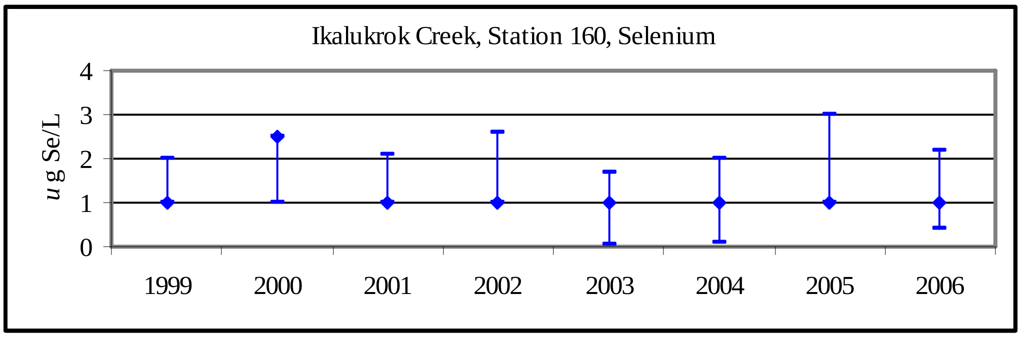

Figure 9. Median, maximum, and minimum concentrations of Se at Station 160.

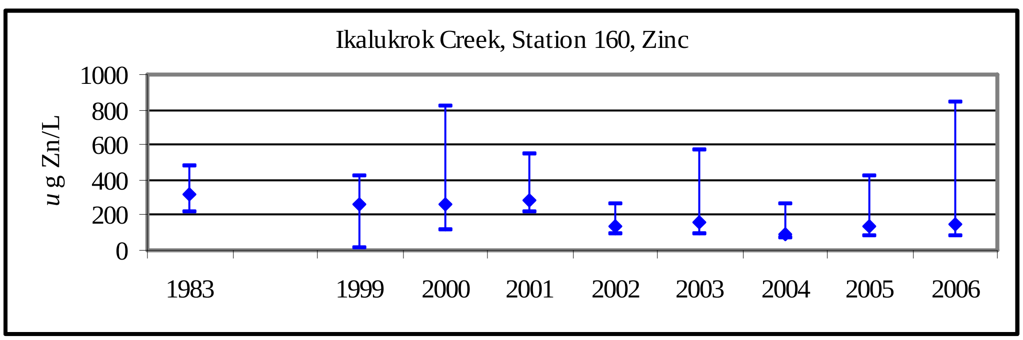

Figure 10. Median, maximum, and minimum concentrations of Zn at Station 160.

Invertebrate Community (Abundance, Density, Taxa richness, and Structure)

Aquatic invertebrate abundance, density, taxa richness, and structure are presented in Figures 11 through 14. Variability among sample years for both abundance and density of aquatic invertebrates is high (Figures 11 and 12). In general, when abundance is higher so is the density of aquatic invertebrates.

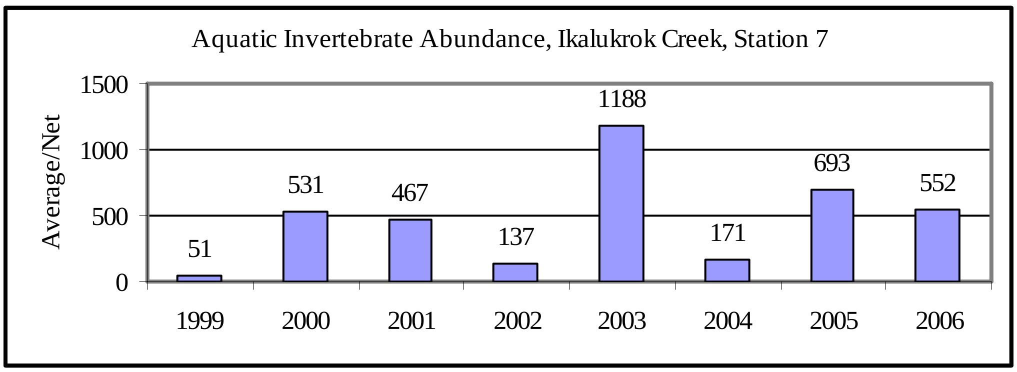

Figure 11. Aquatic invertebrate abundance, Ikalukrok Creek at Station 7.

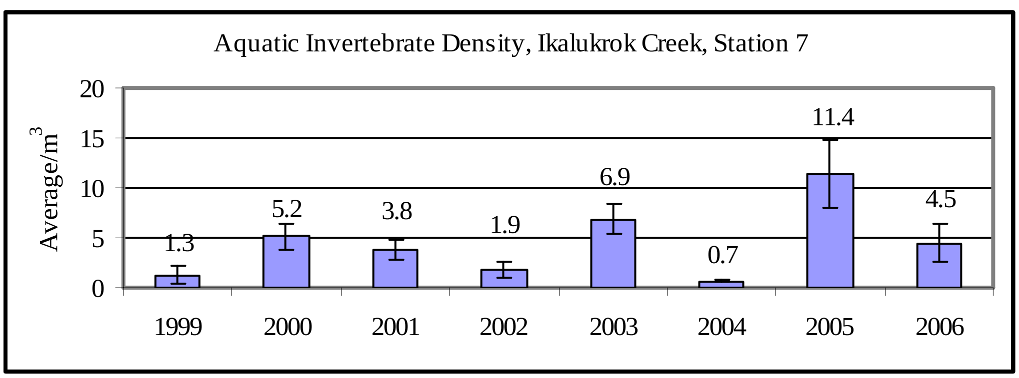

Figure 12. Aquatic invertebrate density, Ikalukrok Creek at Station 7.

Total aquatic taxa in Ikalukrok Creek, downstream of Dudd Creek, varied from a low of 10 to a high of 24 (Figure 13). The proportion of Ephemoptera, Plecoptera, and Tricoptera (EPT) were similar in 6 out of 8 years and ranged from a low of 8% to a high of 39% (Figure 14). Aquatic invertebrate data indicate a productive community at Station 7 in Ikalukrok Creek.

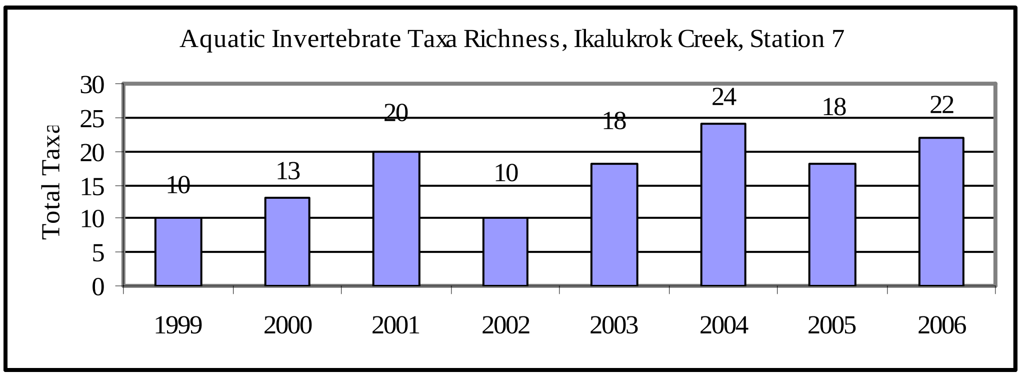

Figure 13. Aquatic invertebrate taxa richness, Ikalukrok Creek at Station 7.

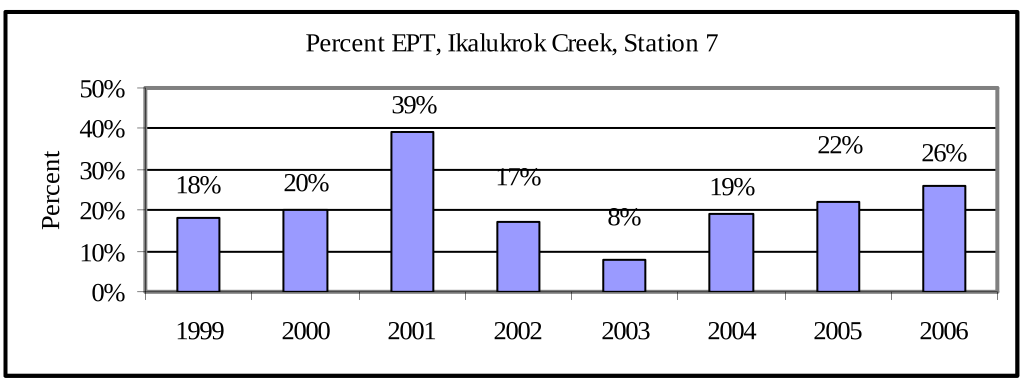

Figure 14. Percent EPT, Ikalukrok Creek at Station 7.

Periphyton Standing Crop

Algae biomass, as estimated by chlorophyll-a concentrations has been fairly consistent at Station 7 with the highest concentrations seen in 2006 (Figure 15). All periphyton samples are collected during early July, with the exception of 2006 when samples were taken in early August due to high water conditions during most of July, 2006.

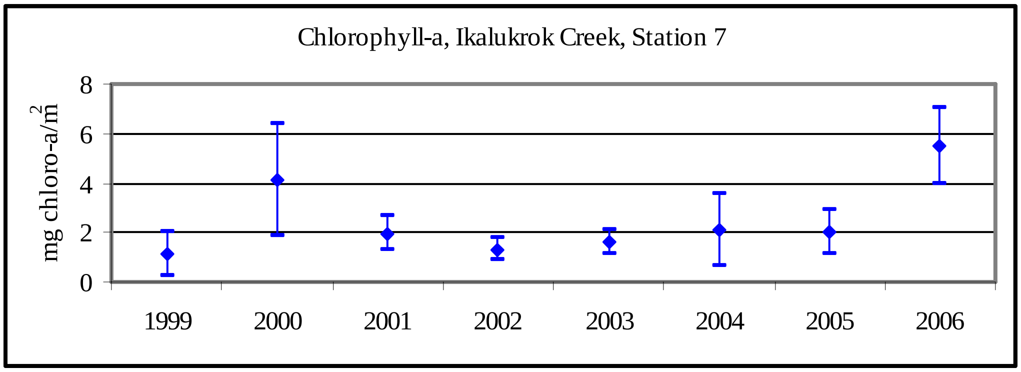

Figure 15. Average concentration of chlorophyll-a, plus and minus one standard deviation, Ikalukrok Creek at Station 7.

Biomonitoring Summary, Ikalukrok Creek Station 7

Table 4. Ikalukrok Creek, Station 7, 1999 to 2006

Water Quality	TDS concentrations below 500 mg/L Median Cd and Zn concentrations lower than baseline Maximum Pb concentrations higher than baseline
Invertebrates	Abundance and density highly variable Taxa Richness, fairly consistent 2003 to 2006 % EPT, fairly consistent 6 out of 8 years
Periphyton	Fairly consistent 5 out of 8 years, peak in August 2006
Larval Fish	Arctic grayling in 2000, 2002, 2003, and 2004 Slimy sculpin in 2004 and 2006

Ikalukrok Creek, Upstream of Dudd Creek

Site Description

Ikalukrok Creek, upstream of Dudd Creek, is a wide, fairly shallow stream up to 40 m wide and 0.5 to 1.5 m deep during summer low flows (Figure 16). Flows in Ikalukrok Creek, when this August 2006 photograph was taken, were much higher than summer low flow conditions. Pools along cut banks or adjacent to rock bluffs are 2 to 4 m deep. The substrate consists mostly of small cobble mixed with medium sized gravel. Streambanks are heavily vegetated with willows, herbaceous plants, and grasses.

Figure 16. Ikalukrok Creek upstream of Dudd Creek.

Water Quality

Water is not sampled in Ikalukrok Creek at our monitoring site, but samples are collected at Station 73 (1999 and 2000) and at Station 150 (2001 to 2006) located upstream of Dudd Creek, but below the mouth of Mainstem Red Dog Creek.

Station 150 is located below the complete mixing of Mainstem Red Dog Creek with Ikalukrok Creek. Only a few minor tributaries enter Ikalukrok Creek between the mouths of Mainstem Red Dog and Ikalukrok creeks. Station 150 is a relatively new station located about 9 km upstream of our biomonitoring site. Concentrations of TDS in Ikalukrok Creek are not to exceed 1,000 mg/L at the end of the mixing zone. TDS concentrations did not exceed the limit of 1,000 mg/L as provided for in ADEC's authorized mixing zone (Figure 17).

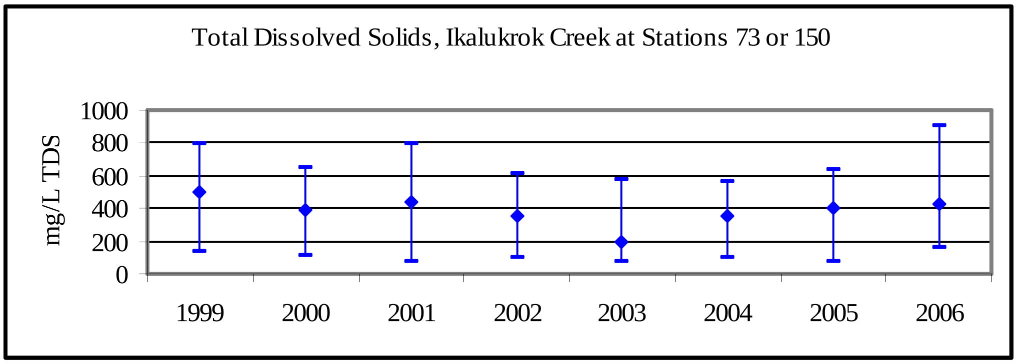

Figure 17. Median, maximum, and minimum TDS concentrations in Ikalukrok Creek at Stations 73 or 150.

Concentrations of Al, Cd, Cu, Pb, Se, and Zn are presented in Figures 18 through 23. Baseline data only are available for Cd, Pb, and Zn. Median Cd and Zn concentrations from 1999 through 2006 are lower than baseline data. Median Pb concentrations are similar to those reported in the baseline data. Maximum Pb concentrations post-mining, in some years, are higher than baseline data.

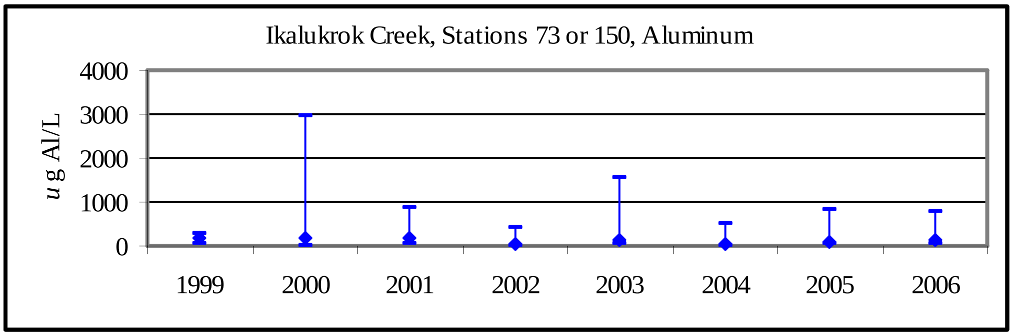

Figure 18. Median, maximum, and minimum concentrations of Al at Stations 73 or 150.

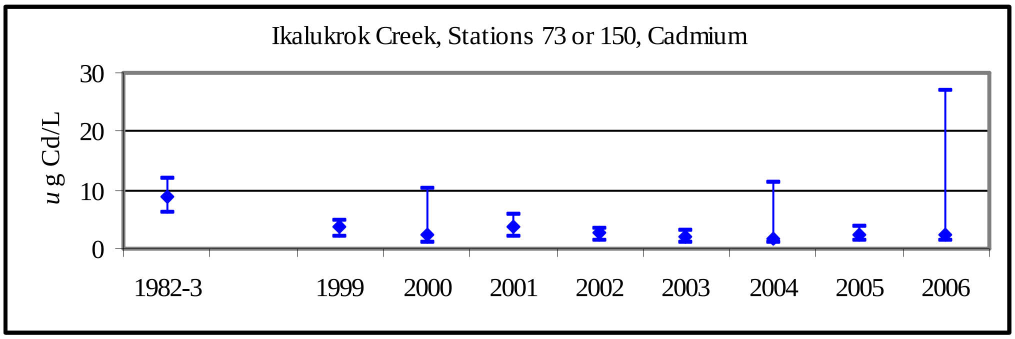

Figure 19. Median, maximum, and minimum concentrations of Cd at Stations 73 or 150.

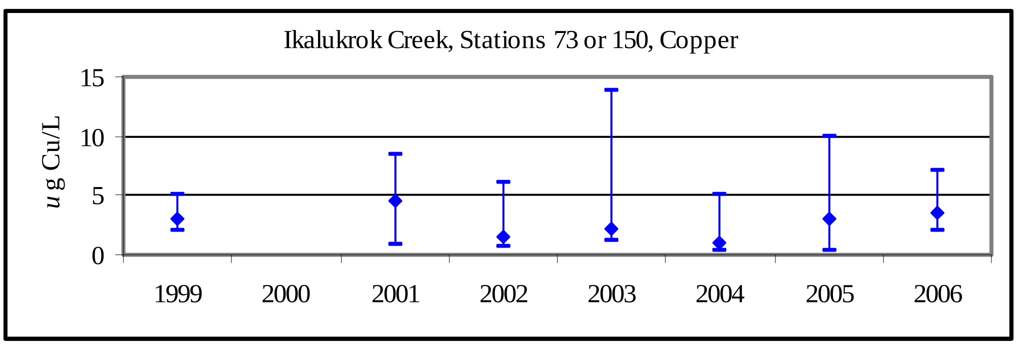

Figure 20. Median, maximum, and minimum concentrations of Cu at Stations 73 or 150.

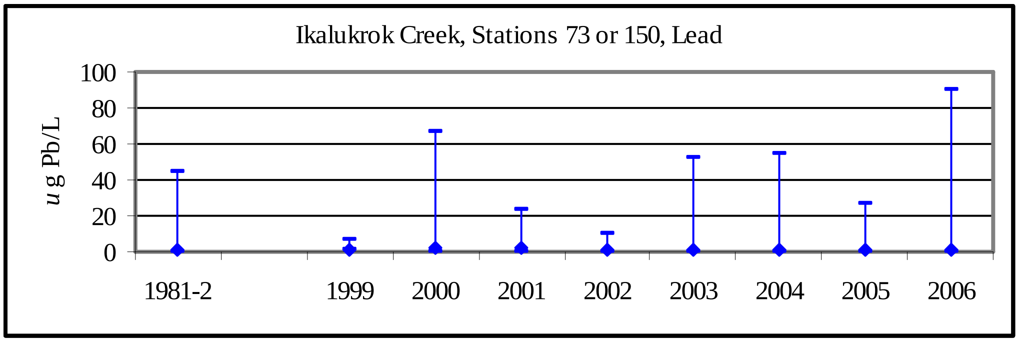

Figure 21. Median, maximum, and minimum concentrations of Pb at Stations 73 or 150.

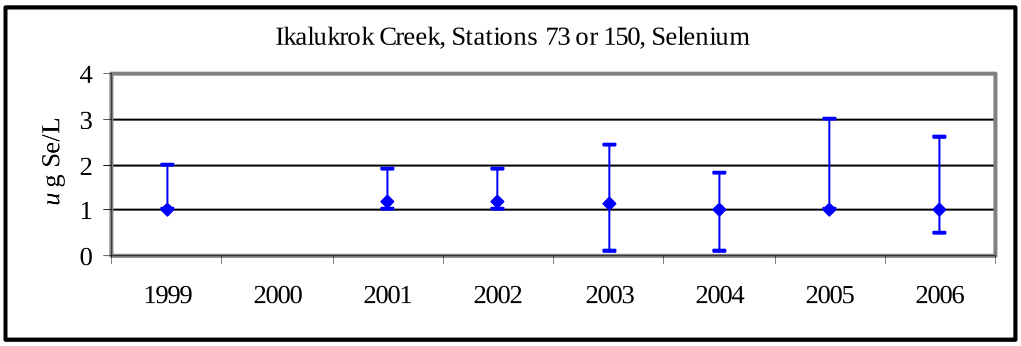

Figure 22. Median, maximum, and minimum concentrations of Se at Stations 73 or 150.

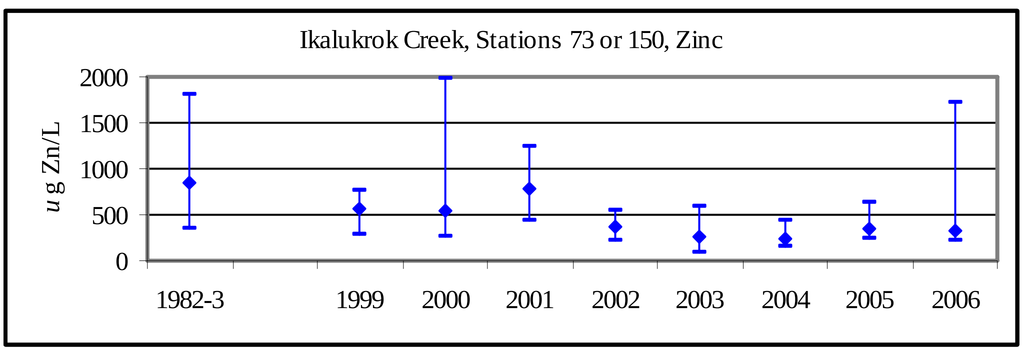

Figure 23. Median, maximum, and minimum concentrations of Zn at Stations 73 or 150.

Invertebrate Community (Abundance, Density, Taxa Richness, and Structure)

Aquatic invertebrate abundance, density, taxa richness, and structure are presented in Figures 24 through 27. Considerable variability in aquatic invertebrate abundance and density are shown in Figures 24 and 25. The lowest densities occurred in 1999, 2002, and 2004 – these are the same years that densities were lowest at Station 7 in Ikalukrok Creek. The pattern between these two sites in terms of abundance and density is similar.

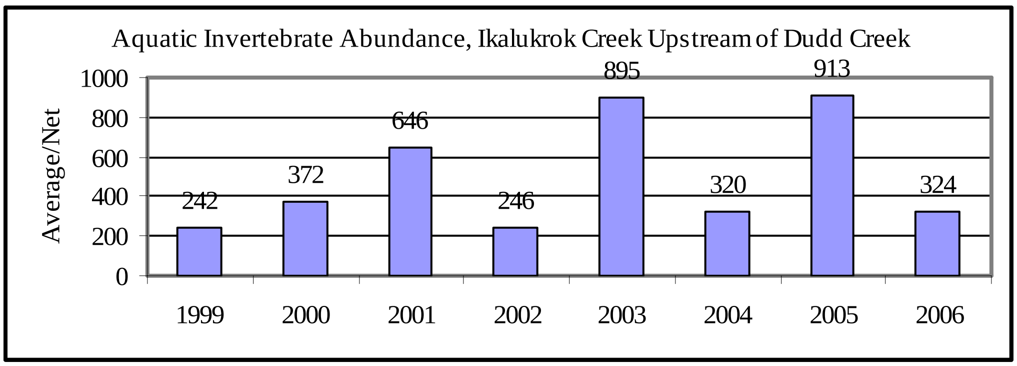

Figure 24. Aquatic invertebrate abundance, Ikalukrok Creek upstream of Dudd Creek.

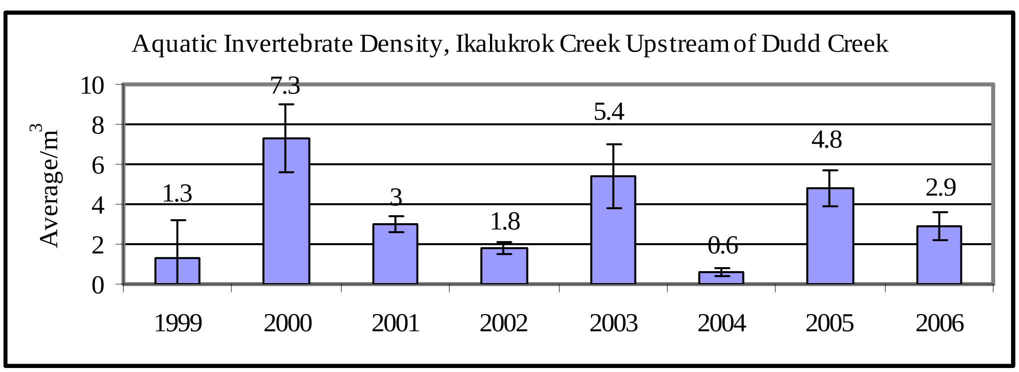

Figure 25. Aquatic invertebrate density, Ikalukrok Creek upstream of Dudd Creek.

Total aquatic taxa in Ikalukrok Creek upstream of Dudd Creek are reported in Figure 26. Taxa richness is fairly consistent among sample years ranging from a low of 13 to a high of 22 (Figure 26).

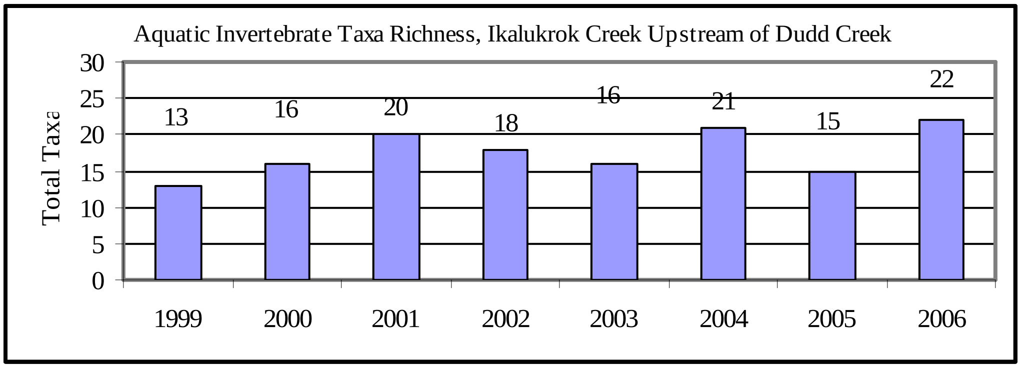

Figure 26. Aquatic invertebrate taxa richness, Ikalukrok Creek upstream of Dudd Creek.

The proportion of EPT in the aquatic invertebrate samples peaked in 2001 at 53% (Figure 27). Peak percent EPT at Station 7 in Ikalukrok Creek downstream of Dudd Creek also was seen in 2001. In 5 out of 8 sample years, the percent EPT was between 20 and 28%.

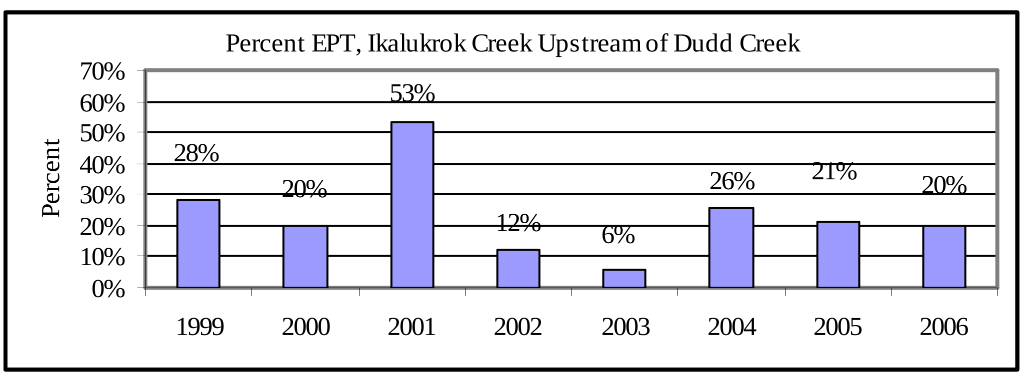

Figure 27. Percent EPT, Ikalukrok Creek upstream of Dudd Creek.

Periphyton Standing Crop

Algae biomass, as estimated by chlorophyll-a concentrations has been fairly consistent over the sample years in Ikalukrok Creek upstream of Dudd Creek (Figure 28).

