FISH AND AQUATIC TAXA REPORT
RED DOG MINE (1998–1999)

Technical Report No. 00-3

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Submitted to

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ACKNOWLEDGEMENTS

We thank Cominco Alaska Inc. for the logistical and financial support they have provided for the annual monitoring of fish and aquatic taxa in the Red Dog Mine area. Without their assistance our field monitoring program would not have been possible, and essential data for decision making would not have been collected. Mr. John Key (General Manager - Cominco Alaska Inc.), Mr. Jim Kulas (Manager, Environmental and Risk), Ms. Charlotte MacCay, Dr. Maria Falutsu, and Mr. John Martinisko have been instrumental in the continuation of our work. Mr. John Wood (Alaska Industrial Development and Export Authority) allowed us the use of their vehicles while conducting field work.

Mr. Fred DeCicco of the Alaska Department of Fish and Game (ADF&G) conducted field data collection and assisted with laboratory work, Mr. Jack Winters (ADF&G) helped prepare fish tissues for laboratory analysis and provided field assistance, and Ms. Nancy Ihlenfeldt (ADF&G) assisted with field data collection and preparation of figures for the report. Mr. Fred DeCicco, Mr. Jack Winters, Ms. Nancy Ihlenfeldt, and Mr. Jim Kulas provided constructive review of our report.

EXECUTIVE SUMMARY

WATER QUALITY CONDITIONS

Station 9 - Ikalukrok Creek above Red Dog Creek - Reference Figures 4 and 5
Median concentrations of Al, Cd, and Zn have been similar from 1995 through 1997, but rose in 1998 and 1999. Maximum TDS, conductivity, and sulfate concentrations were higher in post-mining years with the highest values for all three factors occurring in 1999 in Ikalukrok Creek upstream of Mainstem Red Dog Creek. These changes probably are directly associated with seepage water entering Ikalukrok Creek at Alvinella.

Station 7 - Ikalukrok Creek below Dudd Creek - Reference Figures 9, 10, and Table 3

Median TDS and hardness were highest in 1999, but at no time during the chum salmon spawning period did TDS exceed 500 mg/L.

Station 10 - Mainstem Red Dog Creek - Reference Figures 14 and 15
Metals concentrations in 1996 through 1999 in Mainstem Red Dog Creek were lower than any concentrations reported during baseline studies. Median Se concentrations in water have fallen each year since 1996 when measurement first began.

Station 12 - North Fork Red Dog Creek - Reference Figures 19 and 20
Water in the North Fork Red Dog Creek is low in metals and has not varied over the period sampled.

Rachael Creek - Middle Fork Red Dog Creek Tributary - Reference Figure 21
Since 1995, median concentrations of Al, Cd, and Zn have consistently been elevated, especially Al and Zn.

Sulfur Creek - Middle Fork Red Dog Creek Tributary - Reference Table 6
Since mining, Sulfur Creek continues to have elevated Cd, Pb, and Zn.

Shelly Creek - Middle Fork Red Dog Creek Tributary - Reference Figure 22
Metals concentrations have been sampled in Shelly Creek from 1995 through 1999 and Al, Cd, Pb, and Zn have been elevated. Metals are highest during fall low flow periods, from late August through early September.

Connie Creek - Middle Fork Red Dog Creek Tributary - Reference Figure 23
In 1995 through 1999, Connie Creek frequently contained the lowest median concentrations of metals of any of the tributaries to Middle Fork Red Dog Creek.

MICROTOX TESTS

Reference Figures 25 through 31
Waters from the bypass channel were more toxic to the Microtox test bacteria than waters collected from the outfall, North Fork Red Dog Creek, or Ikalukrok Creek above Mainstem Red Dog Creek. Blend water from Station 140 and Station 12 was toxic at 100%, but toxicity decreased rapidly with the addition of either effluent or natural water.

PERIPHYTON STANDING CROP

Reference Table 9
Periphyton standing crop, estimated by chlorophyll-a concentrations, was highest in North Fork Red Dog Creek. Lowest concentrations of chlorophyll-a continue to occur in Middle Fork Red Dog Creek (Station 20), but increase in Mainstem Red Dog Creek after mixing with waters from North Fork Red Dog Creek. Chlorophyll-a generally is higher in Ikalukrok Creek than Mainstem Red Dog Creek, but concentrations have decreased in Ikalukrok Creek (Station 9) located upstream of the mouth of Mainstem Red Dog Creek. Decreased chlorophyll-a concentrations at Station 9 may be related to mineralized waters coming from the Alvinella area.

Aquatic Invertebrate Communities

Reference Figures 42 through 46 and 48 and 49

Significantly more aquatic invertebrates were collected from North Fork Red Dog Creek and density was significantly higher than at other sampling sites. Density of invertebrates within a site was not correlated with periphyton standing crop or TDS. We found no significant difference in the total numbers of taxa collected among the sites. Aquatic communities from all sites in the Red Dog Mine area were dominated by collectors/scrapers, with shredders forming a smaller, but important component. The terrestrial component of the drift samples was highest in Ikalukrok Creek upstream of Dudd Creek.

Metals Concentrations in Juvenile Dolly Varden

Reference Figures 51 through 53 and 56

Juvenile Dolly Varden from Mainstem Red Dog Creek contained the highest concentrations of Cd and Pb, but concentrations of Se, although somewhat higher in Mainstem Red Dog Creek, were similar for all sample sites. Selenium concentrations were elevated in juvenile Dolly Varden from all the streams sampled in the Red Dog Mine area. Whole body Se concentrations in juvenile Dolly Varden from the Red Dog Mine area were higher in all creeks compared with Se concentrations in juvenile chinook salmon from the Goodpaster River.

Metals Concentrations in Adult Dolly Varden

Reference Figures 64 and 65

Metals monitored in Dolly Varden tend to concentrate in specific tissues. Although certain tissues may have the highest concentrations, especially during periods when metals concentrations are high in the stream water, they are not necessarily the best indicators of metals accumulation for long-term monitoring. Not one of the metals being monitored tends to accumulate in muscle tissue.

Periodic increases in specific metals have been documented since mining began. The most noticeable increases occurred during the early 1990s prior to construction of the clean-water bypass system, in the mid 1990s when metals concentrations peaked in Hilltop Creek and the clean-water bypass and mine sump drainage were extended to capture Hilltop Creek, and in 1998/1999 following changes in water quality in Ikalukrok Creek from seepage waters from the Alvinella area.

Overwintering Dolly Varden

Reference Table 12

We found no increase or decrease in numbers of Dolly Varden that correspond to development and production at the Red Dog Mine. Use of the Wulik River with Dolly Varden concentrated in the reach below the mouth of Ikalukrok Creek remains high. Over 90% of the overwintering Dolly Varden use the reach below Ikalukrok Creek; this pattern of habitat selection has not changed from pre-mining.

Chum Salmon Spawning

Reference Table 13

In 1999, chum salmon counts were low in August, but DeCicco's (1999) late September estimate of 145 adults probably indicates that the fall 1999 return was much higher than reported. Adults were concentrated in lower Ikalukrok Creek but were present throughout the creek from its mouth to the large pool located immediately below the mouth of Dudd Creek in 1997. The number of returning adult chum salmon spawners in Ikalukrok Creek remains lower than pre-mining.

Fish Distribution

Juvenile Dolly Varden - Reference Figures 69 through 71

Patterns of juvenile Dolly Varden use of Ikalukrok Creek tributaries have been studied annually since summer 1990. We caught 945 juvenile Dolly Varden in 1999. Juvenile Dolly Varden were found in all sample reaches with the highest numbers found in Buddy Creek in early August 1999. Relative numbers of fish vary considerably among years. Peak use of tributary streams by juvenile Dolly Varden continues to occur from late July to mid-August. Relative abundance of juvenile Dolly Varden increased substantially from 1997 to 1998 and again from

1998 to 1999 - essentially doubling each year with strong young-of-the-year recruitment in both 1997 and 1998, but less in 1999. Since 1995, we have documented juvenile Dolly Varden rearing in Mainstem Red Dog Creek with numbers increasing each year. Juvenile Dolly Varden were common in upper North Fork Red Dog Creek in August 1999. Pre-mining fisheries work indicated little or no use of Mainstem Red Dog or North Fork Red Dog creeks by juvenile Dolly Varden indicating that habitat changes (e.g., water quality) have resulted in increased fish use.

Arctic grayling - Reference Figure 72 and Tables 14 and 15
Arctic grayling use of North Fork Red Dog Creek varies among years. Successful spawning, judged by presence of young-of-the-year fish, has been observed each year in North Fork Red Dog Creek. Recruitment of Arctic grayling to the population (i.e., fish less than 250 mm) was extremely strong in 1999 - the strongest recruitment seen since our sampling began in 1993.

Mature Arctic grayling adults entered North Fork Red Dog Creek in late May 1999. Low flows, low precipitation, and high water temperature in North Fork Red Dog Creek seem to have contributed to good fry survival and growth. Schools of 50 to 100 young-of-the-year Arctic grayling were common. In August 1999, young-of-the-year Arctic grayling were abundant in backwaters and along the stream margins of Mainstem Red Dog Creek immediately downstream of North Fork Red Dog Creek.

We observed several Arctic grayling in Ikalukrok Creek in July 1999 at three locations: the mouth of Dudd Creek; the mouth of Grayling Junior Creek; and in the headwaters of the Left Fork of Ikalukrok Creek. In August 1999, we again observed large concentrations of adult Arctic grayling at the mouth of Dudd and Grayling Junior creeks.

Slimy Sculpin - Reference Table 16
We have found a few (1-2) slimy sculpin in Mainstem Red Dog Creek each year since 1995. The number of slimy sculpin using the Red Dog Creek drainage is

extremely low, similar to Anxiety Ridge and Buddy creeks. The largest catches of slimy sculpin have occurred in Ikalukrok Creek just above and below the mouth of Dudd Creek.

INTRODUCTION

The Red Dog zinc and lead deposit is located in northwest Alaska, about 130 km north of Kotzebue and 75 km inland from the coast of the Chukchi Sea (Figure 1). The mine site is located on Red Dog Creek in the Delong Mountains of the western Brooks Range. The mine, mill, tailing pond, housing, water treatment facilities, and port facility were described by Ott and Weber Scannell (1996).

The United States Environmental Protection Agency (EPA) issued a National Pollution Discharge Elimination System (NPDES) permit on August 28, 1998 to permit discharge of treated mine effluent to Red Dog Creek (AK003865-2). This permit was a renewal of the original NPDES permit and required biological monitoring in tributaries downstream of the mine. Biological monitoring was required in tributary streams unaffected by the mine. Our report summarizes the results of ADF&G's biological monitoring program at the Red Dog Mine for 1998 and 1999. Specific sections of the report summarize biological monitoring required under the current NPDES Permit for summer 1999. Data on water quality are presented in the report to further understanding of the interactions of aquatic productivity and water quality conditions.

The Red Dog Mine began operation in 1989, about 10 years after baseline studies were completed. Since development of the mine, the Alaska Department of Fish and Game (ADF&G) has conducted numerous studies of the aquatic communities in the Wulik River drainage. In 1991, we began a 3-year study in the Wulik River drainage to document short-term changes in fish distribution during mine development and operation. Our study focused on the distribution and relative abundance of juvenile Dolly Varden (*Salvelinus malma*) and Arctic grayling (*Thymallus arcticus*) in various tributaries downstream and in the vicinity of the mine, metals concentrations in adult Dolly Varden inhabiting the Wulik River, and the numbers of adult Dolly Varden overwintering in the Wulik River.

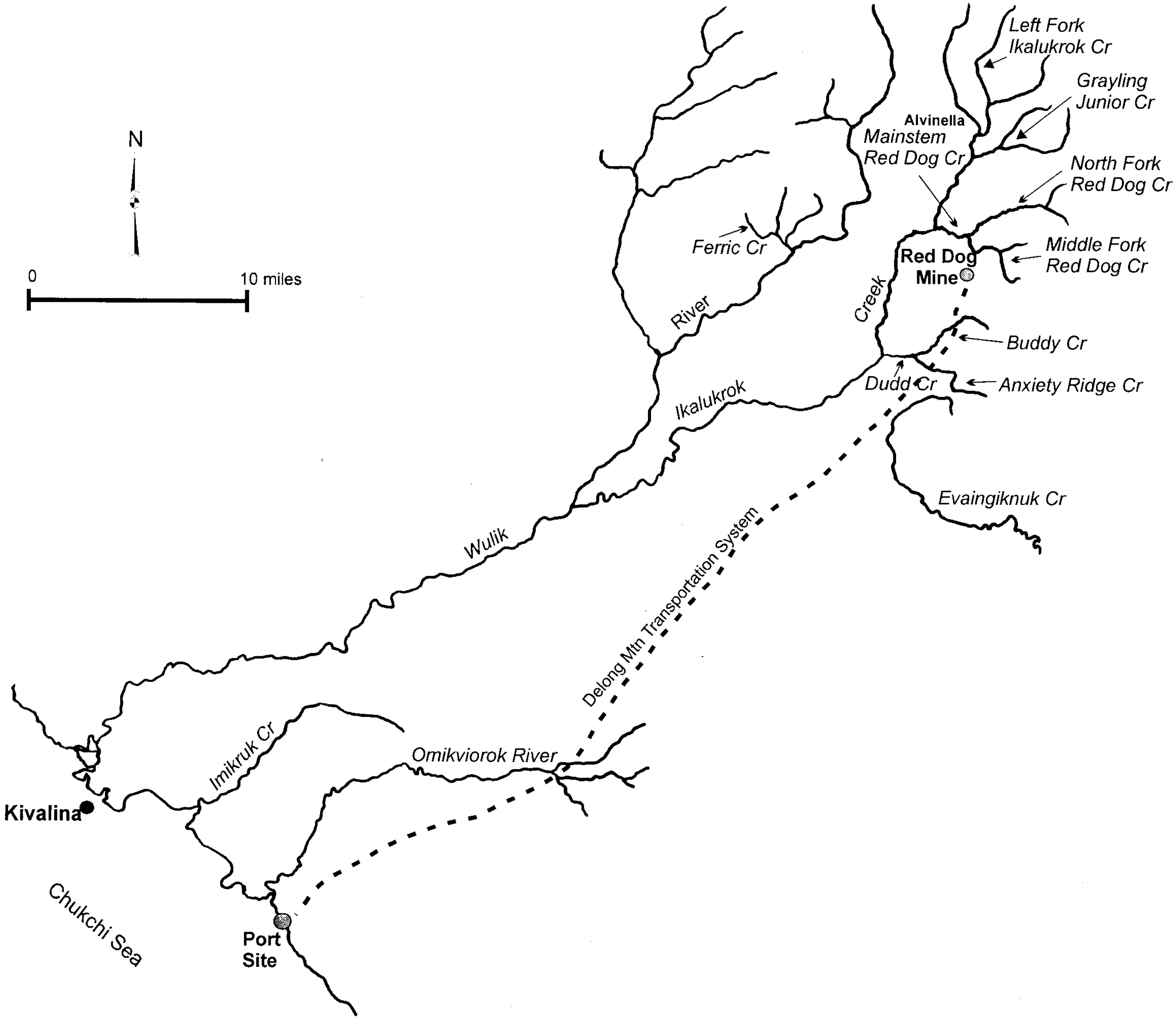


Figure 1. Streams in the vicinity of the Red Dog Mine in northwest Alaska.

Our results, reported in Ott and Weber Scannell (1994), were compared to water quality conditions in the waterways sampled.

Several events have occurred since opening of the mine that have had substantial influences on water quality. Soon after startup, water running through the exposed ore body caused increased metals concentrations in Middle Fork Red Dog Creek. Water quality was degraded in Red Dog Creek and Ikalukrok Creek by low pH and elevated Cd, Pb, and Zn. Cominco Alaska Inc. (Cominco) constructed a cleanwater bypass and mine sump collection system in 1990 and 1991. Construction of this system improved water quality downstream of the ore body; median metals concentrations in downstream waters were lower than measured before mining or in the early years of mining (1989-1990) (Weber Scannell and Ott 1998). Cominco has made further improvements to the water treatment system to reduce concentrations of metals in the treated mine effluent through installation of sand filters to remove particulate metals and expansion of the water treatment plant to discharge higher volumes during periods of high stream flows.

In 1994, ADF&G initiated a 5-year study to document changes in fish distribution, relative abundance, fish species composition, and metals concentrations in adult Dolly Varden tissues (Weber Scannell and Ott 1995, Ott and Weber Scannell 1996). In 1996, we expanded the study to include surveys of chum salmon (*Oncorhynchus keta)* in Ikalukrok Creek.

In 1995 and 1996 we conducted an in-depth study of algal and aquatic invertebrate populations in creeks downstream of and adjacent to the Red Dog Mine (Weber Scannell 1997). This study supported the reclassification of Connie, Hilltop, Rachael, Mainstem Red Dog, Middle Fork Red Dog, Shelly, Sulfur, and Ikalukrok creeks (18AAC 70.230(e)).

In 1997 and 1998, ADF&G sampled aquatic invertebrate and periphyton communities in stream habitats that were directly exposed to mining activity or treated mine effluent (Weber Scannell and Andersen 2000). The purpose of this study was to gather information on aquatic invertebrate and algal communities to better understand and manage effects of the mine operation, including discharge of treated effluent, on aquatic taxa and fish populations found in receiving waters. These data were compared to historical data and data from sites unaffected by the mine to identify any significant changes due to natural or mining related conditions or events.

Copies of the ADF&G reports for Red Dog Mine studies are available from the Alaska Department of Fish and Game, Division of Habitat and Restoration, Fairbanks, Alaska.

METHODS

Fish sampling techniques included visual and aerial surveys, angling, fyke-nets, and minnow traps. Benthic invertebrates were collected using drift nets and periphyton were obtained from the surface of stream bed materials. A detailed description of the sample sites, methods, and quality control/quality assurance were described in the report titled "Methods for Aquatic Life Monitoring to Satisfy Requirements under 1998 NPDES Permit" as submitted to the EPA by Cominco in October 1998 (ADF&G 1998).

RESULTS

Part 1.F.2 (pages 15 and 16 of 45) of the EPA NPDES permit, sample sites and factors to be measured are listed (Table 1). The sample sites and factors to be measured also cover the bioassessment program requirements (Part 1.F.1 - pages 14 and 15 of 45) of the EPA NPDES permit. Specific page references applicable to the required EPA NPDES sample sites and factors are provided in Table 1. Results are presented under the following topic headings: water quality conditions; microtox tests; aquatic invertebrate communities; periphyton standing crop; metals concentrations in juvenile Dolly Varden; metals concentrations in adult Dolly Varden; overwintering Dolly Varden; chum salmon spawning; and fish distribution by species.

Table 1. Sample sites and factors measured for the Red Dog Mine (bioassessment conditions of the Alaska Department of Environmental Conservation Certificate of Reasonable Assurance).

Sample Site	Factors Measured	Results - Refer to Pages
Middle Fork Red Dog Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates: taxonomic richness and abundance	51-61 62-69
North Fork Red Dog Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates: taxonomic richness and abundance Fish presence and use	51-61 62-69 91-109
Mainstem Red Dog Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates: taxonomic richness and abundance Fish presence and use	51-61 62-69 91-109
Ikalukrok Creek, Stations 9, 7, 8, and upstream of Dudd Creek[1]	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates: taxonomic richness and abundance Fish presence and use	51-61 62-69 91-109
Ikalukrok Creek	Fall aerial survey of returning chum salmon	89-90
Wulik River	Metals concentrations in Dolly Varden gill, liver, muscle, and kidney. Fall aerial survey of overwintering Dolly Varden	79-85 86-88
Anxiety Ridge	Fish presence and use	91-109
Evaingiknuk Creek	Fish presence and use	91-109
Buddy Creek	Fish presence and use	91-109

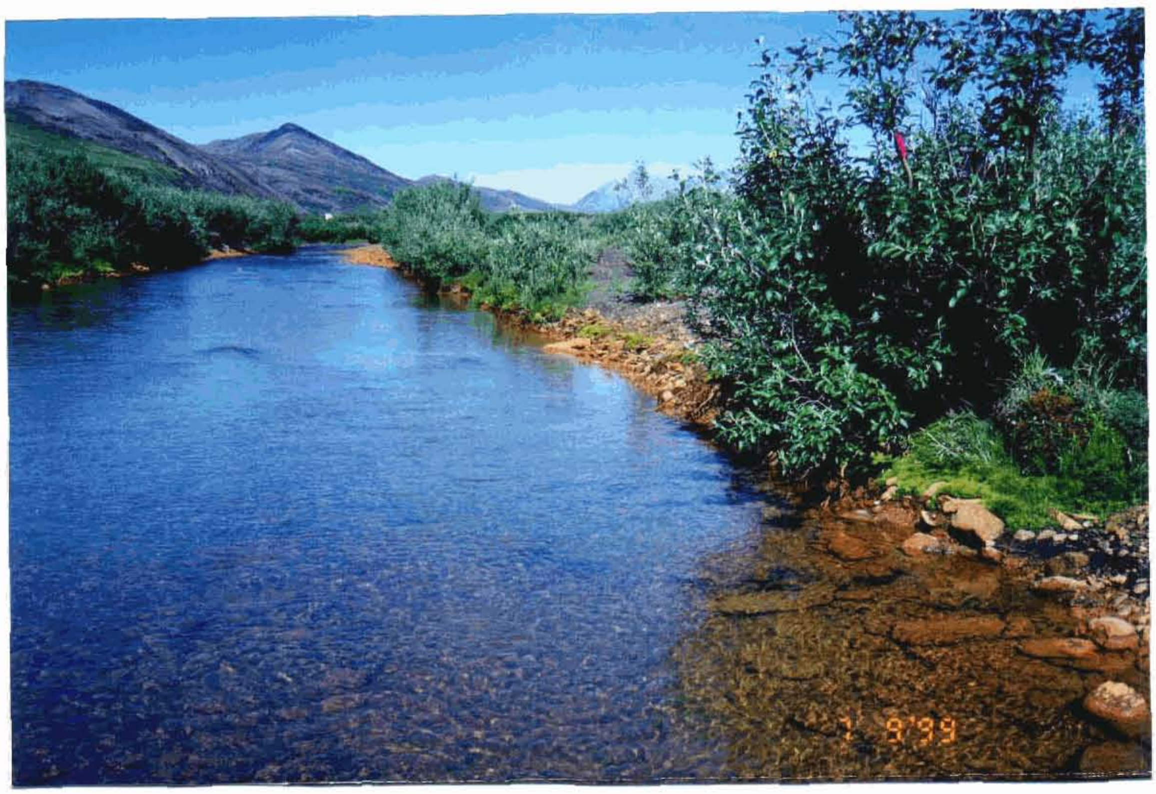
[1]Includes sample stations identified in Part F.1.d and Part F.2 of the EPA NPDES permit.

WATER QUALITY CONDITIONS

Water sample sites and streams in the immediate area of the Red Dog Mine are shown in Figures 2 and 3. Water quality data are presented and discussed for Stations 9, 8, 73, and 7. We also present a summary of water quality information for Mainstem Red Dog, Middle Fork Red Dog, and North Fork Red Dog creeks and tributaries to Middle Fork Red Dog Creek in the immediate area of the mine. Physical characteristics of study streams were described in Weber Scannell and Andersen (1999).

Station 9, Ikalukrok Creek Upstream of Mainstem Red Dog Creek

Ikalukrok Creek above the confluence with Red Dog Creek flows through mineralized zones and red iron precipitate is prevalent in side channels, smaller tributaries, and backwater areas. Streambed rocks frequently are stained orange from iron precipitate (see photo below, Ikalukrok Creek, upstream of Mainstem Red Dog Creek).



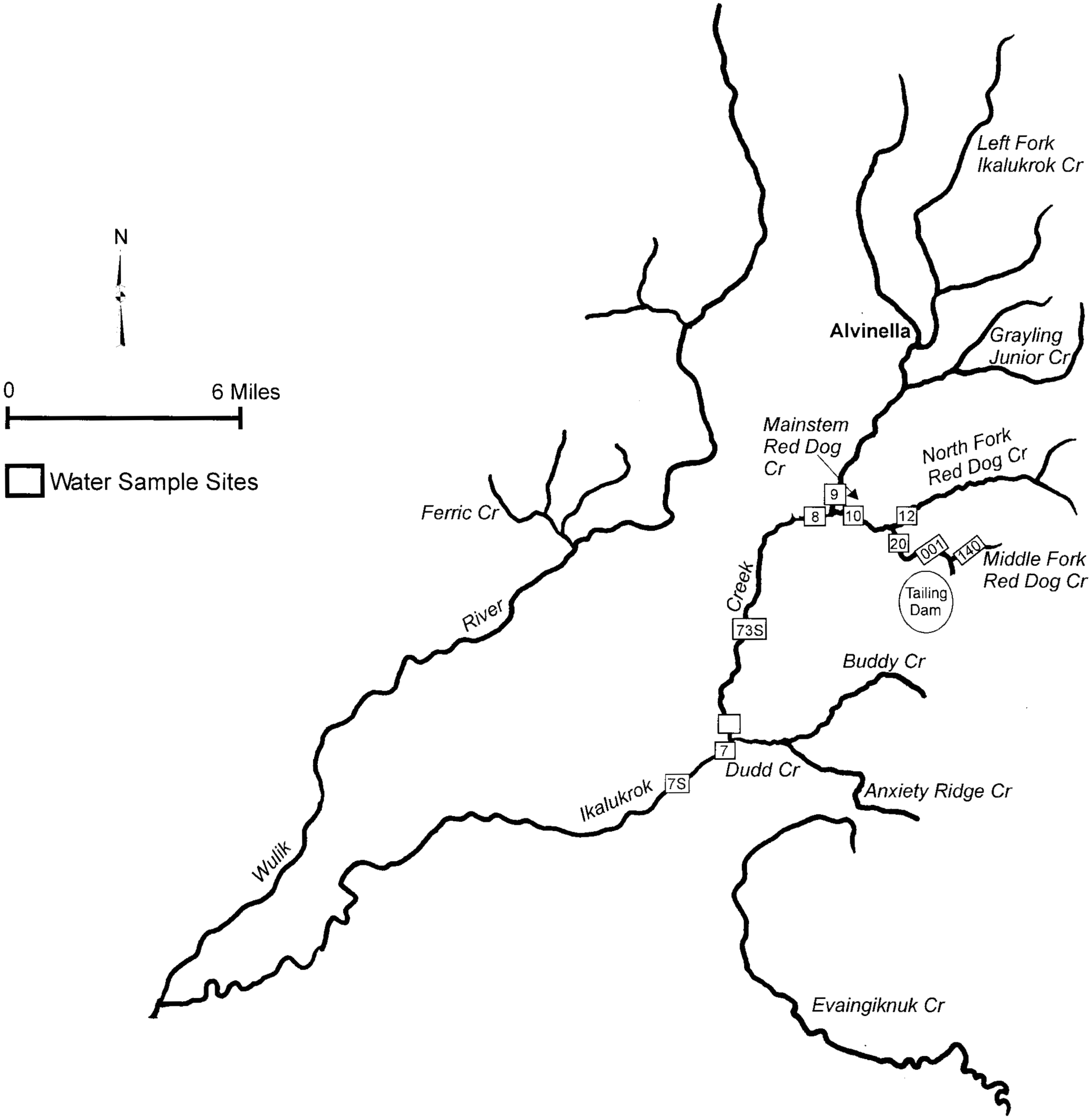


Figure 2. Water sample sites in the Ikalukrok and Red Dog Creek drainages.

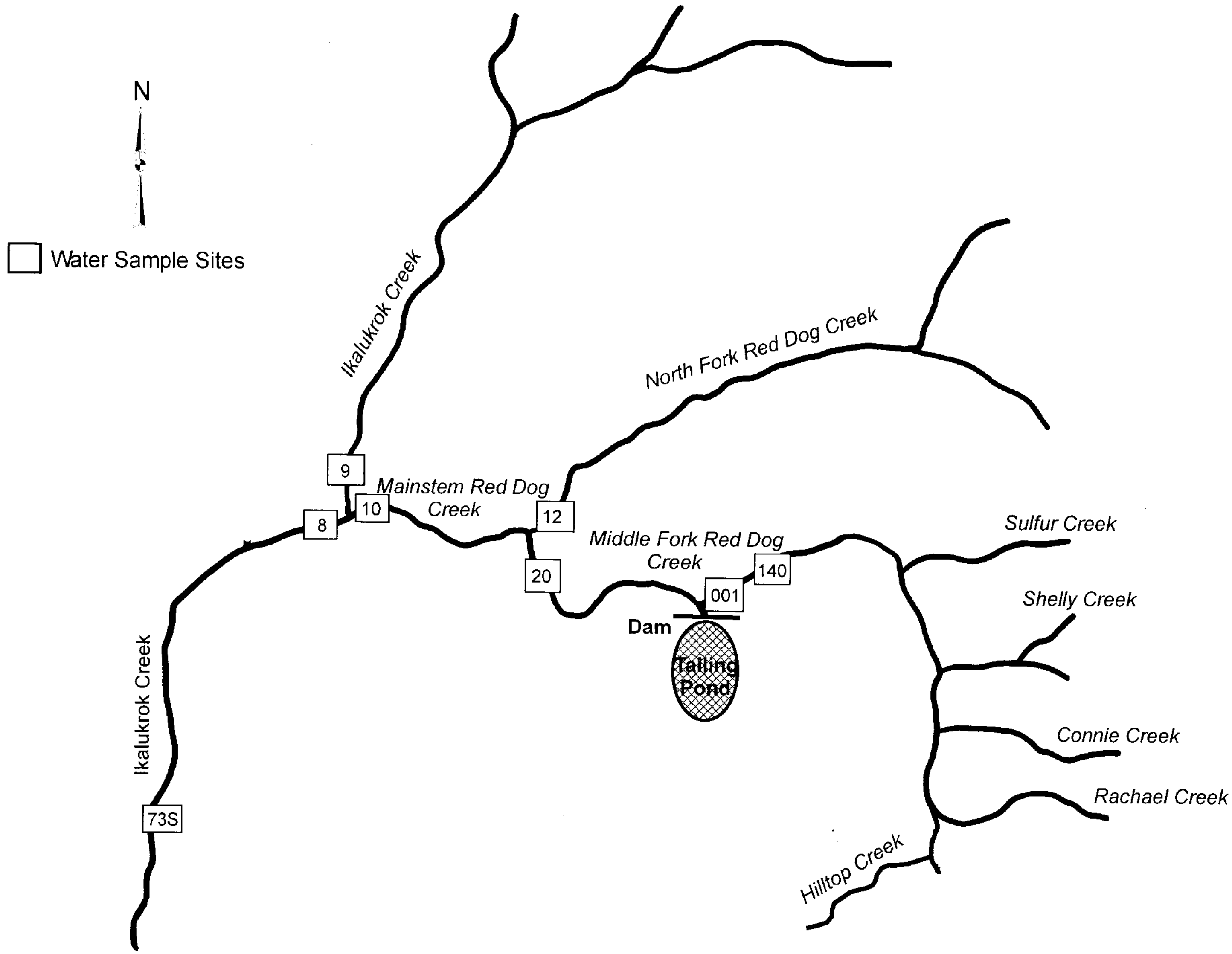


Figure 3. Water sample sites and streams in the immediate vicinity of the Red Dog Mine.

Mining activity, with the exception of upland drill holes, has not disturbed this section of Ikalukrok Creek. Water quality at Station 9 has been monitored intermittently since 1982, with more consistent data gathered during the past five years. Median concentrations of Al, Cd, and Zn similar from 1995 through 1997, rose in 1998 and 1999 (Figure 4). Concentrations of Pb did not increase in 1998 or 1999.

Water quality factors, including hardness, total dissolved solids (TDS), pH, specific conductance, stream flow and sulfate were compared between pre-mining and post-mining years (Figure 5). There was no difference in the median values for any of these factors; however, the maximum TDS, conductance, and sulfate concentrations were higher in post-mining years than during pre-mining. The maximum values of these three factors occurred in 1999.

Station 8, Ikalukrok Creek Downstream of Mainstem Red Dog Creek
Ikalukrok Creek, downstream of Red Dog Creek, contains periodic elevated concentrations of metals from natural mineralization upstream and from mineralization along Red Dog Creek. In 1998 and 1999, the stream bottom was covered with a dense growth of filamentous algae and iron precipitate, especially in July. Water quality and metals were sampled intermittently at Station 8 since 1981, but starting in the mid-1990s, water was sampled more consistently. However, no water samples were collected during 1998 or 1999. In summer 1999, we sampled conductivity across transects at Station 8 and verified that Ikalukrok and Red Dog creeks were not mixed. Therefore, water quality and metals concentration data from Station 8 are of limited value. Data from Station 73 should be used to characterize conditions in Ikalukrok Creek downstream of Mainstem Red Dog Creek and upstream of Dudd Creek.

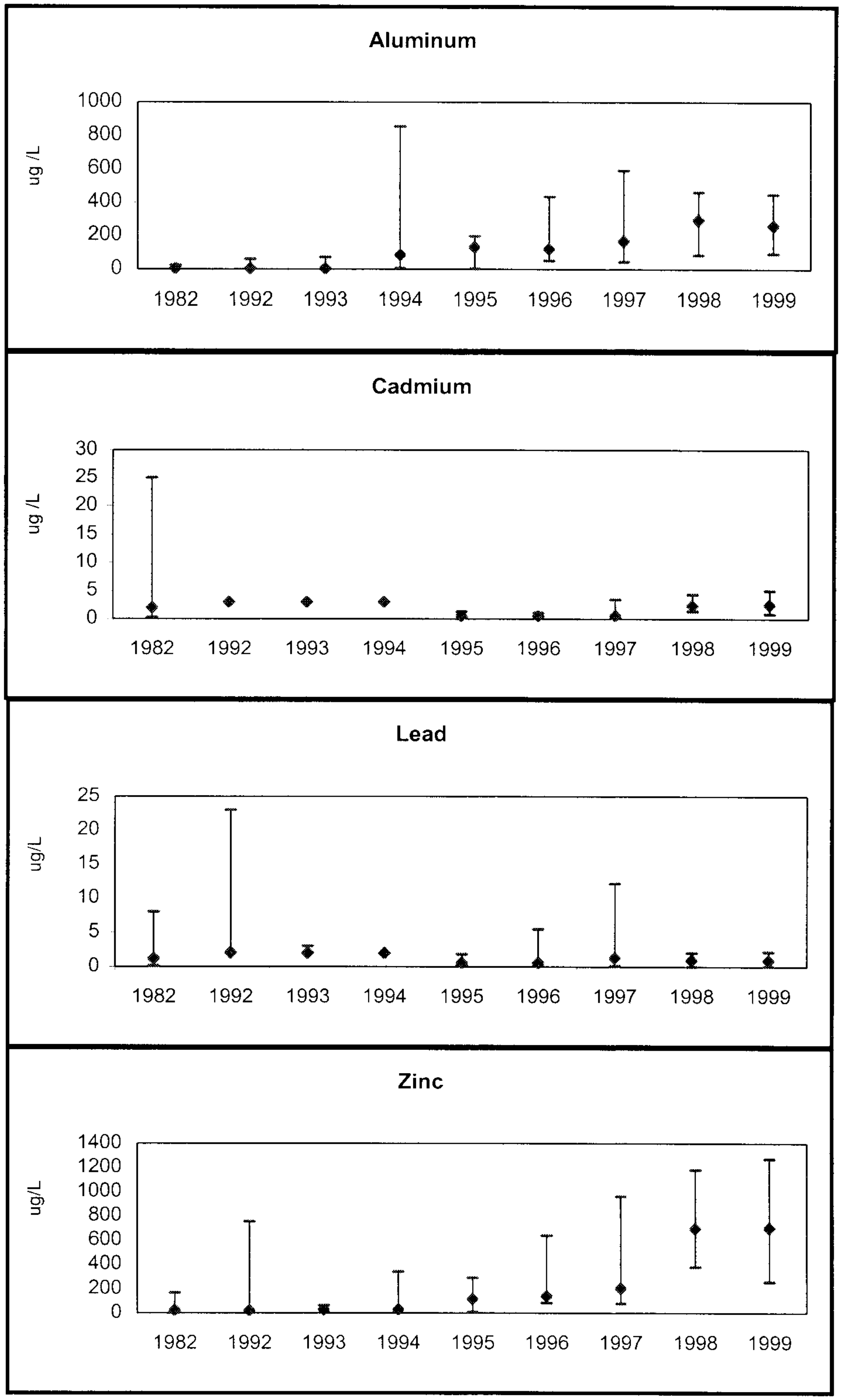


Figure 4. Median, maximum, and minimum concentrations of Al, Cd, Pb, and Zn in Ikalukrok Creek at Station 9, above the confluence with Red Dog Creek, 1993-1999. Data from Cominco.

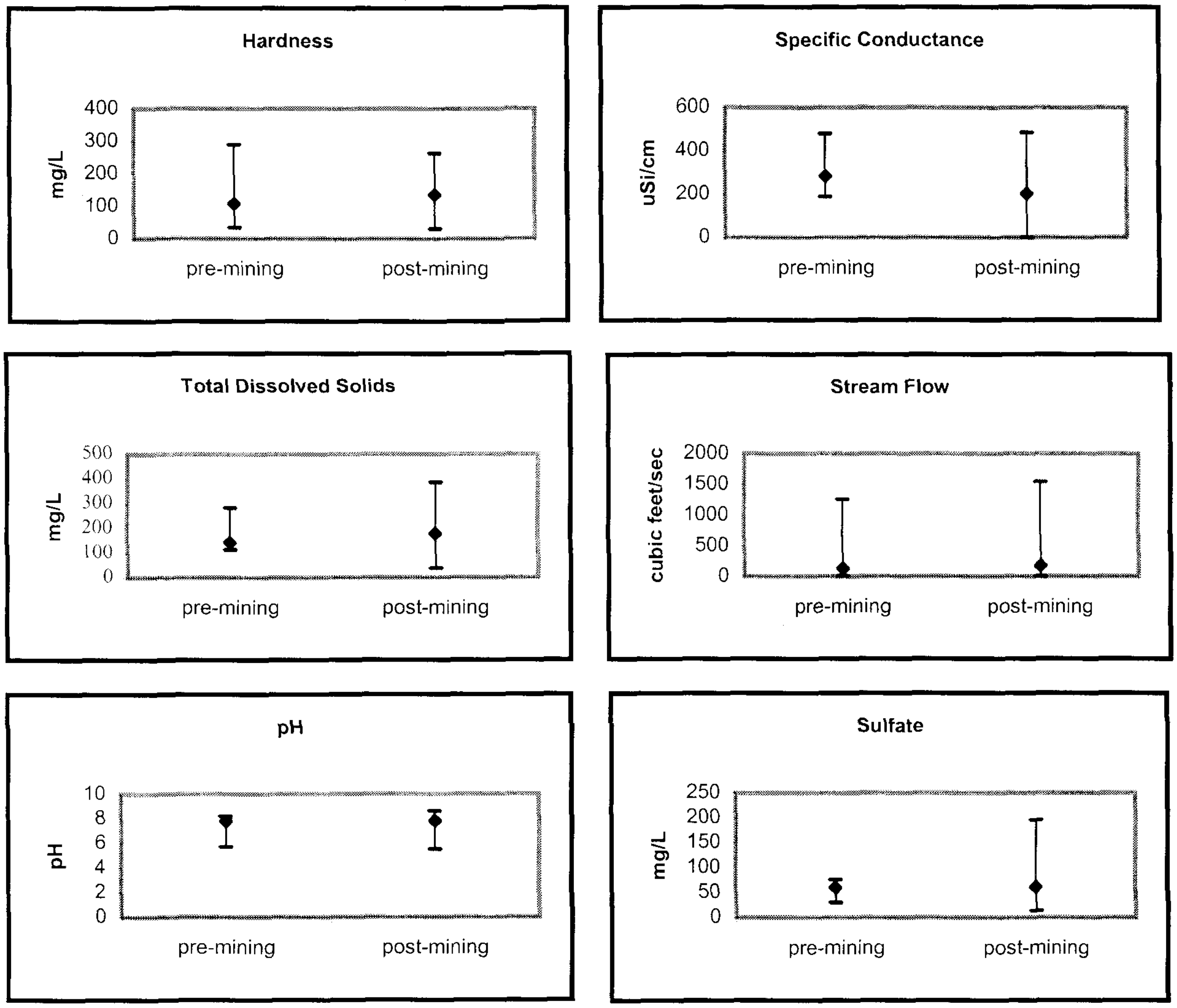


Figure 5. Median, maximum, and minimum concentrations of various water quality factors in pre-mining (1981-1988) and post-mining (1989-1998) years in Ikalukrok Creek at Station 9. Data from Cominco.

Station 73, Ikalukrok Creek Upstream of Dudd Creek

Ikalukrok Creek at Station 73 during mine operation (data for 1993 to present) has hard water with circumneutral to basic pH (Table 2). The mine effluent influences water quality conditions, especially hardness, TDS, and sulfate. Mine effluent TDS are primarily $CaSO_4$ while background TDS is both $CaHCO_3$ and $CaCO_3$. During periods of maximum discharge of treated mine effluent, water hardness and TDS reached maximum values (Table 2). High conductivity (maximum = 919 *u*S/cm) resulted from high TDS from the mine effluent. Low concentrations of TDS, hardness, and sulfate were found during breakup, high rainfall events, or during periods when the mine was not discharging.

Stream flows, measured at Station 73, were highest in late May to early June, following breakup, and mid-to-late August, during seasonal rains. Low flows occur during mid-summer, mid-June through July (Figure 6).

There are no baseline data from Station 73 so comparisons of pre-mining and post-mining metals concentrations can not be made. Water occasionally contained elevated concentrations of Al, Cd, Pb, and Zn (Figure 7), although median concentrations have remained consistently low for all metals since 1993.

We compared median, maximum, and minimum values for hardness, TDS, sulfate, and pH for 1993 through 1999 (Figure 8). The median concentration of TDS was highest in 1999, and maximum concentrations were similar in 1998 and 1999. The single sulfate measurement reported for 1999 was higher than any previously measured. The median pH has been close to 7.7 for all years (1993 through 1999), although the minimum pH was lowest in 1999. The low 1999 pH was measured in mid-September. Values for hardness reflect TDS because calcium is the most prevalent cation in TDS at this site.

Station 7, Ikalukrok Creek Downstream of Dudd Creek

Minimal water quality and stream flow sampling were done during baseline studies; however, since 1990 this site has been regularly monitored. In

Table 2. Summary of water quality characteristics at Station 73, Ikalukrok Creek below the confluence with Red Dog Creek - June through September 1993-1999. Data from Cominco.

Analyte, units	Median	Maximum	Minimum	n
Hardness, mg/L	202	569	43.2	174
TDS, mg/L	265	810	57	188
Sulfate, mg/L	135	410	19	140
pH	7.7	9.9	5.3	135
Temperature, °C	4.75	17.6	0	140
Specific Conductance, *u*S/cm	328	919	50	133
Flow, cfs	287	3000	47	98*

*Flow values do not include data from the automated data recorder.

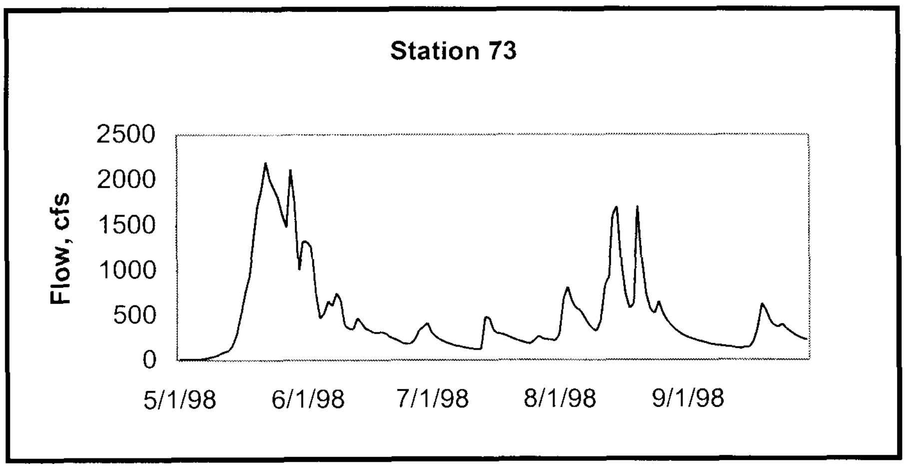


Figure 6. Seasonal stream flow at Station 73 (Ikalukrok Creek) during 1998. Data from US Geological Survey.