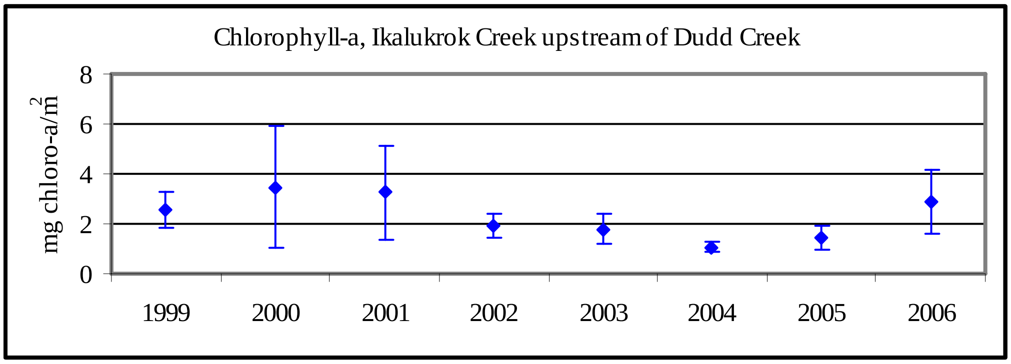

Figure 28. Average concentration of chlorophyll-a, plus and minus one standard deviation, Ikalukrok Creek upstream of Dudd Creek.

Biomonitoring Summary, Ikalukrok Creek Upstream of Dudd Creek

Table 5. Ikalukrok Creek, upstream of Dudd Creek, 1999 to 2006

Water Quality	TDS concentrations below 1,000 mg/L Median Cd and Zn concentrations lower than baseline Maximum Pb concentrations higher than baseline
Invertebrates	Abundance and density highly variable Taxa Richness, fairly consistent 1999 to 2006 % EPT, fairly consistent 5 out of 8 years
Periphyton	Fairly consistent in all sample years
Larval Fish	Arctic grayling in 2000, 2002, and 2003 Slimy sculpin in 2005 and 2006

Ikalukrok Creek, Station 8

Site Description

Ikalukrok Creek, downstream of Mainstem Red Dog Creek, is a relatively fast-flowing stream with medium sized gravel to small cobble substrate (Figure 29). Streambanks are vegetated with various species of willow and gravel bars are exposed at low flows. During summer, the stream bottom frequently is covered with filamentous algae.

Figure 29. Ikalukrok Creek downstream of Mainstem Red Dog Creek, Station 8.

Water samples are not collected at Station 8 in recent years because water from Mainstem Red Dog and Ikalukrok creeks is not mixed until further downstream. Water samples are now collected at Station 150 about 0.5 km downstream of Station 8. Waters are completely mixed under all flow conditions at Station 150.

Invertebrate Community (Abundance, Density, Taxa Richness, and Structure)

Aquatic invertebrate abundance, density, taxa richness, and structure are presented in Figures 30 through 34. Variability for both abundance and density among sample years are high (Figures 30 and 31).

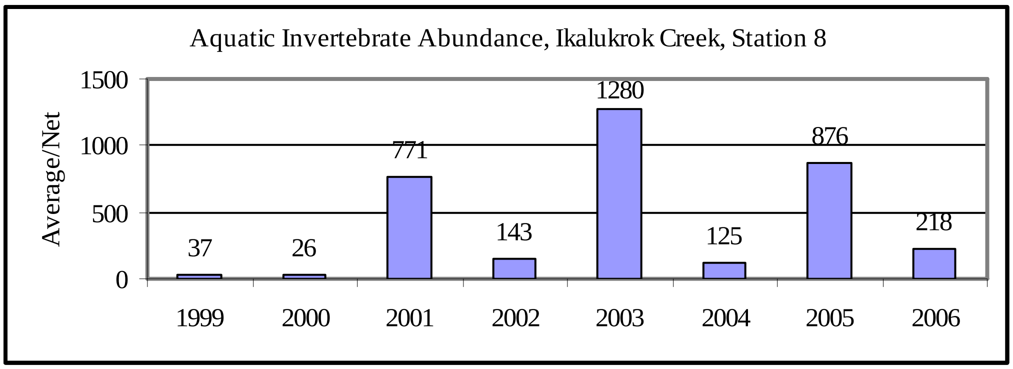

Figure 30. Aquatic invertebrate abundance, Ikalukrok Creek at Station 8.

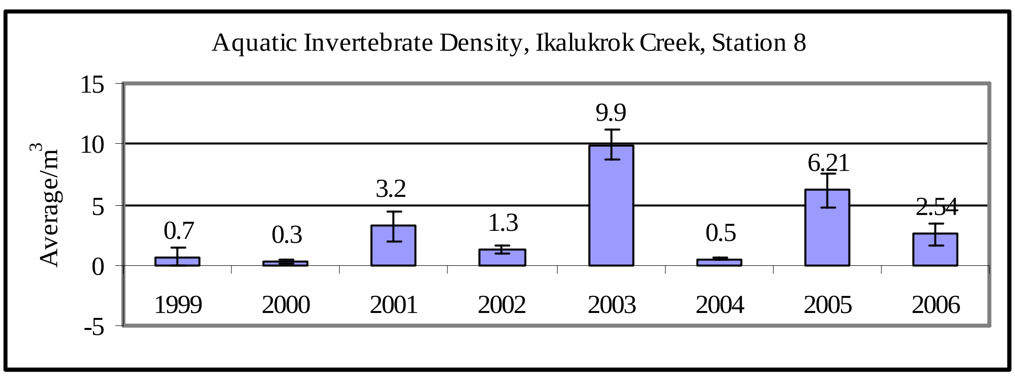

Figure 31. Aquatic invertebrate density, Ikalukrok Creek at Station 8.

Total aquatic taxa present vary from a low of 10 to a high of 24 (Figure 32). Taxa present generally have been higher the last four years (2003 to 2006). The proportion of EPT in samples has been fairly consistent at Station 8 in Ikalukrok Creek and generally as high or higher than the sites located downstream for the last three years (Figure 33).

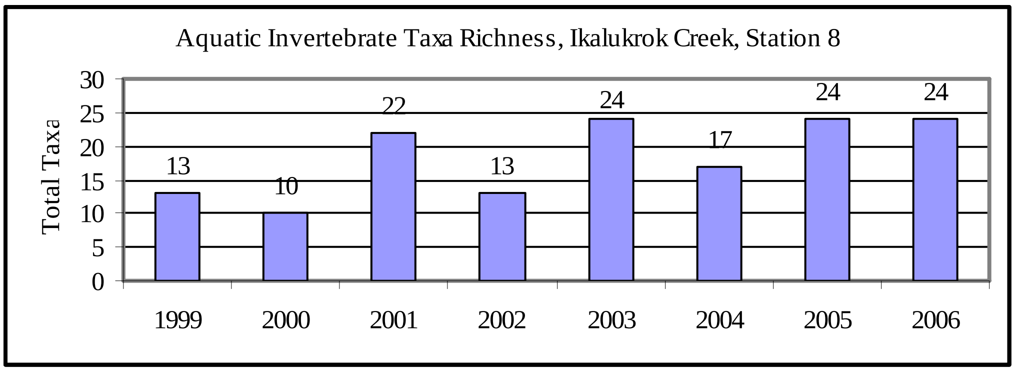

Figure 32. Aquatic invertebrate taxa richness, Ikalukrok Creek at Station 8.

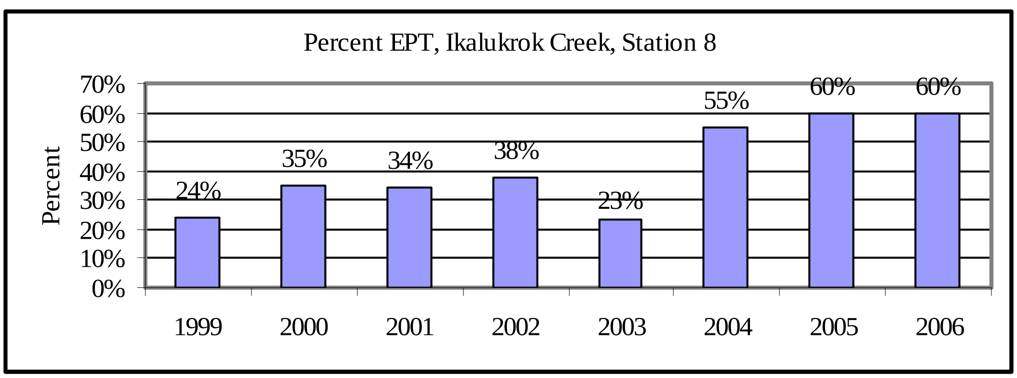

Figure 33. Percent EPT, Ikalukrok Creek at Station 8.

Periphyton Standing Crop

Algae biomass, as estimated by chlorophyll-a concentrations, has been consistent from 1999 through 2003, but higher from 2004 to 2006 (Figure 34).

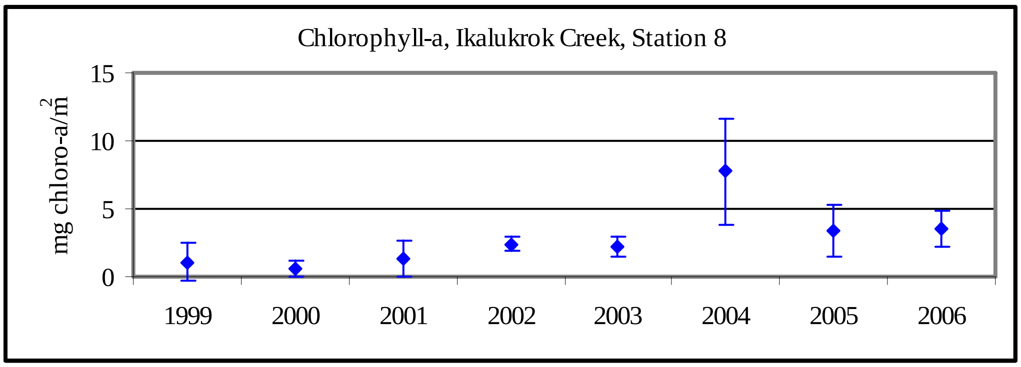

Figure 34. Average concentration of chlorophyll-a, plus and minus one standard deviation, Ikalukrok Creek at Station 8.

Biomonitoring Summary, Station 8

Table 6. Ikalukrok Creek, Station 8, 1999 to 2006.

Water Quality	Ikalukrok and Mainstem Red Dog creeks not mixed, no data presented
Invertebrates	Abundance and density highly variable Taxa Richness, higher in last four years (2003 to 2006) % EPT, higher in last three years (2004 to 2006)
Periphyton	Fairly consistent, but higher last three years (2004 to 2006)
Larval Fish	Arctic grayling in 2000 and 2002

Ikalukrok Creek, Station 9

Site Description

Station 9 is located on Ikalukrok Creek upstream of the confluence with Mainstem Red Dog Creek and near the US Geological Survey gauging station. Ikalukrok Creek, just upstream of Mainstem Red Dog Creek, divides around a large partially vegetated island; the right channel facing downstream carries most of the flow. The substrate consists of gravel and cobble with some boulders with occasional side channels present (Figure 35).

Figure 35. Ikalukrok Creek upstream of Mainstem Red Dog Creek, Station 9.

Water Quality

Water quality at Station 9 is not affected by water discharged from the Red Dog water treatment facility, but is affected by natural mineral seeps located upstream. Since our fieldwork began in 1990, it was not until summer 1997 that we noticed visible effects to water clarity in Ikalukrok Creek. Mineralized seeps are visible along Ikalukrok Creek, upstream of Mainstem Red Dog Creek, at Moil, Noa, Cub, and West Fork Ikalukrok creeks (Weber Scannell and Ott 2006). Visually, the most dramatic seep is Cub Creek. The pH at Station 9 during the ice-free season is shown in Figure 36. The lowest pH values recorded were in 1999 and 2003.

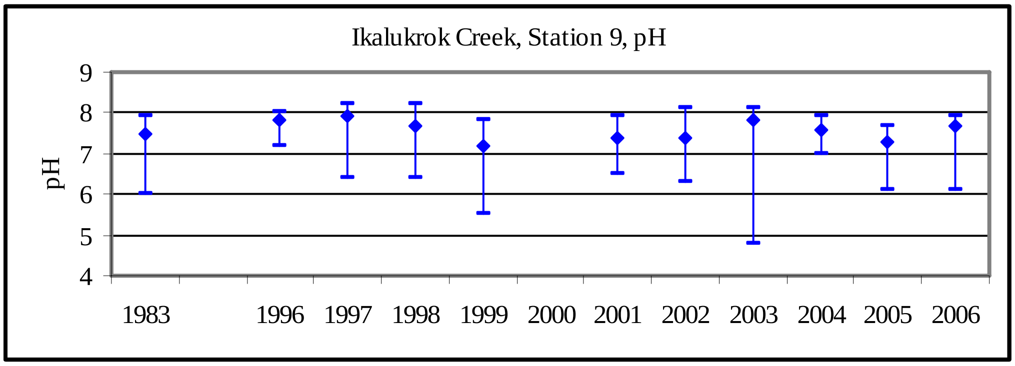

Figure 36. Median, maximum, and minimum pH at Station 9 in Ikalukrok Creek.

Concentrations of Al, Cd, Cu, Pb, Se, and Zn are presented in Figures 37 through 42. Baseline data are available for Al, Cd, Cu, Pb, and Zn. Both Cd and Zn increased from 1999 through 2001 as compared with baseline data, but have shown a decreasing trend since 2002 with the exception of some higher concentrations in summer 2006. Al concentrations are higher than baseline data (Figure 37). Although Zn concentrations decreased from 2002 to 2006, they are still higher than baseline data. The most likely cause of these changes (i.e., increases) is the very active mineral seep at Cub Creek.

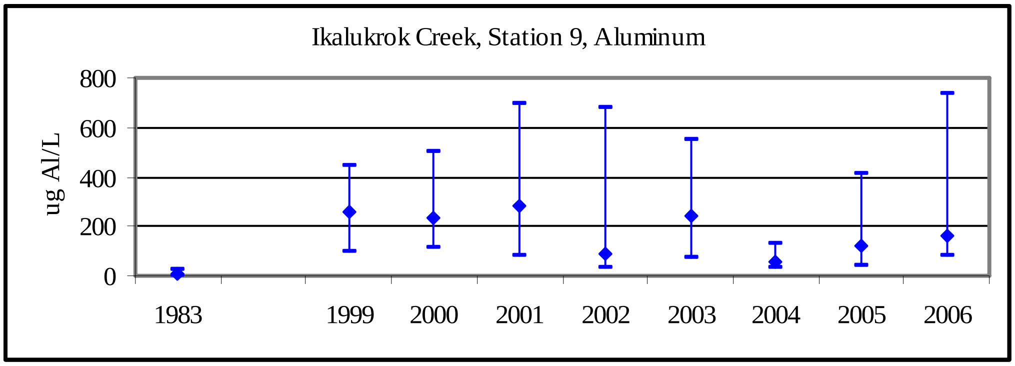

Figure 37. Median, maximum, and minimum concentrations of Al at Station 9.

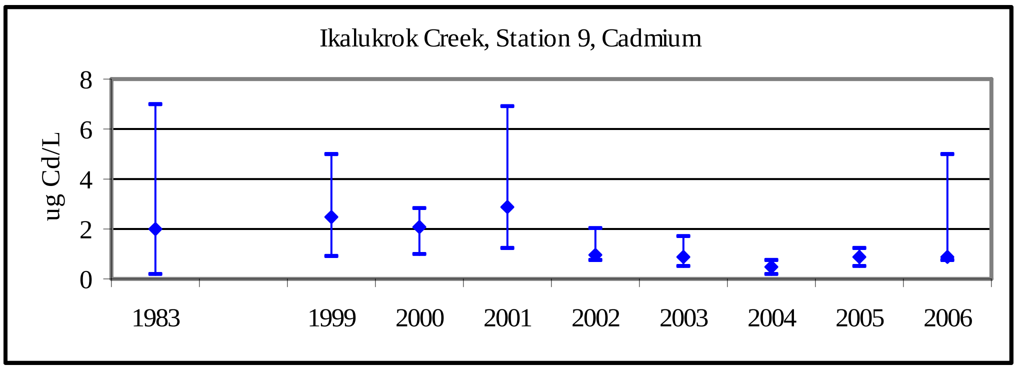

Figure 38. Median, maximum, and minimum concentrations of Cd at Station 9.

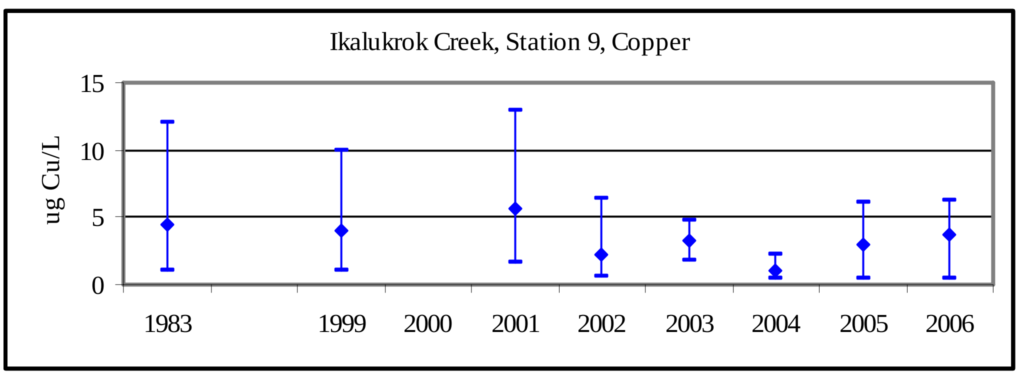

Figure 39. Median, maximum, and minimum concentrations of Cu at Station 9.

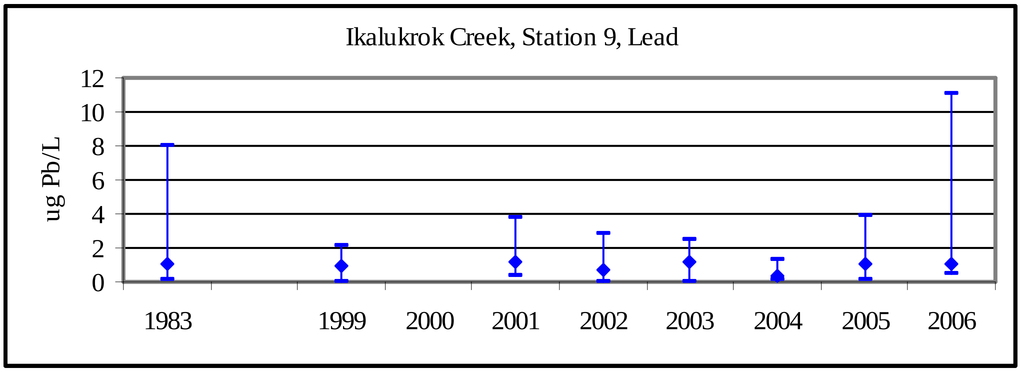

Figure 40. Median, maximum, and minimum concentrations of Pb at Station 9.

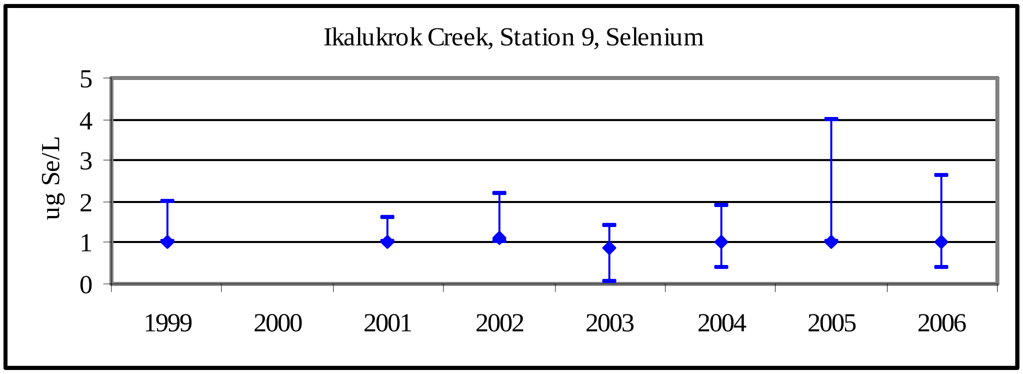

Figure 41. Median, maximum, and minimum concentrations of Se at Station 9.

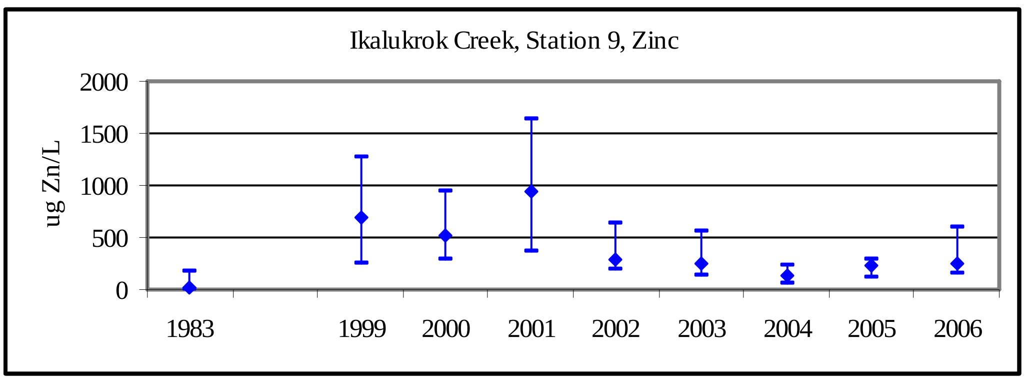

Figure 42. Median, maximum, and minimum concentrations of Zn at Station 9.

Since the effects of the Cub Creek seep were first noticed in summer 1997, we graphed the Cd and Zn data collected by TCAK prior to 1999 (Figures 43 and 44). Data for Cd include 1995 through 2006 and not previous years because method detection limits were high (3 *u*g/L). Zn data are presented from 1991 through 2006. It is apparent, when looking at the long term data base, including baseline data, that Cd and Zn began to increase in 1997, peaked from 1998 through 2001, and have tended to decrease since 2002. These changes are due in large part to metals entering Ikalukrok Creek from natural seeps upstream of Station 9.

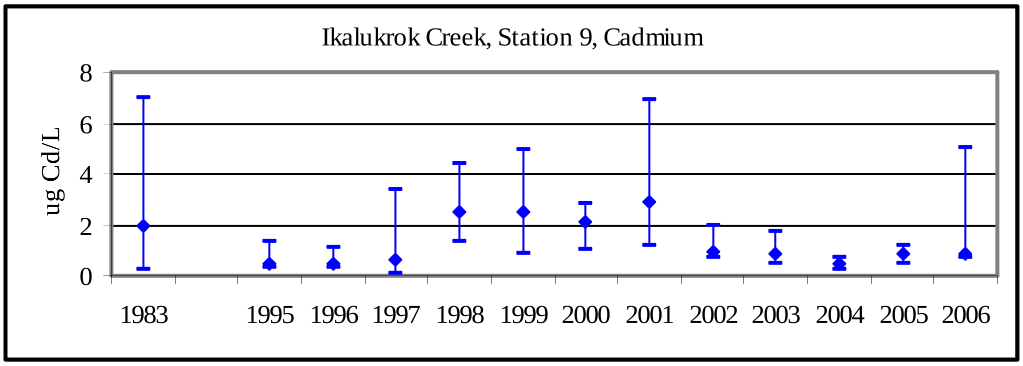

Figure 43. Median, maximum, and minimum concentrations of Cd at Station 9 (1983 and 1995 to 2006).

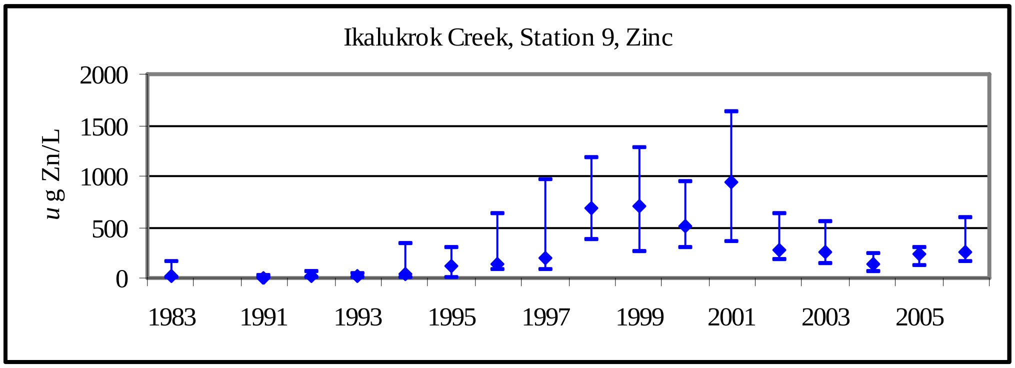

Figure 44. Median, maximum, and minimum concentrations of Zn at Station 9 (1983 and 1995 to 2006).

Invertebrate Community (Abundance, Density, Taxa Richness, and Structure)

Aquatic invertebrate abundance, density, taxa richness, and structure are presented in Figures 45 through 48. Abundance and density of aquatic invertebrates is highly variable among sample years (Figures 45 and 46). Although highly variable, there are similarities between Stations 8 and 9, with lower overall aquatic invertebrates in 1999, 2000, 2002, 2004, and 2006.

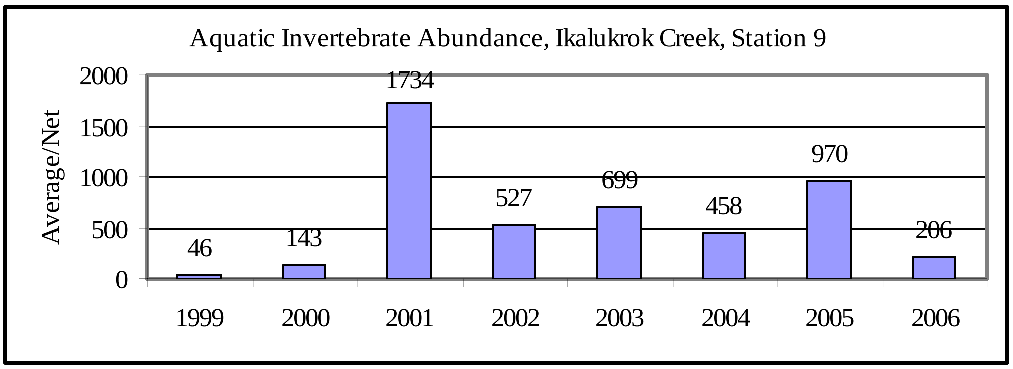

Figure 45. Aquatic invertebrate abundance, Ikalukrok Creek at Station 9.

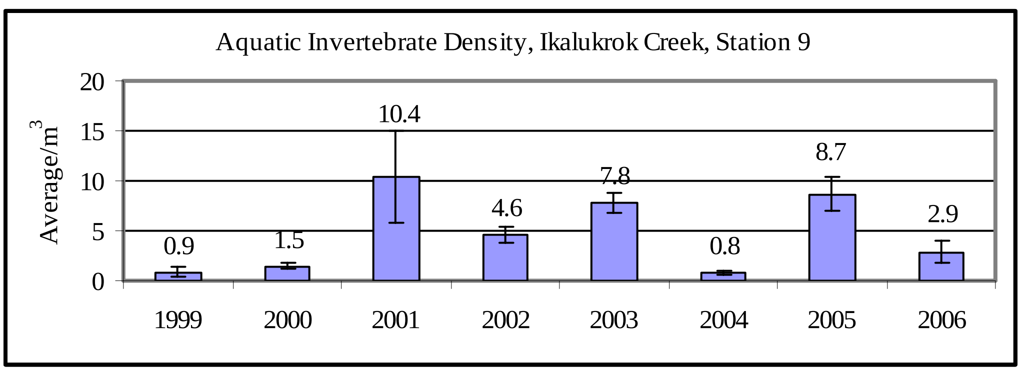

Figure 46. Aquatic invertebrate density, Ikalukrok Creek at Station 9.

Total aquatic taxa in Ikalukrok Creek, upstream of Mainstem Red Dog Creek, varied from a low of 8 to a high of 20 (Figure 47). The percent EPT was highest in 2005 (Figure 48). Generally, EPT percentages are higher at Stations 8 and 9 than at the two other sites on Ikalukrok Creek near the mouth of Dudd Creek.