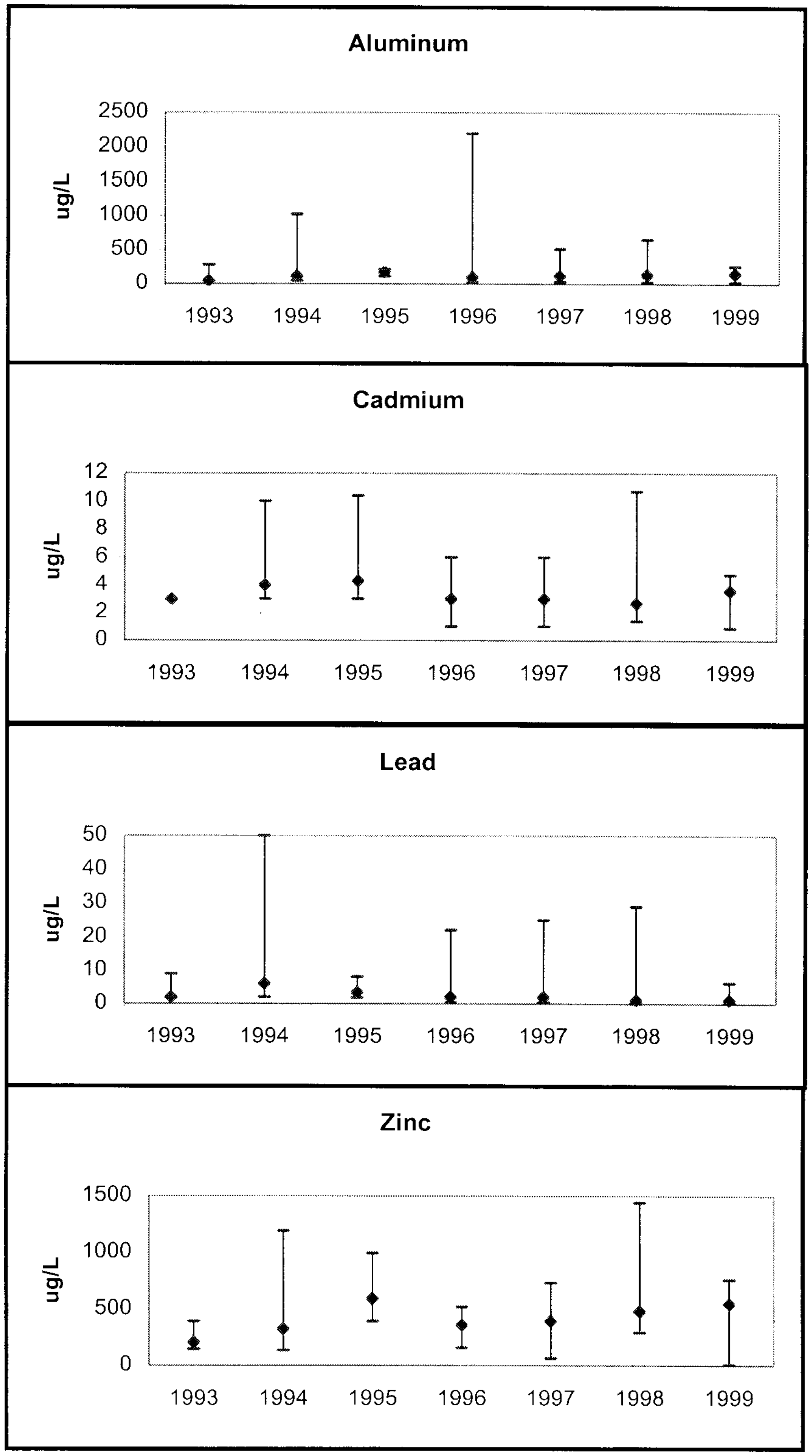


Figure 7. Median, maximum, and minimum concentrations of Al, Cd, Pb, and Zn in Ikalukrok Creek at Station 73, below the confluence with Red Dog Creek, 1993-1999. Data from Cominco.

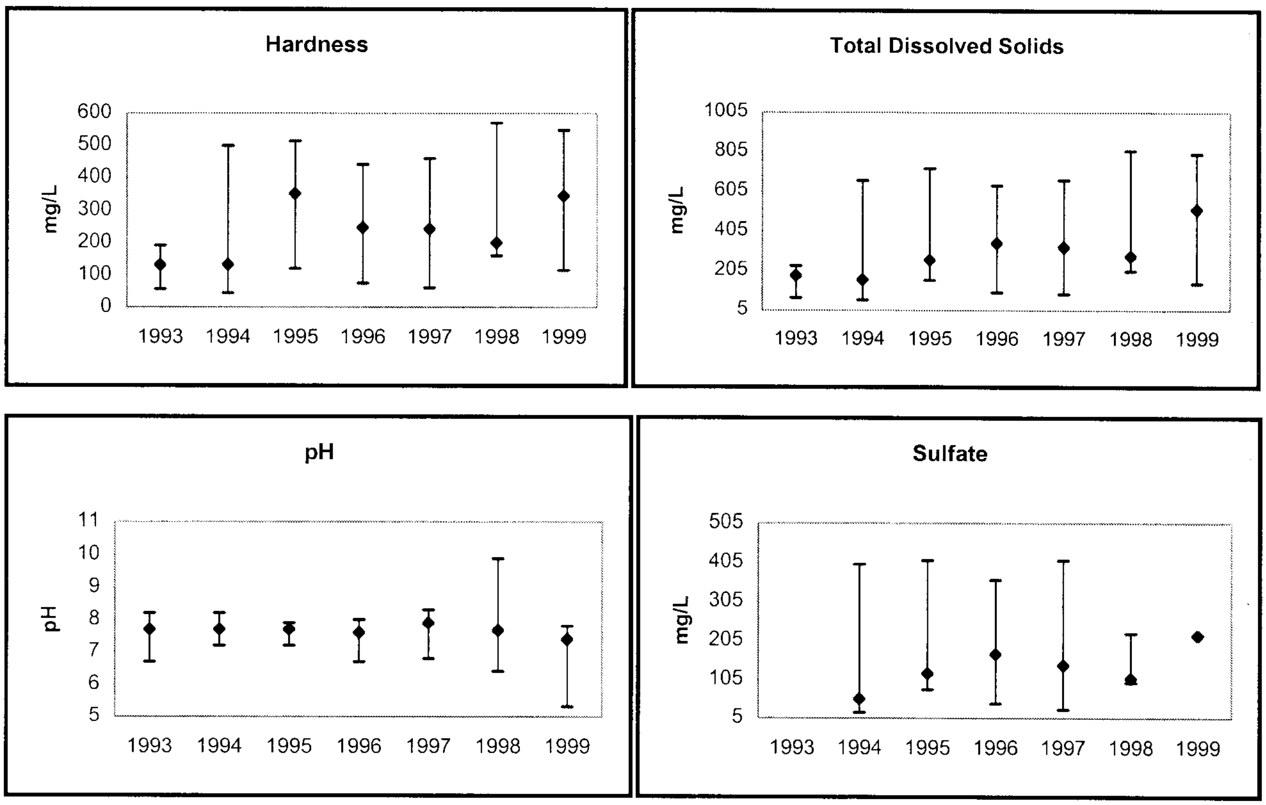


Figure 8. Median, maximum, and minimum concentrations of various water quality factors in pre-mining and post-mining years in Ikalukrok Creek at Station 73. Data from Cominco.

spring 1999, an automated stream gauge was installed about 8.5 km below the confluence with Dudd Creek (Section 26, T30N, R20W, Noatak D-3 Quad). Data recorded at the new. Station 7 includes stream flow, temperature, and conductivity. The station was relocated downstream to a site with good channel geometry for measuring stream flow and to ensure waters from Ikalukrok and Dudd creeks were completely mixed at different discharges.

We compared the median, maximum, and minimum values for hardness, TDS, and pH from 1990 through 1995, and 1998 and 1999 (Table 3, Figure 9). Median TDS and hardness were highest in 1999, although maximum values were higher in 1998 for both factors. The concentration of TDS remained below 700 mg/L.

Table 3. Median, maximum, and minimum concentrations of water quality factors at Station 7, Ikalukrok Creek below Dudd Creek, June through October 1990-1995 and 1998-1999. Data from Cominco.

Analyte, units	Median	Maximum	Minimum	n
Hardness, mg/L	195	523	31	59
TDS, mg/L	293	679	51	79
Sulfate, mg/L	160	380	16	30
pH	7.6	8.1	5.3	64
Temperature, °C	6.8	15.3	0	42
Specific Conductance, *u*S/cm	405	998	0.1	29

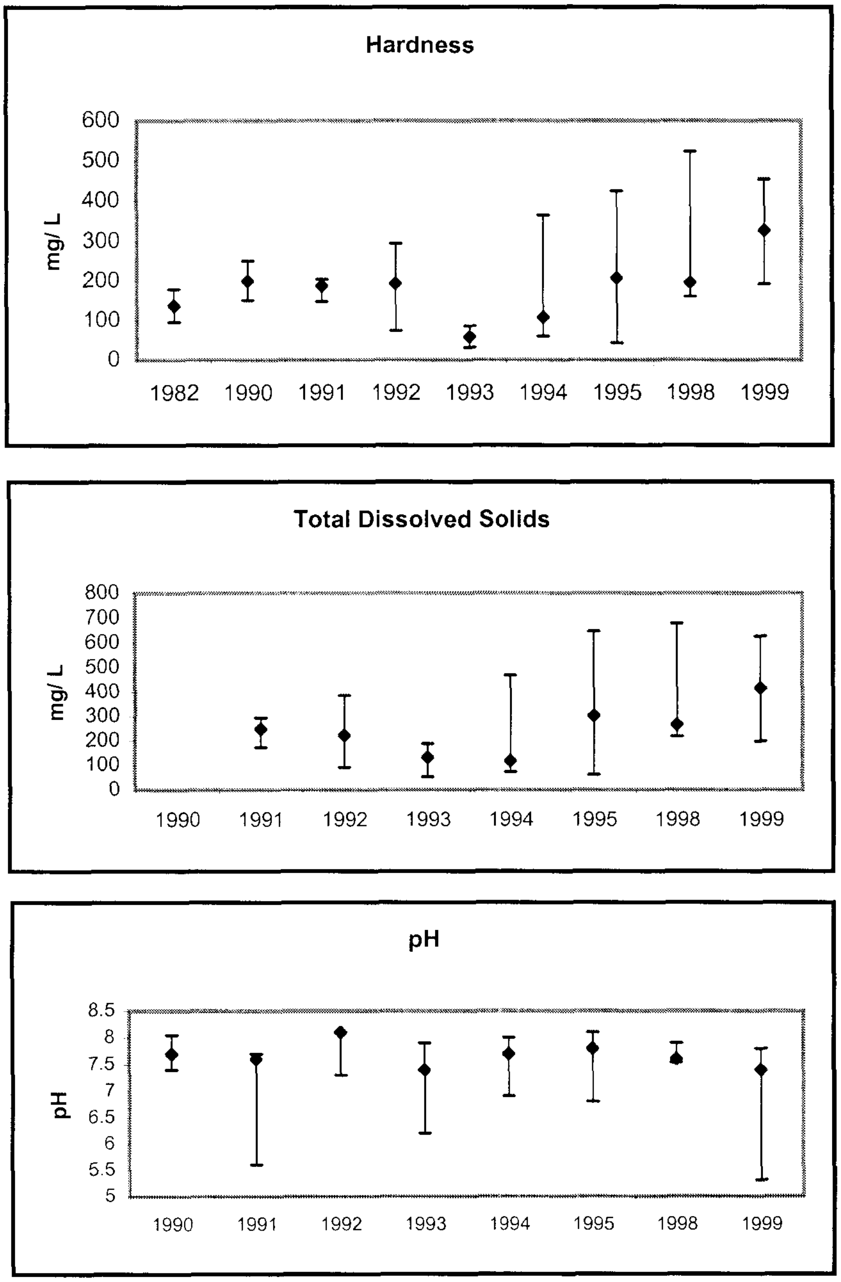


Figure 9. Median, maximum, and minimum concentrations of TDS, hardness, and pH at Station 7, Ikalukrok Creek below Dudd Creek, 1990-1995 and 1998-1999. Data from Cominco.

In 1999, we requested that the mine discharge be limited to ensure that TDS remained below 500 mg/L in Ikalukrok Creek below Dudd Creek where the chum salmon spawn from July 25 to August 30. At no time during the spawning period did TDS exceed 500 mg/L (Figure 10).

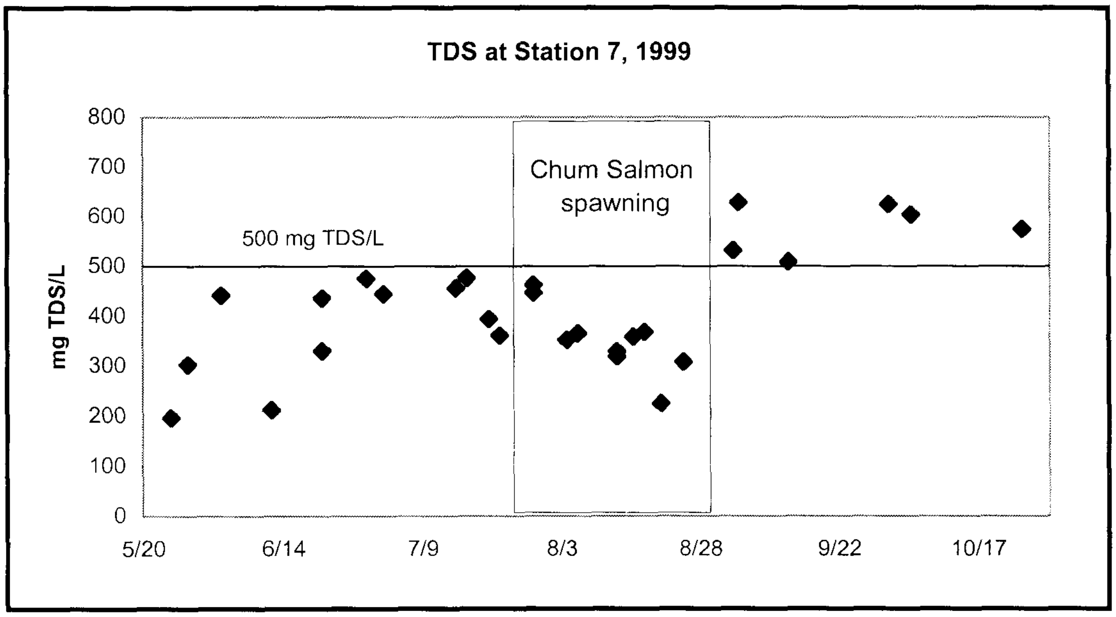


Figure 10. TDS at the new Station 7 during summer 1999 in relation to the peak of chum salmon spawning in lower Ikalukrok Creek.

Following construction of the stream bypass system at the mine in the winter of 1990-1991, median metals concentrations decreased at Station 7 (Figure 11), although maximum concentrations of Al and Pb were elevated in 1995. Maximum concentrations of all metals were lower after 1995; this coincides with the extension of the clean water ditch upstream and the diversion of Hilltop Creek into the mine sump collection channel.

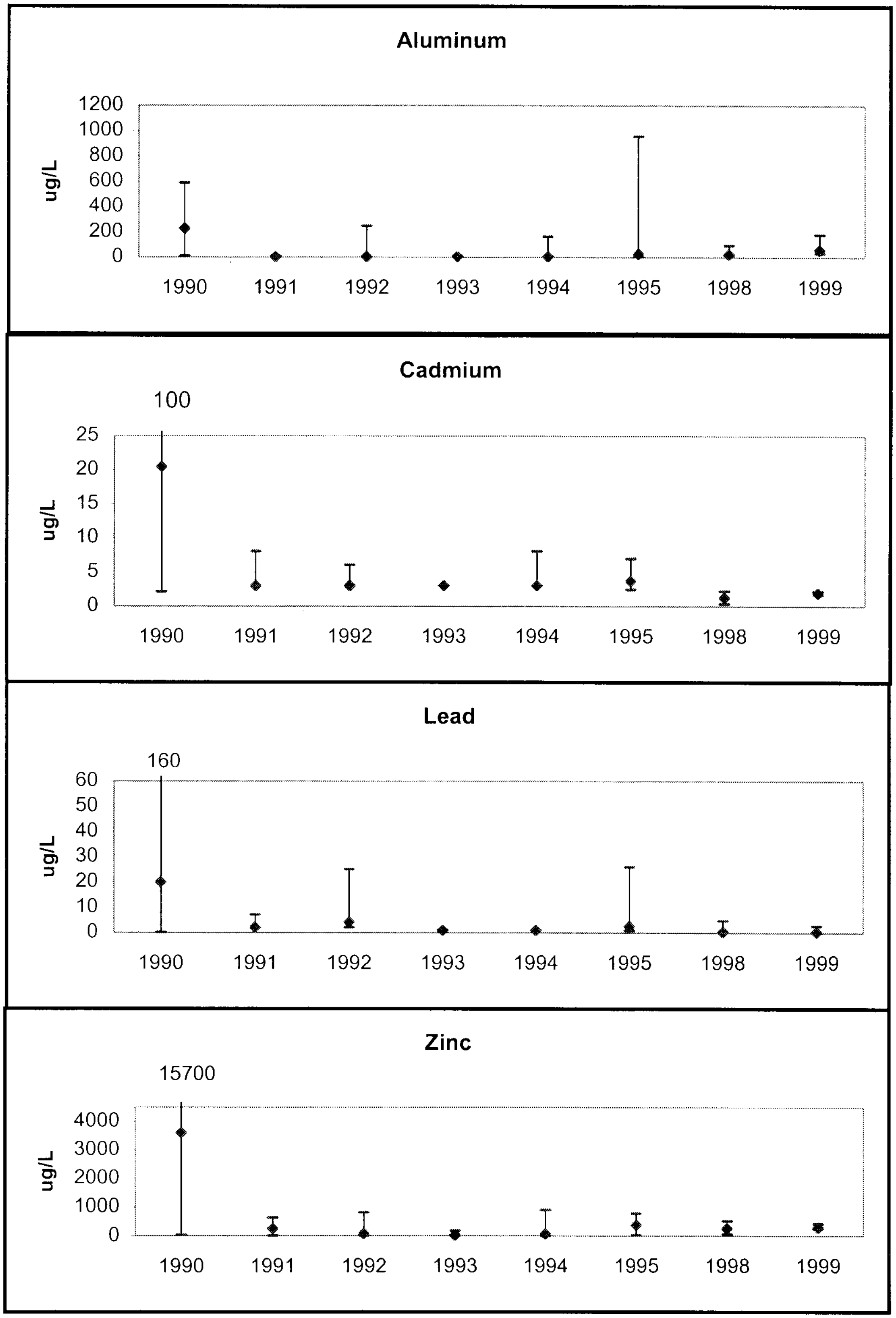


Figure 11. Median, maximum, and minimum concentrations of select metals in Ikalukrok Creek at Station 7, below Dudd Creek, 1990-1995 and 1998-1999. Data from Cominco.

Station 10, Mainstem Red Dog Creek

Mainstem Red Dog Creek has a drainage area of 64 km^2 (24.6 mi^2) of which 10 km^2 (3.8 mi^2) does not contribute to the flow because it is impounded behind the tailing dam. Stream flows are low just before breakup, but then increase to about 445 cfs. Summer low flows occur from late June through early August; late August high flows reach about 600 cfs (Figure 12).

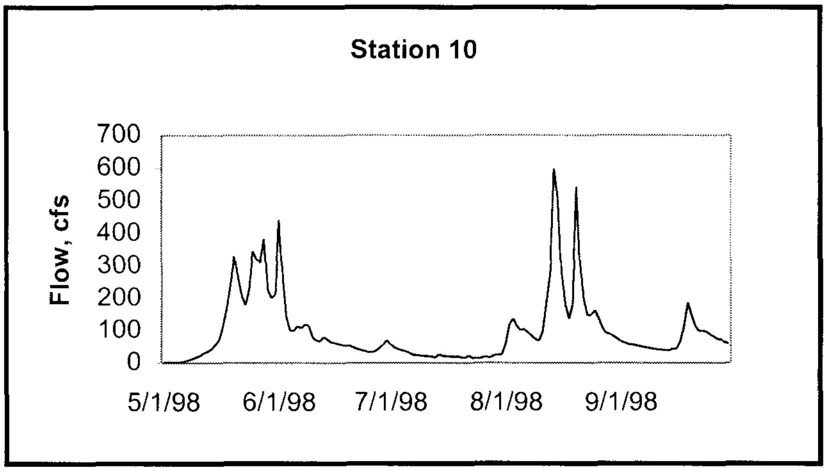


Figure 12. Seasonal stream flow at Station 10 (Mainstem Red Dog Creek) during 1998. Data from Cominco.

Baseline data showed Mainstem Red Dog Creek (Station 10) contained moderately hard water with neutral to acidic pH. During winter (measured in March), water was high in TDS, sulfate, and hardness, a result of ice formation (Weber Scannell and Andersen 2000).

Pre-mining concentrations of Zn were elevated above the reported chronic toxic concentrations of 0.09 - 7.21 mg/L for salmonid fish (USEPA 1980a) and often contained elevated concentrations of Al and Cd (Table 4). Median concentrations of Pb were below the limit of detection. Baseline studies (Dames and Moore 1983) reported that Arctic graying migrated through Mainstem Red Dog Creek to North Fork Red Dog Creek during spring high flows when metals concentrations were lower.

Table 4. Baseline water quality conditions in Mainstem Red Dog Creek at Station 10, 1982-1983. Data from Dames and Moore 1983.

Analyte, units	median	maximum	minimum	n
Hardness, mg/L	127	227	21	21
TDS	198	876	9	11
Sulfate, mg/L	70	440	8	11
Al, *u*g/L	150	1190	20	38
Cd, *u*g/L	28	98	<2	43
Cu, *u*g/L	4	19	<2	15
Pb, *u*g/L	<80	100	<80	43
Zn, *u*g/L	3700	13000	567	43
pH	7	7	6	10
Temperature, °C	4	17	0	8
Specific Conductance, *u*S/cm	328	1090	154	8
Flow, cfs	32	126	3	25

Since the opening of the Red Dog Mine in 1989 and subsequent discharge of treated mine effluent, Mainstem Red Dog Creek has had elevated hardness and TDS (Figure 13), especially during periods of maximum discharge from the wastewater treatment plant. Concentrations of TDS reached a maximum 2470 mg/L, and hardness a maximum 1540 mg/L. Elevated TDS and hardness correspond to periods of high discharge of mine effluent and low stream flows (Weber Scannell and Ott 1998).

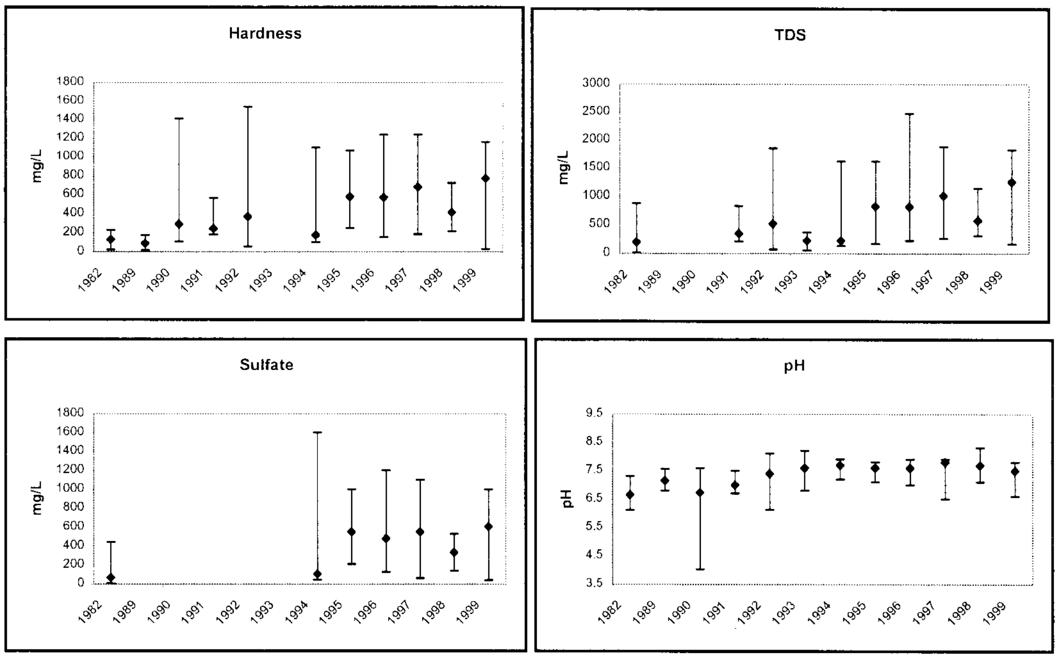


Figure 13. Median, maximum, and minimum concentrations of hardness, TDS, sulfate, and pH in Mainstem Red Dog Creek at Station 10, June through mid-October 1982-1999. Data from Cominco.

Water was sampled for sulfate during baseline studies, but not again until 1994. Median sulfate concentrations in 1995 through 1999 are substantially higher than reported during baseline. Median pH levels have not changed since baseline studies; the minimum pH level recorded in 1990 occurred before construction of the clean water bypass and mine sump collection ditch. Following construction of the water bypass and collection system, the pH in Mainstem Red Dog Creek has not measured below 6.0.

Baseline concentrations of Zn were elevated above the reported chronic toxic concentrations of 0.09 - 7.21 mg/L for salmonid, fish based on 22 96 h LC-50s for rainbow trout (USEPA 1980a) (Figure 14). Zinc concentrations increased substantially in 1989 and 1990 and then decreased (Figure 14). Median Se concentrations have fallen each year since 1996 when measurement first began (Figure 14).

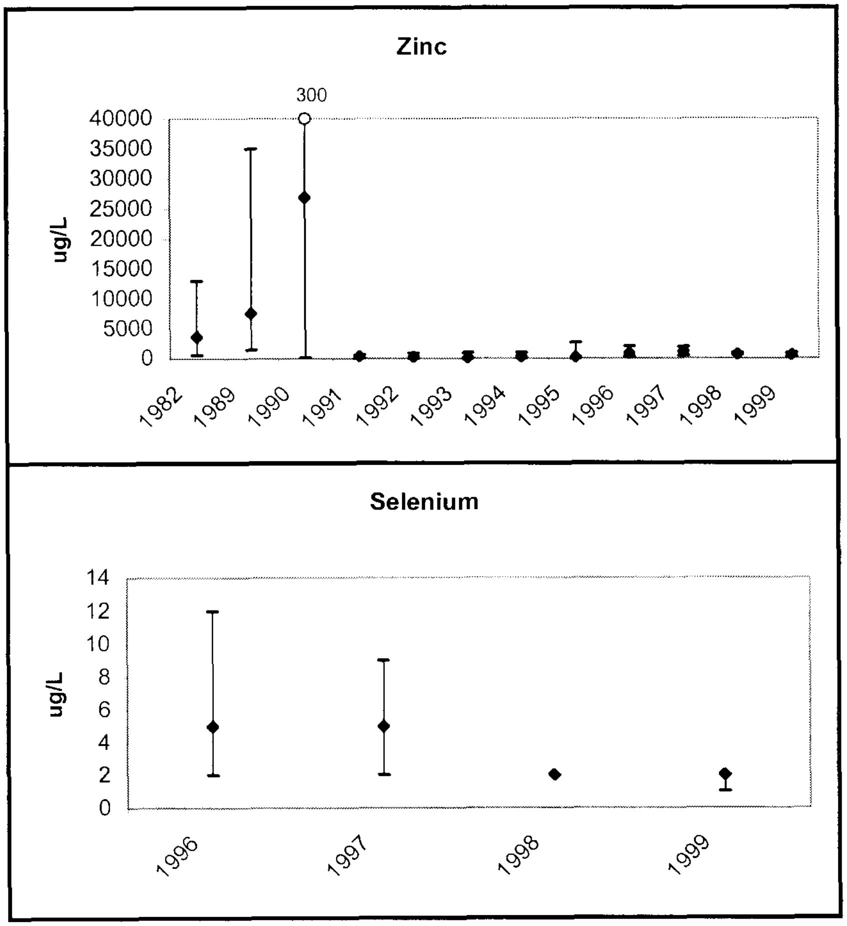


Figure 14. Median, maximum, and minimum concentrations of Zn and Se in Mainstem Red Dog Creek at Station 10, June through mid-October 1982 (pre-mining) and 1989-1999. Data from Cominco.

Baseline concentrations of Cd were elevated (Figure 15). Median concentrations of Pb were below the limit of detection. The sources of metals were identified as seepage water around the ore body.

In 1991, Cominco Alaska Inc. constructed a clean water bypass and mine sump collection ditch to separate the relatively cleaner water of Red Dog Creek from the mine seepage water. Construction of this bypass system had a profound effect on reducing metals concentrations. Since 1991, various improvements have been made in the bypass system, including intercepting mineralized Hilltop Creek in late-fall 1995. Metals concentrations in 1996 through 1999 in the Mainstem Red Dog Creek were lower than any concentrations reported during baseline studies (Figures 14 and 15).

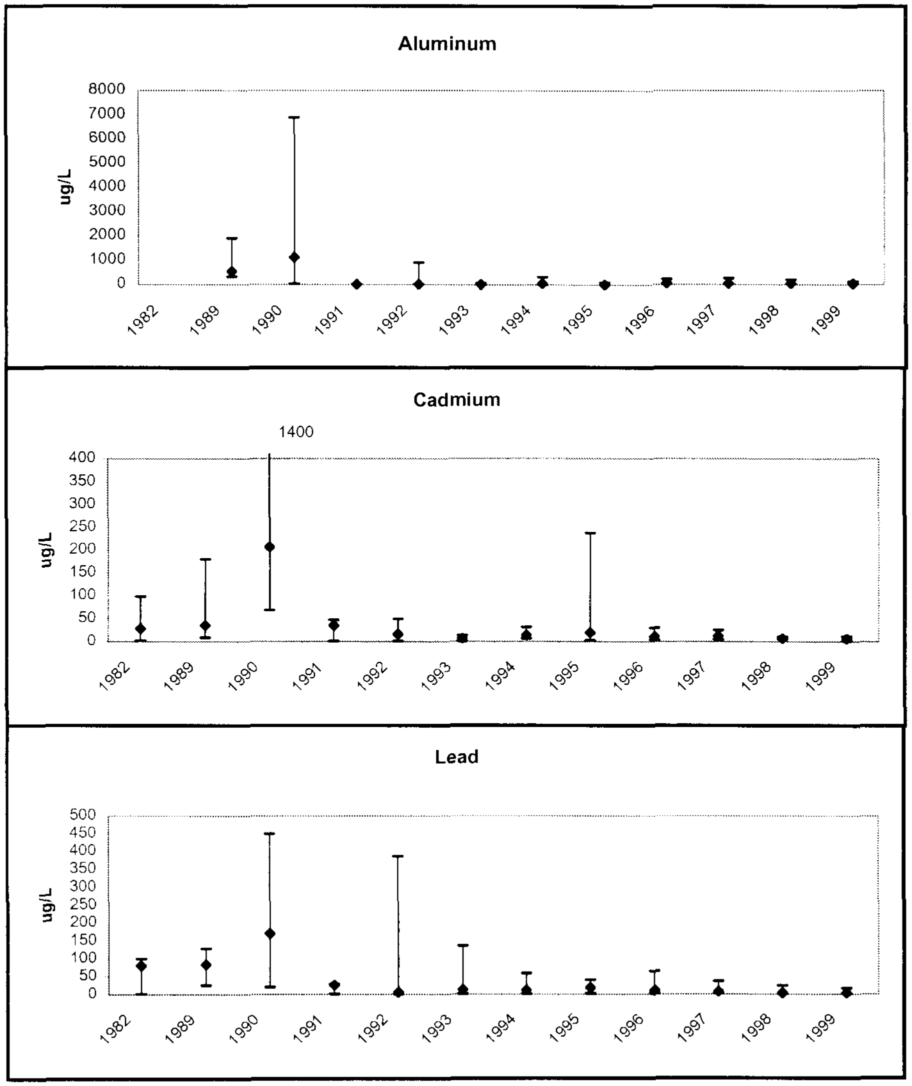


Figure 15. Median, maximum, and minimum concentrations of Al, Cd, and Pb in Mainstem Red Dog Creek at Station 10, June through mid-October 1982 (pre-mining) and 1989-1999. Data from Cominco.

Station 20, Middle Fork Red Dog Creek

In 1997 the Middle Fork Red Dog Creek, including Station 20, was reclassified to industrial use only. No fish are present in Middle Fork Red Dog Creek. Mine effluent is estimated to contribute up to 90% of the stream flow at Station 20 during low flow conditions (Figure 16). Water quality samples were collected and analyzed at least weekly from 1992 through 1997 and twice per month in 1998 and 1999 (Figure 17). The high ratio of effluent to stream flow created elevated TDS (maximum of 3420 mg/L) and sulfate (maximum of 1900 mg/L) in 1997. TDS and sulfate were not reported for 1998 and 1999 (except one sample in 1998).

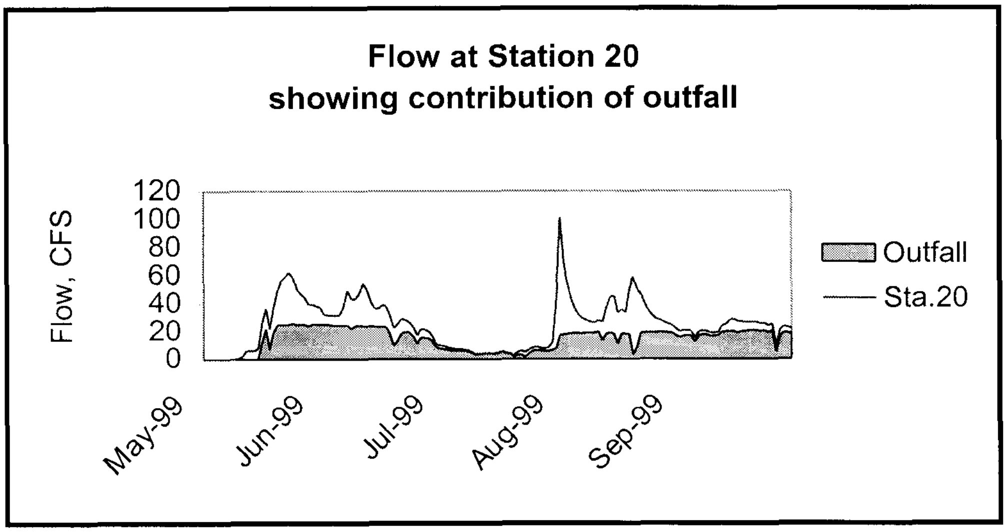


Figure 16. Seasonal stream flow and the contribution of the mine effluent at Station 20, Middle Fork Red Dog Creek, June through October 1999. Data from Cominco.

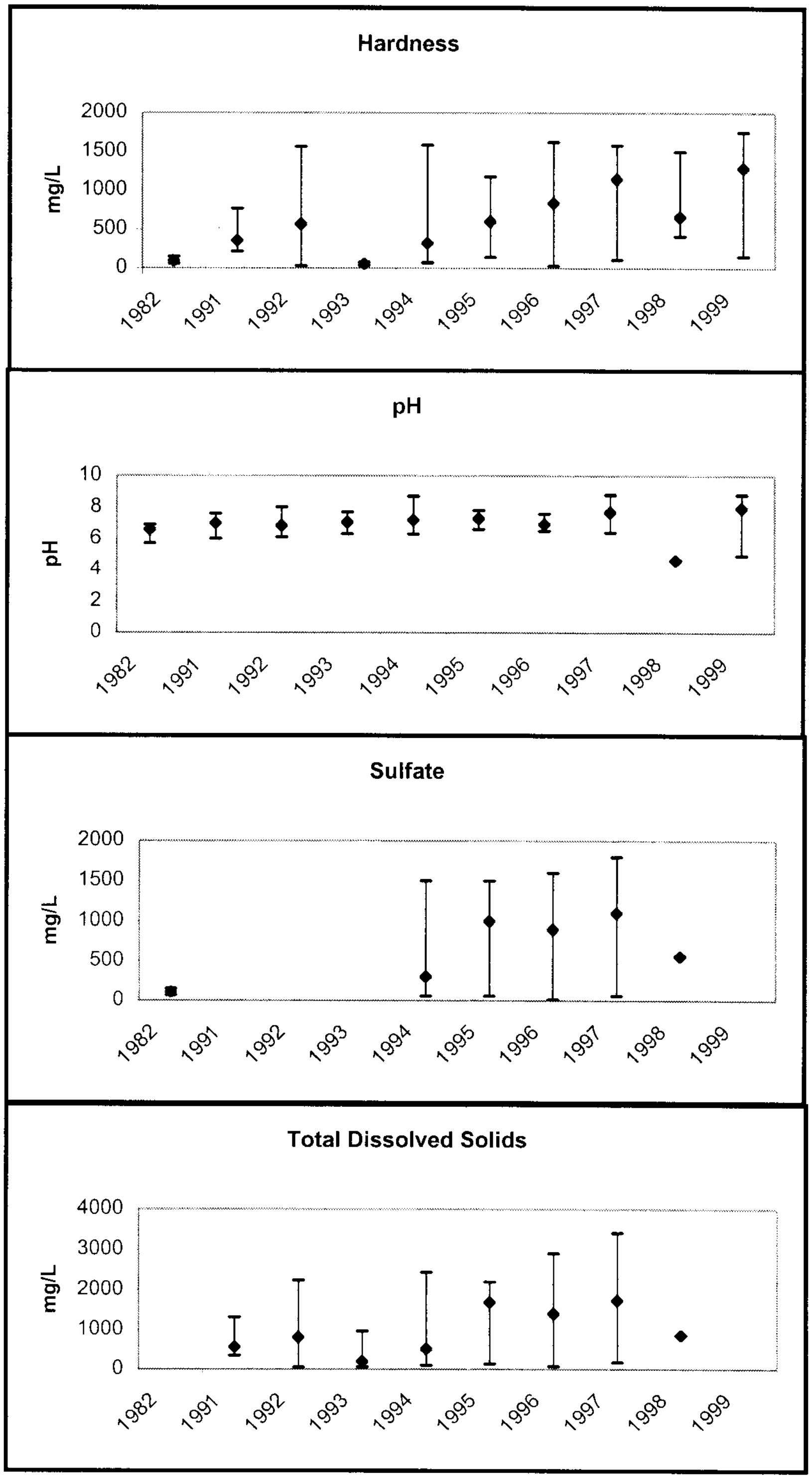


Figure 17. Median, maximum, and minimum concentrations of hardness, sulfate, TDS, and pH in Middle Fork Red Dog Creek at Station 20, June through October 1982 and 1991-1999. Data from Cominco.

Station 12, North Fork Red Dog Creek

North Fork Red Dog Creek has some mineralization in the left fork; however, metals concentrations in the lower reaches are low. North Fork Red Dog Creek is a clear water stream with high dissolved oxygen concentrations during summer. The creek has abundant streamside vegetation, deep pools, wide riffle areas, and mineral staining is not evident (see photo below).

During the open flow period in 1998, seasonal high flows up to 487 cfs in mid-August and seasonal low flows of 8 cfs in mid-July were recorded (Figure 18).

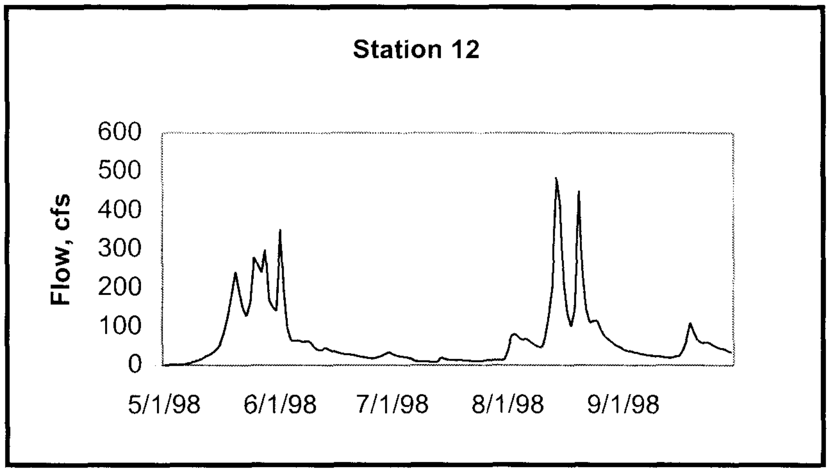


Figure 18. Seasonal stream flows in North Fork Red Dog Creek. Data from Cominco.

The median pH is slightly basic (Figure 19). The water ranges from soft (defined as hardness less than 160 mg $CaCO_3$/L) at breakup to hard (defined as hardness from 320 to 460 mg $CaCO_3$/L) during summer and fall low flows. Concentrations of TDS are related to hardness and show similar seasonal fluctuations. Median sulfate concentrations are low, usually less than 100 mg/L.

Water in North Fork Red Dog Creek is low in metals (Figure 20). Median concentrations of Al, Cd, and Pb are lower than or in the same range as metals concentrations found in Ikalukrok Creek (Stations 7 and 73). Concentrations of Zn are lower in North Fork Red Dog Creek than in Ikalukrok Creek.

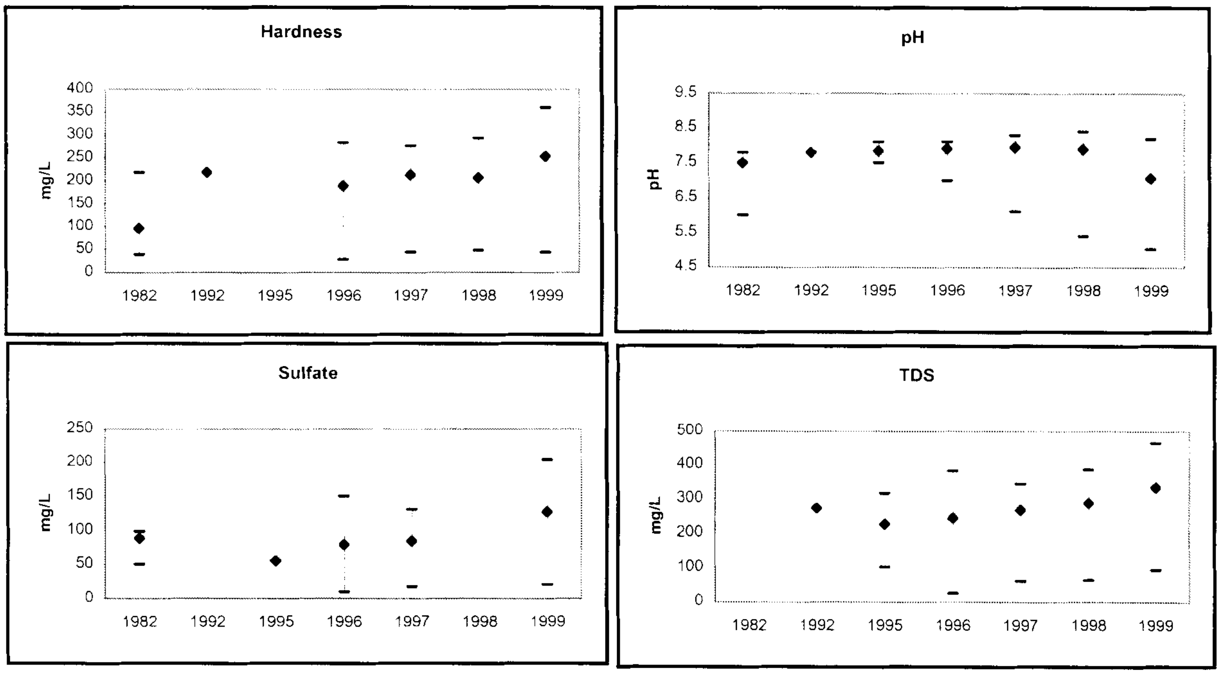


Figure 19. Median, maximum, and minimum concentrations of hardness, sulfate, TDS, and pH in North Fork Red Dog Creek at Station 12, June through October 1982, 1992, and 1995-1999. Data from Cominco.

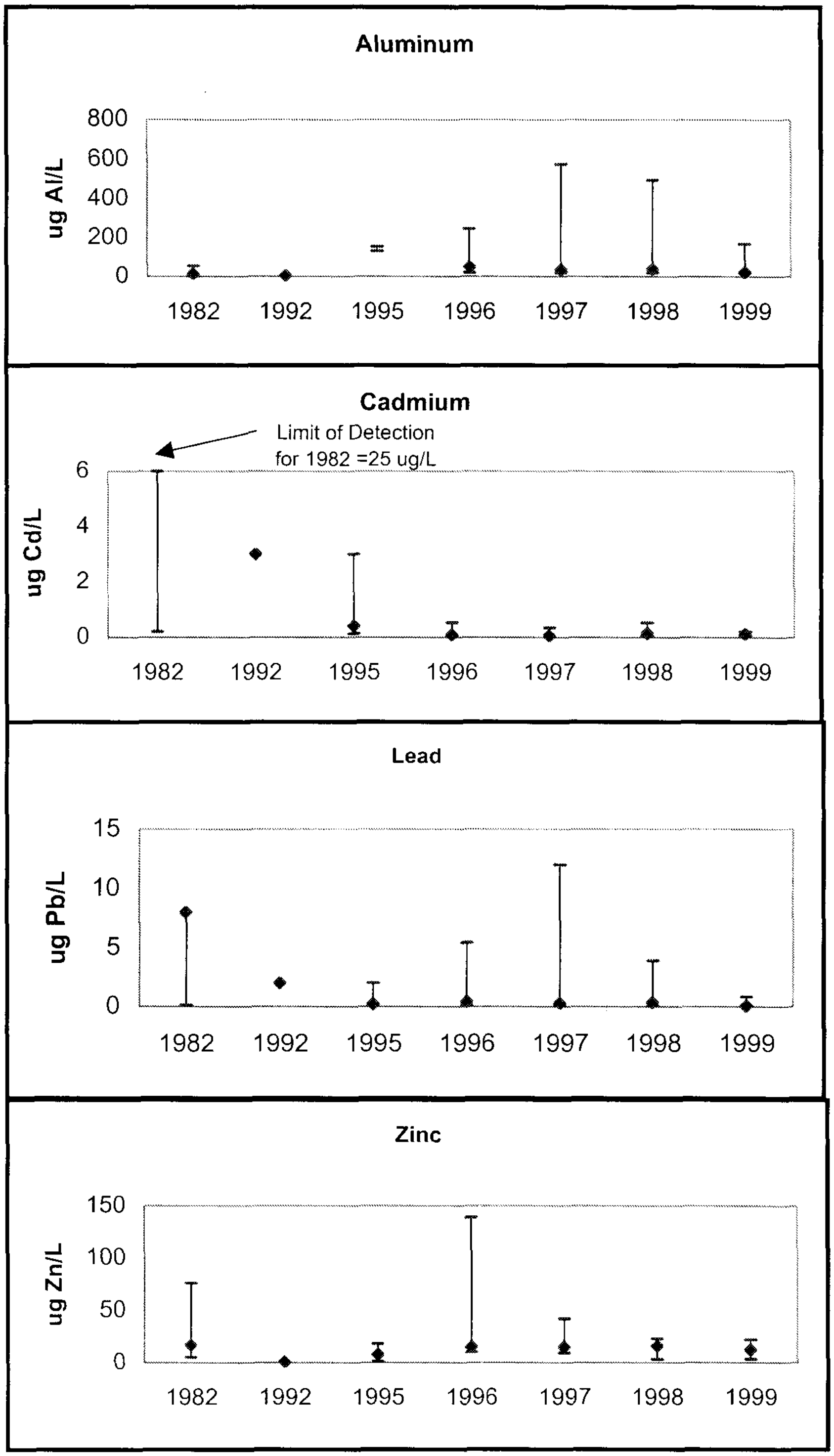


Figure 20. Median, maximum, and minimum concentrations of select metals in North Fork Red Dog Creek at Station 12, June through mid-October 1982, 1992, and 1995-1999. Data from Cominco.