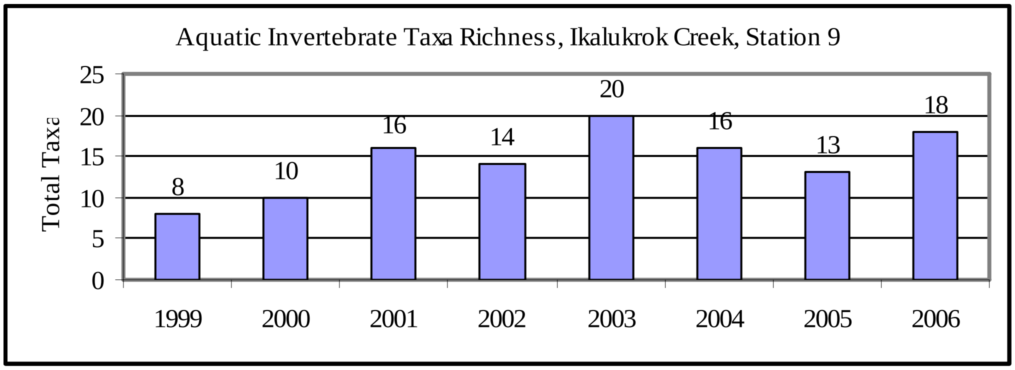

Figure 47. Aquatic invertebrate taxa richness, Ikalukrok Creek at Station 9.

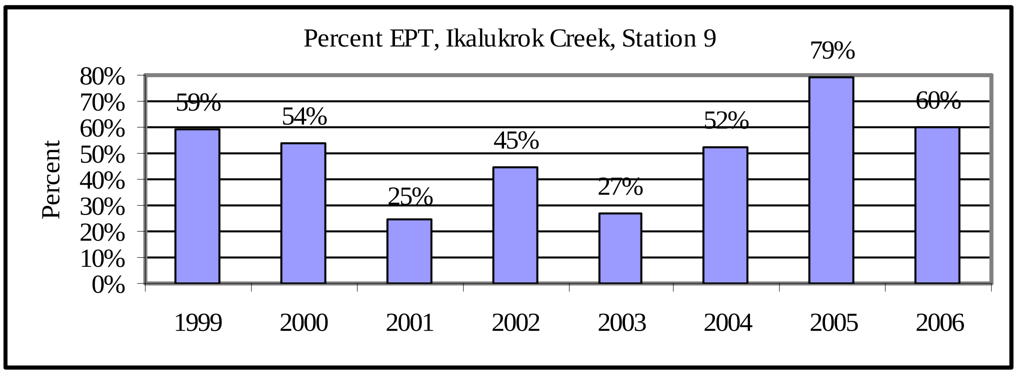

Figure 48. Percent EPT, Ikalukrok Creek at Station 9.

Periphyton Standing Crop

Algal biomass, as estimated by chlorophyll-a concentrations, is lower from 1996 to 2001 than from 2002 through 2006 (Figure 49). All periphyton samples are collected in early July, with August 2006 being an exception. These periphyton data track very closely with Zn and Cd concentrations measured over similar time frames. Improved water quality in Ikalukrok Creek in recent years has resulted in increased periphyton standing crop.

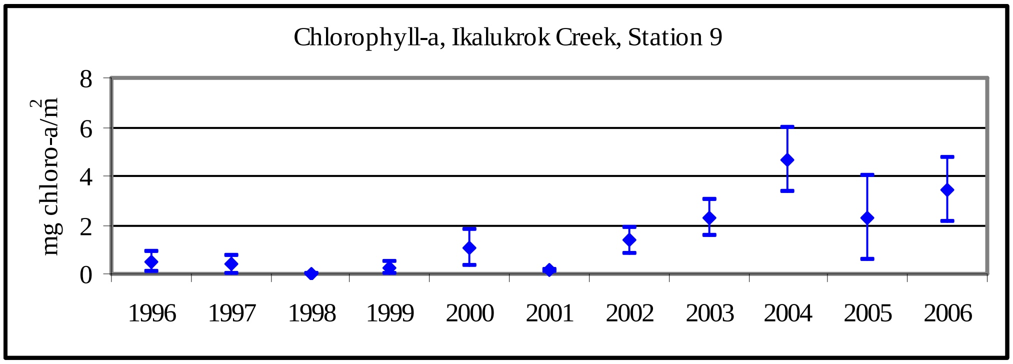

Figure 49. Average concentration of chlorophyll-a, plus and minus one standard deviation, Ikalukrok Creek at Station 8.

Biomonitoring Summary, Ikalukrok Creek Station 9

Table 7. Ikalukrok Creek, Station 9, 1999 to 2006.

Water Quality	Cd and Zn began to increase in 1997, peaked from 1998 to 2001, and have tended to remain stable since 2002
Invertebrates	Abundance and density highly variable Taxa Richness, higher in last three years (2004 to 2006) % EPT, higher in last three years (2004 to 2006)
Periphyton	Low from 1996 to 2001, but higher 2002 to 2006, appear to track with improvements in water quality
Larval Fish	Arctic grayling in 1999 and 2000 Slimy sculpin in 2004

Mainstem Red Dog Creek, Station 10

Site Description

Mainstem Red Dog Creek varies in width from 3.5 to 18 m and water depths range from 0.06 to 2.5 m. The streambed consists mostly of gravel, small cobbles, and boulders (Figure 50). The creek has some meanders and areas where the channel has shifted location. Deep pools (>2 m) are found along cut banks with rock outcroppings. Dense mats of filamentous green algae are common along reaches of the creek.

Figure 50. Mainstem Red Dog Creek, Station 10.

Water Quality

Discharge volume and quality from the water treatment system at Red Dog is regulated to control the TDS concentrations in Mainstem Red Dog Creek. Concentrations of TDS have been limited to 500 mg/L during Arctic grayling spawning in spring by permit condition. However, a TDS site specific criterion (SSC) of 1,500 mg/L during Arctic grayling spawning was made by ADEC and became effective on February 15, 2006. The US Environmental Protection Agency approved the 1,500 mg/L TDS SSC on April 21, 2006. TDS concentrations at Station 10 in Mainstem Red Dog Creek during the 2006 discharge season are shown in Figure 51. TDS concentrations did not exceed the 1,500 mg/L SSC.

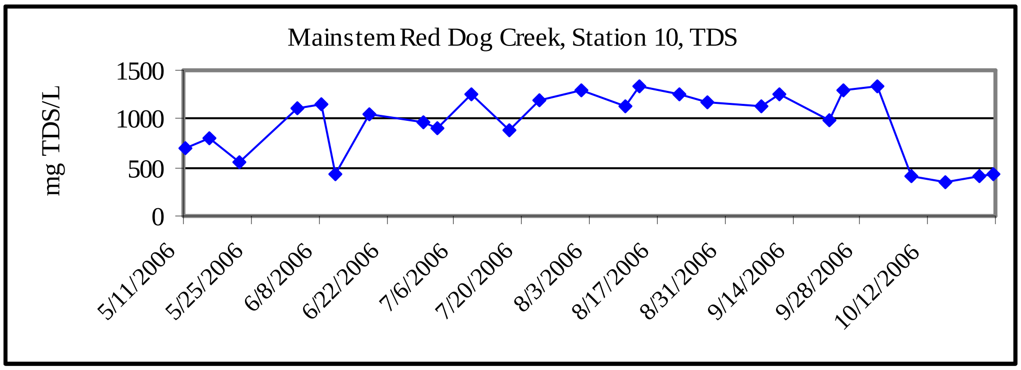

Figure 51. TDS concentrations in Mainstem Red Dog Creek, Station 10.

Monitoring of the spring migration of adult Arctic grayling into Mainstem Red Dog and North Fork Red Dog creeks continued in spring 2006 (Ott and Morris 2006a). Breakup was late with a warming trend in late May, followed by cold weather and snow in early June. Two fyke nets were fished in North Fork Red Dog Creek near Station 12. Angling was used to capture Arctic grayling in North Fork Red Dog Creek downstream of the fyke nets and in Mainstem Red Dog Creek. Turbidity and organic debris were high due to extensive aufeis and associated erosion.

Fyke nets were set on June 11, but it was not until June 14 that we were able to extend one of the net wings to block upstream movement of fish. Spent Arctic grayling females were first caught on June 14. On June 15, 8 of 12 females handled were spent. On June 16, we caught 4 females (one spent, one had globby amorphous eggs, and two were either non-spawners or fully recovered from spawning). We caught 12 Arctic grayling on June 17 (two males, 9 immature, and 1 female non-spawner or fully recovered).

Based on our fyke net catches, fish caught by angling, water temperatures (Figure 52), and our observations of fish movement and condition, it is our conclusion that the majority of Arctic grayling spawning in Mainstem Red Dog Creek was completed by June 15, 2006.

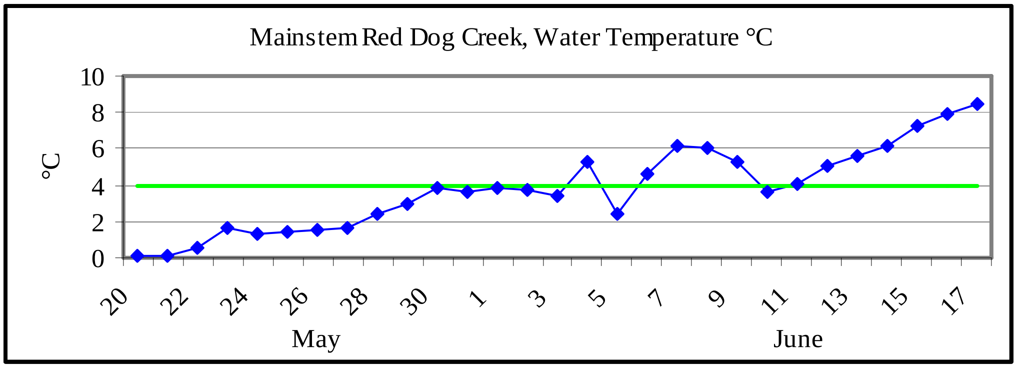

Figure 52. Peak water temperatures in Mainstem Red Dog Creek in spring 2006. Note, the horizontal line shown at 4°C. Conservatively, there could be limited spawning at water temperatures that exceed 3°C. Spawning judged to be complete on June 15.

Concentrations of specific metals in Mainstem Red Dog Creek at Station 10 were high before mining, highest in 1990, and lower after construction of the clean water bypass in March/April 1991 (Figure 53). Improvements to the clean water bypass system have occurred periodically since 1991 (Appendix 1).

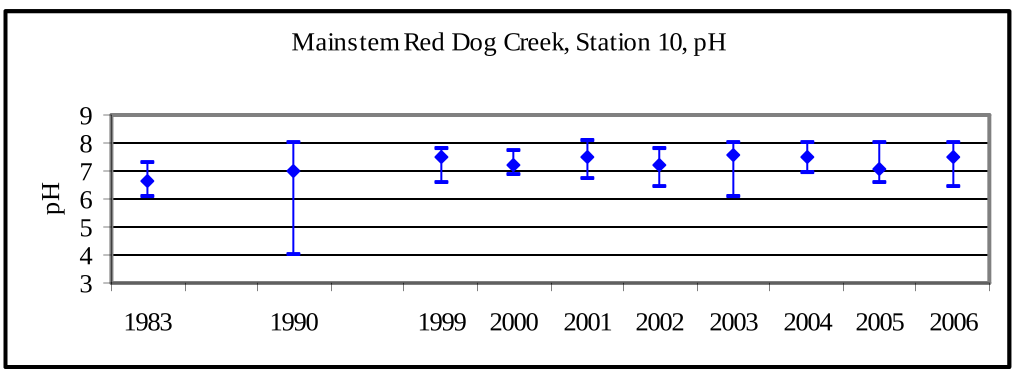

Figure 53. Median, maximum, and minimum pH values, Mainstem Red Dog Creek, Station 10.

Concentrations of Al, Cd, Cu, Pb, Se, and Zn are presented in Figures 54 through 59. Median concentrations of Cd, Pb, and Zn are lower from 1999 through 2006 as compared to baseline data. We see several peak Pb and Al concentrations that exceed baseline data.

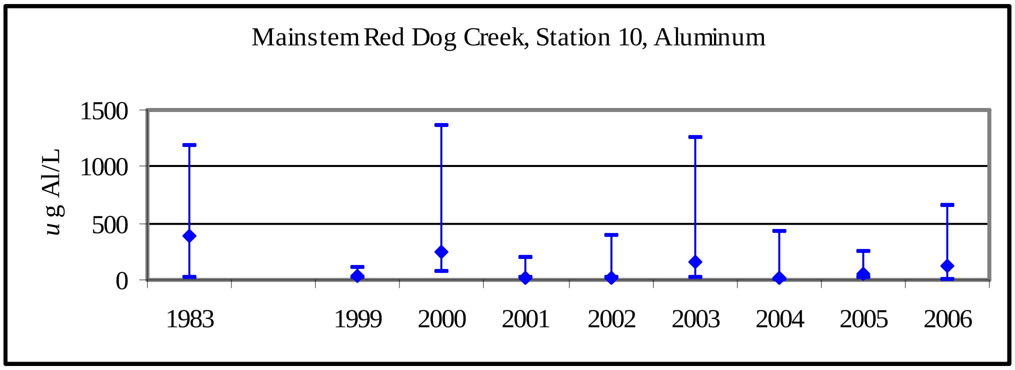

Figure 54. Median, maximum, and minimum concentrations of Al at Station 10.

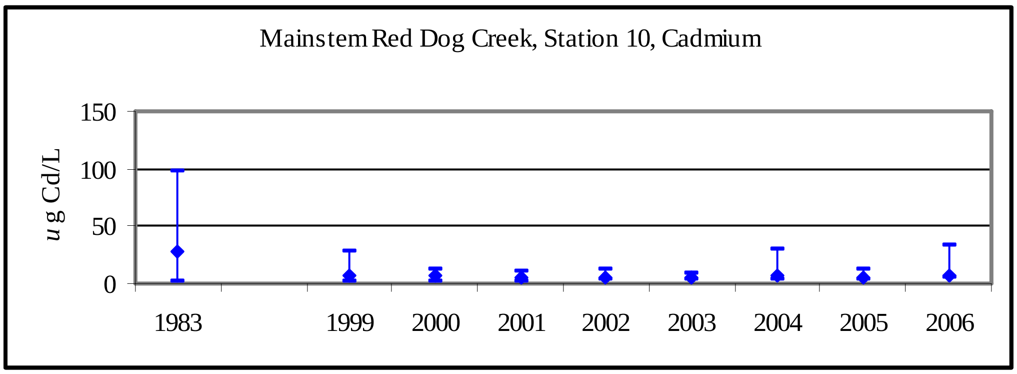

Figure 55. Median, maximum, and minimum concentrations of Cd at Station 10.

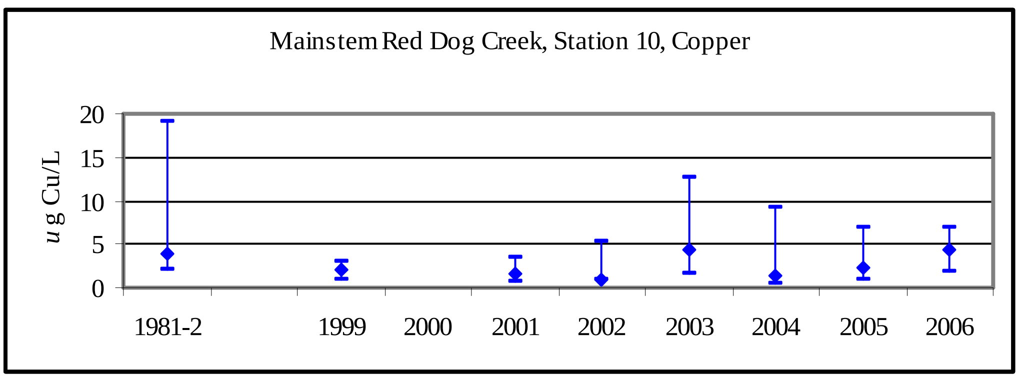

Figure 56. Median, maximum, and minimum concentrations of Cu at Station 10.

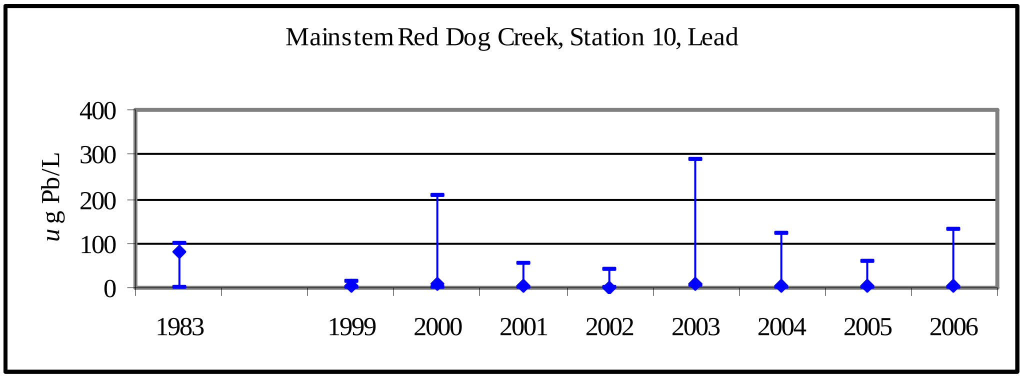

Figure 57. Median, maximum, and minimum concentrations of Pb at Station 10.

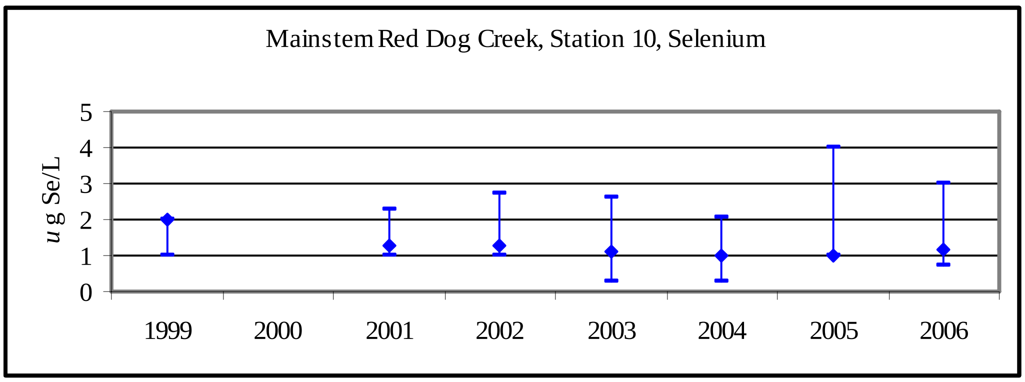

Figure 58. Median, maximum, and minimum concentrations of Se at Station 10.

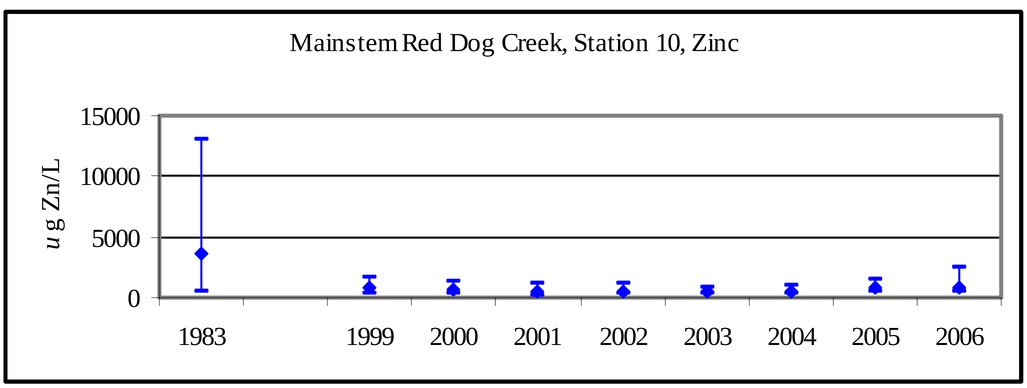

Figure 59. Median, maximum, and minimum concentrations of Zn at Station 9.

Invertebrate Community (Abundance, Density, Taxa Richness, and Structure)

Aquatic invertebrate abundance, density, taxa richness, and structure are presented in Figures 60 through 63. High variability among years in abundance and density of aquatic invertebrates is shown in Figures 60 and 61.

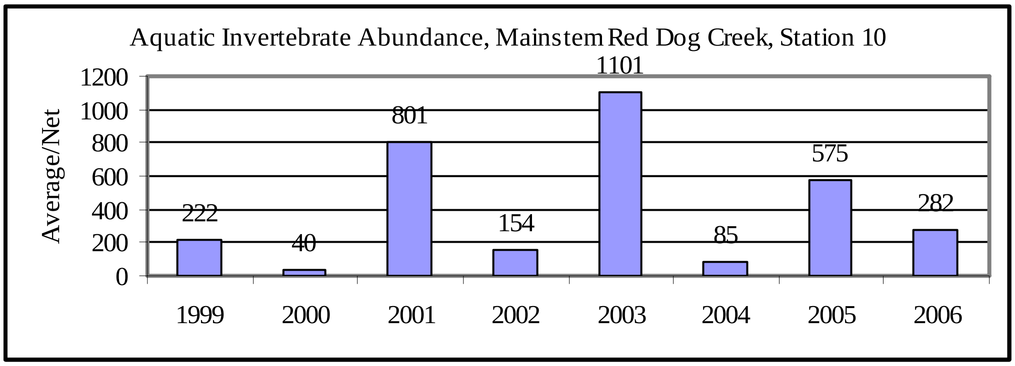

Figure 60. Aquatic invertebrate abundance, Mainstem Red Dog Creek at Station 10.

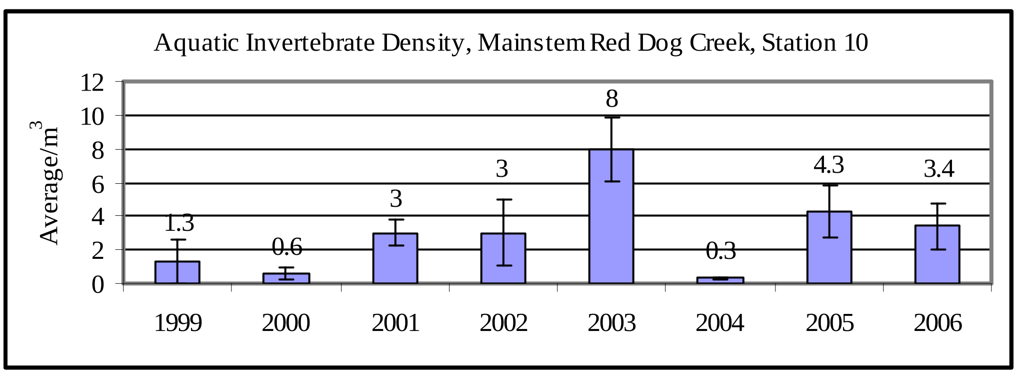

Figure 61. Aquatic invertebrate density, Mainstem Red Dog Creek at Station 10.

Taxa richness varied from a low of 10 in 2000 to a high of 20 in three different sample years (Figure 62). Percent EPT in our samples was highly variable, with a high of 55% in 2003 and a low of 5% in 2001 (Figure 63.

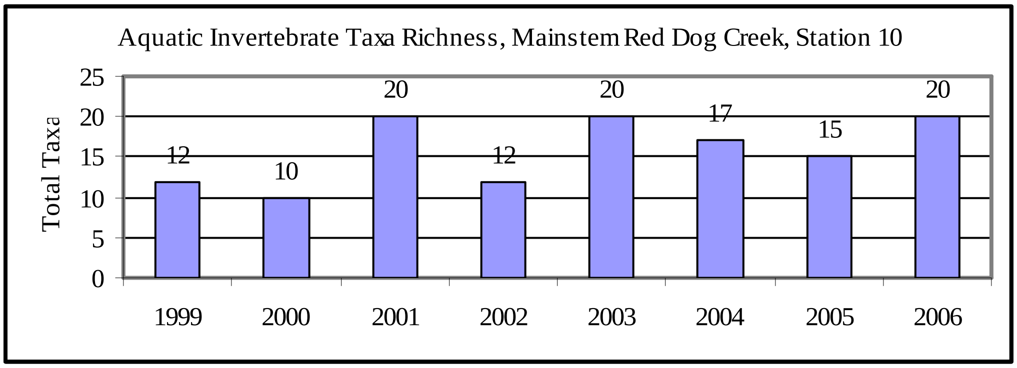

Figure 62. Aquatic invertebrate taxa richness, Mainstem Red Dog Creek at Station 10.

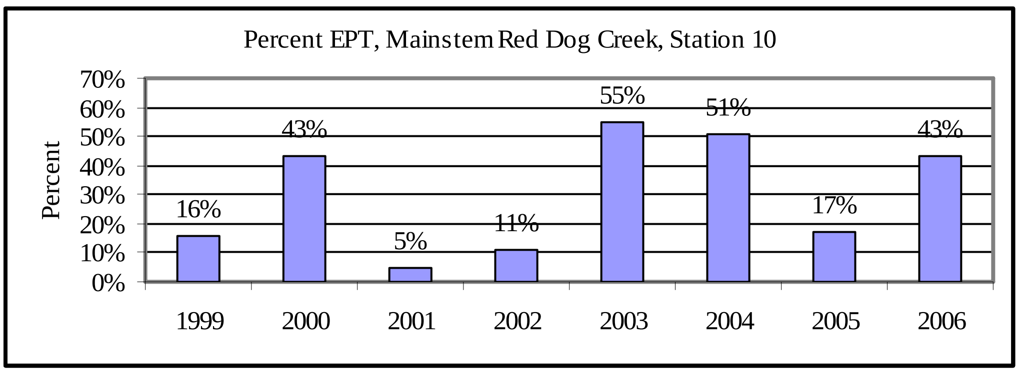

Figure 63. Percent EPT, Mainstem Red Dog Creek at Station 10.

Periphyton Standing Crop

Algal biomass, as estimated by chlorophyll-a concentrations, is presented in Figure 64. The highest periphyton standing crop measured from 1999 to 2006 was in 2004 when the average concentration was 10.1 (Figure 64). There may be an indication that the trend over time, within our sample period, has been for a slight increase in chlorophyll-a at Station 10.

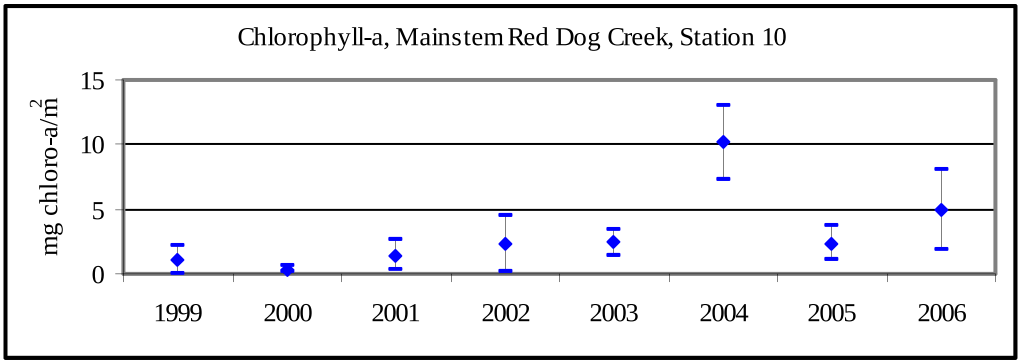

Figure 64. Average concentration of chlorophyll-a, plus and minus one standard deviation, Mainstem Red Dog Creek at Station 10.

Biomonitoring Summary, Mainstem Red Dog Creek Station 10

Table 8. Mainstem Red Dog Creek, Station 10, 1999 to 2006.

Water Quality	TDS limit changed in 2006 to not exceed 1,500 mg/L TDS concentrations did not exceed 1,500 mg/L Median concentrations Cd, Pb, and Zn consistently lower
Invertebrates	Abundance and density highly variable Taxa Richness, slightly higher from 2003 to 2006 % EPT, higher in three of last four years (2004 to 2006)
Periphyton	general trend for a slight increase in periphyton
Larval Fish	Arctic grayling in 1999, 2000, 2002, and 2003

North Fork Red Dog Creek, Station 12

Site Description

North Fork Red Dog and Middle Fork Red Dog creeks merge to form Mainstem Red Dog Creek. North Fork Red Dog Creek has a drainage area of 41 km^2, abundant streamside vegetation, deep pools, and wide riffle areas (Figure 65). Channel widths vary from 7 to 15 m and depths range from 0.1 to 2 m. Arctic grayling spawn in North Fork Red Dog Creek. Juvenile and resident Dolly Varden and juvenile and adult Arctic grayling rear in the creek during the ice-free season.

Figure 65. North Fork Red Dog Creek, Station 12.