Tributaries to Middle Fork Red Dog Creek

Rachael Creek. Rachael Creek, at the headwaters of Middle Fork Red Dog Creek, is a small, partially undercut stream flowing from the base of Deadlock Mountain. Rachael Creek flows into the clean water bypass then into Middle Fork Red Dog Creek. The creek has moderately hard water and is slightly acidic (Table 5).

Table 5. Median, maximum, and minimum concentrations of hardness, sulfate, TDS, pH, temperature, and conductivity in Rachael Creek, June through October, 1995-1999. Data from Cominco.

Analyte, units	Median	Maximum	Minimum	n
Hardness, mg $CaCO_3$/L	256	491	164	5
TDS, mg/L	216.5	1020	61	10
Sulfate, mg/L	100	769	5.3	11
pH	6	7.1	4.7	13
Temperature, °C	5.3	12.5	0.4	11
Conductivity, *u*S/cm	534	1091	176	11

The water in Rachael Creek is periodically high in Al, Cd, Pb, and Zn (Figure 21). In 1996 the creek contained elevated concentrations of Al, Cd, Pb, and Zn; except for Al, metals concentrations were lower in the following years. Baseline water sampling in Rachael Creek was limited to four samples in 1982. Dames and Moore (1983) described the water as clear, of low turbidity, and with high dissolved oxygen concentrations. Cd and Zn concentrations were low, ranging from 2 to 8 *u*g Cd/L and 79 to 142 *u*g Zn/L. Since 1995, median concentrations of Al, Cd, and Zn have consistently been elevated, especially Al and Zn (Figure 21).

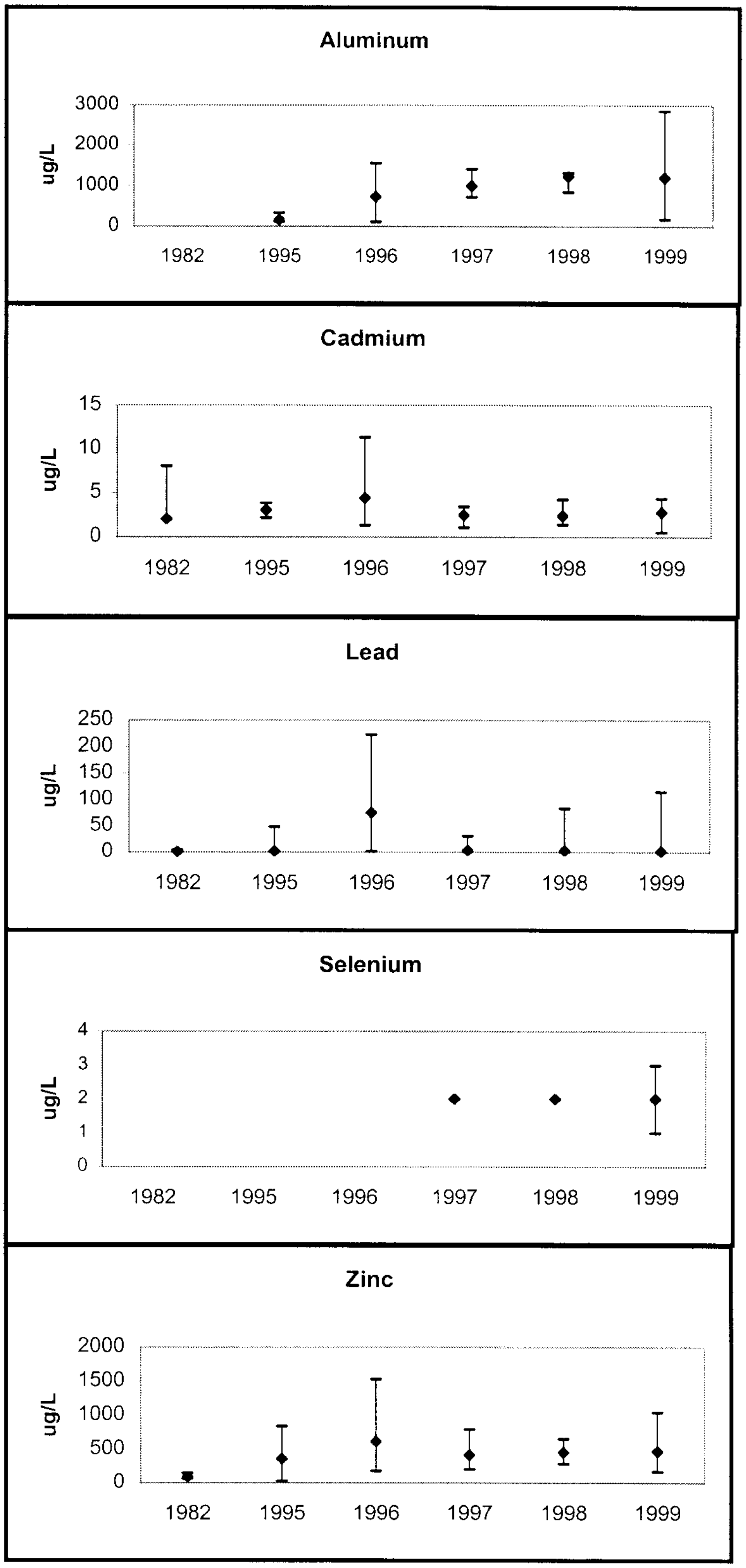


Figure 21. Median, maximum, and minimum concentrations of select metals in Rachael Creek, June through mid-October 1982, and 1995-1999. Data from Cominco.

Sulfur Creek. Sulfur Creek is a small, intermittent stream flowing into the northwest side of the ore body. The creek remains dry until periods of heavy rainfall, usually in August. Limited water quality data collected by Dames and Moore (1983) describe Sulfur Creek as having elevated concentrations of Pb and Zn (average of three samples = 128 *u*g Pb/L and 754 *u*g Zn/L) and slightly elevated concentrations of Cd (average of three samples = 7 *u*g/L) (Weber Scannell 1997). Flow ranged from 0.07 to 1.2 cfs, dissolved oxygen concentrations were near saturation, and pH was slightly acidic. The highest Zn concentration measured (of three samples) was 1,167 *u*g/L. In 1995, Cominco initiated additional water sampling in Sulfur Creek. When flowing, Sulfur Creek has moderately hard water and elevated concentrations of Cd, Pb, and Zn (Table 6, Figure 22).

Table 6. Water quality and metals concentrations in Sulfur Creek, 1995-1999. Data from Cominco.

Analyte, units	Median	Maximum	Minimum	n
TDS, mg/L	92	208	30	5
SO_4, mg/L	13	31	3.5	5
Al, *u*g/L	62	2150	5	30
Cd, *u*g/L	5.5	268	0.6	29
Cu, *u*g/L	2.7	24	1	27
Pb, *u*g/L	273.5	6890	18.1	29
Se, *u*g/L	2	2	2	10
Zn, *u*g/L	494	21400	19	30
pH	7.2	7.8	4.6	10
Temperature, °C	4.1	10	1	8
Conductivity, *u*S/cm	221	980	49	8

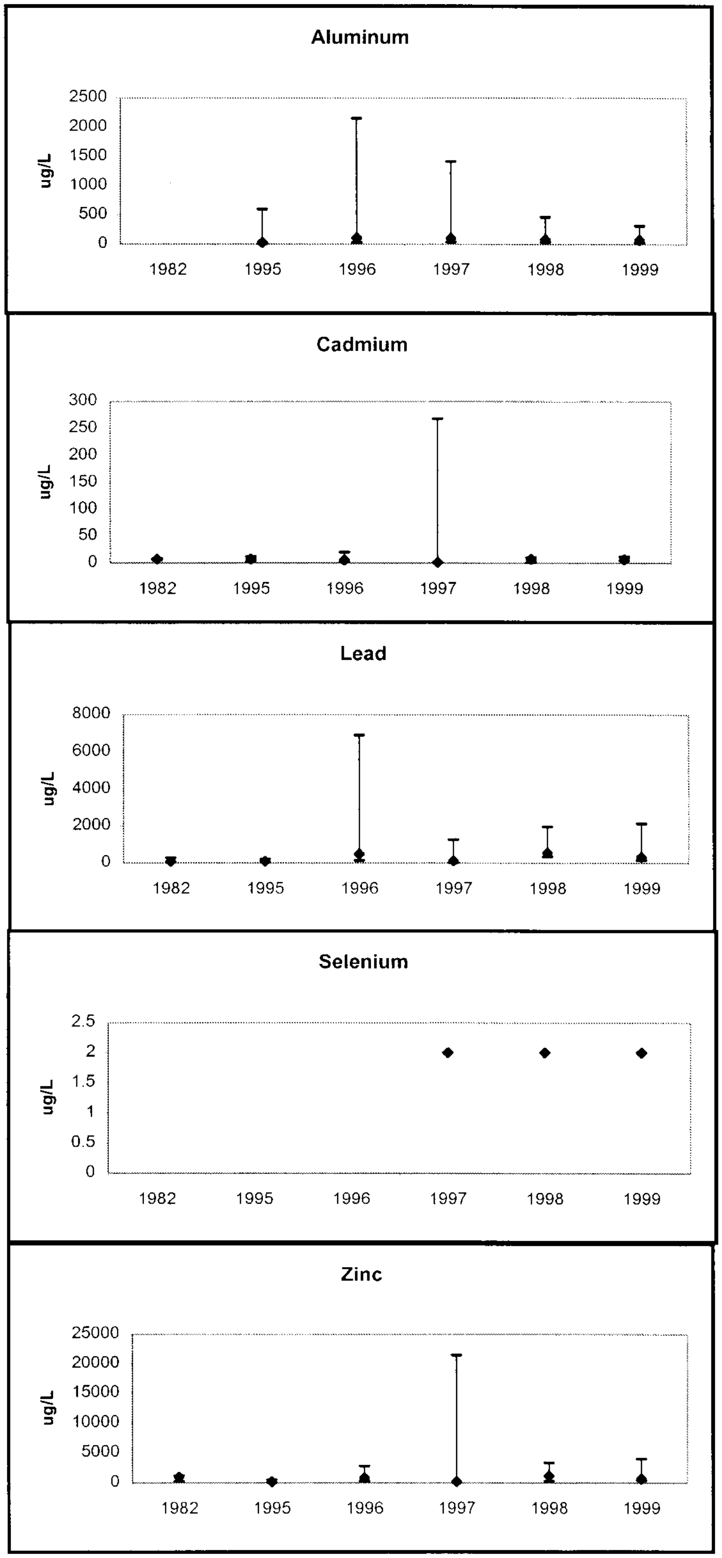


Figure 22. Median, maximum, and minimum concentrations of select metals in Sulfur Creek, June through mid-October 1982, and 1995-1999. Data from Cominco.

Shelly Creek. Shelly Creek flows into Middle Fork Red Dog Creek from the northeast. There were no baseline data collected on hardness, TDS, flow, or dissolved oxygen. Water quality monitoring has been conducted from 1995 through 1999. Shelly Creek has soft water (defined as hardness less than 160 mg/L; hardness is primarily from calcium). The median pH is around neutral and sulfates are low (Table 7). Conductivity is high during summer low flows, but low during breakup or seasonally rainy periods.

Table 7. Water Quality in Shelly Creek, 1995-1999.

Analyte, units	Median	Maximum	Minimum	n
Hardness, mg/L	61.9	116	33.1	5
Ca, mg/L	15950	30300	3490	4
Na, mg/L	2170	4600	747	4
TDS, mg/L	121	198	29	11
SO4, mg/L	39.1	138	6.9	11
pH	7.0	7.4	6.1	14
Temperature, °C	5.7	12.3	1.3	10
Conductivity, *u*S/cm	153.4	888	39	10

Baseline water samples were limited to one sample in 1981 and four in 1982. Concentrations of both Cd and Zn exceeded Maximum Allowable Concentrations in all of the samples collected (USEPA 1985a, USEPA 1980a); Pb was not elevated (USEPA 1985b). The maximum concentration of Cd was 28 *u*g/L, Pb 80 *u*g/L, and Zn 2300 *u*g/L (Weber Scannell 1997).

Metals concentrations have been sampled in Shelly Creek from 1995 through 1999. Aluminum, Cd, Pb, and Zn have been elevated in Shelly Creek throughout the 5-year period (Figure 23). Metals are highest during fall low flows, from late August through early September.

Weber Scannell (1997) reported elevated concentrations of Al and Cd that were above the reported chronic/acute toxicity levels (79% of samples for Al and 36% of samples for Cd) (USEPA 1986). Seventy nine percent of the water samples contained concentrations of Cd that were above the Maximum Allowable Concentration and 93% of the samples exceeded the Maximum Allowable Concentration for Zn. Concentrations of Fe ranged from 190 to 1220 *u*g Fe/L. Median concentrations of Al, Cd, Cu, Pb, and Zn were lower in 1996 than 1995 (Weber Scannell 1997). Concentrations of Cd and Zn increased throughout the summer each year, and reached highest concentrations in September. In late summer 1995 and 1996, concentrations of Cd reached approximately nine times the acute limit for aquatic life and Zn was approximately 4.5 times the aquatic life limit.

Connie Creek. Connie Creek is the largest of the tributaries to Middle Fork Red Dog Creek. Limited water quality and metals data (Dames and Moore 1983) collected in Connie Creek during baseline studies showed this creek to have moderately good water quality for most analytes. Cadmium concentrations were above, but close to, the Maximum Allowable Concentration for aquatic life, and ranged from 0.002 to 0.021 mg/l.

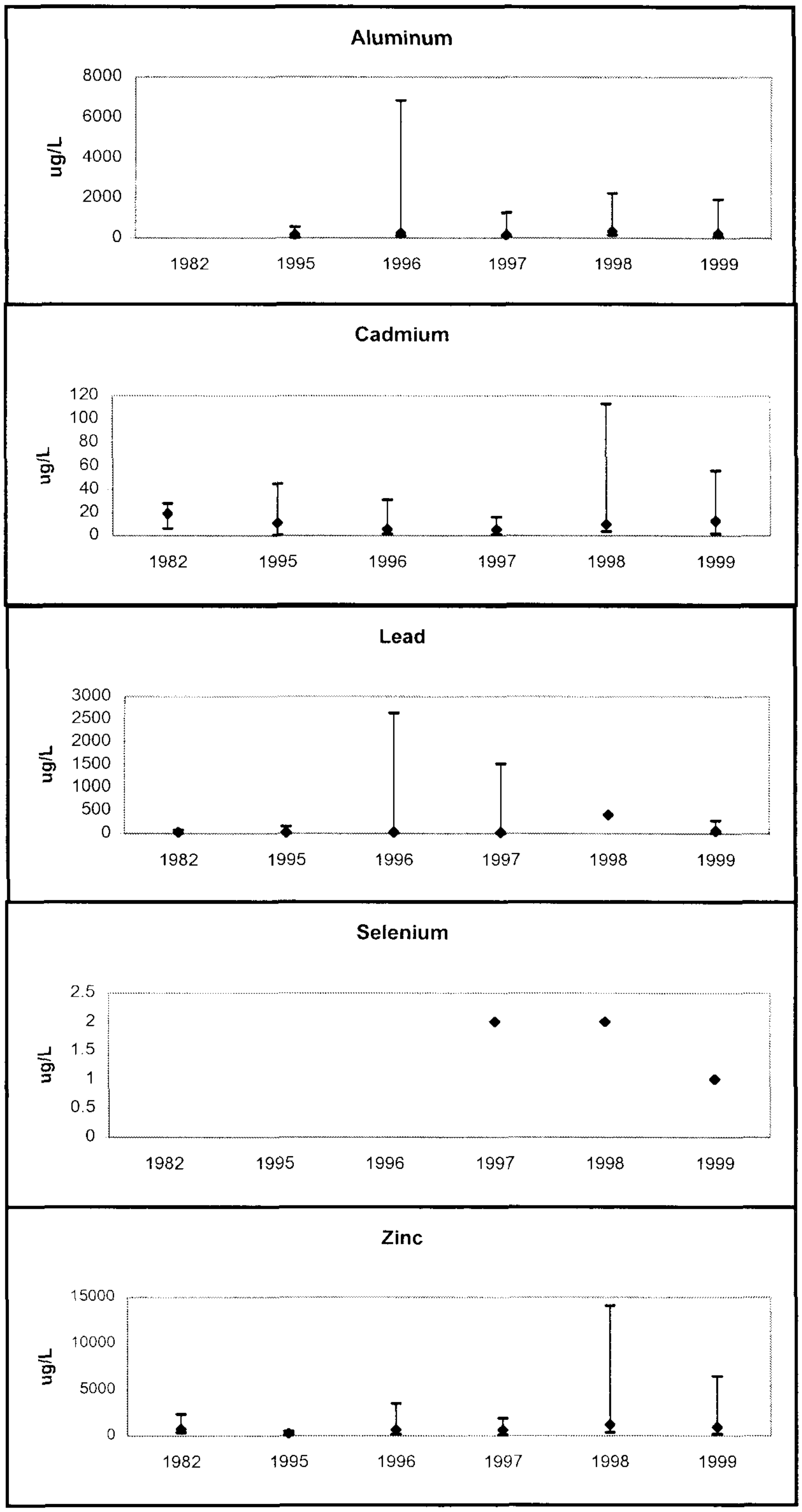


Figure 23. Concentration of Al, Cd, Pb, Se, and Zn in Shelly Creek, 1982 and 1995 through 1999. Data from Cominco.

Connie Creek has moderately soft water with low concentrations of TDS, low sulfates, and pH near neutral (Table 8).

Table 8. Water Quality in Connie Creek, 1995-1999.

Analyte, units	Median	Maximum	Minimum	n
Hardness, mg/L	79.1	148	51.2	5
TDS, mg/L	85	310	38	10
SO4, mg/L	44.35	169	15	10
TSS, mg/L	5	5	5	2
pH	7.21	7.7	6.2	15

In 1995 through 1999, Connie Creek frequently contained the lowest median concentrations of metals of any of the tributaries to Middle Fork Red Dog Creek (Figure 24). Aluminum, Cd, and Pb have occasionally been elevated in samples collected during fall low flows.

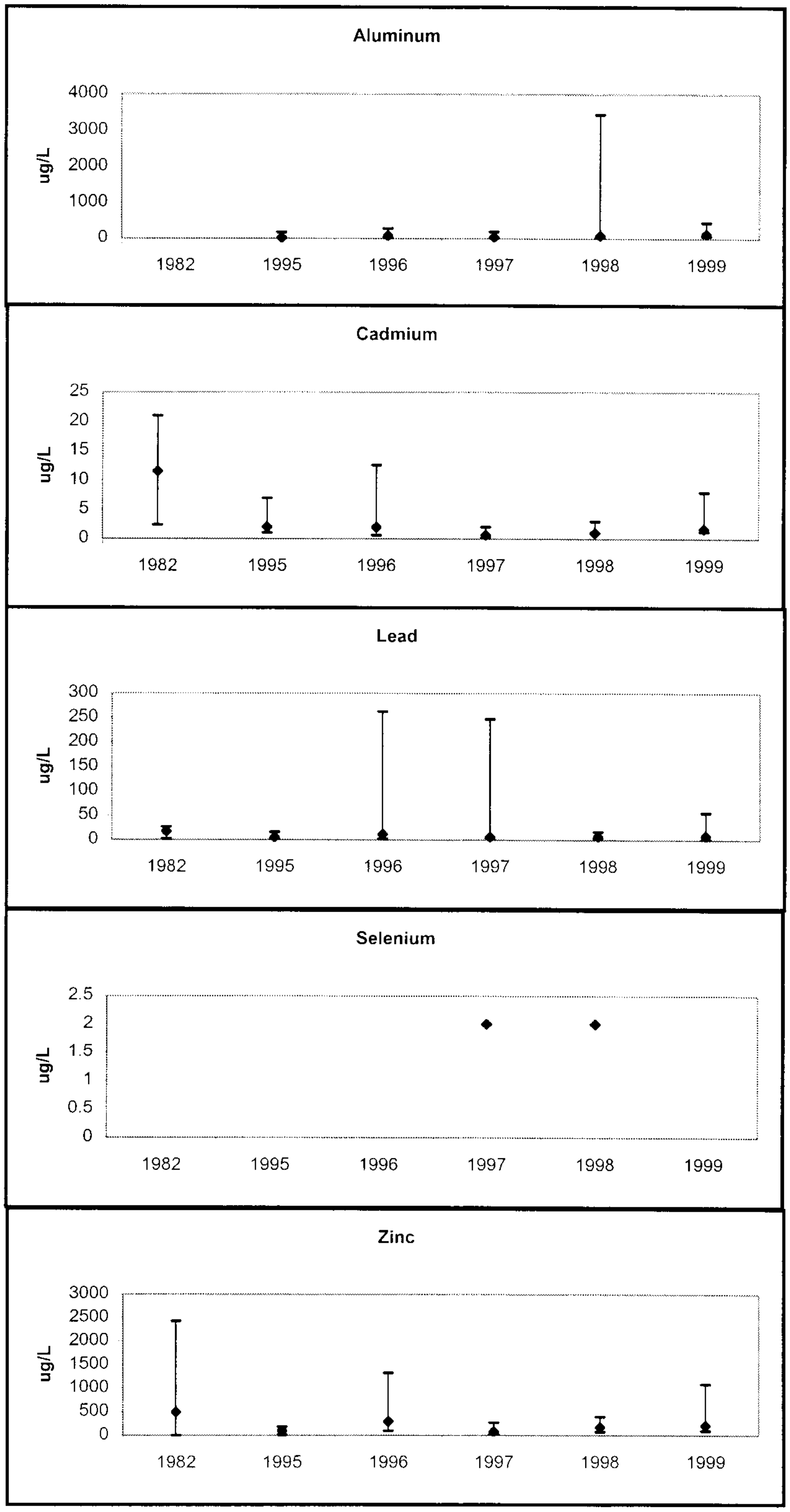


Figure 24. Median, maximum, and minimum concentrations of Al, Cd, Pb, Se, and Zn in Connie Creek. Data from Cominco.

MICROTOX TESTS

The Microtox test uses the marine bioluminescent bacteria *Vibrio fischeri*. When grown under optimum conditions, the bacteria produce light as a by-product of their cellular respiration. Bacterial bioluminescence is tied directly to cell respiration, and any inhibition of cellular activity (toxicity) results in a decreased rate of respiration and a corresponding decrease in the rate of luminescence. The more toxic the sample, the greater the percent light loss from the test suspension of luminescent bacteria (Azur Test Manual 1999).

The Microtox test accurately measures the effect of metals and other non-biological toxicants (Azur 1999) and the test has good repeatability (Figure 25). Chronic Microtox tests were used with standard dilutions of 45.5%, 22.25%, 11.12%, and 5.7%. Water was collected from Stations 140 (below bypass channel and upstream of effluent outfall), 001 (effluent), 12 (North Fork Red Dog Creek), and 9 (Ikalukrok Creek upstream of Mainstem Red Dog Creek) at the same time water samples were collected for Whole Effluent Toxicity tests.

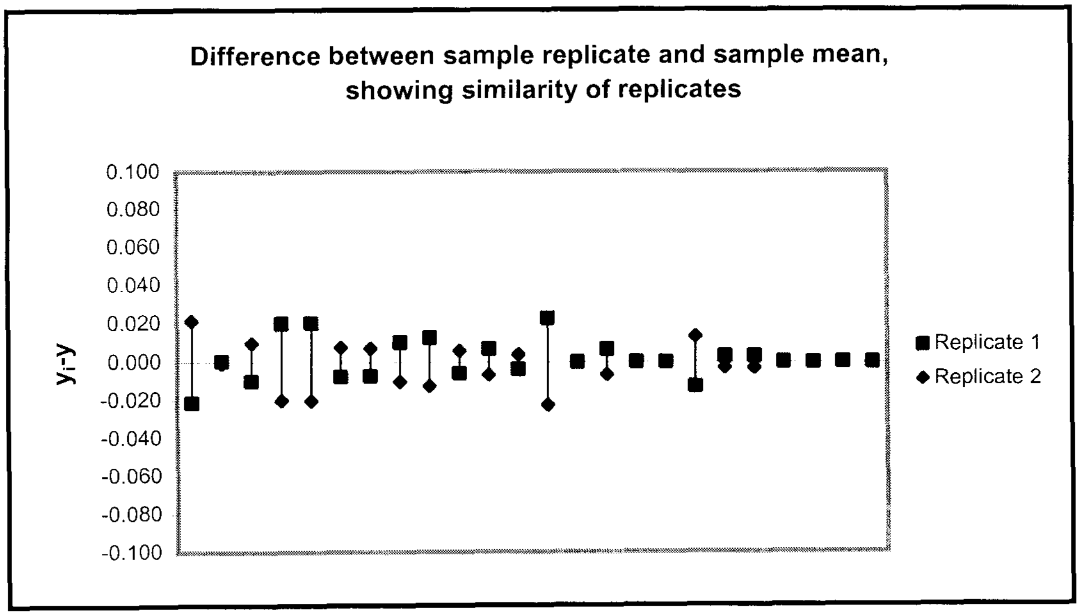


Figure 25. The percent of Microtox bacteria effected - replicate samples.

Objectives of Microtox Tests

Waters in the Red Dog Creek and Ikalukrok Creek drainages range from having few metals to having a complex and often varying mixture of Al, Cd, Cu, Pb, Zn, Ni, Se, and other metals. Changes in stream flow, rainfall, and groundwater can have substantial effects on the chemistry of these waters. The Microtox procedure was tested to determine if it would be a suitable test to identify changes in the toxicity of these waters and to determine its usefulness in screening for different toxic responses. Microtox results were compared with results from the Whole Effluent Toxicity (WET) testing done during summer 1999 to determine if Microtox results correlated with WET results (Scannell 2000).

Additional Microtox tests were done using a blend of water from Station 140 and Station 12 in the approximate proportions of the respective stream flows. This blend was diluted with effluent water to determine the extent toxicity changed with different additions. A similar test was done by diluting the Station 140-Station 12 blend with natural water. For natural water, Fort Knox Gold Mine water supply reservoir water was used. Waters in the water supply reservoir are low in metals and known to support populations of Arctic grayling and burbot (*Lota lota*).

Comparisons of Microtox Tests Among Sites

The IC-25, or inhibition concentration for 25% of the population was calculated for each of the sites for each of the dates sampled (Figures 26 through 31). Results from the basic, or chronic test, only show inhibition effects in water from the bypass channel upstream of the effluent discharge point (Station 140). Waters from the bypass channel are more toxic to the bioluminescent bacteria *Vibrio fischeri* than waters collected from the outfall (the effluent), North Fork Red Dog Creek, or Ikalukrok Creek above Mainstem Red Dog Creek.

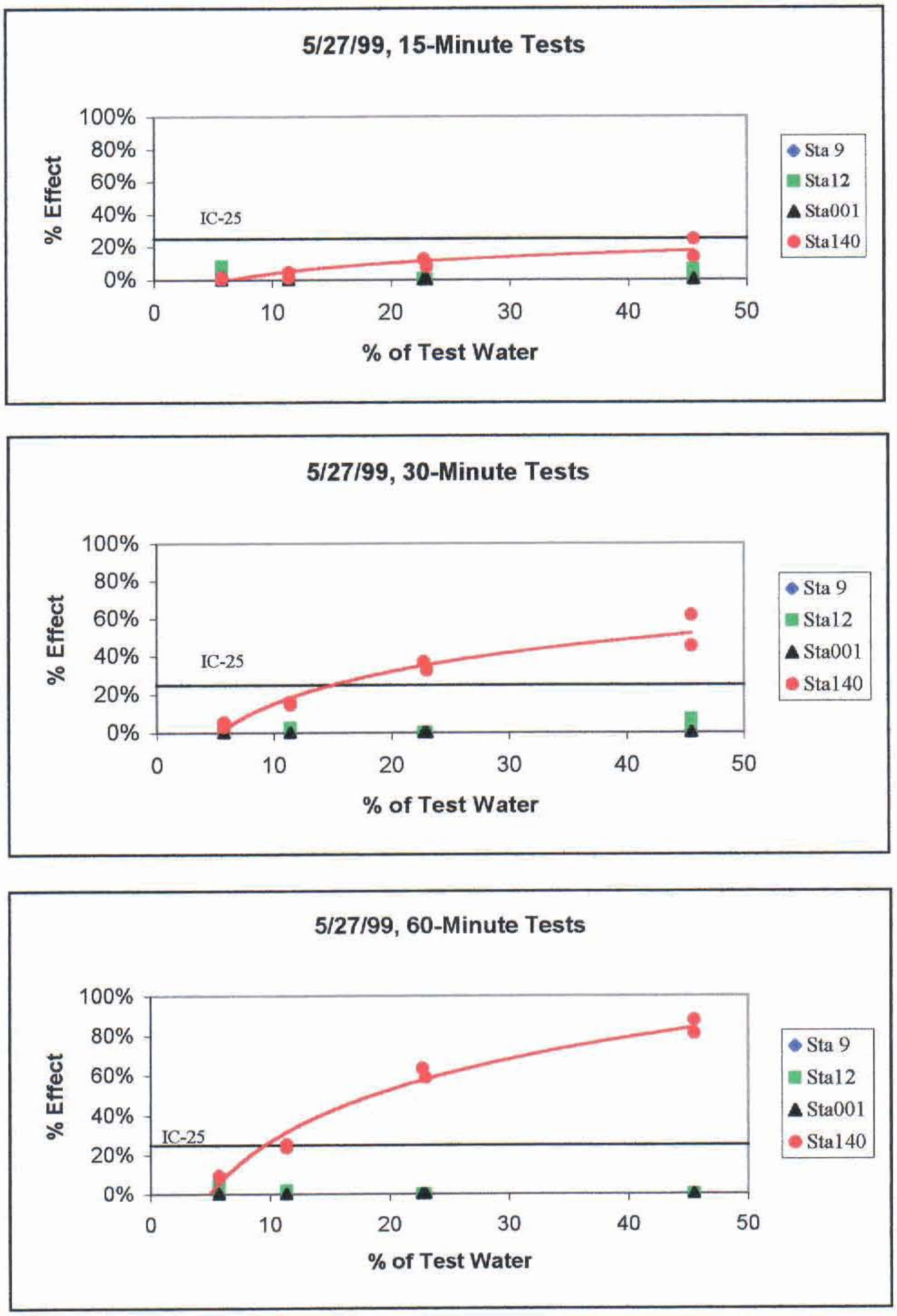


Figure 26. The percent effect to *Vibrio fishcheri* from waters collected from Stations 9, 12, 001, and 140 on May 27, 1999.

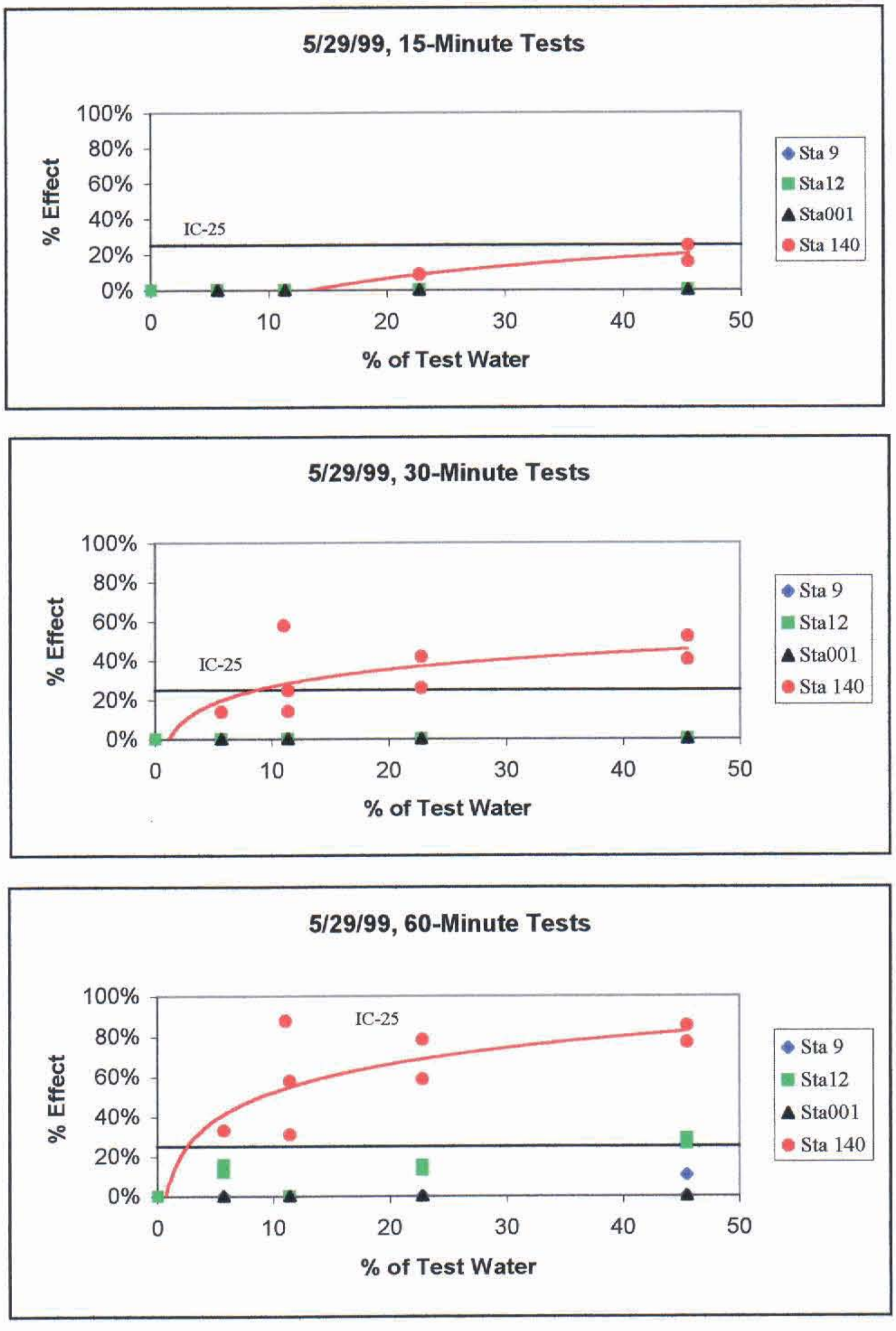


Figure 27. The percent effect to *Vibrio fishcheri* from waters collected from Stations 9, 12, 001, and 140 on May 29, 1999.

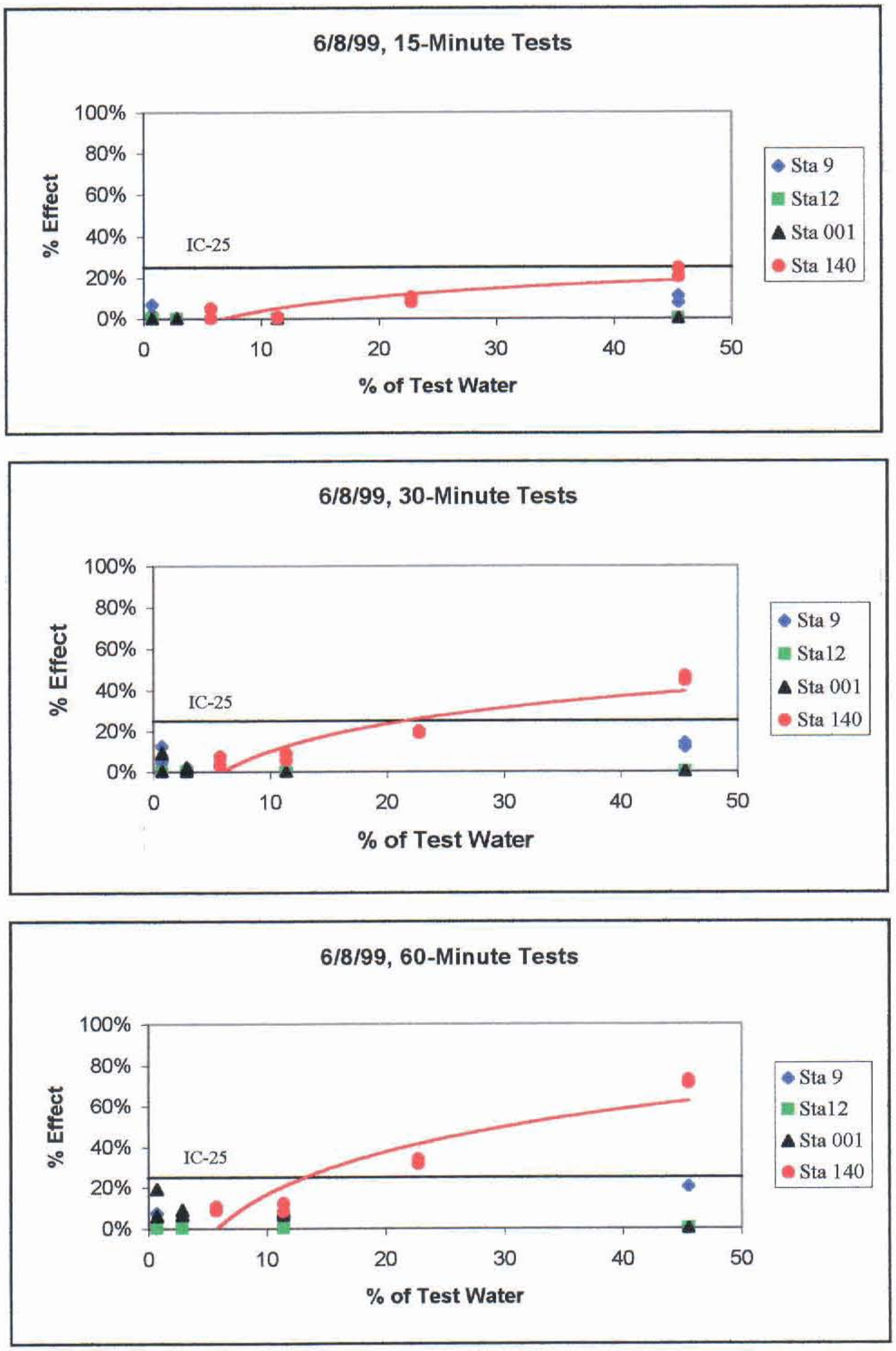
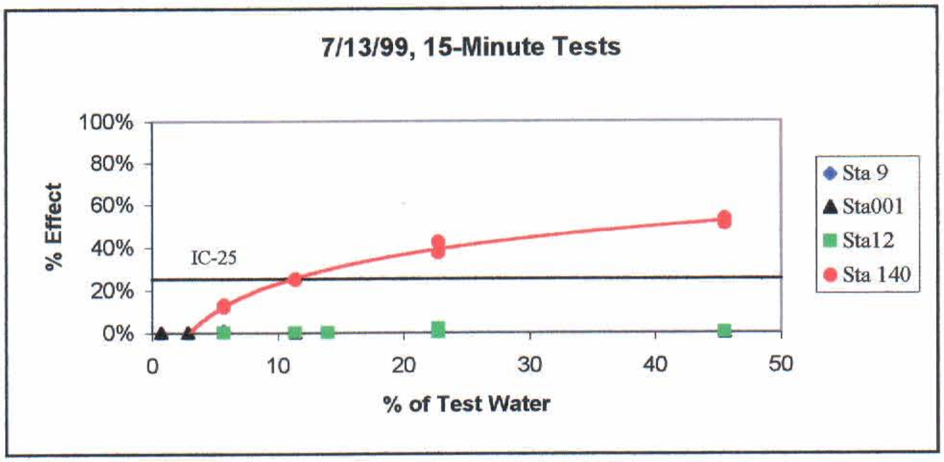
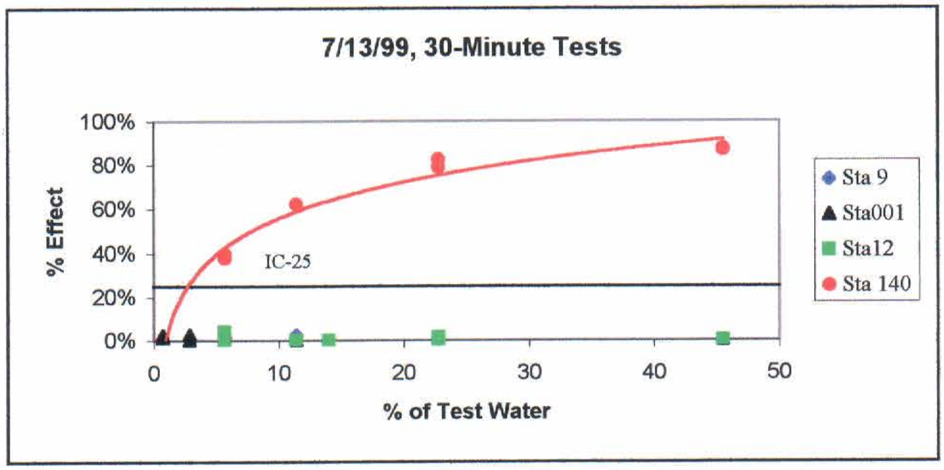


Figure 28. The percent effect to *Vibrio fishcheri* from waters collected from Stations 9, 12, 001, and 140 on June 8, 1999.





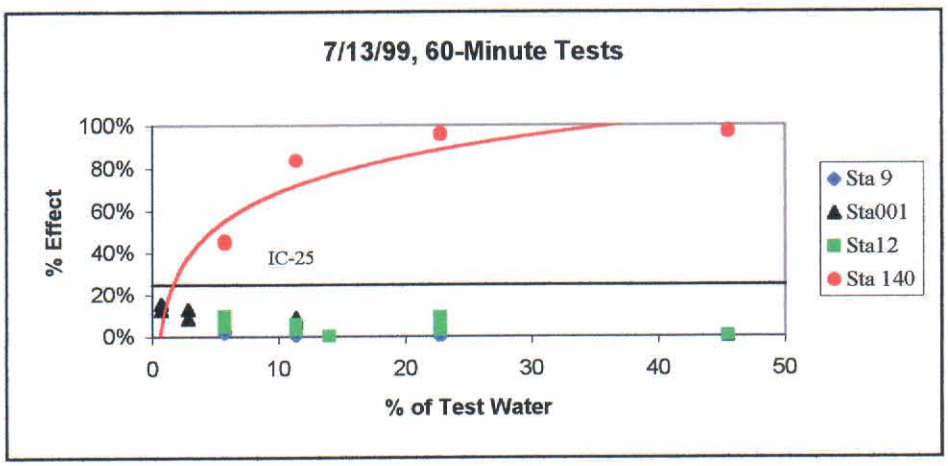


Figure 29. The percent effect to *Vibrio fishcheri* from waters collected from Stations 9, 12, 001, and 140 on July 13, 1999.

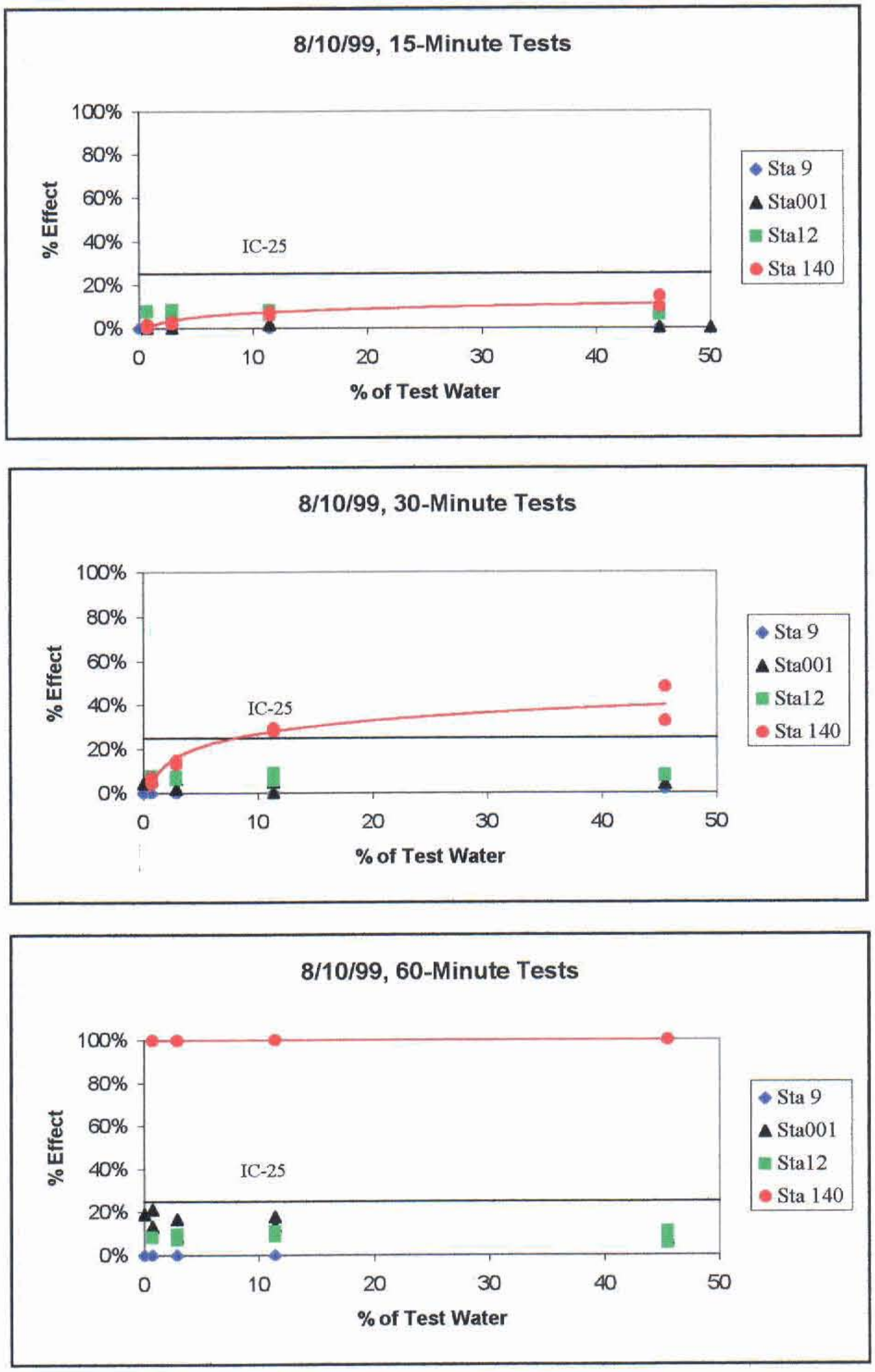


Figure 30. The percent effect to *Vibrio fishcheri* from waters collected from Stations 9, 12, 001, and 140 on August 10, 1999.