Water Quality

North Fork Red Dog Creek is a clearwater stream that drains areas containing ice-rich soils. Field sampling in North Fork Red Dog Creek began in summer 1992. Thermal degradation in the upper part of the drainage causing periodic increases in turbidity was first seen in summer 2000. Turbid water conditions have been observed every year since 2000, but most times North Fork Red Dog Creek flows clear. Several years of total suspended solids data are available (Figure 66). Generally, TDS concentrations are low, but peaks are seen. The general trend appears to be for decreasing TDS concentrations in the creek over time.

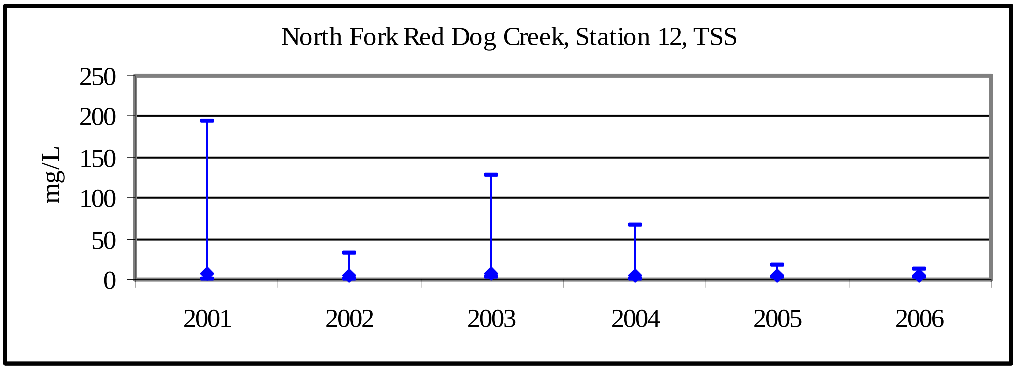

Figure 66. Total suspended sediment in North Fork Red Dog Creek at Station 12.

Concentrations of Al, Cd, Cu, Pb, Se, and Zn are presented in Figures 67 through 72. Maximum concentrations of Al and Pb have exceeded baseline data in some years, but these peak concentrations may be related to sediment input from the upper part of the basin. Median concentrations of Cd, Cu, and Pb appear slightly lower than baseline data.

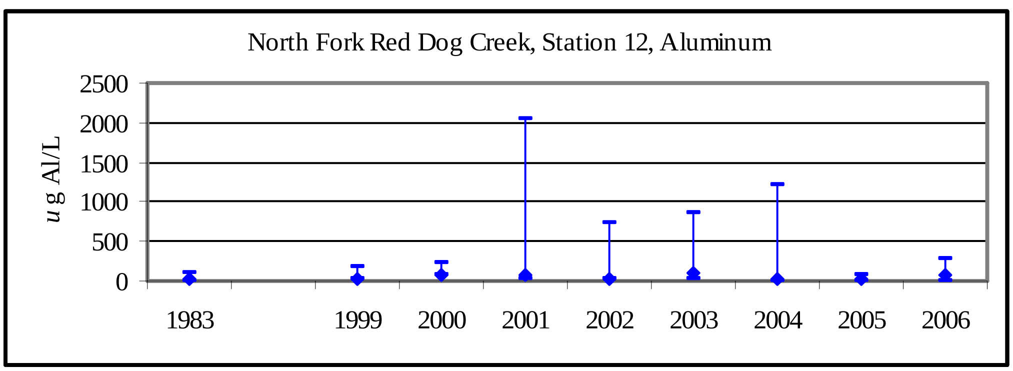

Figure 67. Median, maximum, and minimum concentrations of Al at Station 12.

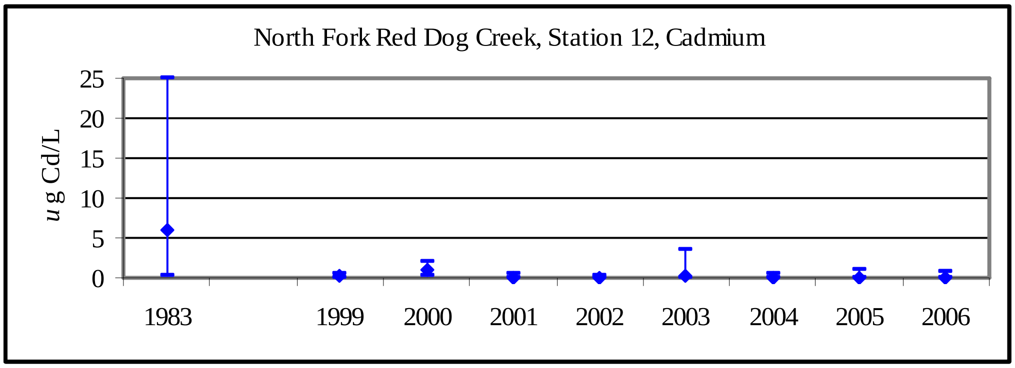

Figure 68. Median, maximum, and minimum concentrations of Cd at Station 12.

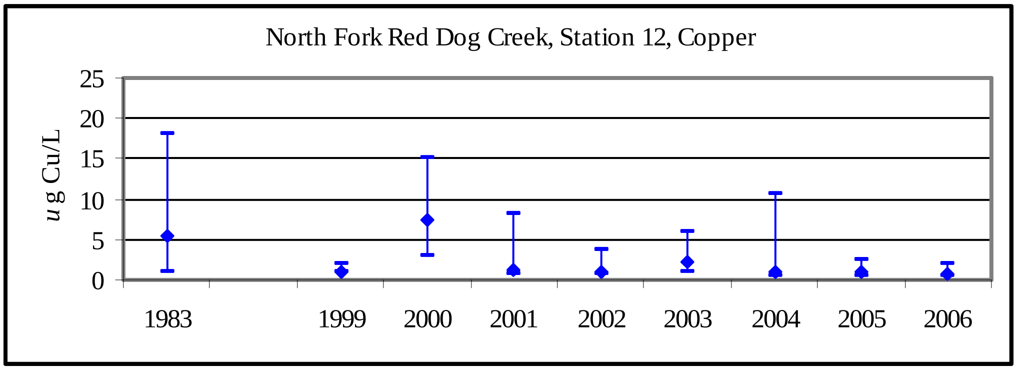

Figure 69. Median, maximum, and minimum concentrations of Cu at Station 12.

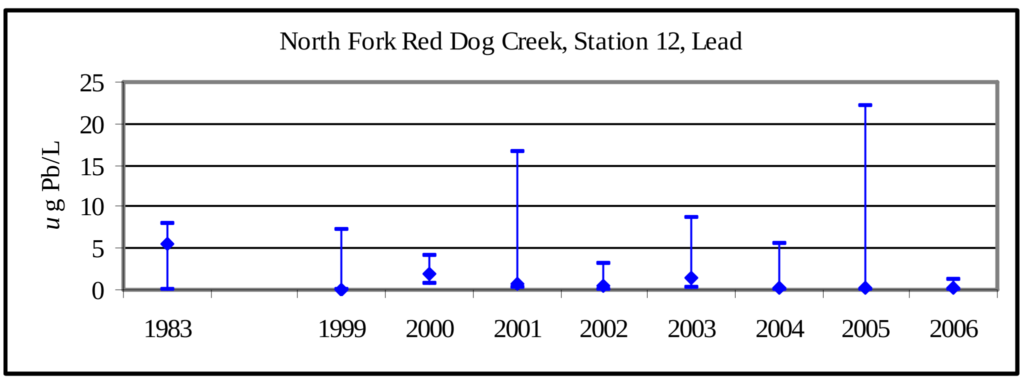

Figure 70. Median, maximum, and minimum concentrations of Pb at Station 12.

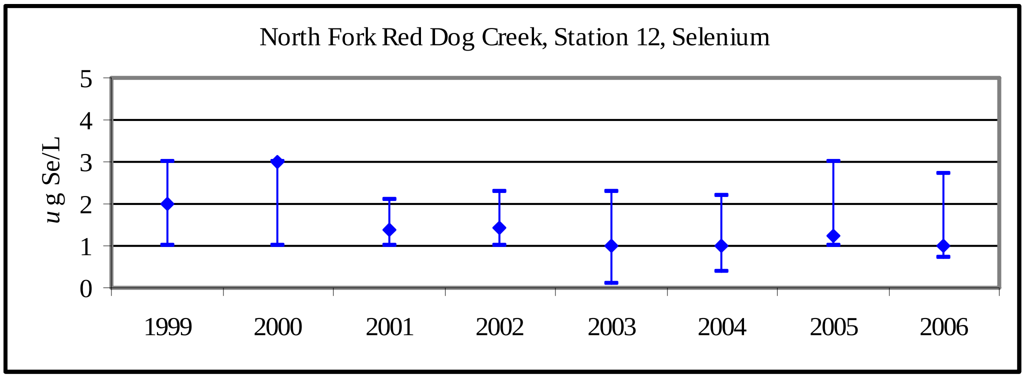

Figure 71. Median, maximum, and minimum concentrations of Se at Station 12.

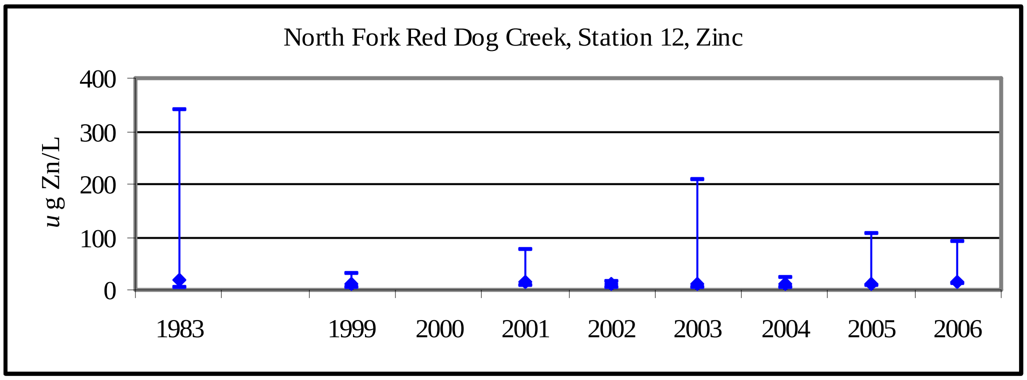

Figure 72. Median, maximum, and minimum concentrations of Zn at Station 12.

Invertebrate Community (Abundance, Density, Taxa Richness, and Structure)

Aquatic invertebrate abundance, density, taxa richness, and structure are presented in Figures 73 through 76. Invertebrate abundance in North Fork Red Dog Creek has ranged from a low of 87 in 2004 to a high of 1,688 in 2006 (Figure 73). Density of aquatic invertebrates also was highest in 2006 (Figure 74).

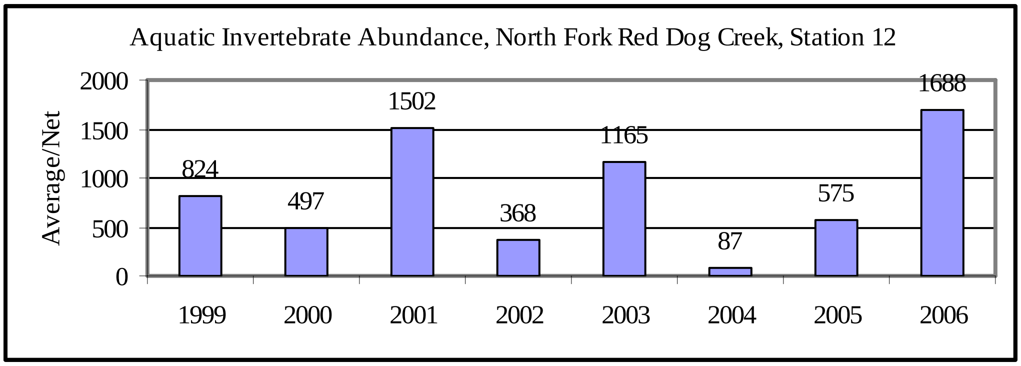

Figure 73. Aquatic invertebrate abundance, North Fork Red Dog Creek at Station 12.

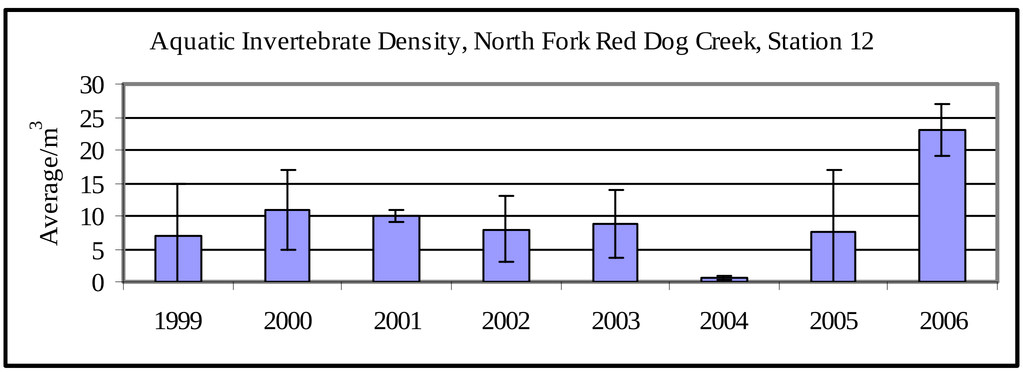

Figure 74. Aquatic invertebrate density, North Fork Red Dog Creek at Station 12.

Taxa richness has been fairly consistent among sample years in North Fork Red Dog Creek (Figure 75). Percent EPT in aquatic samples also has varied among the sample years, but is trending upward with time (Figure 76).

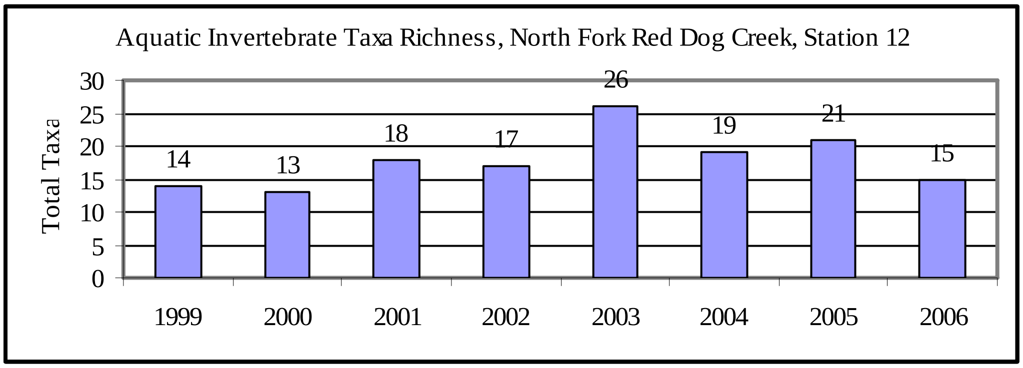

Figure 75. Aquatic invertebrate taxa richness, North Fork Red Dog Creek at Station 12.

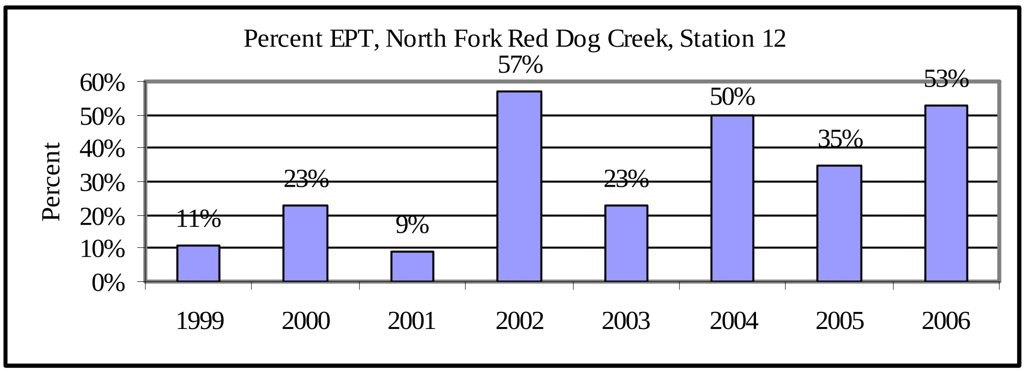

Figure 76. Percent EPT, North Fork Red Dog Creek at Station 12

Periphyton Standing Crop

Algae biomass, as estimated by chlorophyll-a concentrations is presented in Figure 77. Abundant algae is present every year, except summer 2004 (Figure 77). It is worth noting that abundance and density of aquatic invertebrates also was the lowest measured in 2004. In 2004, streambed materials were more heavily covered with sediment than in other sample years.

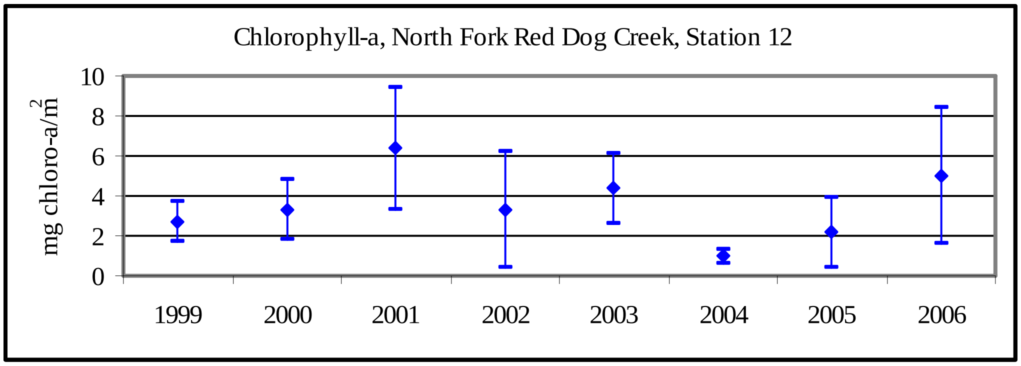

Figure 77. Average concentration of chlorophyll-a, plus and minus one standard deviation, North Fork Red Dog Creek at Station 12.

Biomonitoring Summary, North Fork Red Dog Creek Station 12

Table 9. North Fork Red Dog Creek, Station 12, 1999 to 2006

Water Quality	Turbid water conditions first observed in 2000 Peak Al and Pb concentrations higher than baseline data Median concentrations of Cd, Cu, and Pb slightly lower
Invertebrates	Abundance is highly variable among sample years Density, higher than other sample sites in all but one year Taxa richness is fairly consistent %EPT, slight trend upwards with time
Periphyton	Fairly consistent in most years, except low in 2004
Larval Fish	Arctic grayling in 1997, 1999, 2000, and 2001

Middle Fork Red Dog Creek

Site Description

Water a Station 20 in Middle Fork Red Dog Creek consists of water from the clean water bypass system and the treated mine effluent. Upper Middle Fork Red Dog Creek and tributaries (Sulfur, Shelly, Connie, and Rachel) flow into the clean water bypass system. Middle Fork Red Dog Creek has wide meanders with channel widths varying from 3 to 10 m and depths from 0.3 to 0.45 m (Figure 78).

Figure 78. Middle Fork Red Dog Creek, Station 20

A gabion basket weir blocks migration of fish into Middle Fork Red Dog Creek. The weir is located downstream of Station 20 and immediately upstream of the confluence of Middle Fork and North Fork that form Mainstem Red Dog Creek.

Water Quality

Before mining, the pH ranged from 5.7 to 6.9 in Middle Fork Red Dog Creek (Figure 79). The pH values from 2000 through 2006 are higher than pre-mining. The higher pH values are related to a higher pH in the wastewater mine effluent and higher pH values in the clean water bypass due to interception of highly acidic waters by the dirty water collection system that are then pumped to the tailing facility.

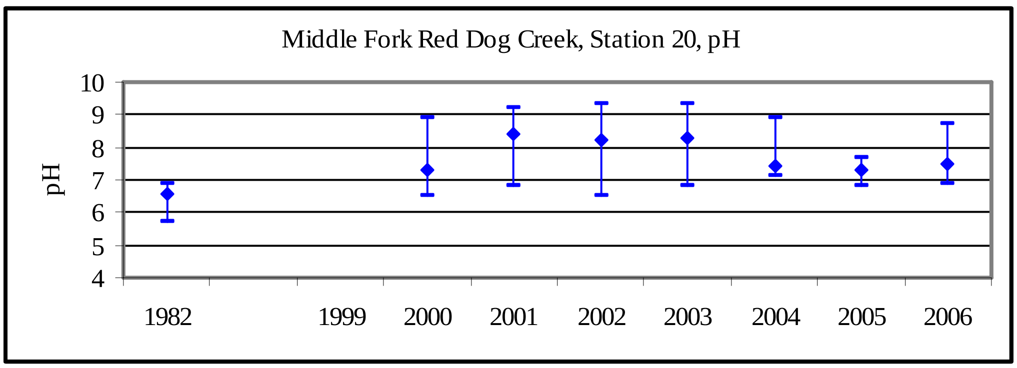

Figure 79. Median, maximum, and minimum pH at Station 20 in Middle Fork Red Dog Creek.

During our August 2006 Red Dog field trip, we observed a substantial amount of precipitate (orange colored) and the water quality was opaque (Ott and Timothy 2006) (Figure 80). The orange colored precipitate extended downstream of the effluent discharge point for at least 1 km. The orange precipitate continued to be present upstream of the discharge point. On August 9, 2006, we drove up the clean water bypass access road and observed the following conditions: Sulfur Creek was clear; Shelly Creek was clear; Connie Creek was orange; Rachel Creek was orange/yellow; and Middle Fork Red Dog Creek upstream of the bypass was clear. TCAK proceeded to collect water samples from these tributaries in the vicinity of the clean water bypass.

Figure 80. Middle Fork Red Dog Creek, just below mine effluent discharge.

Concentrations of Al, Cd, Cu, Pb, Se, and Zn are presented in Figures 81 through 86. Concentrations of Cd and Zn are consistently lower than baseline data. A slight upward trend was noted in Cd and Zn concentrations from 2004 to 2006.

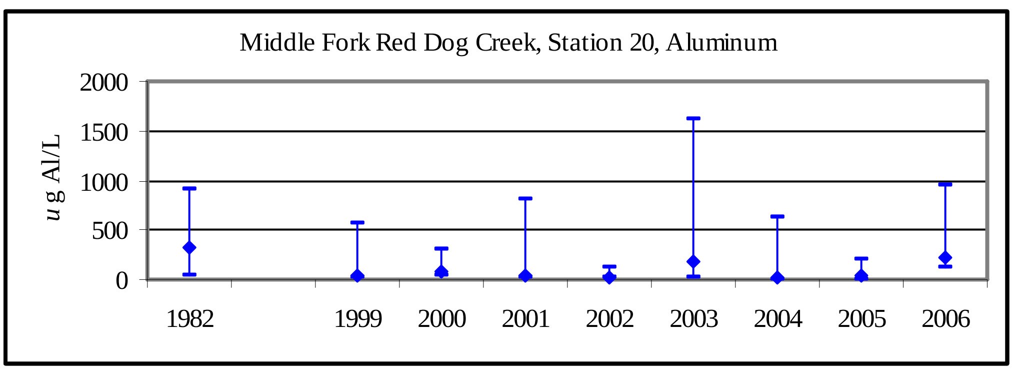

Figure 81. Median, maximum, and minimum concentrations of Al at Station 20.

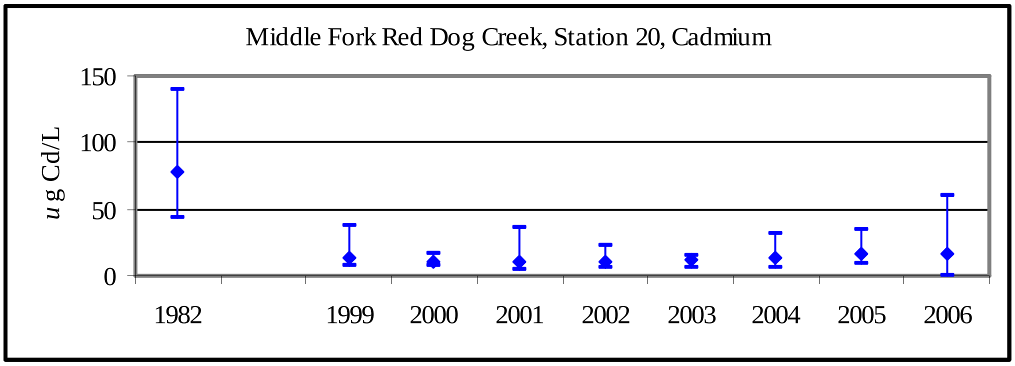

Figure 82. Median, maximum, and minimum concentrations of Cd at Station 20.

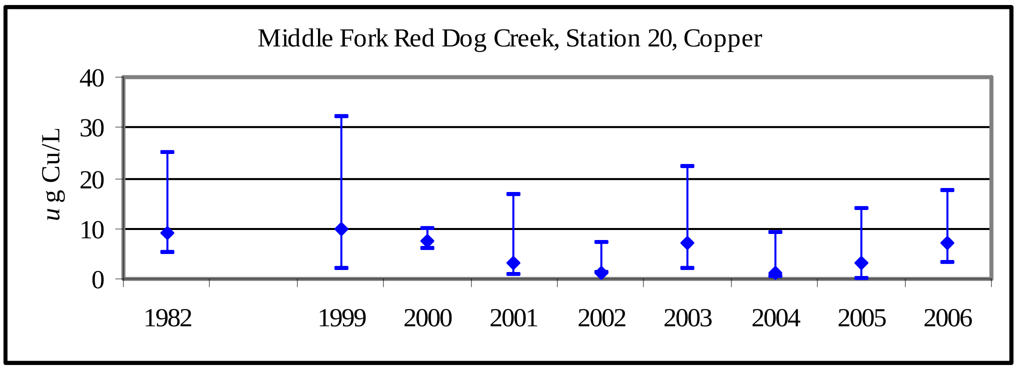

Figure 83. Median, maximum, and minimum concentrations of Cu at Station 20.

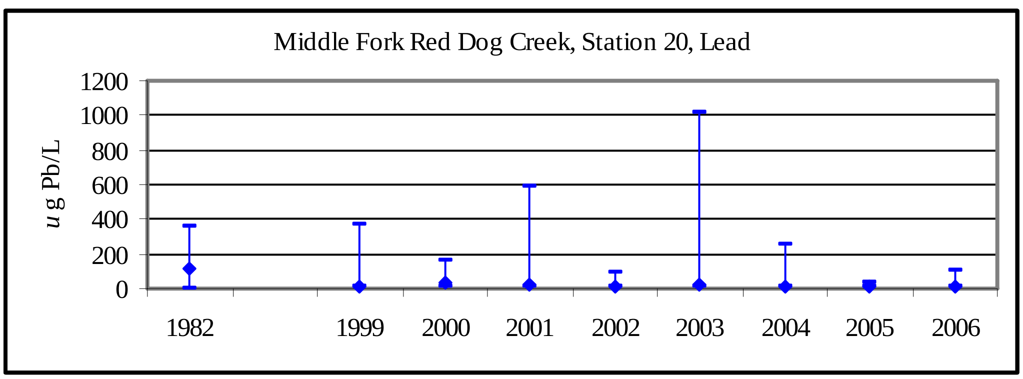

Figure 84. Median, maximum, and minimum concentrations of Pb at Station 20.

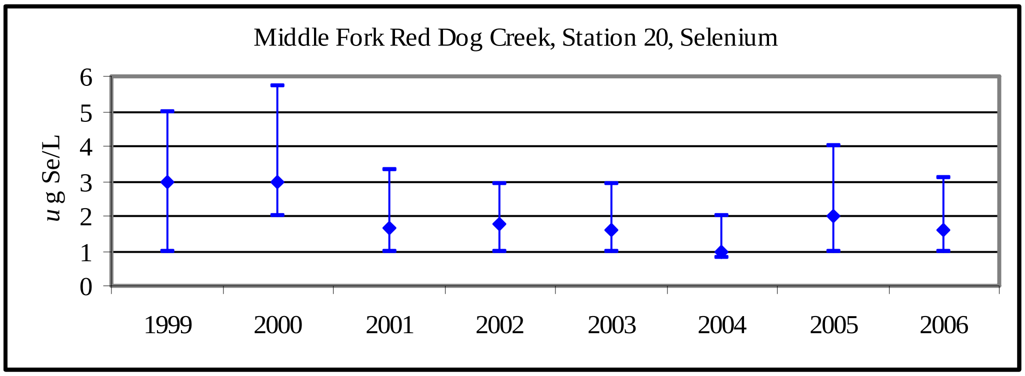

Figure 85. Median, maximum, and minimum concentrations of Se at Station 20.