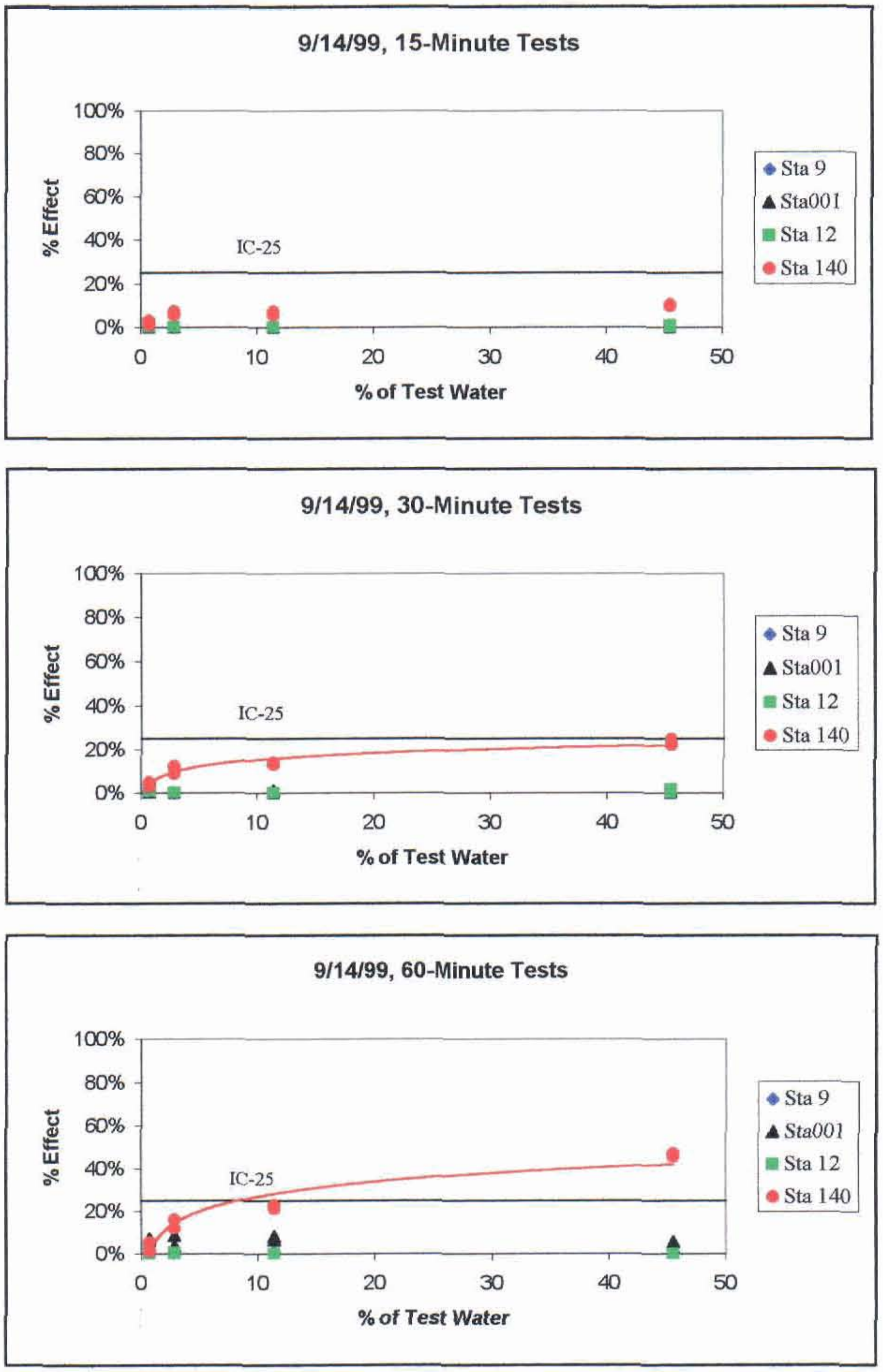


Figure 31. The percent effect to *Vibrio fishcheri* from waters collected from Stations 9, 12, 001, and 140 on September 14, 1999.

Changes in Toxicity from Effluent

The blended water from Station 140 and Station 12 was toxic at 100% (no dilution with either effluent or natural water). Toxicity decreased rapidly with the addition of either effluent or natural water; at 50% dilution, there was no measurable toxicity (Figure 32).

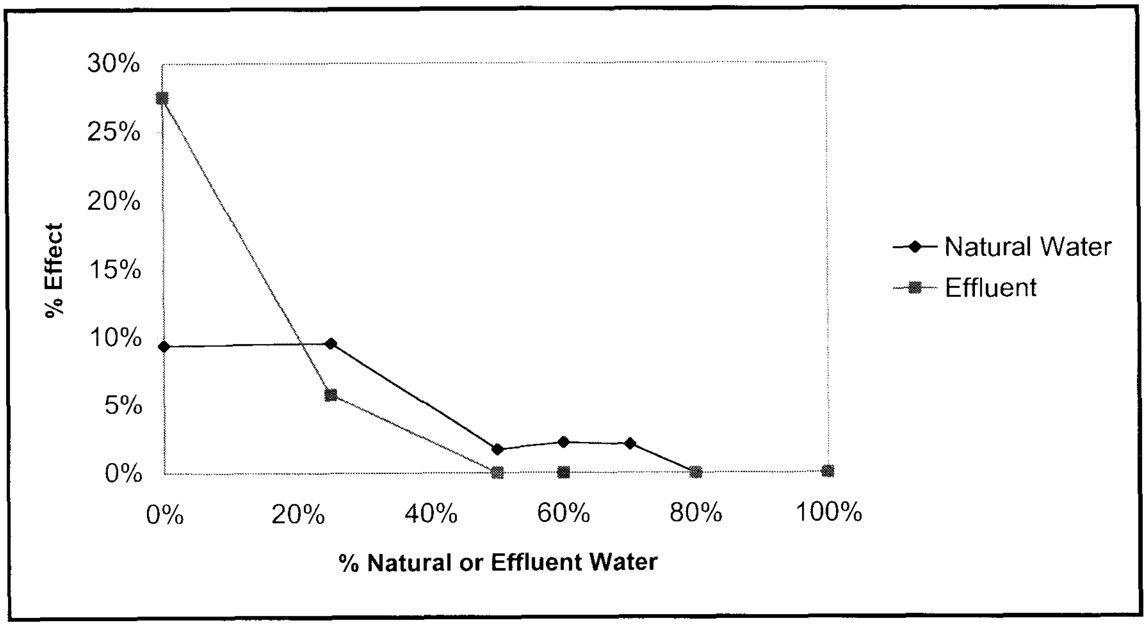
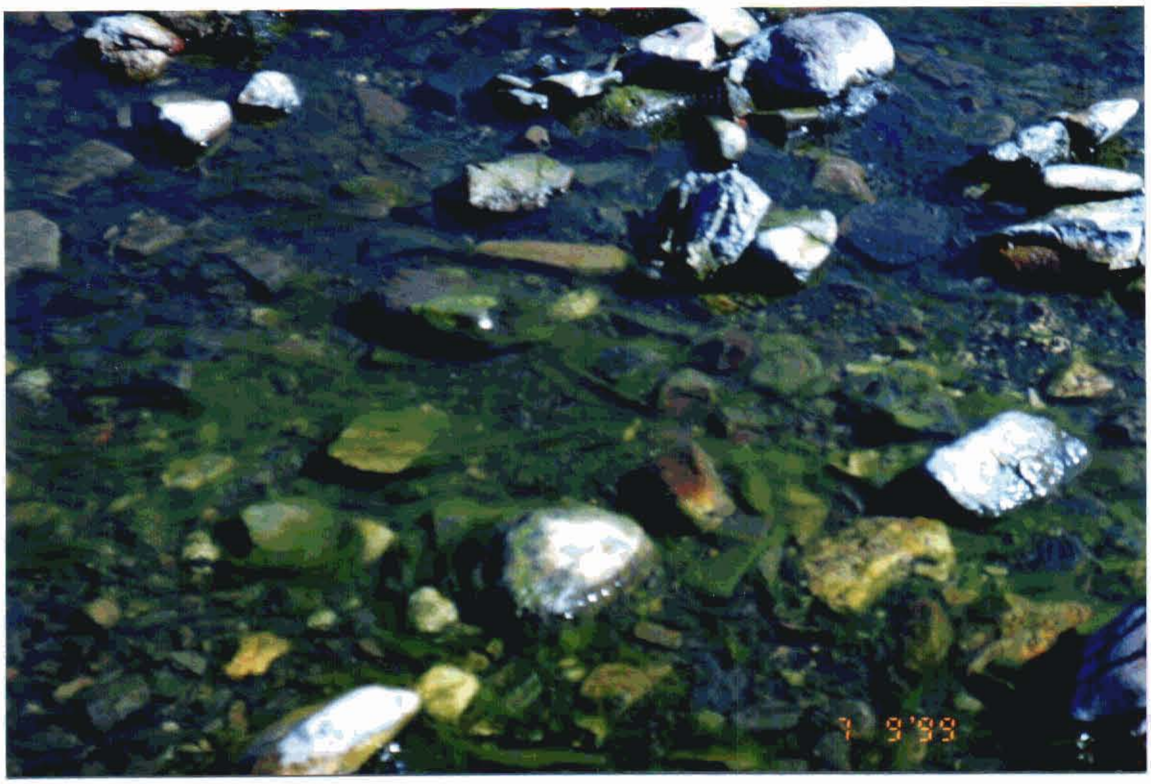


Figure 32. Changes in toxicity to blended water (Stations 140 and 12) with the addition of effluent or natural water.

PERIPHYTON STANDING CROP

Periphyton, or attached micro-algae, are sensitive to changes in water quality and often used in monitoring studies to detect changes in aquatic communities. The presence of periphyton in a stream system documents continued in-situ productivity. Unlike fish, which are migratory, the presence of micro-algae on the streambed documents suitability of that stream, including its physical and chemical characteristics to support productivity. Thus measures of periphyton density document the productivity of individual stream reaches with specific water quality conditions. Since 1995, we have sampled stream periphyton in stream reaches downstream and adjacent to the Red Dog Mine (see photo below, Mainstem Red Dog Creek, Station 10, July 9, 1999).



Stream periphyton, or attached algae, was sampled in late June 1999 from all sites (Figure 33). Chlorophyll was dissolved from samples with 90% buffered acetone. A fluorometer (ADF&G 1998) was used to read all samples. Samples with sufficient concentrations of chlorophyll to exceed limits of detection were read on the spectrophotometer. None of the ten samples collected from Station

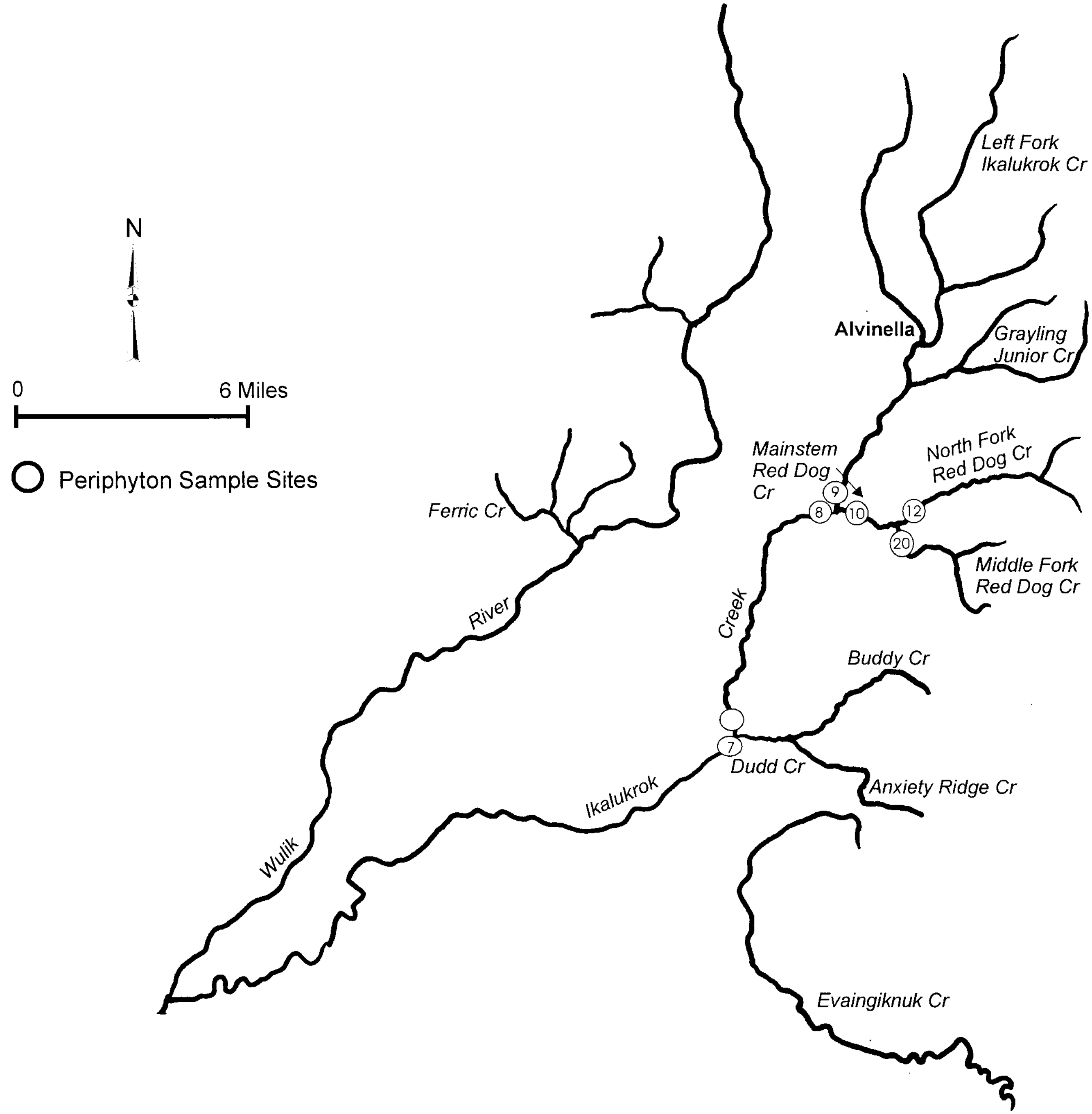


Figure 33. Periphyton sample sites at the Red Dog Mine.

20 contained amounts of chlorophyll-a that were above the limit of detection (the limit of detection was about 0.05 mg/m^2). Chlorophyll-a samples from Station 9 also were low (Table 9), with an average concentration of 0.25 mg/m^2 and three samples below the limit of detection. The highest concentrations of chlorophyll-a were found in North Fork Red Dog Creek and Ikalukrok Creek upstream of Dudd Creek (Table 9) where the average amounts were 2.68 mg/m^2 and 2.59 mg/m^2.

Table 9. Summary of chlorophyll-a concentrations from samples collected at the NPDES study sites.

Site	Average	Maximum	Minimum	Standard Deviation	Number of Samples less than Limit of Detection
Station 20	0.00	0.0	0	0.000	10
Station 9, LF	0.25	0.7	0	0.260	3
Station 10	1.06	2.8	0	1.140	1
Station 8	1.06	4.9	0.0672	1.410	0
Ik d/s Dudd	1.16	3.2	0.3865	0.878	0
Ik u/s Dudd	2.59	4.1	1.7976	0.710	0
North Fork	2.68	4.3	1.3032	0.978	0

Changes in Chlorophyll-a within Each Site Over Sample Years

Stream periphyton was sampled at about the same time (late June) for most of the sample sites from 1995 to 1999. We compared the average, maximum, and minimum concentrations of chlorophyll-a measured at each site to detect annual variations that may be attributed to water quality changes. Data from all sites were graphed with the same scale to facilitate inter-site comparisons.

Middle Fork Red Dog Creek (Station 20) consistently has low algal growth. We measured a slight increase during 1998 (Figure 34) when communities of filamentous algae formed on the stream bottom. Most samples from this site are less than the detection limit of a fluorometer; no samples could be read on a spectrophotometer. Because most of the samples collected each year are below detection, there is no interannual variation.

The low concentrations of chlorophyll-a are likely determined by high metals concentrations (Weber Scannell and Andersen 2000). Water quality sampling conducted throughout the sampling period (1995 through 1999) show upper Red Dog Creek and its tributaries, Rachael, Shelly, and Connie creeks contribute substantial amounts of Al, Cd, Pb, and Zn to Middle Fork Red Dog Creek (Weber Scannell and Andersen 2000).

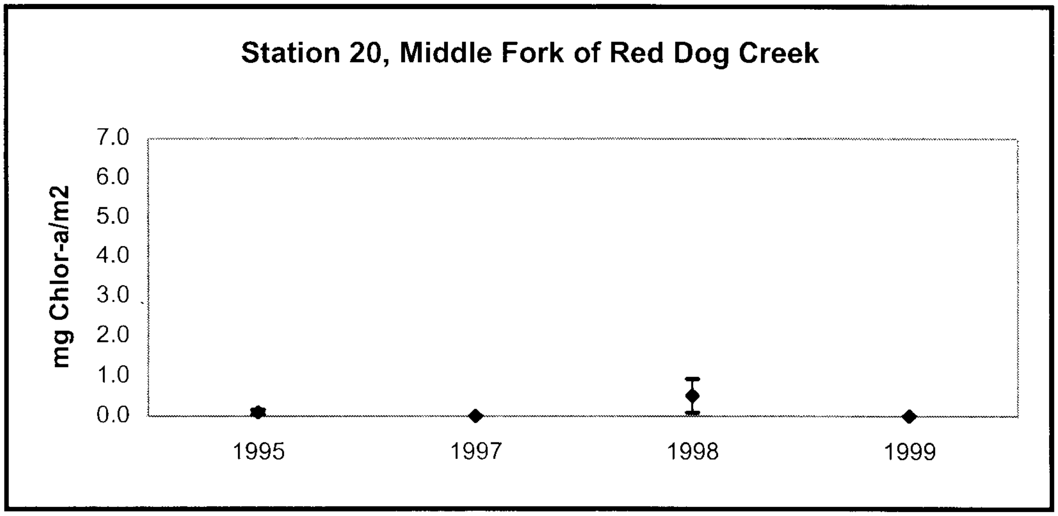


Figure 34. Average, maximum, and minimum concentrations of chlorophyll-a sampled from Middle Fork Red Dog Creek (Station 20) in June, 1995-1999.

Mainstem Red Dog Creek begins at the confluence of Middle Fork (containing water from the effluent outfall) and North Fork Red Dog creeks. After mixing, Mainstem Red Dog Creek shows a substantial increase in algal productivity. Flow in North Fork Red Dog Creek is three to four times greater than the discharge in Mainstem Red Dog Creek (without the mine effluent), so dilution is substantial. Average concentrations of chlorophyll-a collected from Station 10 are lower than those found in Ikalukrok or North Fork Red Dog creeks, but considerably higher than at Station 20. The average concentrations for each year, 1995 through 1999, are similar (Figure 35).

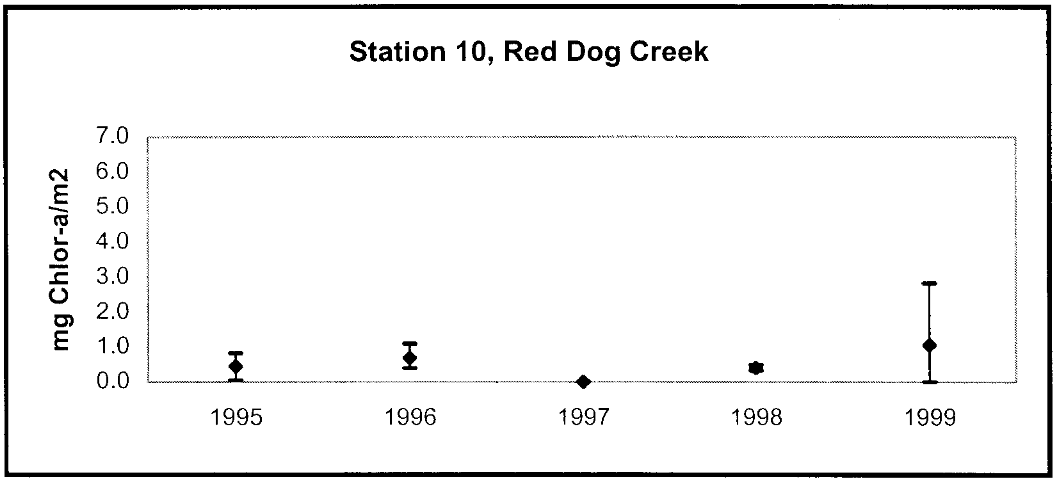


Figure 35. Average, maximum, and minimum concentrations of chlorophyll-a sampled from Mainstem Red Dog Creek (Station 10) in June, 1995-1999.

North Fork Red Dog Creek showed high productivity of stream periphyton. The stream is relatively low in metals (Weber Scannell and Andersen 2000) and has dense riparian vegetation. Concentrations of chlorophyll-a were higher in the North Fork Red Dog Creek than in any other site sampled (Table 9). We detected some annual changes in chlorophyll-a concentrations among years sampled (Figure 36). Concentrations were highest in 1995, declined in 1997, and were similar in 1998 and 1999, as shown by both averages and ranges.