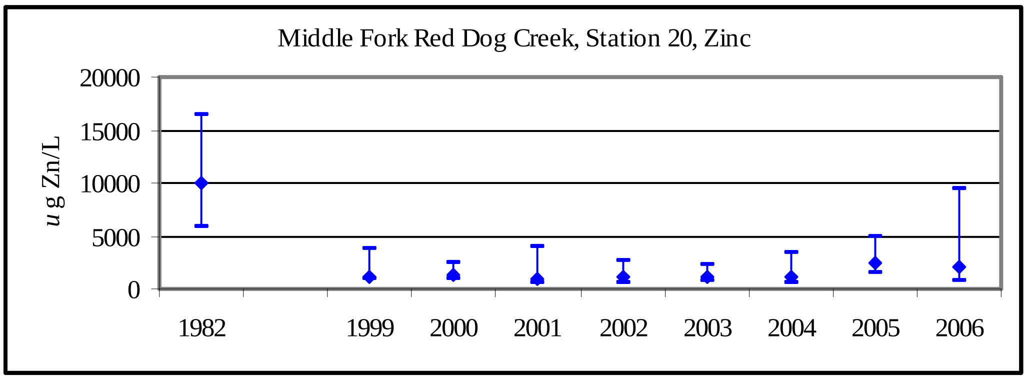

Figure 86. Median, maximum, and minimum concentrations of Zn at Station 20.

Invertebrate Community (Abundance, Density, Taxa Richness, and Structure)

Aquatic invertebrate abundance, density, taxa richness, and structure are presented in Figures 87 through 90. Abundance and density of aquatic invertebrates exhibits high variability among sample years (Figures 87 and 88). Densities of aquatic invertebrates generally are much lower here than in North Fork Red Dog Creek, but comparable with Mainstem Red Dog Creek at Station 10. Total aquatic taxa ranged from 14 to 28 from 1999 to 2006. Percent EPT was highest in 2004 and 2006 – although the percentage is higher, the abundance and density of all aquatic invertebrates was very low.

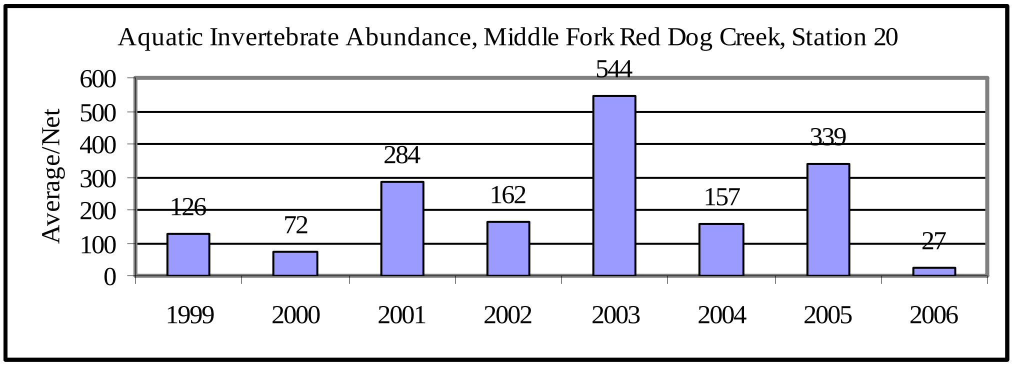

Figure 87. Aquatic invertebrate abundance, Middle Fork Red Dog Creek at Station 20.

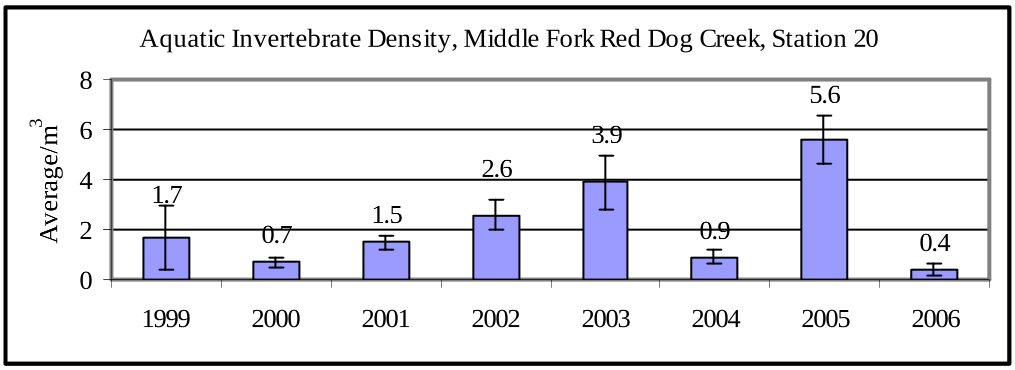

Figure 88. Aquatic invertebrate density, Middle Fork Red Dog Creek at Station 20.

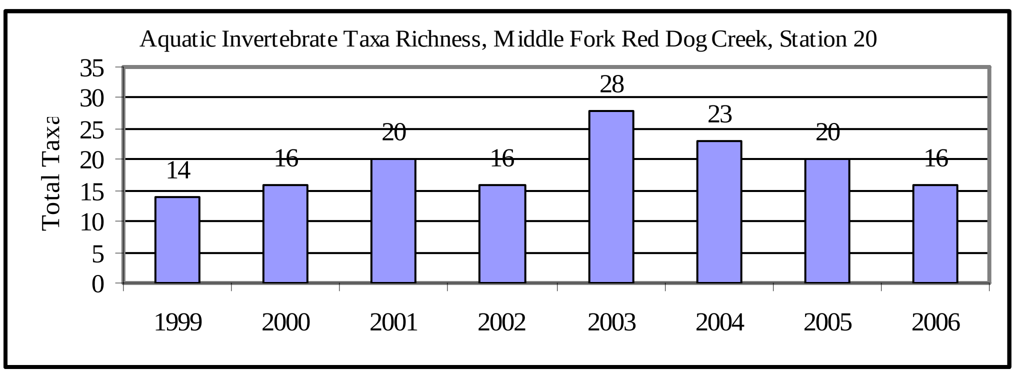

Figure 89. Aquatic invertebrate taxa richness, Middle Fork Red Dog Creek at Station 20.

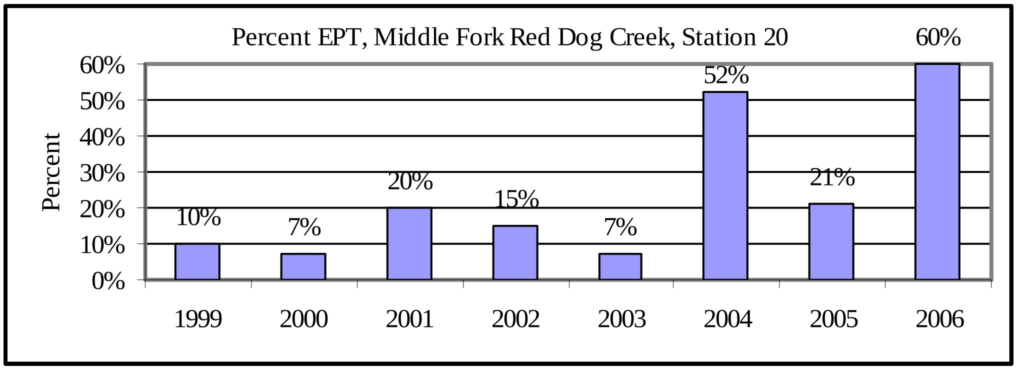

Figure 90. Percent EPT, Middle Fork Red Dog Creek at Station 20.

Periphton Standing Crop

Algae biomass, as estimated by chlorophyll-a concentration, is presented in Figure 91. Chlorophyll-a at Station 20 is consistently low and lower than measurements made at all the other NPDES sample sites. Generally, chlorophyll-a in Middle Fork Red Dog Creek is below detection limits.

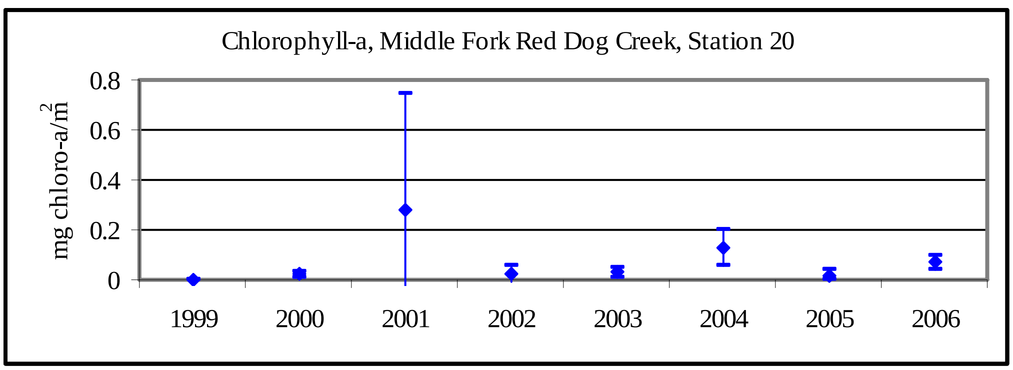

Figure 91. Average concentration of chlorophyll-a, plus and minus one standard deviation, Middle Fork Red Dog Creek at Station 20.

Biomonitoring Summary, Middle Fork Red Dog Creek Station 20

Table 10. Middle Fork Red Dog Creek, Station 20, 1999 to 2006

Water Quality	pH values higher than pre-mining Cd and Zn concentrations lower than pre-mining Slight upward trend in Cd and Zn from 2004 to 2006
Invertebrates	Abundance is highly variable among sample years Density, generally much lower than other sites Taxa richness highly variable, appears to be decreasing %EPT higher in 2004 and 2006
Periphyton	very low, all years
Larval Fish	none

Middle Fork Red Dog Creek, Station 140

Site Description

Station 140 is located in Middle Fork Red Dog Creek downstream of clean water bypass and upstream of the discharge point at outfall 001. Fish, invertebrate, and periphyton sampling are not done at this site, but water quality data are collected. The pH for Middle Fork Red Dog Creek is presented in Figure 92. The pH values are consistently higher at Station 140 as compared to pre-mining conditions, except in 2006 when a pH of 5.7 was recorded.

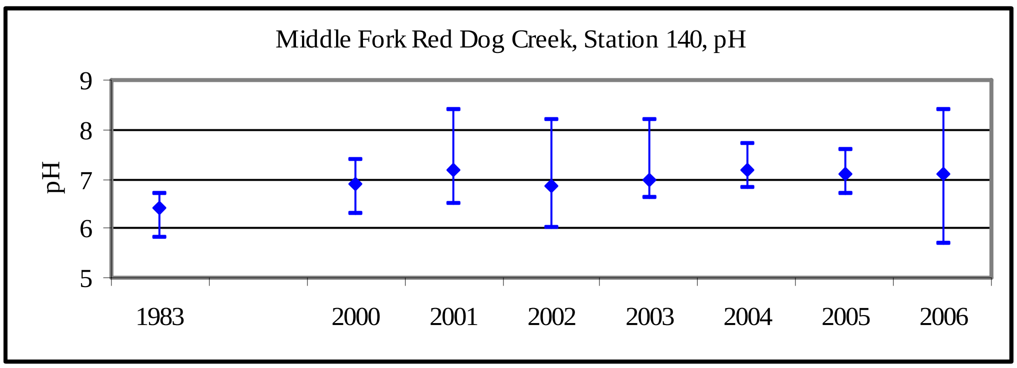

Figure 92. Median, maximum, and minimum pH at Station 140 in Middle Fork Red Dog Creek.

Concentrations of Cd, Pb, and Zn are presented in Figures 93 through 95. These analytes were selected because pre-mining data are available. Median concentrations of Cd, Pb, and Zn at Station 140 are consistently lower (1999 through 2006) than pre-mining, indicating that the clean water bypass system is working to reduce loading of metals. However, peaks in Cd and Zn during 2006 exceeded those reported in baseline data.

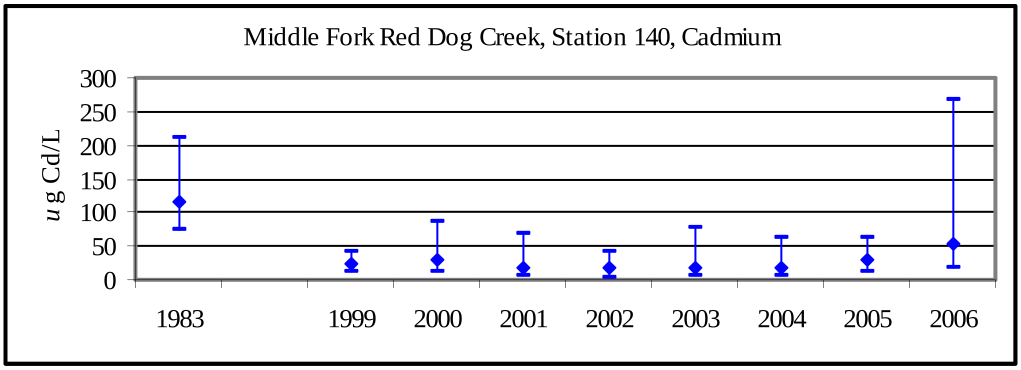

Figure 93. Median, maximum, and minimum concentrations of Cd at Station 140.

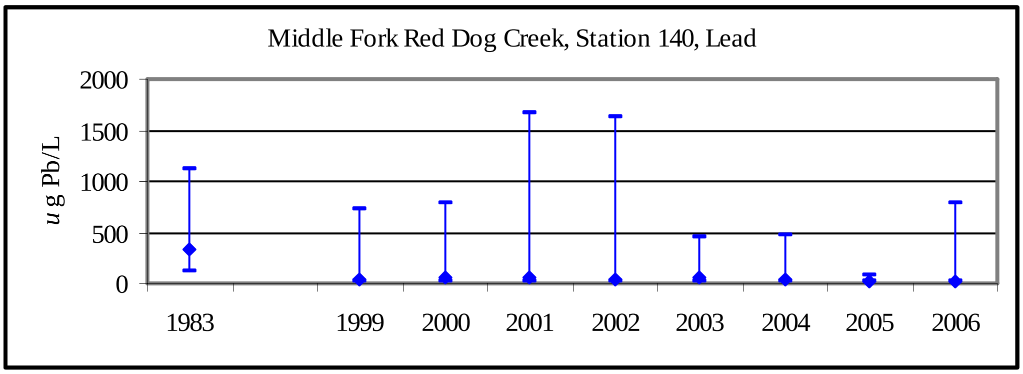

Figure 94. Median, maximum, and minimum concentrations of Pb at Station 140.

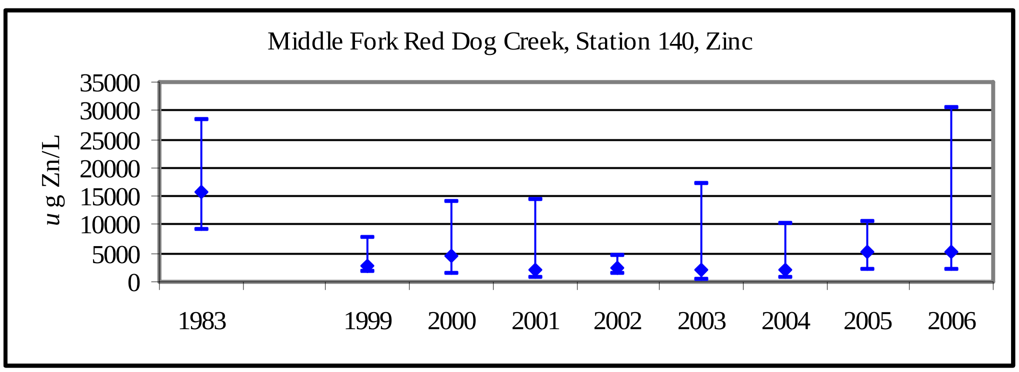

Figure 95. Median, maximum, and minimum concentrations of Zn at Station 140.

Metals concentrations in Adult Dolly Varden, Wulik River

Since 1990, we have sampled adult Dolly Varden from the Wulik River at Station 2 near Tutak Creek for metals concentrations (Al, Cd, Cu, Pb, and Zn) in gill, kidney, liver, and muscle tissue (Weber Scannell et al. 2000). In 1997, we added Se and in 1998 we started sampling reproductive tissues, when available. In 2003, we added Hg and Ca to the analytes being tested. In 2004, 2005, and 2006, Dolly Varden tissues were analyzed for Al, Cd, Cu, Pb, Se, Zn, and Hg. The number of fish in each sample period is 6, except for fall 2002 when only 5 fish were caught.

The purpose of sampling adult Dolly Varden for metals concentrations is to monitor long-term condition of fish over the life of the mine and to identify changes in metals concentrations that may be related to mining activities. All laboratory work has been done with Level III Quality Assurance.

Metals are know to concentrate preferentially in certain organs; however, the relationship of organ concentration of metals to ambient environmental concentrations is unknown. Concentrations of metals vary with season, age, size, weight, and feeding habits of fish (Jenkins 1980) and in the case of anadromous Dolly Varden, the metals vary with exposure to freshwater and marine environments. Our data from the Wulik River suggest the following:

- Al concentrates in gill tissue (Figure 96);
- Cd concentrates in kidney tissue (Figure 97);
- Cu concentrates in liver tissue (Figure 98);
- Pb concentrates in gill tissue (Figure 99)
- Se concentrates in kidney and ovarian tissue (Figure 100);
- Zn concentrates in ovarian tissue (Figure 101);
- Hg concentrates in kidney tissue (Figure 102);
- none of the analytes concentrate in muscle tissue

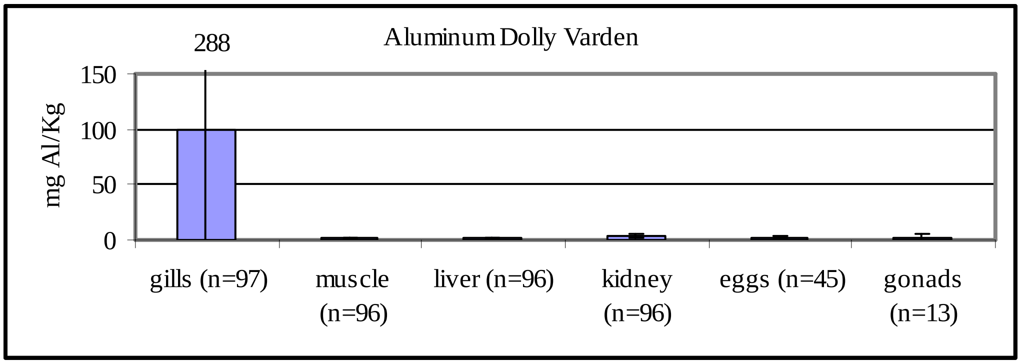

Figure 96. Average Al concentrations of all fish collected from 1999 to 2006, plus and minus one standard deviation.

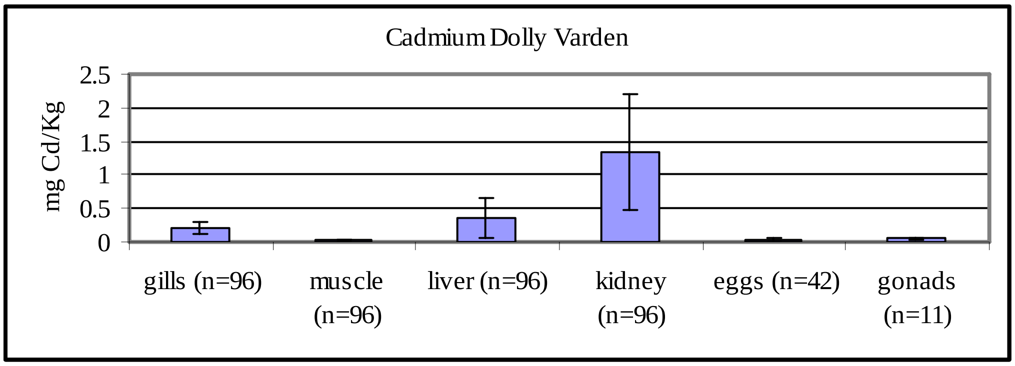

Figure 97. Average Cd concentrations of all fish collected from 1999 to 2006, plus and minus one standard deviation.

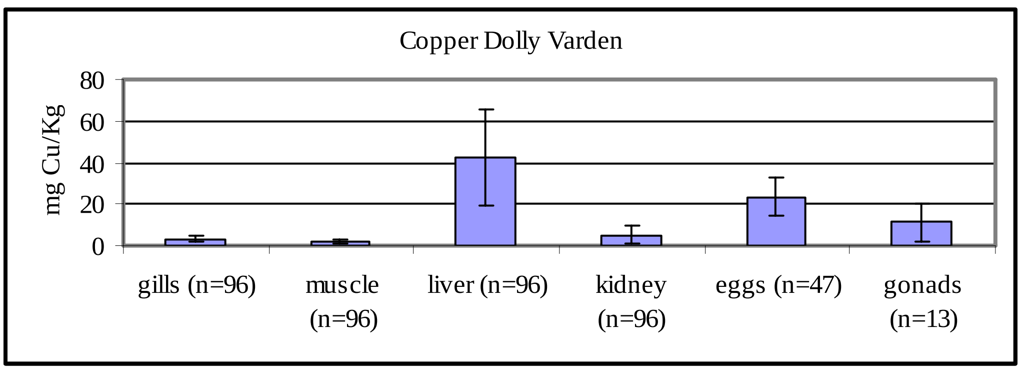

Figure 98. Average Cu concentrations of all fish collected from 1999 to 2006, plus and minus one standard deviation.

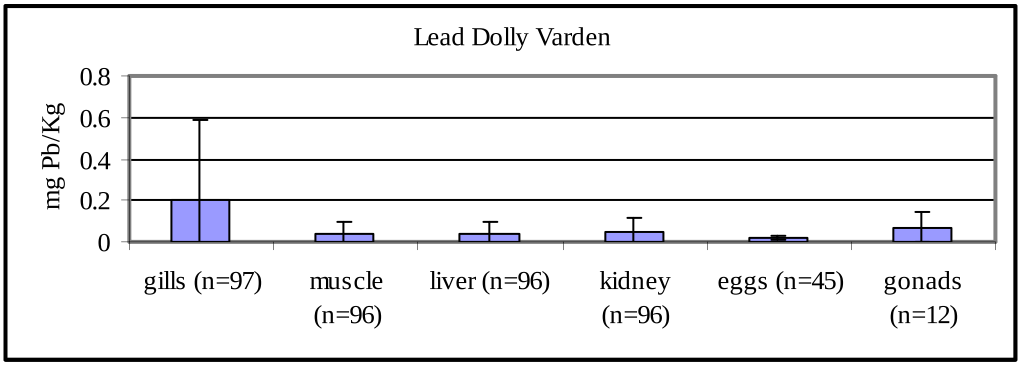

Figure 99. Average Pb concentrations of all fish collected from 1999 to 2006, plus and minus one standard deviation.

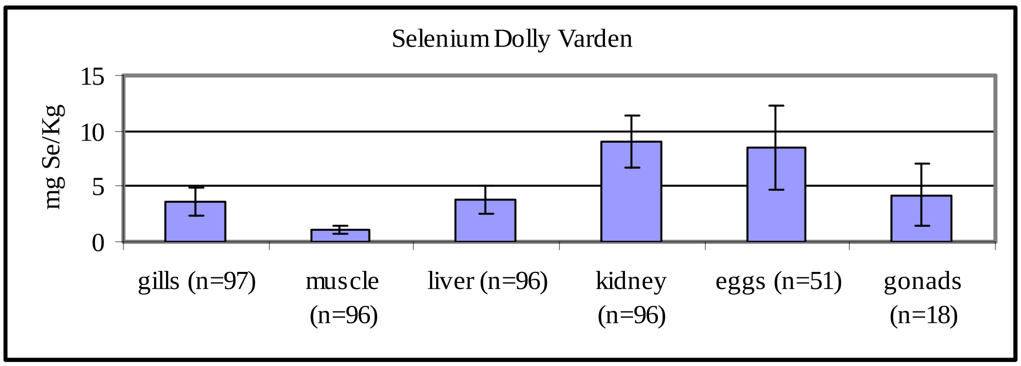

Figure 100. Average Se concentrations of all fish collected from 1999 to 2006, plus and minus one standard deviation.

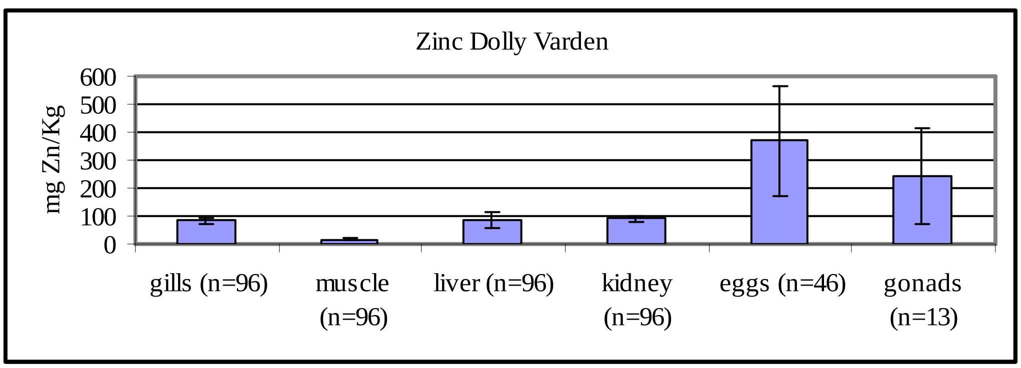

Figure 101. Average Zn concentrations of all fish collected from 1999 to 2006, plus and minus one standard deviation.

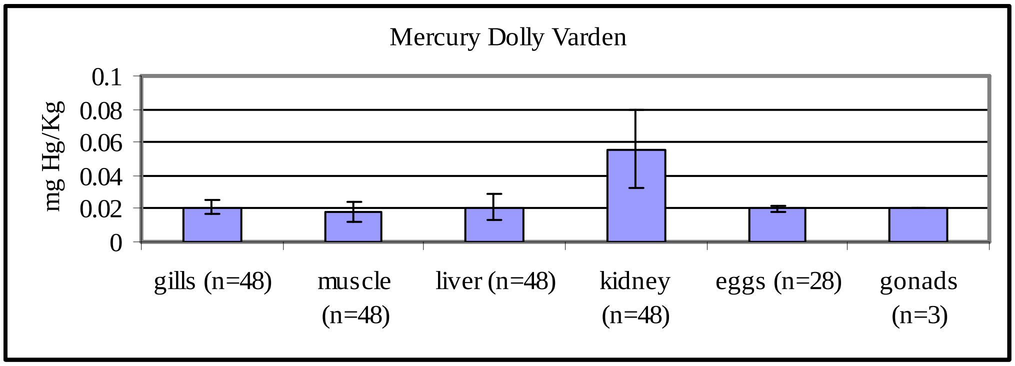

Figure 102. Average Hg concentrations of all fish collected from 1999 to 2006, plus and minus one standard deviation.

Aluminum

Median concentrations of Al in gill tissue are highly variable within samples and between the spring and fall sample events (Figure 103). No real pattern or trend appears to exist for Al in gill tissue, other than the fact that it is highly variable.

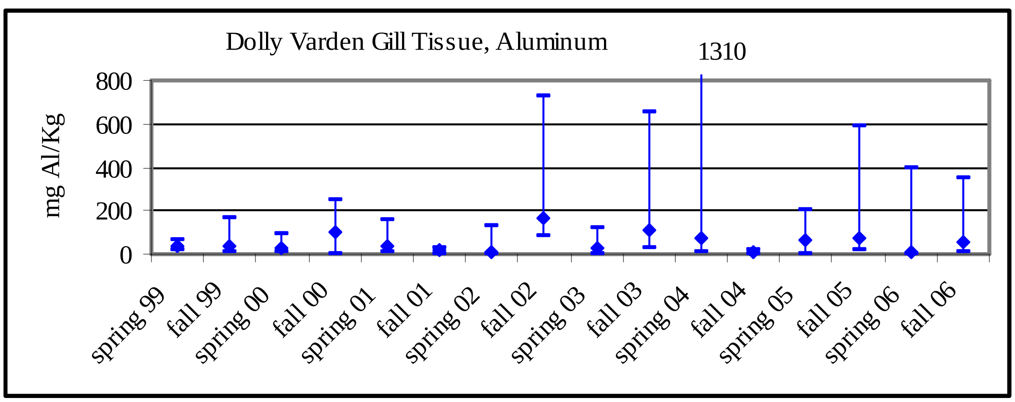

Figure 103. Median, maximum, and minimum concentrations of Al (dry weight) in Dolly Varden gill tissue (1999 to 2006). No baseline data for Al exists.

Cadmium

Median Cd concentrations in Dolly Varden kidney tissue from 1999 to 2006, both spring and fall, are lower than baseline data (Figure 104). Fall-caught fish generally have lower Cd concentrations than spring-caught fish. Over the last three years, Cd concentrations have been stable and lower than those reported previously.

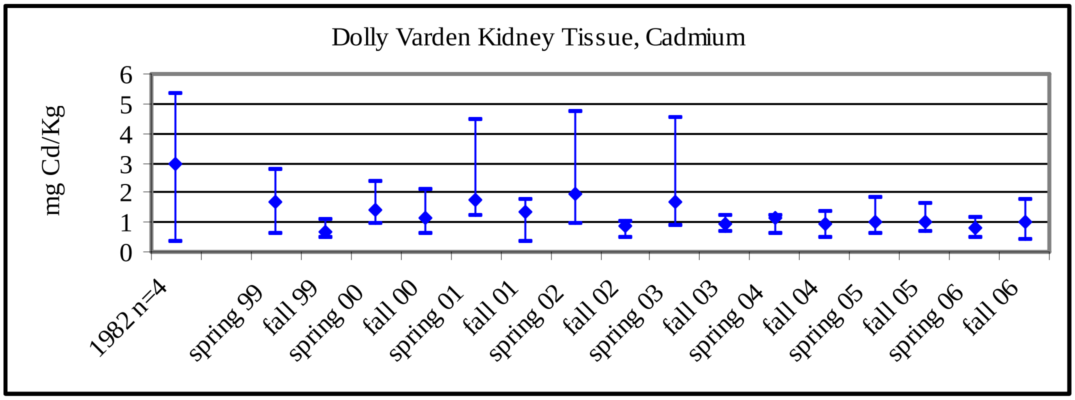

Figure 104. Median, maximum, and minimum concentrations of Cd (dry weight) in Dolly Varden kidney tissue (1982 and 1999 to 2006).

Copper

Median copper concentrations in liver tissue are consistently higher than baseline data (Figure 105). Spring-caught fish generally are higher in Cu than fall-caught fish.

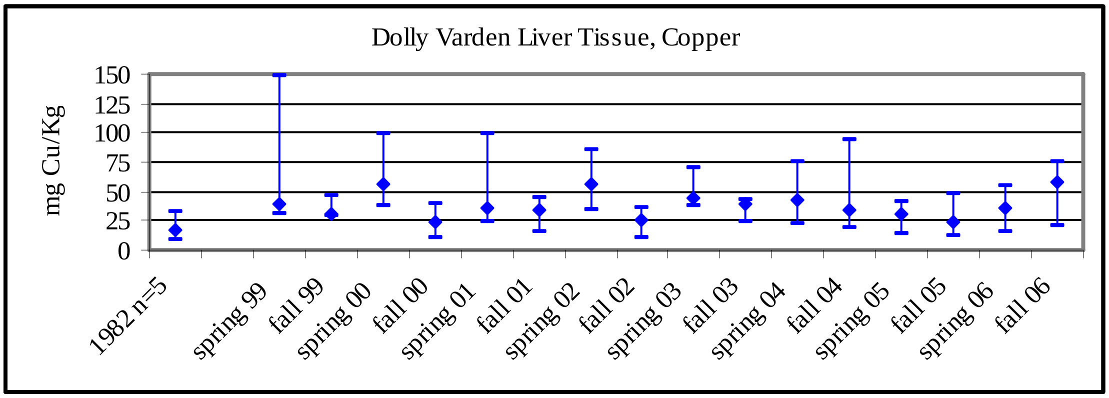

Figure 105. Median, maximum, and minimum concentrations of Cu (dry weight) in Dolly Varden liver tissue (1982 and 1999 to 2006).

Lead

The concentration of Pb in Dolly Varden gill tissue from fish collected prior to mining was below the detection limits (0.03 or 0.04 mg/Kg). Median concentrations of Pb in gill tissue are higher than those reported in baseline data (Figure 106).

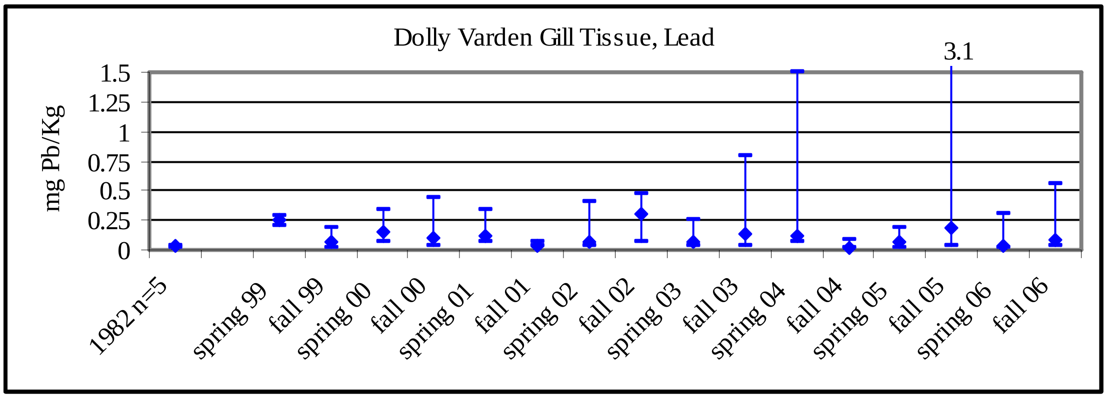

Figure 106. Median, maximum, and minimum concentrations of Pb (dry weight) in Dolly Varden gill tissue (1982 and 1999 to 2006).

Selenium

Median Se concentrations in ovarian tissue are consistently higher in fall-caught fish (Figure 107). Highest Se concentrations occurred in fall 2002 and fall 2005.

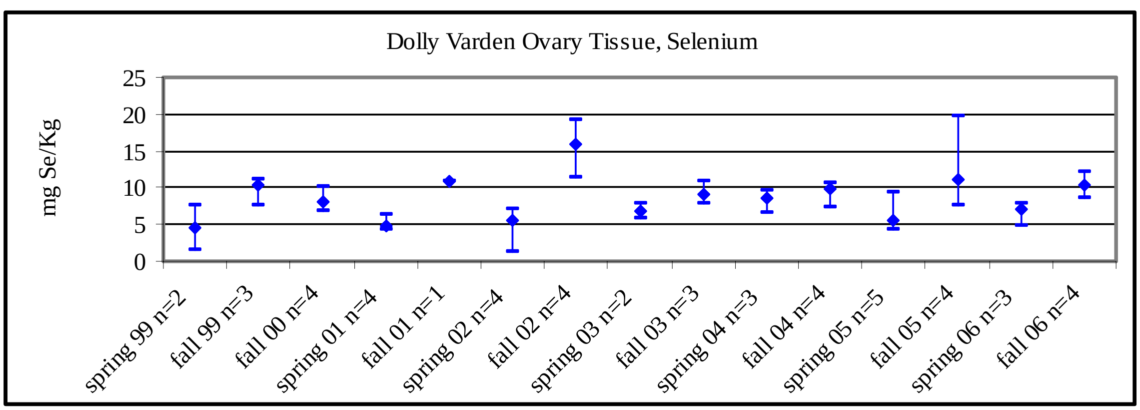

Figure 107. Median, maximum, and minimum concentrations of Se (dry weight) in Dolly Varden ovary tissue (1999 to 2006). No baseline data for Se exists.

Zinc

Median Zn concentrations in ovarian tissue have remained fairly consistent during the sample period (Figure 108). Generally, except for 2006, Zn concentrations are higher in fall-caught fish.

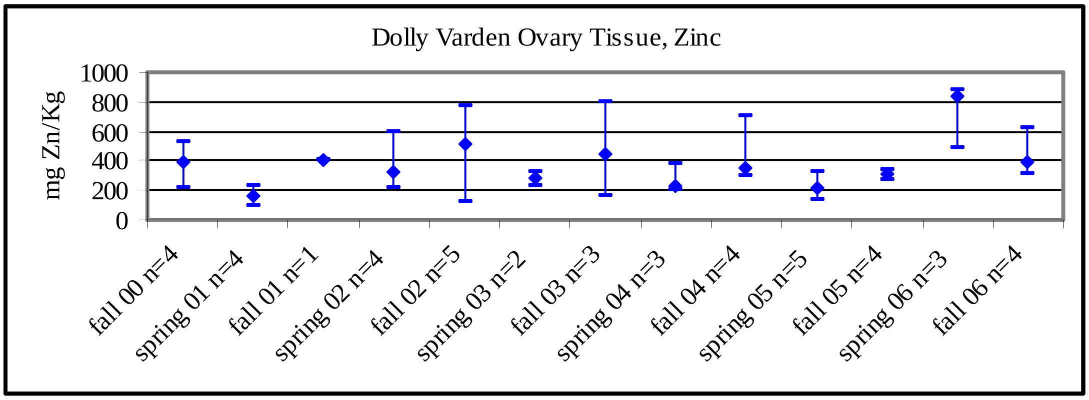

Figure 108. Median, maximum, and minimum concentrations of Zn (dry weight) in Dolly Varden ovary tissue (1999 to 2006). No baseline data for Zn exists.

Mercury

Generally, the concentrations of Hg in all tissues, except kidney, are at or below the detection limit of 0.02 mg/Kg. Hg concentrations in kidney tissue are similar from 2003 to 2006 (Figure 109).

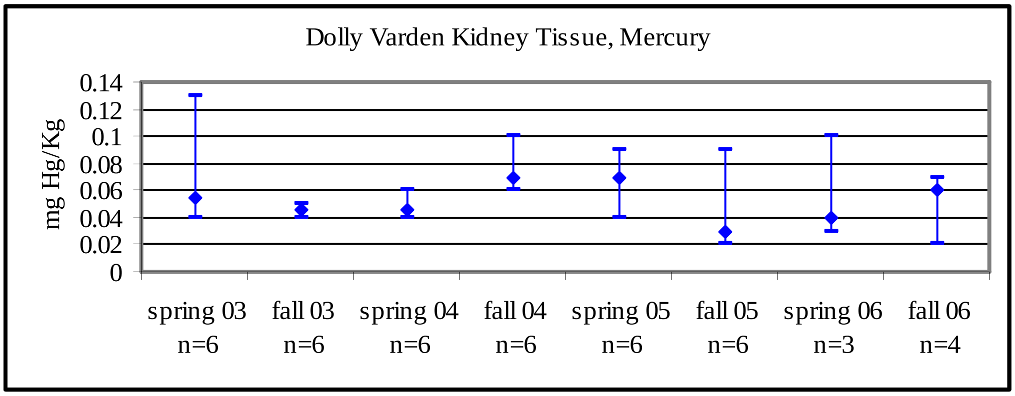

Figure 109. Median, maximum, and minimum concentrations of Hg (dry weight) in Dolly Varden kidney tissue (2003 to 2006). No baseline data for Hg exists.

Distribution of Fish

Overwintering Dolly Varden

The Dolly Varden fall aerial survey in the Wulik River was conducted on October 5, 2006. Overall survey conditions were adequate, but not great. There was a west wind near the coast that resulted in chop on the water, but the sky was clear. About halfway through the survey it became overcast (DeCicco 2006). There appeared to be very few small Dolly Varden on October 5, 2006 – normally there are large schools of small Dolly Varden (1st year migrants 250 to 325 mm long). DeCicco's 2006 estimate should be considered to be the minimum number of fish present.

Number of Dolly Varden estimated in fall in the Wulik River varies annually (Figure 110, Appendix 2). Surveys conducted through fall 2006, suggest that over 90% of the Dolly Varden are seen downstream of Ikalukrok Creek. Only in 2004 was the percent of fish below Ikalukrok Creek less than 90% and as DeCicco (2004) stated, conditions for aerial observations in the lower river in fall 2004 were poor due to overcast skies.

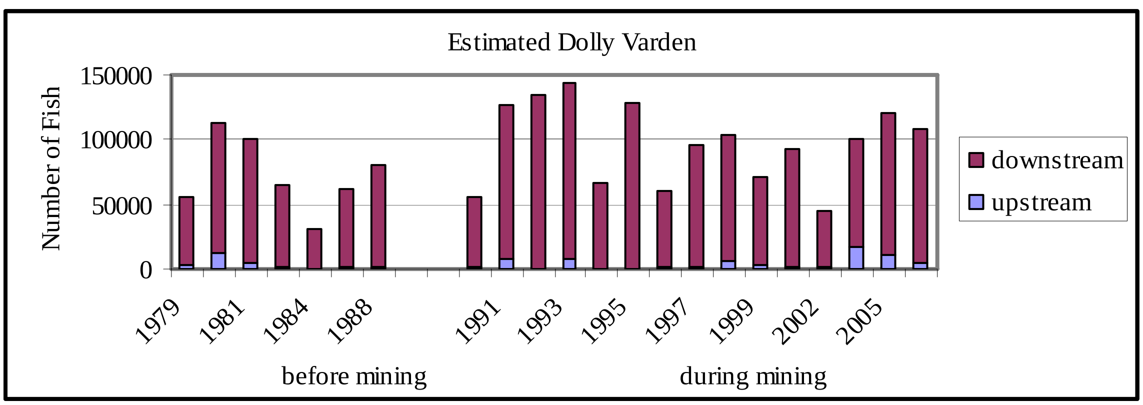

Figure 110. The number of Dolly Varden estimated in the Wulik River.

Chum Salmon

ADNR conducts annual surveys to assess the distribution of adult chum salmon in Ikalukrok Creek from its mouth (i.e., confluence with Wulik River) upstream to Dudd Creek (Table 11 and Appendix 3). In fall 2006, we flew one helicopter survey along Ikalukrok Creek from its mouth to its confluence with Dudd Creek. The survey was conducted under partly cloudy skies, mild winds, and overall conditions were judged to be good (Ott and Timothy 2006). Water levels were not high, but there was a slight off-color to the water in the deeper reaches of the creek. Our estimate should be viewed as the minimum number present as more fish were likely present than counted. Spawning chum salmon were seen along the entire length of Ikalukrok Creek until about 8 km downstream of Station 160 where few, if any chum salmon were seen. Our total count of chum salmon was 4,185 – the highest number estimated since our surveys began in 1990. Dead, spawned-out, chum salmon also were seen, but we estimated that these represented less than 5% of the fish observed. No chinook salmon were observed in Ikalukrok Creek or in a slough (N 67.56.45 W 163.24.91) where 56 spawners were seen in fall 2004.

Counts of chum salmon in Ikalukrok Creek after mine development in 1990 and 1991 were lower than reported in baseline studies. Surveys began again in 1995, with the highest return of chum salmon seen in fall 2006. The most chinook salmon observed during surveys was in fall 2004 and most of these fish were in a side slough of Ikalukrok Creek. Large returns of chum salmon in recent years, particularly 2001, 2002, and 2006, are good indications that the population has recovered from the low counts made in the early 1990s.

Table 11. Number of chum salmon adults in Ikalukrok Creek.

Survey Time	Number of Chum Salmon	Reference
September 1981	3,520 to 6,960	Houghton and Hilgert 1983
August September 1982	353 to 1,400	Houghton and Hilgert 1983
August 1984	994	DeCicco 1990b
August 1986	1,985	DeCicco 1990b
August 1990	<70	Ott et al. 1992
August 1991	<70	Ott et al. 1992
August 16, 1995	49	Townsend and Lunderstadt 1995
August 1995	300 to 400	DeCicco 1995
August 11, 1996	180	Townsend and Hemming 1996
August 12, 1997	730 to 780	Ott and Simpers 1997
1998	no survey	
August 9, 1999	75	Ott and Morris 1999
2000	no survey	
August 7, 2001	850	Morris and Ott 2001
August 28, 2001	2,250	DeCicco 2001b
August 29, 2001	1,836	DeCicco 2001b
September 23, 2001	500	DeCicco 2001c
October 8, 2001	232	DeCicco 2001a
August 5, 2002	890	Ott and Townsend 2002
August 11, 2003	218	Townsend and Ingalls 2003
August 26, 2004	405	Townsend and Conley 2004
August 29, 2005	350	Thompson 2005
August 14, 2006	4,185	Ott and Timothy 2006

Dolly Varden

Limited pre-mining juvenile Dolly Varden distribution and use data are available for most of the streams in the vicinity of the Red Dog Mine, including Ikalukrok, Evaingiknuk, Buddy, Mainstem Red Dog, and North Fork Red Dog creeks. In the early 1990s, we found the highest use by juvenile Dolly Varden occurred in Anxiety Ridge Creek. Anxiety Ridge Creek was identified as the most productive stream system in the project area by Houghton and Hilgert (1983). Buddy Creek, downstream of the falls located below the haul road, was, however, not sampled during pre-mining site investigations.

We have conducted annual sampling of juvenile Dolly Varden in Evaingiknuk, Anxiety Ridge, and Ikalukrok creeks since 1990 to assess seasonal patterns of fish use. Since 1990, we have added new sample sites and increased the number of minnow traps per sample site. Currently, we sample ten sites, as listed in Table 12 (Appendix 4) using ten minnow traps per sample reach with a fishing time of 24 hours.

Table 12. Location of juvenile Dolly Varden sample sites.

Site Name	Station No.	Year Sampling Started
Evaingiknuk Creek		1990
Anxiety Ridge Creek		1990
Buddy Creek		1996
North Fork Red Dog Creek	12	1993
Mainstem Red Dog Creek	11	1995
Mainstem Red Dog Creek	10	1996
Ikalukrok Creek above Mainstem	9	1996
Ikalukrok Creek below Mainstem	8	1996
Ikalukrok Creek above Dudd		1990
Ikalukrok Creek below Dudd	7	1990

Relative abundance (i.e., catches) of juvenile Dolly Varden varies considerably among sample years (Figures 111 and 112). Natural environmental conditions such as duration of breakup, patterns and magnitude of rainfall events, and ambient temperature affect distribution of juveniles during the ice-free season. Perhaps the most substantial variable affecting abundance is the number of age 1 fish present from the previous years spawning population. Consecutive years of good recruitment of age 1 fish lead to high catches of Dolly Varden followed by a substantial decrease in numbers when fish outmigrate as smolts.

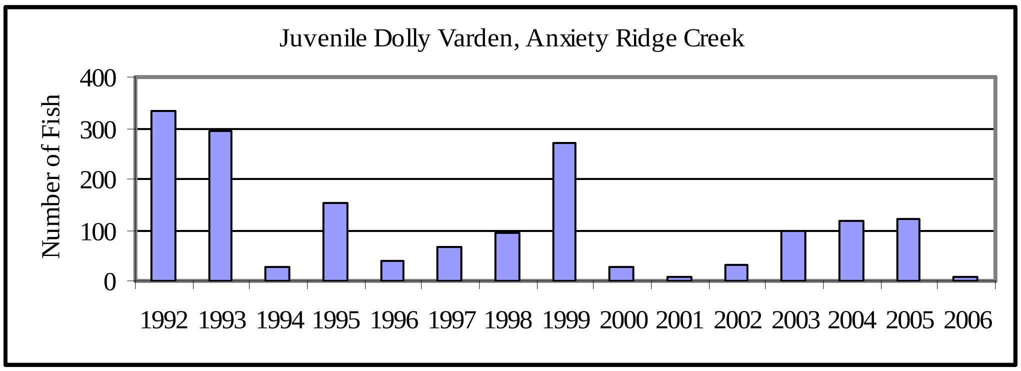

Figure 111. Number of Dolly Varden in Anxiety Ridge Creek. Sample method ten minnow traps each year with a sample time in late July to late August of each year.

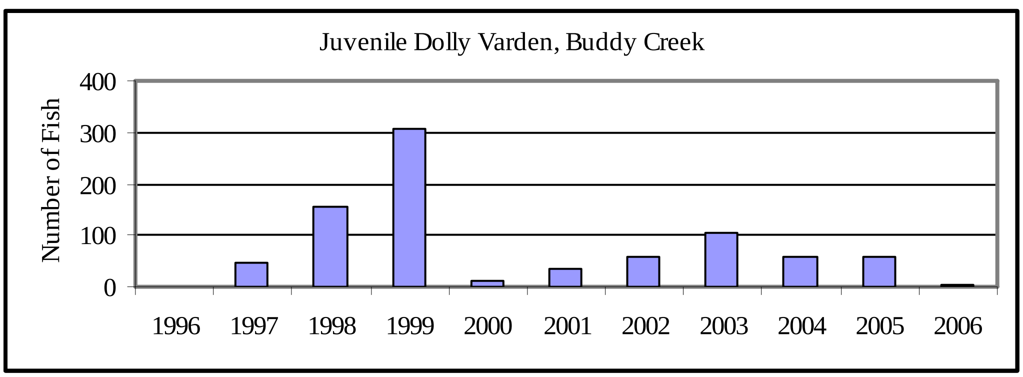

Figure 112. Number of Dolly Varden in Buddy Creek. Sample method ten minnow traps each year with a sample time in late July to late August of each year.

Juvenile Dolly Varden are most abundant in our Red Dog sample sites from late July to mid-August. Generally, abundance is higher in the upper portion of each stream and peak usage continues until the onset of freezing conditions when most fish outmigrate to overwintering areas. Catches of Dolly Varden in the early 1990s, when sampling occurred from spring through late fall, were very low in spring, peaked in the fall, and then decreased as freezeup approached. Sampling suggests that few Dolly Varden winter in these streams, but that overwintering is limited to Anxiety Ridge and Evaingiknuk creeks.

Sampling of the 10 NPDES sites in July and August has been conducted each year since 1997. Our highest catches were in 1999, and the lowest in 2000, 2001, and 2006 (Appendix 5). Late summer catches of Dolly Varden for Anxiety Ridge and Buddy creeks are presented in Figure 113. The highest catches of Dolly Varden are consistently found in these two creeks.

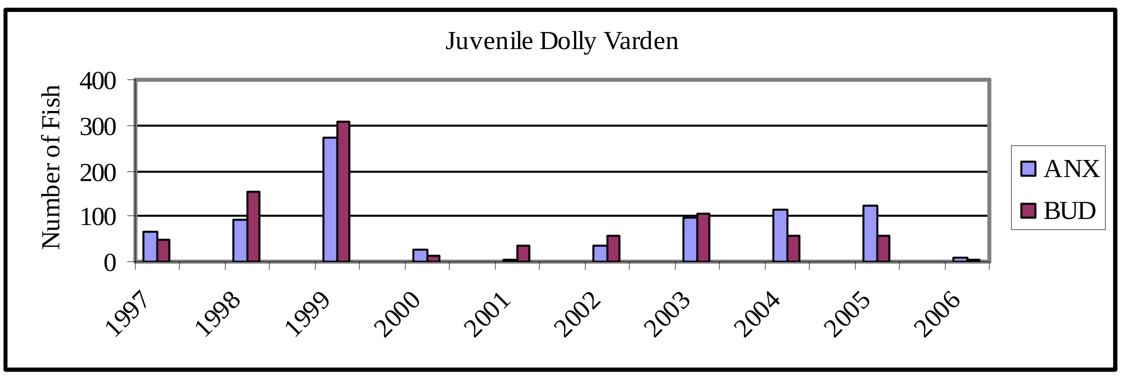

Figure 113. Catches of juvenile Dolly Varden in Anxiety Ridge (ANX) and Buddy (BUD) creeks, 1997 to 2006.

Catches in Mainstem Red Dog Creek (upper and lower sample reaches) are presented in Figure 114. From 1997 to 2001, catches followed a pattern similar to Anxiety Ridge and Buddy creeks. However, lower catches have now been seen for the last five years.

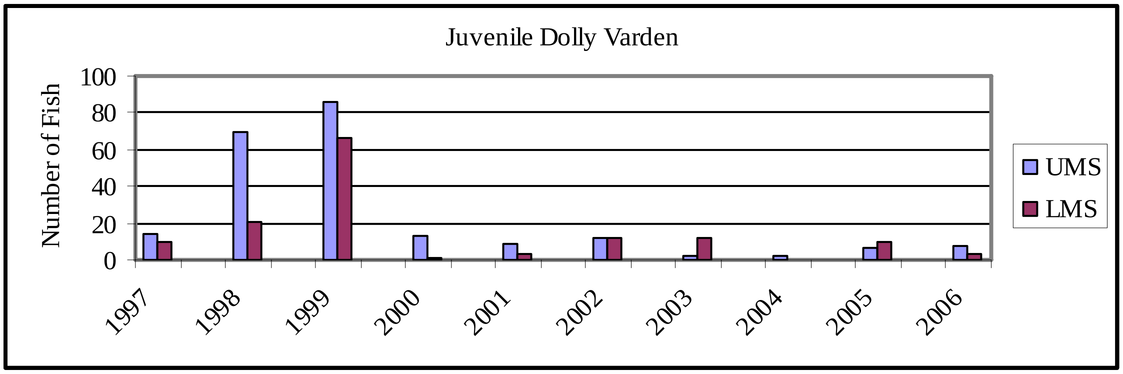

Figure 114. Catches of juvenile Dolly Varden in upper Mainstem Red Dog (UMS) and lower Mainstem Red Dog (LMS) creeks, 1997 to 2006.

As we reported last year (Ott and Morris 2006b), a natural mineral seep located on Cub Creek in upper Ikalukrok Creek has affected water quality. The Cub Creek seep is located upstream of the mouth of Mainstem Red Dog Creek. Visible effects to water clarity were first noted in 1997 and water quality data (1999 through 2006) indicate generally improving conditions. One possible explanation for the continued low catches of fish in Mainstem Red Dog Creek is that with improved water quality in Ikalukrok Creek, more Dolly Varden moved upstream to rearing habitats in Ikalukrok Creek and its tributaries (e.g., Grayling Junior Creek).

The length frequency distribution of juvenile Dolly Varden, especially the presence of fry, indicates successful reproduction and survival. Dolly Varden less than 65 mm in late July and early August are assumed to be age-0. Length frequency distributions of juvenile Dolly Varden captured in fall 1997 through fall 2006 are presented in Appendix 6. Smolting can occur as early as age 2, but more commonly at age 3 (DeCicco 1990a). Higher catches of Dolly Varden fry are seen in 1997, 1998, 1999, 2004, and 2005 (Appendix 6). Catches of Dolly Varden in 1997 and 1998 likely explain the large catch of juvenile fish in fall 1999. Catches of Dolly Varden in both 2004 and 2005 were relatively high, thus we expected fairly good catches in fall 2006. However, our catches in fall 2006 were very low and other than the fact that water was generally high with frequent rainstorm events in summer 2006, we have no apparent explanation.

During our spring sample event for Arctic grayling adults returning to North Fork Red Dog Creek to spawn, we caught 27 Dolly Varden. The 27 Dolly Varden ranged in size from 147 to 245 mm (Figure 115). The larger Dolly Varden caught each spring in North Fork Red Dog Creek with fyke nets appear to be resident fish (i.e., larger than smolts, obvious parr marks, and distinct orange/pink dots). In baseline studies, Houghton and Hilgert (1983) only found one Dolly Varden in the headwaters of North Fork Red Dog Creek. Our late May to early June sampling from 2000 through 2006 with fyke nets has caught a number of resident Dolly Varden each year (Figure 115). It is not known whether this consistent change in fish use is related to improved water quality in Mainstem Red Dog Creek or simply due to increased sample effort and the use of fyke nets.

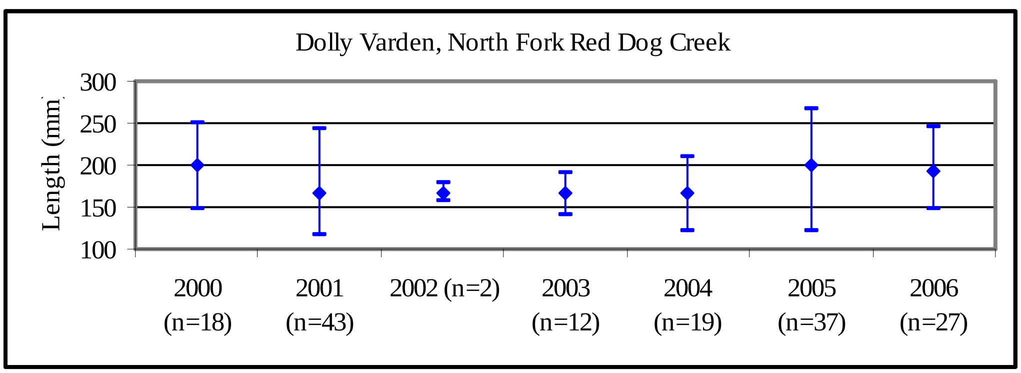

Figure 115. Dolly Varden caught in fyke nets in North Fork Red Dog Creek in spring during Arctic grayling spawning run.

Arctic Grayling

Before mine development, Arctic grayling adults migrated through Mainstem Red Dog Creek in spring when discharge was high and metals concentrations low (EVS and Ott Water Engineer 1983, Ward and Olson 1980, and Houghton and Hilgert 1983). Arctic grayling moved through Mainstem Red Dog Creek to spawn in North Fork Red Dog Creek, but no spawning was reported to occur in Mainstem Red Dog Creek. Arctic grayling fry reared in North Fork Red Dog Creek and were displaced downstream by high-water events or outmigrated as water temperatures cooled in the fall. Very few, if any, juvenile Arctic grayling were found in North Fork Red Dog Creek during the ice-free season.

Arctic Grayling Spawning

Water temperature is the most likely factor determining spawning time, emergence of fry, and first year growth. We have closely monitored Arctic grayling spawning during spring in North Fork Red Dog and Mainstem Red Dog creeks since 2001 (Table 13).

Table 13. A summary of Arctic grayling spawning in Mainstem Red Dog Creek from 2001 to 2006.

Year	Date When Limited Spawning Started (3°C)	Date When Spawning Complete (Condition of Females)	Number of Days Peak Temperatures Exceeded 4°C[1]
2001	June 6	June 15	6
2002	May 29	June 8	8
2003	June 7	June 14	6
2004	May 25	May 31	4
2005	May 27	June 6	9
2006	May 30	June 15	10

[1]Does not include the day spawning was judged to be complete since the fyke net is worked in the early morning prior to peak temperatures on that day.

The purpose of the Arctic grayling spring sampling is to assess the condition of females and determine when spawning in Mainstem Red Dog Creek is complete. Spawning activity generally continues in North Fork Red Dog Creek after it is completed in Mainstem Red Dog Creek as water temperatures warm more quickly in Mainstem Red Dog Creek.

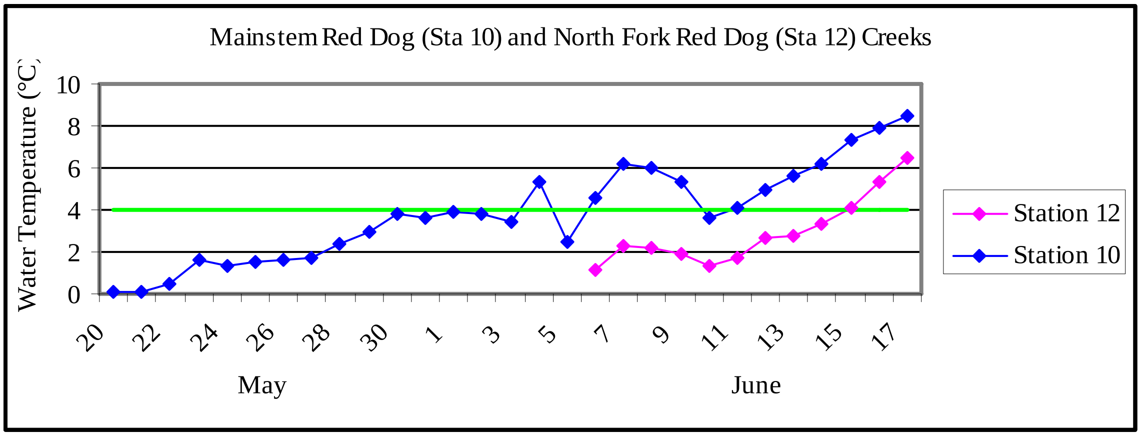

Figure 116. Peak daily water temperatures in Mainstem Red Dog and North Fork Red Dog Creeks in spring 2006. Note, temperature probe in North Fork Red Dog Creek was not functioning until June 6.

We observed a post-spawning outmigration of large mature Arctic grayling during our spring sample period – we have not seen this occur during previous spring sampling events. The cold temperatures in North Fork Red Dog Creek continued well beyond the normal time frame for Arctic grayling spawning. We believe that Arctic grayling entered North Fork Red Dog Creek in late May and due to cold water temperatures, abandoned spawning. We have noted similar findings with Arctic grayling at the Ft. Knox mine. Last Chance Creek supports a spawning population of Arctic grayling, but only in those years when aufeis is minimal and water temperatures warm to above 4°C during the normal spawning time. Extensive aufeis in Last Chance Creek has kept water temperatures below 4°C and has limited spawning to only spring 2004 and 2005 since the spring of 1999 (Ott and Morris 2006).

Arctic Grayling Mark/Recapture

In spring 2006, we caught 74 Arctic grayling in North Fork Red Dog and Mainstem Red Dog creeks (Tables 14 and 15). Thirty-two of the fish were judged to be immature. Most of the recaptured Arctic grayling were originally tagged in North Fork Red Dog Creek (Table 14). One of the recaptured fish was first tagged in either 1995 and had not been caught in 11 years. Four of the Arctic grayling captured in spring 2006 are fish tagged in Bons Pond. The Bons Pond population of Arctic grayling is the result of a fish transplant made in 1994 and 1995 (Ott and Townsend 2003). Fish that leave Bons Pond travel over a waterfall that is impassable to upstream movement of fish. We know based on field work in summer 2005 that a number of Arctic grayling have left Bons Pond and entered the Buddy and Bons Creek drainages downstream of the freshwater reservoir. Fish from Bons Pond are recruiting to the North Fork Red Dog Creek population, where the original group of fish transplanted originated.

Table 14. Arctic grayling recaptures in spring 2006 in North Fork Red Dog Creek.

Tag Number	Color	Gear Type	Length (mm)	Sex	Date Captured	Site Captured	Recapture Date	Recapture Site	Length (mm)
15874	White	Fyke Net	394	Male	6/3/2005	North Fork	6/14/2006	North Fork	406
15850	White	Fyke Net	265	Male	6/4/2005	North Fork	6/14/2006	North Fork	310
1784	White	Angling	233	Female	8/11/1995	North Fork	6/15/2006	North Fork	386
13129	Green	Fyke Net	351	Female	7/11/2000	North Fork	6/4/2005	North Fork	366
							6/15/2006	North Fork	368
1606	White	Fyke Net	309	Female	7/1/1998	North Fork	7/11/2000	North Fork	354
							6/15/2006	North Fork	394
15616	White	Fyke Net	344	Female	5/29/2004	North Fork	6/3/2005	North Fork	360
							6/15/2006	North Fork	365
15619	White	Fyke Net	398	Female	5/29/2004	North Fork	6/15/2006	North Fork	400
1793	White	Fyke Net	271	Female	8/11/1995	North Fork	6/10/2001	North Fork	375
							6/15/2006	North Fork	400
13267	Green	Fyke Net	380	Male	6/1/2002	Mainstem	6/16/2006	North Fork	426
11646	Orange	Fyke Net	215	Immature	7/5/2003	Bons Pond	6/15/2006	North Fork	285
11001	Orange	Fyke Net	222	Male	7/7/2003	Bons Pond	6/6/2004	Bons Pond	234
							6/15/2006	North Fork	285
15937	White	Fyke Net	276	Male	5/29/2005	Bons Pond	6/15/2006	North Fork	307
9144	Orange	Fyke Net	224	Male	6/13/2003	Bons Pond	5/27/2004	Bons Pond	246
							6/15/2006	North Fork	306

Table 15. Arctic grayling caught in North Fork Red Dog and Mainstem Red Dog Creek in spring 2006.

Tag Number	Color	Gear	Length (mm)	Sex	Condition	Tag Scar Recap	Date Captured	Site Captured
17680	Gray	Fyke-Net	329	Male	Ripe		6/12/2006	North Fork West Net
17679	Gray	Fyke-Net	255	Immature			6/12/2006	North Fork West Net
17678	Gray	Fyke-Net	290	Immature			6/12/2006	North Fork West Net
17728	Gray	Angling	465	Male	Ripe		6/13/2006	Mainstem
17727	Gray	Fyke-Net	260	Immature			6/13/2006	North Fork East Net
17726	Gray	Fyke-Net	246	Immature			6/14/2006	North Fork West Net
17725	Gray	Fyke-Net	280	Female	?		6/14/2006	North Fork West Net
17774	Gray	Fyke-Net	240	Immature			6/14/2006	North Fork West Net
15874	White	Fyke-Net	406	Male	Ripe	Recap	6/14/2006	North Fork West Net
17823	Gray	Fyke-Net	355	Female	Spent		6/14/2006	North Fork West Net
17822	Gray	Fyke-Net	311	Male	Ripe		6/14/2006	North Fork West Net
17821	Gray	Fyke-Net	410	Female	Ripe		6/14/2006	North Fork West Net
17820	Gray	Fyke-Net	274	Immature			6/14/2006	North Fork West Net
17819	Gray	Fyke-Net	354	Male	Ripe		6/14/2006	North Fork West Net
15850	White	Fyke-Net	310	Male	Not Ripe	Recap	6/14/2006	North Fork West Net
17818	Gray	Fyke-Net	267	Immature			6/14/2006	North Fork West Net
17817	Gray	Fyke-Net	263	Immature			6/14/2006	North Fork West Net
17816	Gray	Fyke-Net	403	Female	Ripe		6/14/2006	North Fork East Net
17815	Gray	Fyke-Net	379	Female	Ripe		6/14/2006	North Fork East Net
17814	Gray	Fyke-Net	394	Female	P/Spent		6/14/2006	North Fork East Net
17813	Gray	Fyke-Net	417	Male	Ripe		6/15/2006	North Fork East Net
17812	Gray	Fyke-Net	251	Immature			6/15/2006	North Fork West Net
17811	Gray	Fyke-Net	264	Immature			6/15/2006	North Fork West Net
11646	Orange	Fyke-Net	285	Immature		Recap	6/15/2006	North Fork West Net
17810	Gray	Angling	335	Female	Ripe		6/15/2006	North Fork at Mainstem
17809	Gray	Angling	279	Immature			6/15/2006	North Fork at Mainstem
1784	White	Angling	386	Female	Spent	Recap	6/15/2006	North Fork at Mainstem
17835	Gray	Angling	380	Female	Spent		6/15/2006	North Fork at Mainstem
11001	Orange	Fyke-Net	285	Male	Ripe	Recap	6/15/2006	North Fork West Net
13129	Green	Fyke-Net	368	Female	Spent	Recap	6/15/2006	North Fork West Net
1606	White	Fyke-Net	394	Female	Spent	Recap	6/15/2006	North Fork West Net
17834	Gray	Fyke-Net	346	Male	Ripe		6/15/2006	North Fork West Net
15937	White	Fyke-Net	307	Male	Ripe	Recap	6/15/2006	North Fork West Net
17833	Gray	Fyke-Net	336	Immature			6/15/2006	North Fork West Net
17832	Gray	Fyke-Net	272	Immature			6/15/2006	North Fork West Net
17831	Gray	Fyke-Net	250	Immature			6/15/2006	North Fork West Net
17830	Gray	Fyke-Net	246	Immature			6/15/2006	North Fork West Net
17829	Gray	Fyke-Net	240	Immature			6/15/2006	North Fork West Net

Table 15. Arctic grayling (concluded).

Tag Number	Color	Gear	Length (mm)	Sex	Condition	Tag Scar Recap	Date Captured	Site Captured
15616	White	Fyke-Net	365	Female	Spent	Recap	6/15/2006	North Fork East Net
17828	Gray	Fyke-Net	426	Male	Ripe		6/15/2006	North Fork East Net
17827	Gray	Fyke-Net	404	Female	Ripe		6/15/2006	North Fork East Net
15619	White	Fyke-Net	400	Female	Ripe	Recap	6/15/2006	North Fork East Net
		Fyke-Net		Female	Spent		6/15/2006	North Fork East Net
17826	Gray	Fyke-Net	284	Immature			6/15/2006	North Fork East Net
17825	Gray	Fyke-Net	391	Female	Spent		6/15/2006	North Fork East Net
17874	Gray	Fyke-Net	299	Male	Ripe		6/15/2006	North Fork East Net
17873	Gray	Fyke-Net	332	Female	Ripe		6/15/2006	North Fork East Net
1793	White	Fyke-Net	400	Female	P/Spent	Recap	6/15/2006	North Fork East Net
17872	Gray	Fyke-Net	267	Immature			6/16/2006	North Fork West Net
9144	Orange	Fyke-Net	306	Male	Ripe	Recap	6/16/2006	North Fork West Net
17871	Gray	Fyke-Net	279	Male	Ripe		6/16/2006	North Fork West Net
17870	Gray	Angling	294	Male			6/16/2006	North Fork at Mainstem
17869	Gray	Angling	355	Male			6/16/2006	Mainstem
17868	Gray	Angling	343	Female	?		6/16/2006	Mainstem
17867	Gray	Angling	338	Female			6/16/2006	Mainstem
17866	Gray	Angling	295	Female	?		6/16/2006	Mainstem
17865	Gray	Angling	260	Immature			6/16/2006	Mainstem
17864	Gray	Angling	278	Female	Spent		6/16/2006	Mainstem
11001	Orange	Angling	286	Male	Ripe	Recap	6/16/2006	Mainstem
17894	Gray	Fyke-Net	234	Immature			6/16/2006	North Fork West Net
17893	Gray	Fyke-Net	275	Immature			6/16/2006	North Fork West Net
17892	Gray	Fyke-Net	269	Immature			6/16/2006	North Fork West Net
17891	Gray	Fyke-Net	324	Male	Ripe		6/16/2006	North Fork East Net
17890	Gray	Fyke-Net	320	Male	Ripe		6/16/2006	North Fork East Net
13267	Green	Fyke-Net	426	Male	Ripe	Recap	6/16/2006	North Fork East Net
17889	Gray	Fyke-Net	399	Male	Ripe		6/17/2006	North Fork East Net
17888	Gray	Fyke-Net	441	Male	Ripe		6/17/2006	North Fork East Net
17868	Gray	Fyke-Net	343	Female	?	Recap	6/17/2006	North Fork West Net
17887	Gray	Fyke-Net	327	Immature			6/17/2006	North Fork West Net
17886	Gray	Fyke-Net	281	Immature			6/17/2006	North Fork West Net
17885	Gray	Fyke-Net	277	Immature			6/17/2006	North Fork West Net
17884	Gray	Fyke-Net	255	Immature			6/17/2006	North Fork West Net
17883	Gray	Fyke-Net	261	Immature			6/17/2006	North Fork West Net
17882	Gray	Fyke-Net	244	Immature			6/17/2006	North Fork West Net
17881	Gray	Fyke-Net	278	Immature			6/17/2006	North Fork West Net
17880	Gray	Fyke-Net	260	Immature			6/17/2006	North Fork West Net
17879	Gray	Fyke-Net	262	Immature			6/17/2006	North Fork West Net

Arctic Grayling Fry

Since 1992, we have observed adult and fry Arctic grayling in North Fork Red Dog Creek. We have visual observations of active spawning in North Fork Red Dog Creek and have captured fry (12 to 15 mm long) in drift nets at Station 10 in Mainstem Red Dog Creek and at Station 12 in North Fork Red Dog Creek. We also conduct visual surveys along North Fork Red Dog Creek in July to assess relative abundance of fry (Table 16). We have not observed large numbers of fry in North Fork Red Dog Creek since summer 1999 (Table 16).

Arctic Grayling Distribution

Aerial surveys for adult Arctic grayling in the Ikalukrok Creek drainage have been made annually since summer 2000. In summer 2006, due to generally high water conditions throughout most of the summer, aerial surveys for Arctic grayling were not done.

Table 16. Relative abundance of Arctic grayling fry in North Fork Red Dog Creek (1992 to 2006).

Year	Relative Abundance of Fry	Comments
1992	high	100's of fry, late July
1993	low	Few fry in early August, high water
1994	low	High water after spawning probably displaced fry
1995	low	Fry small (<25 mm) in mid-July
1996	high	Schools of 50 to 200 fry common
1997	high	Average size of fry was 10 mm greater than in 1996
1998	low	Cold water, late breakup, high water after spawning
1999	high	Low flows, warm water after spawning, schools of 50 to 100 fry common
2000	low	Cold water, late breakup, spawning 90% done June 13/14, fry small (<25 mm) and rare in mid-July
2001	low	Cold water, late breakup, spawning 90% done June 19, fry small (<25 mm) and rare in mid-July
2002	low	High flows, spawning 90% done June 8, fry small (<35 mm) in early August and rare, more fry seen in Ikalukrok Creek in early July, probably displaced by high water
2003	low	Cold water, late breakup, spawning 90% done June 14, fry small (<25 mm) and rare in early August
2004	low	Early breakup, spawning 90% done by May 31, fry (<30 mm) on July 10
2005	low	Spawning 90% done by June 7, fry present in early July, several groups of 25 to 30 observed
2006	low	Spawning partially abandoned due to cold water temperatures, no fry observed in early August, July surveys not possible due to high water

Slimy Sculpin

Houghton and Hilgert (1983) found slimy sculpin in Ikalukrok and Dudd creeks, but none were found in the Red Dog Creek drainage. In 1995, we caught slimy sculpin in Mainstem Red Dog and North Fork Red Dog creeks (Weber Scannell and Ott 1998). Slimy sculpin are infrequently caught in the Red Dog Creek drainage and in Anxiety Ridge Creek. Catches of slimy sculpin generally have been highest in Ikalukrok Creek near Dudd Creek. The total catch of slimy sculpin for all sample areas, except Evaingiknuk Creek, is presented in Figure 117. Catches were low in 2006 due to reduced sample effort (i.e., July sample not done due to high water).

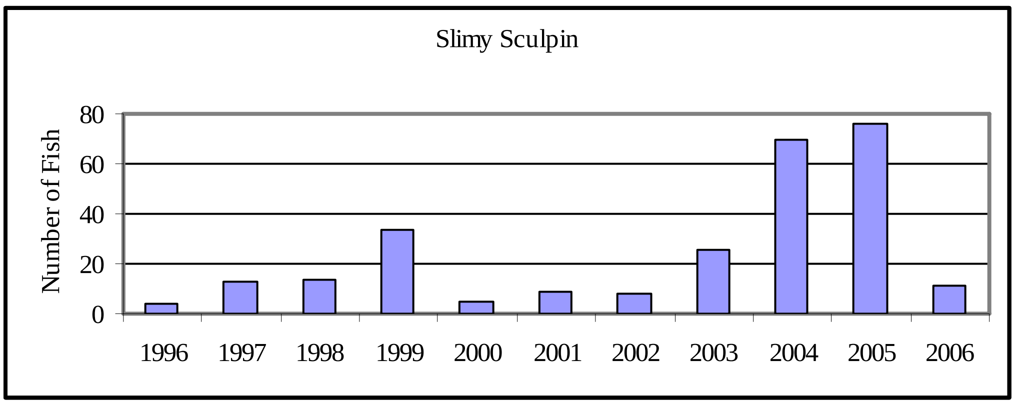

Figure 117. Slimy sculpin caught in Ikalukrok, Red Dog, Buddy, and Anxiety Ridge creeks, 1996 to 2006.

Trends in total numbers indicate an increasing presence of slimy sculpin from 1996 through 1999, with a decrease from 2000 to 2002, and then an increasing trend through 2005.

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Appendix 1. Summary of Mine Development and Operations

1982

- Baseline studies initiated, Cominco agreement with NANA finalized

1983

- EIS process initiated, alternatives for mine and road to port site identified

1984

- Stream surveys conducted along proposed road by private consultant

1985

- Permit applications prepared for regulatory agencies
- Implementation of wastewater treatment plant deferred to ADEC by ADF&G
- Wastewater discharge limited to summer
- Potential for acid rock drainage and metals mobilization not recognized

1986

- ADEC solid waste permit and bonding not required
- ADEC permit preceded solid waste regulations
- AIDEA bonds to build road and port site issued

1987

- Construction of road began, budget request to AIDEA prepared by ADF&G
    - Reimbursement agreement for logistics with ADF&G to monitor construction made by AIDEA

1988

- Ore body developed
- Road and port site construction began
    - Notice of Violation issued to AIDEA by ADF&G for failed road crossing by-passes
- Uniform Summons and Complaint issued for illegal water removal
- AIDEA provided funding to ADF&G for monitoring
- Rehabilitation plans for streams developed and implemented

Appendix 1 (continued).

1989

- Agreement to close-out old solid waste site finalized with Cominco
- Civil work on ore body and surface water drainage control begun
- Complaints about water quality in Ikalukrok Creek received
    - Tailing dam becomes full, Cominco's request to siphon untreated water over the dam denied by State
    - Elevated metals concentrations identified by red precipitation, were observed in Ikalukrok Creek below the mine
- Winter discharge of treated water authorized by State
    - State regulatory agencies and Cominco in disagreement over whether metals exceeded background conditions

1990

- Biomonitoring of fish populations proposed and initiated by ADF&G
- Dead fish from the Wulik River were discovered by the public
- ADF&G sampling indicated very few fish remaining in Ikalukrok Creek
    - Installation of sumps and pumps by Cominco prevented metals-laden water from entering Red Dog Creek
- Baseline and current water quality data reviewed by ADF&G
- Clean water bypass system requested by ADF&G
- Zinc levels in Ikalukrok Creek exceeded 40 mg/L
    - State regulatory agencies and Cominco in disagreement over cause and extent of water quality problems
    - Compliance Order by Consent for water quality violations affecting anadromous fish issued by ADEC
    - Notice of Violation for water quality violations affecting anadromous fish issued by ADF&G
- Cominco directed to design and construct a clean water bypass system
    - Perceived impairment to the subsistence fishery initiated involvement by the community of Kivalina

1991

- Clean water bypass system designed by Cominco, approved by state agencies
- ADF&G fisheries study funded by Cominco
- Clean water bypass system built
- Clean water bypass system repaired
- Improvements to water quality were documented

Appendix 1 (continued).

1992
- Fish study continued
- Water quality improvements to downstream receiving water continued
- Increasing water volume in tailing impoundment continued
    - Water from dirty water collection system entering tailing impoundment increased volume
- Water treatment plant modifications made

1993
- Fish study continued
- Sand filters to remove particulate zinc installed

1994
- Fish study continued
- Use attainability studies of several streams initiated for reclassification
- Water treatment capacity increased by thickening tank conversion
- Wastewater discharge increased from 7.5 cfs to 23 cfs
- Ore processing capability expanded by Cominco

1995
- Fish study expanded to include other aquatic biota
- Work on stream reclassification and site-specific criteria continued by ADF&G
    - Metals concentrations in the clean water bypass system increased; contributing sources were identified: Hilltop Creek (Zn), Shelly Creek (Cd), and Rachel Creek (Al)
- Clean water bypass system extended to collect water from Hilltop Creek
- Reserves were doubled after exploration drilling located more ore
- Possible metals contamination in Bons Creek identified by ADF&G

1996
- Public notice for stream reclassification sent out
    - Bons Creek water samples from above and below the Kivalina shale dump collected
- Fish and aquatic biota study continued

Appendix 1 (continued).

1997

- Stream reclassification incorporated into regulation (18 AAC 70.50)
- Fish barrier constructed across Middle Fork Red Dog Creek
- Water bypass around the Kivalina shale dump and interceptor trench at the head of the tailing impoundment built
- Gray-white precipitate observed in Middle Fork Red Dog Creek
- Heavy red staining and precipitate seen in Ikalukrok Creek; originated from seep near headwaters of Ikalukrok Creek, located upstream of mining activity
- Laboratory experiments of TDS on egg fertilization and early egg development initiated
- Fish and aquatic biota studies continue
- US EPA brings enforcement action for water quality violations; Cominco initiates Supplemental Environmental Projects
- Two-year aquatic community study in upper Ikalukrok Creek, above and below the Red Dog Mine discharge initiated by ADF&G
- Ground water monitoring wells installed and monitored below tailing dam by Cominco

1998

- Wet fertilization studies to test effects of TDS on fish embryos continued
- Draft 401 certification for a new NPDES permit prepared by ADEC and reviewed by ADF&G
- Discussed extension of the clean water bypass system up Shelly and Connie Creeks to ensure bypass of clean water and collection of seepage water from newly disturbed areas
- Heavy red staining in headwaters of Ikalukrok Creek, originating from seep in headwaters of Ikalukrok Creek, upstream of mining activity, staining extends downstream about 30 km
- Site-specific criteria for Zn in Mainstem Red Dog and Ikalukrok Creeks approved by EPA
- Heavy rains cause an unanticipated release of water into Bons Creek from the Kivalina stockpile
- Plans to increase port site capacity for direct loading of ships released to public
- NPDES permit reissued by US EPA
- Two-year aquatic community study completed
- Biomonitoring, including studies of fish and aquatic biota, required under 1998 NPDES permit

Appendix 1 (continued).

1999

- Two-year drilling program (Shelly and Connie Creeks) proposed
- New station 7 on Ikalukrok Creek established by Cominco, USGS, and ADF&G
- Fish and aquatic biota study expanded to upper North Fork Red Dog, Ikalukrok, and Ferric creeks
- Biomonitoring and USGS gauging work proposals submitted to Cominco
- Study of periphyton communities exposed to different concentrations of TDS in Mainstem Red Dog Creek done by ADF&G and Cominco Alaska Inc.
- Request to increase TDS for periphyton colonization experiment not approved
- Effects to Ikalukrok Creek from Alvinella Creek seepage water continued to below Dudd Creek mouth
- Arctic grayling females in ripe spawning condition collected from North Fork Red Dog Creek for selenium analysis of livers and ovaries

2000

- Effects to Ikalukrok Creek from Cub Creek seep continued; red stain and precipitate observed several km below mouth of Mainstem Red Dog Creek
- North Fork Red Dog Creek silty at breakup, previously not observed
- Minimal precipitate in Middle Fork Red Dog Creek below effluent outfall observed
- Civil work performed in Connie Creek to isolate surface from subsurface flows and bypass flow through disturbed areas
- Effectiveness of pump back system at the Kivalina rock dump verified by presence of juvenile Arctic grayling in creek immediately south of dump
- Site-specific criteria for TDS requested by Cominco
- Biomonitoring study continued
- Baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect begun

Appendix 1 (continued).

2001

- Effects to Ikalukrok Creek from Cub Creek seep continued, red stain and precipitate observed in Ikalukrok Creek to Station 8 below Mainstem Red Dog Creek, affects minor near mouth of Dudd Creek
- North Fork Red Dog Creek, siltation (natural) less than in summer 2000
- Minimal precipitate in Middle Fork Red Dog Creek below effluent outfall
- Water quality was monitored in Shelley, Rachel, Connie, and Middle Fork Red Dog creeks upstream and downstream of surface disturbance, catch-box and pipeline (about 430 m) placed in Shelley Creek to move water pass disturbance
- Juvenile Arctic grayling observed in Bons Creek just south of the Kivalina rock dump, pump-back system working based on fish use
- Fish weir repairs made during 2000, no problems observed in 2001
- Stream survey of cross drainage structures made along the Delong Mountains Transportation System, some minor work at some crossings identified
- Site-specific criteria for TDS still being worked, data on Arctic grayling spawning/water temperature collected in North Fork Red Dog and Mainstem Red Dog creeks, supplemental data gathered at the Ft. Knox mine
- Studies expanded to include the Delong Mountains Transportation System based on a National Park Service report that metals concentrations adjacent to road were elevated, water sites established upstream and downstream of road and sampled by Teck Cominco, juvenile Dolly Varden samples collected in Omikviorok River and Aufeis Creek, vegetation sampling started by Teck Cominco
- New haul trucks brought on site, hard-covered trucks to minimize loss of zinc and lead concentrates during transport
- Exploratory drilling (ore and shallow gas) continued, focus on North Fork Red Dog Creek and Wulik River basins near Anarraaq and Lik, including west of the Wulik River, another ore prospect found northwest of Anarraaq, shallow gas results promising
- State and Teck Cominco agree to start the state’s large mine team to work on issues, key issue identified was development of a solid waste permit with bonding for the tailing dam, other issues include site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
- Biomonitoring study continued, baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect continued for the second field season, four new sites added to study tributaries on west side of Wulik in the area of the Lik Deposit and potential shallow gas development

Appendix 1 (continued).

2002

- Effects to Ikalukrok Creek from Cub Creek seep continued, red stain and precipitate observed in Ikalukrok Creek to Station 8 below Mainstem Red Dog Creek, affects minor near mouth of Dudd Creek
- North Fork Red Dog Creek, siltation minor during summer 2002
- Minor precipitate in Middle Fork Red Dog Creek below effluent outfall
- Fish weir operating as designed
- Data on Arctic grayling spawning/water temperature collected in North Fork Red Dog Creek, supplemental data gathered at Ft. Knox
- Pit expansion continues to the north of the clean-water bypass system, road crossing added for access
- A bypass was installed for Connie Creek during winter 2001/2002. The bypass captures the upstream creek and carries the water in a pipe to the clean-water bypass system
- The bypass system for Shelly Creek was modified during summer 2002 to correct an overflow problem that occurred during breakup (the overflow water was captured in the pit and did not affect downstream waters). The modification involved adding a lined ditch to contain overflowing clean water and direct the water to the clean-water bypass system
- Juvenile Dolly Varden collected at eight sites located upstream and downstream of the Delong Mountains Regional Transportation System, whole body metals analyses for Cd, Pb, Se, and Zn
- Site-specific criteria for total dissolved solids is still being worked
- State and Teck Cominco continue to work on key issues, e.g., solid waste permit with bonding for the tailing dam, site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
- Biomonitoring study continued, baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect and shallow gas exploration
- Arctic grayling adults remained in North Fork Red Dog Creek through early August, only the second time since 1992 that most of the adults stayed in the creek during summer, most years adults outmigrate shortly after spawning in spring
- Arctic grayling adults present in Buddy Creek just below the falls, about 50 adult fish in sample reach (0.3 km) in early July, all gone by early August
- About 50 to 60 adult Dolly Varden in Ikalukrok Creek at mouth of Dudd Creek from early July through late August
- Effluent discharge ceased on October 5, 2002, to allow time to winterize the water treatment plant

Appendix 1 (continued).

2003

- Effects to Ikalukrok Creek from Cub Creek seep continued but were much less than seen in the last two to three years
- North Fork Red Dog Creek, natural siltation throughout most of the summer was minor in summer 2003
- Minor precipitate in Middle Fork Red Dog Creek below effluent outfall
- Fish weir operating as designed
- Data on Arctic grayling spawning/water temperature collected in North Fork Red Dog Creek, supplemental data gathered at Ft. Knox
- Site-specific criteria for total dissolved solids was finalized
- USEPA modified the NPDES effective August 22, 2003, to incorporate the ADEC Site Specific Criteria and mixing zones for total dissolved solids in Mainstem Red Dog and Ikalukrok creeks with conditions that ensure total dissolved solids are at or below 500 mg/L during Arctic grayling spawning in Mainstem Red Dog Creek and during chum salmon and Dolly Varden spawning in Ikalukrok Creek, the modified permit was appealed by the Kivalina Relocation Planning Committee
- State and Teck Cominco continue to work on key issues, e.g., solid waste permit with financial assurance for the tailing dam, site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
- Arctic grayling adult returns to North Fork Red Dog Creek were low, number of adult Arctic grayling seen in the Ikalukrok Creek drainage was the lowest seen since aerial surveys were begun in the late 1990s
- Arctic grayling population estimate was completed for Bons Pond the site of a fish transplant made in 1994 and 1995, estimated population in the reservoir was 6,773
- Modification to Shelly Creek bypass ditch completed, a better designed and constructed lined ditch was built and commissioned in August, 2003
- In 2003, a permanent lined ditch was constructed parallel to the Connie Creek diversion pipeline to avoid spring freeze-up issues
- In 2003, a permanent monitoring station was established at the end of the mixing zone in Mainstem Red Dog Creek, the location designation is Station 151, and is fitted with real time total dissolved solids and flow determination equipment and telemetry to link the station directly into the mill process control system
- Station 150, at the end of the mixing zone in Ikalukrok Creek, was fitted with real time total dissolved solids and flow determination equipment and telemetry to link the station directly into the mill process control system

Appendix 1 (continued).

2004

- Wastewater discharge began on May 20, ended on September 26, total discharge about one billion gallons
- Effects to Ikalukrok Creek from Cub Creek seep continued but were minor
- North Fork Red Dog Creek, natural siltation minor during ice-free season
- Minor precipitate in Middle Fork Red Dog Creek below effluent outfall
- Fish weir operating as designed
- Arctic grayling spawning/water temperature data collected, Arctic grayling from North Fork Red Dog Creek used for TDS fertilization experiment
- State and Teck Cominco continued to work on key issues associated with the solid waste permit and closure plan for the mine
- Arctic grayling adult returns to North Fork Red Dog Creek were low, number of adults seen in Ikalukrok Creek drainage remained low as in summer 2003
- Bons Pond (the site of a fish transplant made in 1994 and 1995), estimated Arctic grayling population for summer 2003 was 6,773 and for summer 2004 was 5,739
- Chinook salmon juveniles were documented for the first time in Ikalukrok Creek, near Dudd Creek, and in Anxiety Ridge Creek
- Age-1 Arctic grayling were caught in minnow traps fished in Ikalukrok, Mainstem, and Buddy creeks, since age-1 fish are seldom captured in minnow traps this may indicate good survival of fry spawned in spring 2003
- Red Dog Creek diversion (clean water ditch) was realigned to the west side of the pit. Realigned configuration is a combination of large diameter culvert and open lined ditch

2005

- Wastewater discharge began on May 10, 2005, ended on October 6, 2005, total discharge about 1.501 billion gallons
- Major precipitate observed on streambed in Middle Fork Red Dog Creek below effluent outfall in July and August, precipitates (gray colored) evident for at least 1 km downstream of effluent outfall
- Fish weir operating as designed
- Effects to Ikalukrok Creek from Cub Creek seep substantially greater than seen for past several years, water opaque and streambed coated with red precipitate at confluence with Mainstem Red Dog Creek, TCAK water sample from Cub Creek seep with a pH of 3.3
- Arctic grayling spawning/water temperature data collected, Arctic grayling from North Fork Red Dog Creek used for TDS fertilization experiment
- Attended and participated in a NPDES permit renewal meeting in Seattle with EPA, TCAK, and Nana, identified and discussed key issues

Appendix 1 (continued).

2005

- Red Dog Creek diversion (clean water ditch) mine engineering drawings (r4) were provided by TCAK showing the culverts and lined ditch that carry water from tributaries and Middle Fork Red Dog Creek through the pit area
- Recommendations for changes to the Red Dog biomonitoring program based on field data collection and analyses since 1999 were made for possible incorporation into the renewed NPDES permit or ADEC's solid waste permit for the tailing impoundment
- TCAK distributed the 2005 draft report on Arctic grayling fertilization studies that concluded TDS concentrations at or below 1,500 mg/L at Station 10 in Mainstem Red Dog Creek would provide for proper protection of Arctic grayling in the Red Dog Creek drainage, OHMP supported these findings in a letter to Pete McGee (ADEC) dated August 17, 2005
- Dr. Weber Scannell prepared comments on fish tissue data (Dolly Varden from Wulik and Kivalina rivers) collected by Maniilaq Association and compared these data with existing information from other sources in both Alaska and nationwide
- OHMP prepared a summary report (letter to Jim Kulas dated August 23, 2005) on temperature/spawning data collected for Arctic grayling in Mainstem Red Dog and North Fork Red Dog creeks from 2001 through 2005, a recommendation for determining start and completion of spawning based on temperature was developed for Mainstem Red Dog Creek
- State and TCAK continued to work on key issues associated with the solid waste permit and closure plan for the mine ADEC
- Wastewater Treatment Plant (WTP) #3 began operations in late summer 2005 to treat mine sump water and drainage from waste rock dumps prior to placement of these waters into the tailing impoundment, purpose is to improve water quality in tailing impoundment over time
- Exploratory drilling and flow testing for gas in North Fork Red Dog Creek basin was conducted, access road and pads inspected, corrugated pipes installed to provide cross drainage, no evidence of erosion noted along road to and connecting the drill pads
- A road was constructed to Station 151 (end of mixing zone in Mainstem Red Dog Creek
- Work to expand and relocate the water treatment plant sand filters was initiated

Appendix 1 (concluded).

2006

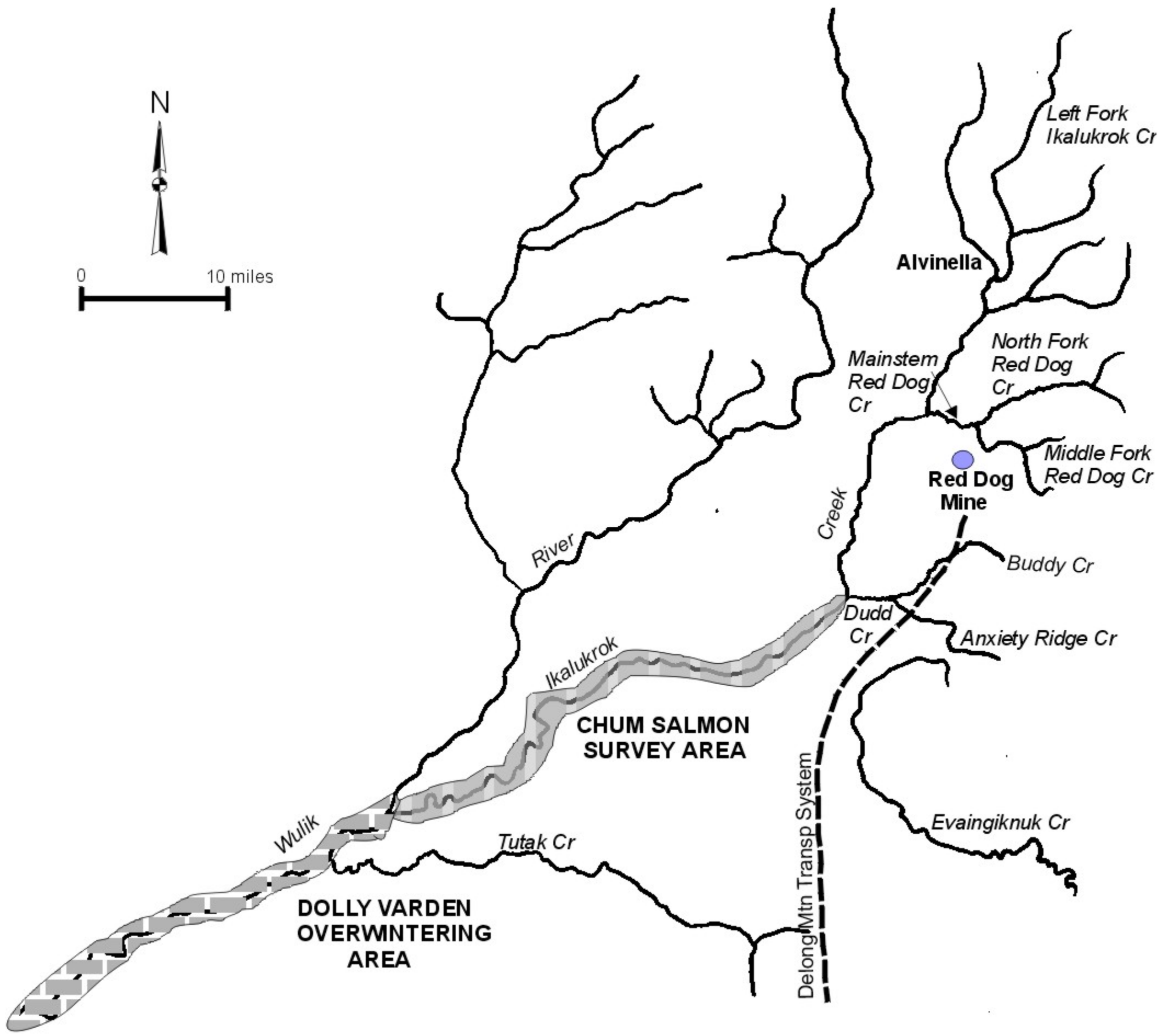
- ADEC amended the site-specific criteria (SSC) for TDS in Mainstem Red Dog Creek, the 500 mg/L limit during Arctic grayling spawning was removed and replaced with a 1,500 mg/L limit on February 15, 2006, and EPA approved the new SSC in April 2006
- North Fork Red Dog Creek, extensive areas of aufeis existed, turbidity and organic debris high due to erosion and thermal degradation, in several reaches flow was not in stream channel due to aufeis
- Arctic grayling spawning/water temperature data collected, early spring warming followed by cold weather, adult Arctic grayling entered North Fork Red Dog Creek in late May and due to cold water temperatures abandoned spawning and outmigrated from the creek in mid-June
- Four Arctic grayling captured in North Fork Red Dog Creek in spring 2006 were fish that had been marked in Bons Pond
- Review of ADEC's draft 401 certification to the renewal of the NPDES was completed and we provided a letter of support (March 10, 2006) to ADEC, including our concurrence with ADEC's decision to not require Whole Effluent Toxicity (WET) limits
- Effects to Ikalukrok Creek from Cub Creek seep continued, but were minor
- Major precipitate observed on streambed in Middle Fork Red Dog Creek below effluent outfall in August, precipitates (orange colored) evident for at least 1 km downstream of effluent outfall and precipitates continued upstream through the clean water bypass to Connie and Rachel creeks
- Fish weir operating as designed
- Work continued on the design for the Red Dog tailing backdam, the dam will be located on the south side of the tailing pond and will be constructed of earth fill with a concrete/soil aggregate/bentonite cutoff wall, the dam will be constructed to a final height of 986 ft., construction anticipated during 2006 and 2007
- In July 2006, windrows of dead capelin were documented at the Port Site, die off after spawning is normal, only a small percentage survive spawning
- Total count of chum salmon in Ikalukrok Creek on August 16 was 4,185, the highest number reported since 1990
- In 2006, slightly elevated Zn concentrations persisted and TCAK initiated a field investigation comprised of sampling along the clean water bypass, although not definitive, results indicated that the Mine Sump might have been the source of increased Zn concentrations, modifications were made in operational procedures to ensure containment of contaminated waters in the Mine Sump

Appendix 2. Dolly Varden Aerial Surveys

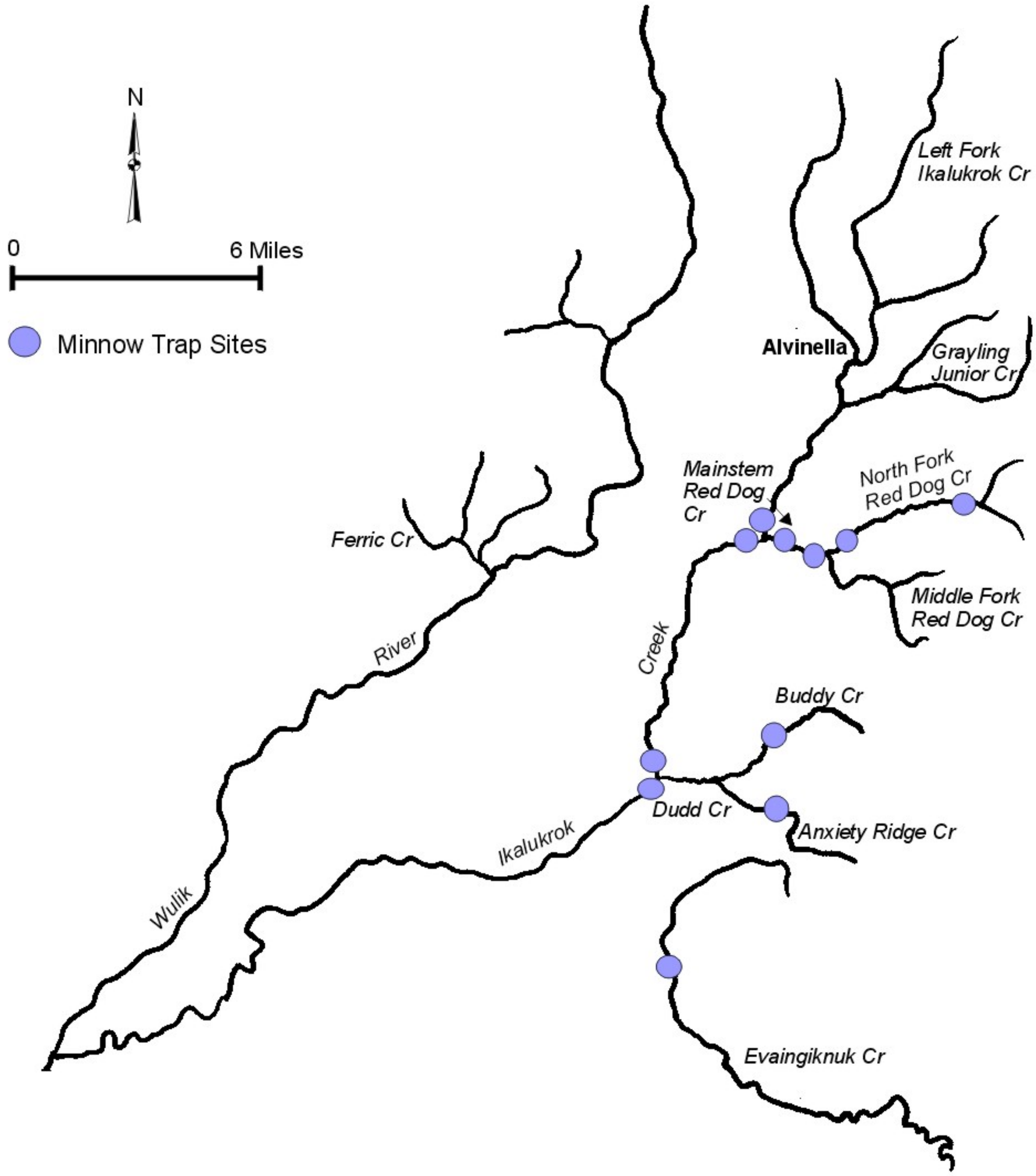
Estimated number of overwintering Dolly Varden in the Wulik River before freezeup. Surveys conducted by ADF&G (DeCicco 1989, 1991-1999, 2001-2002, and 2004-2006.

Year	Wulik River upstream of Ikalukrok Creek	Wulik River downstream of Ikalukrok Creek	Total Fish	Percent of Fish downstream of Ikalukrok Creek
Before Mining				
1979	3,305	51,725	55,030	94
1980	12,486	101,067	113,553	89
1981	4,125	97,136	101,261	96
1982	2,300	63,197	65,497	97
1984	370	30,483	30,853	99
1987	893	60,397	61,290	99
1988	1,500	78,644	80,144	98
During Mining				
1989	2,110	54,274	56,384	96
1991	7,930	119,055	126,985	94
1992	750	134,385	135,135	99
1993	7,650	136,488	144,138	95
1994	415	66,337	66,752	99
1995	240	128,465	128,705	99
1996	1,010	59,995	61,005	98
1997	2,295	93,117	95,412	98
1998	6,350	97,693	104,043	94
1999	2,750	67,954	70,704	96
2001	2,020	90,594	92,614	98
2002	1,675	42,582	44,257	96
2004	16,486	84,320	100,806	84
2005	10,645	110,203	120,848	91
2006	4,758	103,594	108,352	96
The population estimate (mark/recapture) for winter 1988/1989 for fish >400 mm				
was 76,892 (DeCicco 1990b)				
The population estimate (mark/recapture) for winter 1994/1995 for fish >400 mm				
was 361,599 (DeCicco 1996c)				
Fall 2000 aerial survey was not made due to weather.				
Fall 2003 aerial survey was not made due to weather.				

Appendix 3. Dolly Varden and Chum Salmon Survey Areas



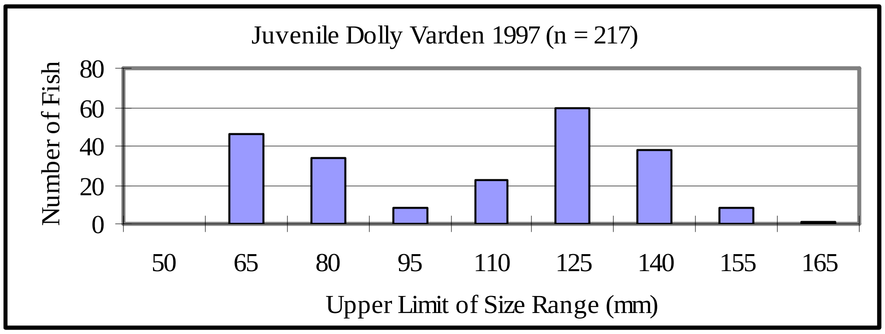
Appendix 4. Juvenile Dolly Varden Sampling Sites

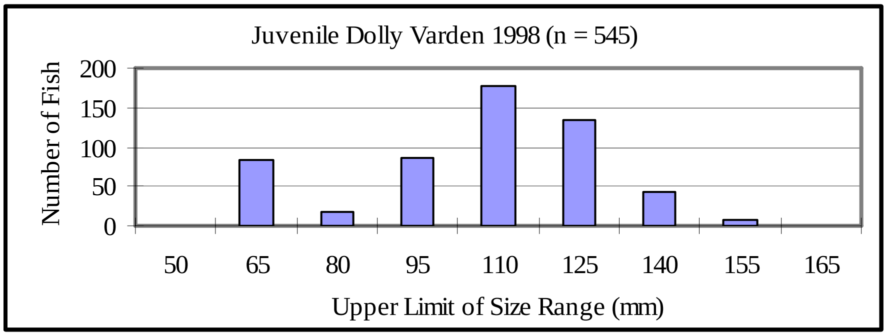


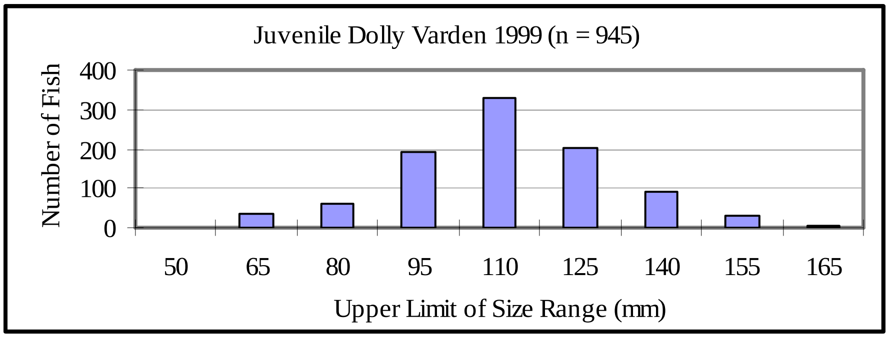
Appendix 5. Juvenile Dolly Varden Catches

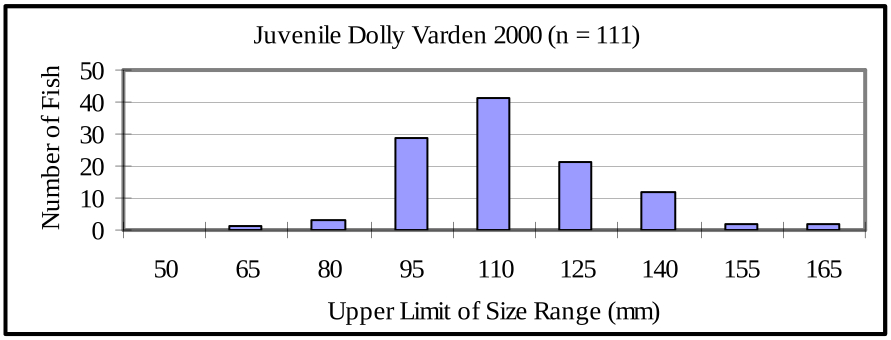
Number of Dolly Varden Caught in Late-July/Early August with ten minnow traps per sample site										
Sample Site Description	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Evaingiknuk (Noatak Tributary)	54	27	38	2	7	20	64	71	29	4
Anxiety Ridge	68	94	271	27	6	33	98	116	121	8
Buddy	48	154	306	11	34	57	104	59	59	5
North Fork Red Dog Creek (Sta 12)	0	12	17	1	1	1	0	1	8	0
Mainstem (below North Fork)	14	70	86	13	9	12	2	2	6	8
Mainstem (Station 10)	10	21	66	1	3	12	12	0	10	3
Ikalukrok Creek (below Dudd)	13	51	55	31	6	17	17	27	36	2
Ikalukrok Creek (above Dudd)	3	53	37	14	0	22	27	11	6	0
Ikalukrok Creek (below Mainstem)	4	19	28	6	11	15	3	2	0	0
Ikalukrok Creek (above Mainstem)	3	44	41	5	2	18	3	12	0	5
Total Catch Dolly Varden	217	545	945	111	79	207	330	301	275	35

Appendix 6. Length-frequency Distribution of Juvenile Dolly Varden

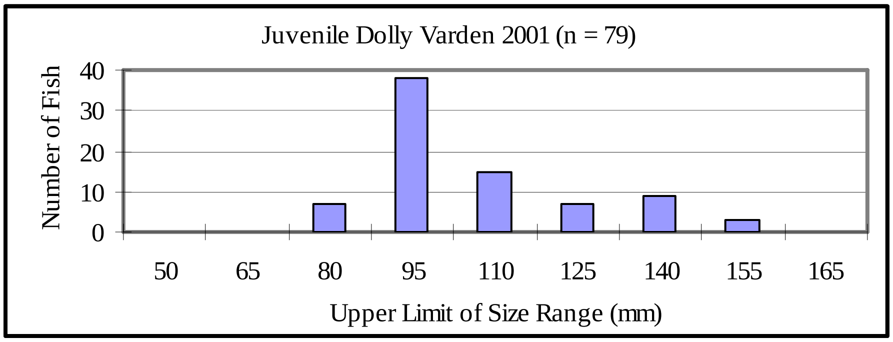


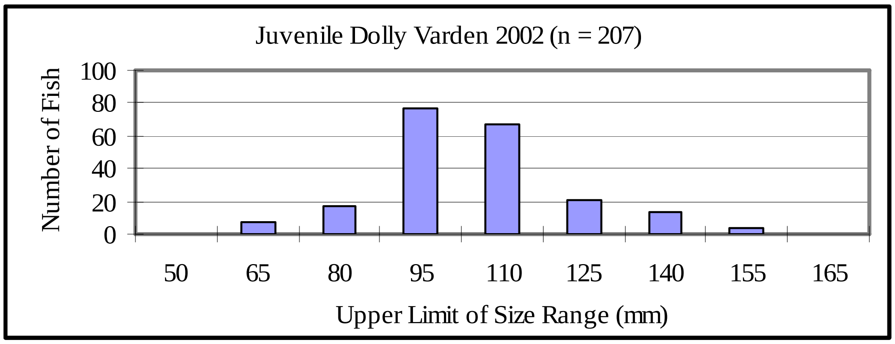


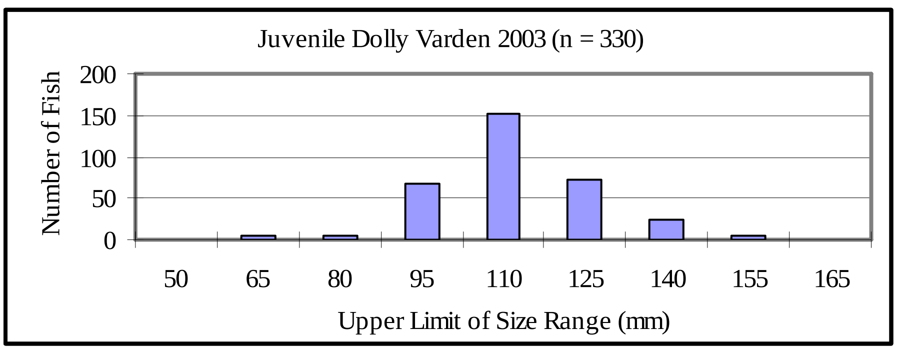


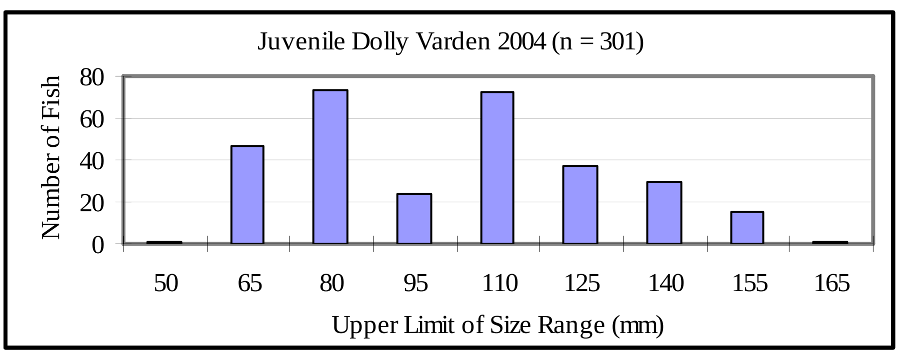


Appendix 6 (continued).









Appendix 6 (concluded).