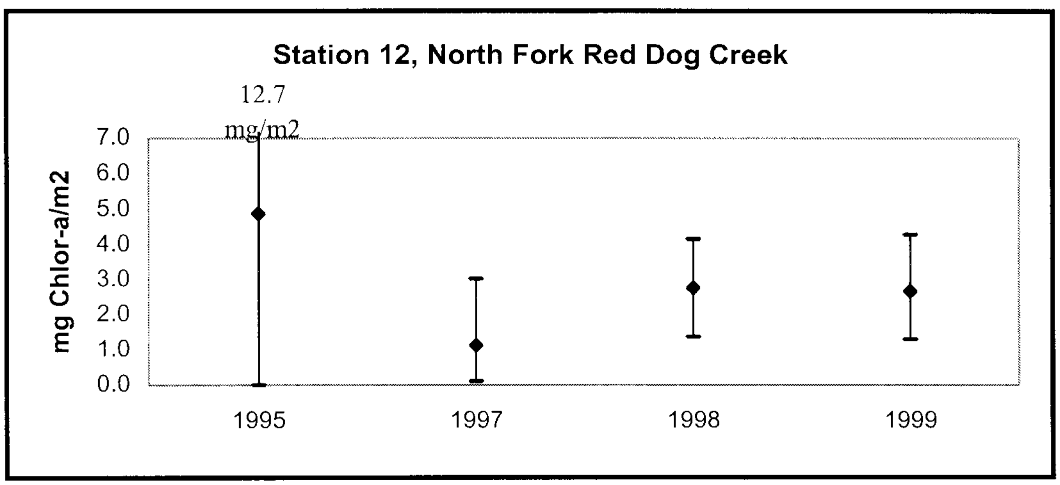


Figure 36. Average, maximum, and minimum concentrations of chlorophyll-a sampled from North Fork Red Dog Creek (Station 12) in June, 1995-1999.

Stream periphyton in Ikalukrok Creek shows a general increase from the upstream site (Station 9, upstream of Mainstem Red Dog Creek) downstream to just below Dudd Creek (Table 9). Changes in chlorophyll-a concentrations from 1996 through 1999 (there are no data for 1995) are slight, and all samples are low (Figure 37).

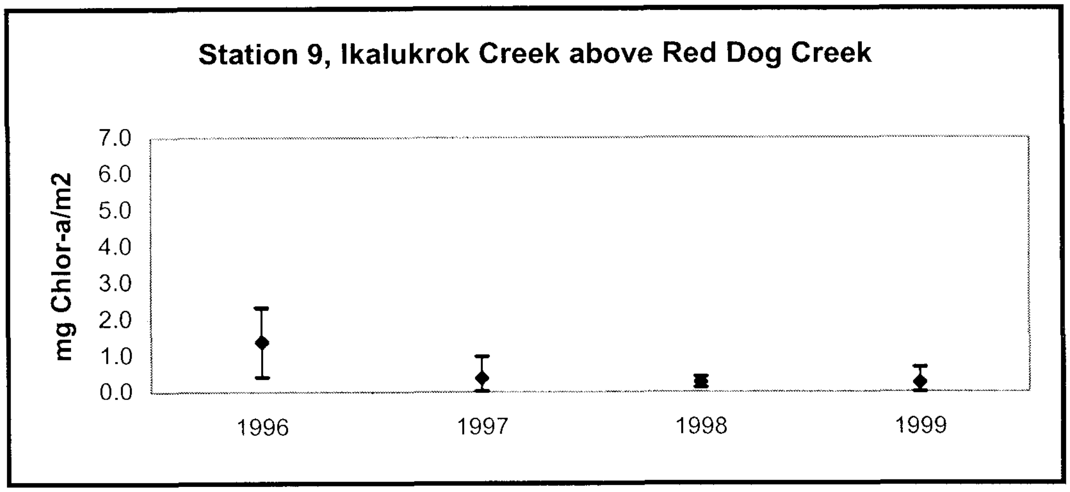


Figure 37. Average, maximum, and minimum concentrations of chlorophyll-a sampled from Ikalukrok Creek upstream of Mainstem Red Dog Creek (Station 9) in June, 1996-1999.

The water in Ikalukrok Creek at Station 8 is not mixed (Weber Scannell and Andersen 2000). The proportions of water from Ikalukrok and Mainstem Red Dog creeks at a given spot at Station 8 depend upon stream flow. It is not possible to isolate the influence of water quality on periphyton communities. The fact that periphyton biomass (as estimated by chlorophyll-a concentrations) varied among the years sampled (Figure 38) is more a reflection of the stream flows and degree of mixing than of water quality characteristics in either Mainstem Red Dog or upper Ikalukrok creeks.

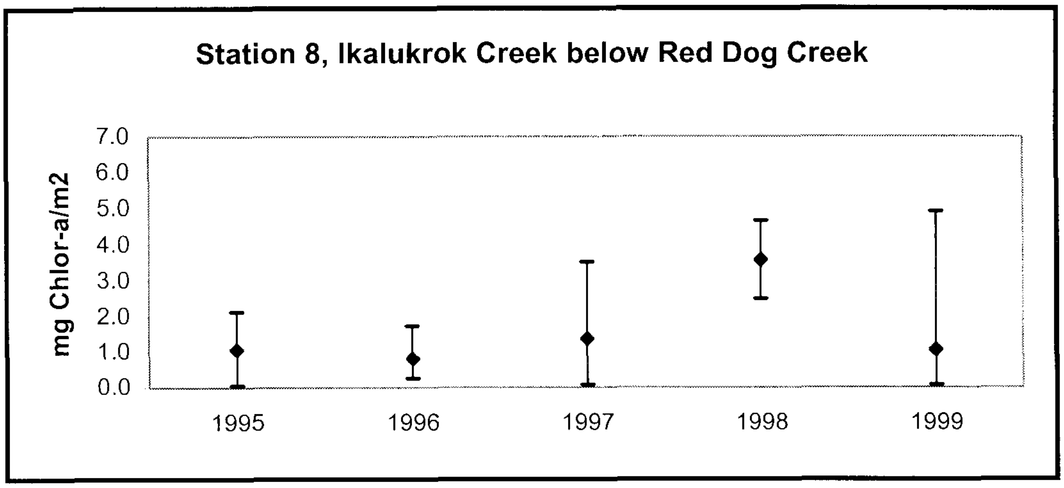


Figure 38. Average, maximum, and minimum concentrations of chlorophyll-a sampled from Ikalukrok Creek downstream of Mainstem Red Dog Creek (Station 8) in June, 1996-1999.

Ikalukrok Creek upstream and downstream of Dudd Creek has similar periphyton biomass. Chlorophyll-a was highest in 1998 at both sites (Figures 39 and 40), although neither site showed substantial changes. Dudd Creek contributes little flow to the drainage at this point (Weber Scannell and Andersen 2000).

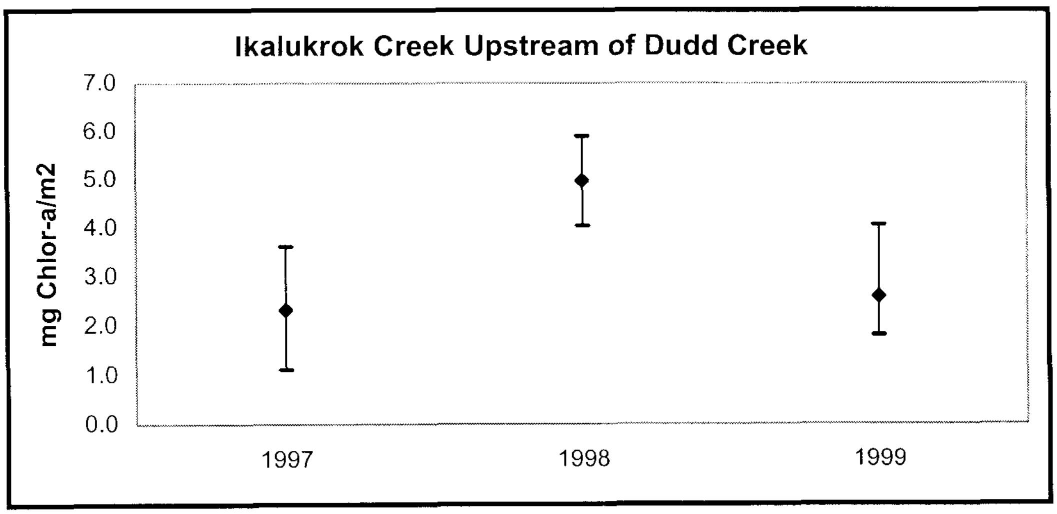


Figure 39. Average, maximum, and minimum concentrations of chlorophyll-a sampled from Ikalukrok Creek upstream of Dudd Creek in June, 1997-1999.

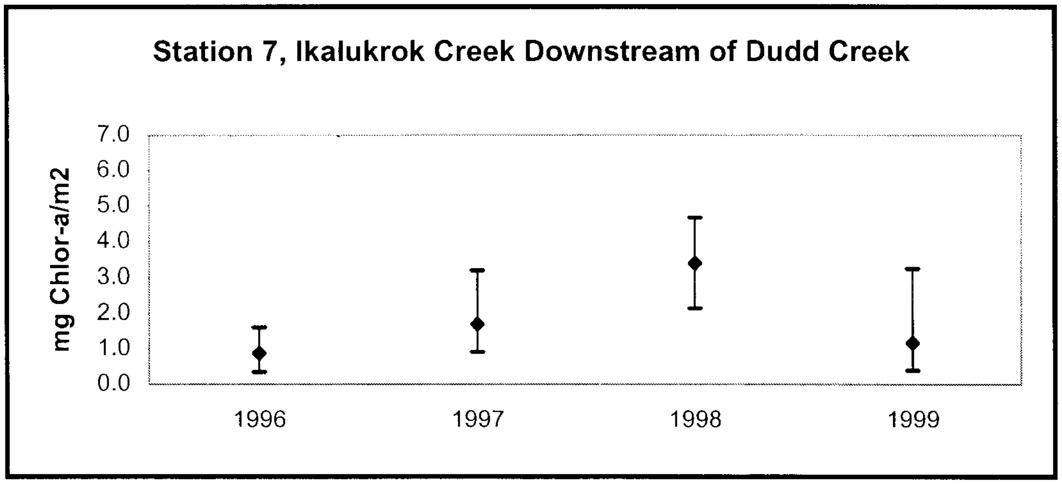


Figure 40. Average, maximum, and minimum concentrations of chlorophyll-a sampled from Ikalukrok Creek downstream of Dudd Creek (Station 7) in June, 1996-1999.

Correlation of Algal Biomass with Metal Concentrations

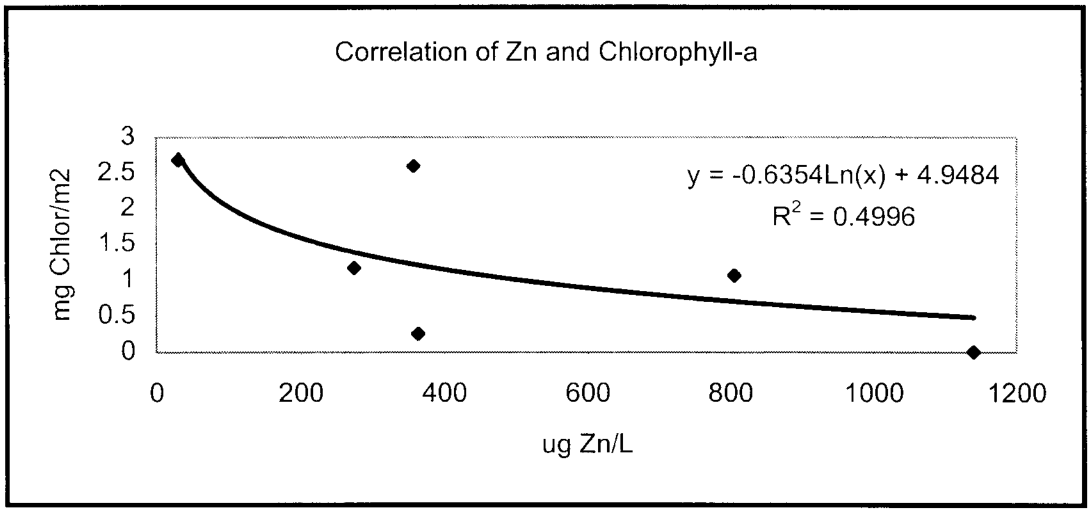
Although concentrations of metals in the water may not be the only factor controlling periphyton communities, concentrations of chlorophyll-a are lowest in sites with the highest concentrations of Zn or Cd (Figure 41). Although the correlations of chlorophyll-a with Cd and Zn were weak (R^2=0.4 and 0.5 for Cd and Zn), previous results (Weber Scannell and Andersen 2000) identified concentrations of Cd and Zn as primary factors controlling periphyton concentrations. The strongest correlation (R^2 =0.83) was found between hardness and chlorophyll-a. Correlations between chlorophyll-a and TDS were not made because there were no TDS data from Station 20. There was no apparent correlation between chlorophyll-a and Ni, Pb, Cr, or Al.

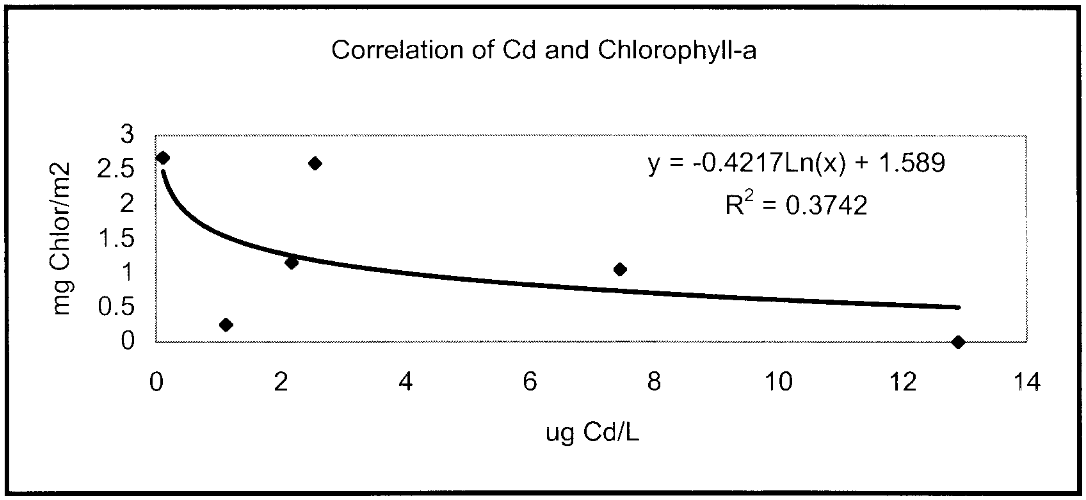
Eisler (1993) listed various algal species with the chronic toxic effect of Zn at a given concentration (Table 10). Chronic toxicity is not moderated by hardness, so hardness values are not given. The median concentrations of Zn from all sites are substantially higher than amounts reported to cause growth inhibition. The median concentration of Zn in Station 20 is from 40 times higher than the

Table 10. Effects of different concentrations of Zn to freshwater alga species. Data from Eisler (1993).

Species	Zn, ppb	Effect
Freshwater alga		
Selenastrum capricornutum	30	Some growth inhibition in 7 days
S. cupricornutum	40-68	95% growth inhibition in 14 days
S. capricornutum	100	100% growth inhibition in 7 days
Diatom		
Skeletonema costatum	19.6	Adverse effects
S. costatum	50-100	Growth reduced 20-23%, 10-15 days
S. costatum	200	Growth stimulated in 1-5 days
S. costatum	265	Metabolic disruption in 3 days
Diatom		
Thalassiosira pseudonana	65	Adverse effects
T. pseudonana	500	Growth reduced 41% in 11-15 days
T. pseudonana	823	Growth reduced 50% in 72 h
Green macroalga		
Ulva lactuca	65	BCF of 255 in 6 days

BCF = bioconcentration factor





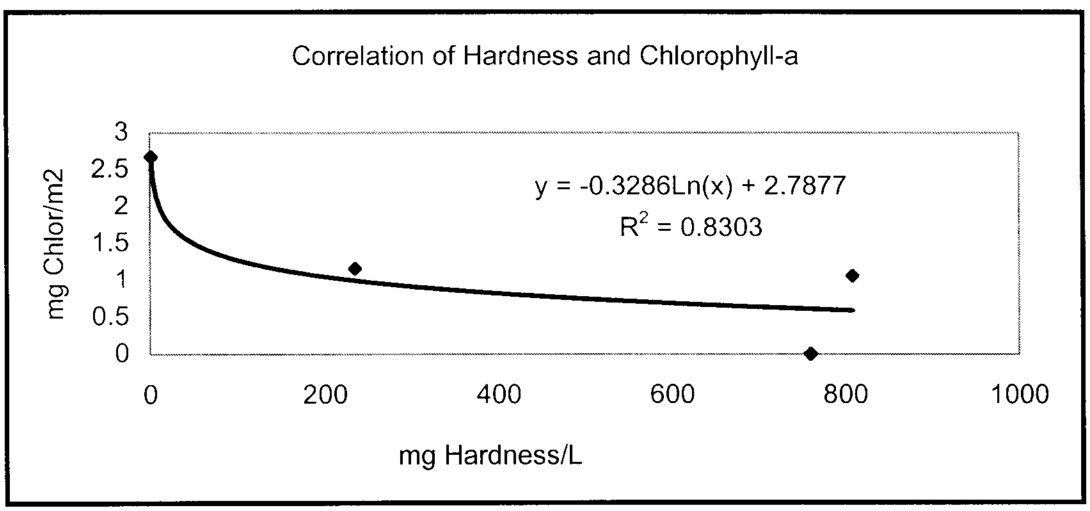


Figure 41. Correlation of Zn, Cd, and hardness with chlorophyll-a.

lowest concentration and 1.5 times higher than the highest concentration reported to cause adverse effects on algal growth.

Alabaster and Lloyd (1980) summarized literature on effects of Cd to freshwater algae (Table 11). They reported concentrations of Cd causing inhibition of algal growth that were higher than median amounts found at all sites.

Table 11. Summary of concentrations of Cd shown to cause adverse effects to freshwater algae. From Alabaster and Lloyd (1980).

Species	Concentration *ug*/L	Effect
Selenastrum capricornutum	300	lethal
	50	inhibited growth
Scenedesmus quadricuada	50-500	reduced growth
	6.1	reduction in growth
	61	severe inhibition
Lemna valvidiana	10	25% growth inhibition
	50	80% growth inhibition

Aquatic Invertebrate Communities

Five drift nets were placed in each study stream and left to collect invertebrates for one hour. The volume of water flowing through individual nets was measured and recorded. All invertebrates were counted and identified to the lowest possible taxonomic level. More mature specimens were identified to genus where northern genera were described. A complete list of the taxonomic groups identified in this study is presented in Appendix I.

Abundance of Invertebrates

The abundance of aquatic invertebrates (defined as average number of invertebrates per net) collected in June was compared among sites (Figure 42). There were significantly more invertebrates collected from North Fork Red Dog Creek than in any of the other sites (ANOVA, single factor, $P<0.001$, 34 df, Figure 43). The multiple comparison test showed that the total number of invertebrates collected from North Fork Red Dog Creek was significantly higher than all other sites. The numbers of invertebrates collected from Stations 10 and 20 and Ikalukrok Creek upstream of Dudd Creek were significantly higher than the numbers collected at Stations 7, 8, or 9 (Figure 43).

The number of invertebrates collected from each net was standardized by the volume of water flowing through each net to determine invertebrate densities. The density (as invertebrates per m^3 of water) of invertebrates collected from North Fork Red Dog Creek was significantly higher than from any of the other sites (ANOVA, $p<0.001$, Figure 44). There was no significant difference in invertebrate densities among the other sites sampled (multiple comparison test, $p>0.5$).

We compared the invertebrate density with the periphyton standing crop (as chlorophyll-a) and concentration of TDS at each site (Figures 45 and 46) and found no correlations. The density of invertebrates within a site is not predicted by the periphyton standing crop or the TDS at that site ($r^2 < 0.01$ for periphyton and $r^2 < 0.06$ for TDS).

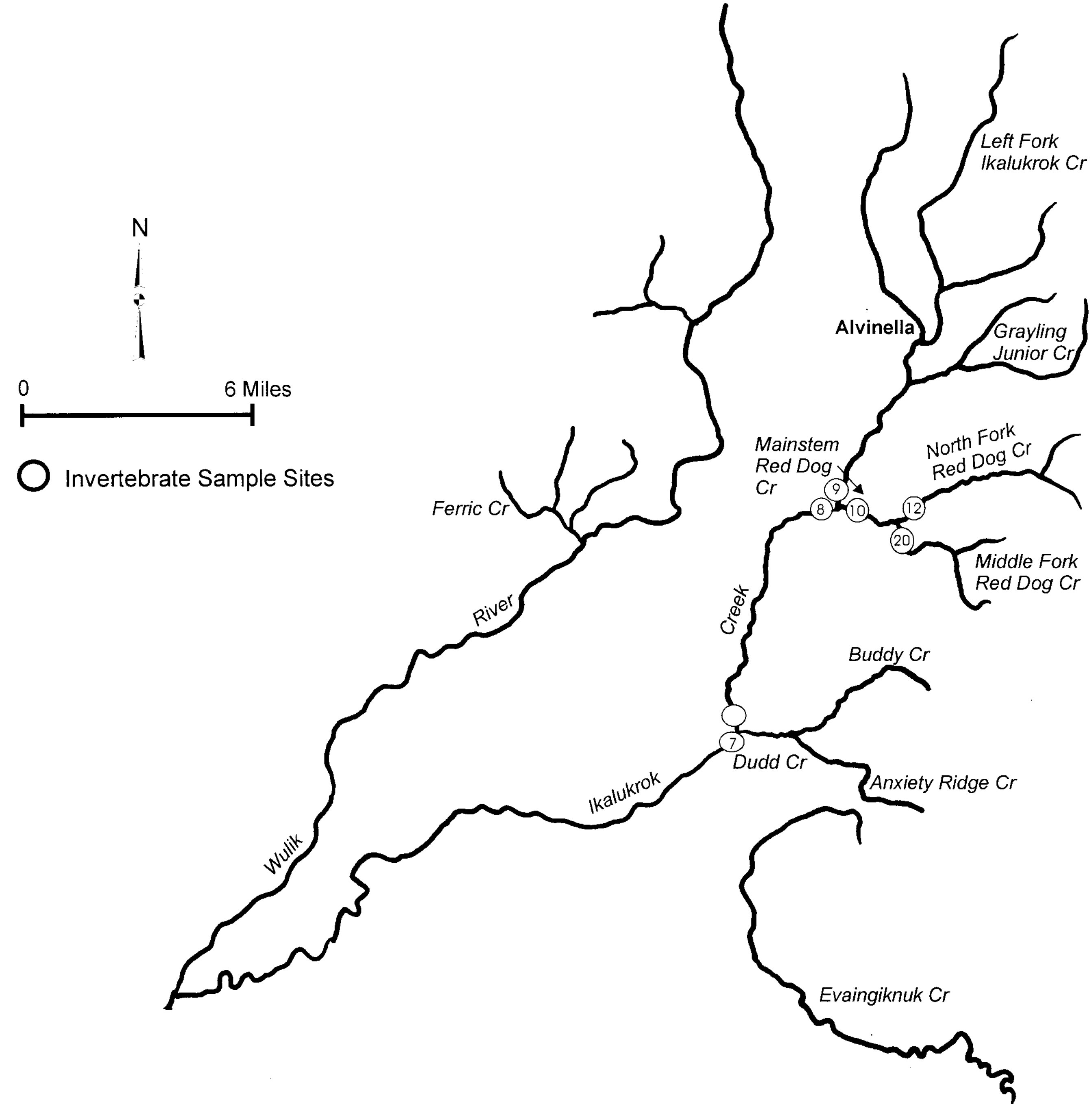


Figure 42. Location of aquatic invertebrate sample sites.

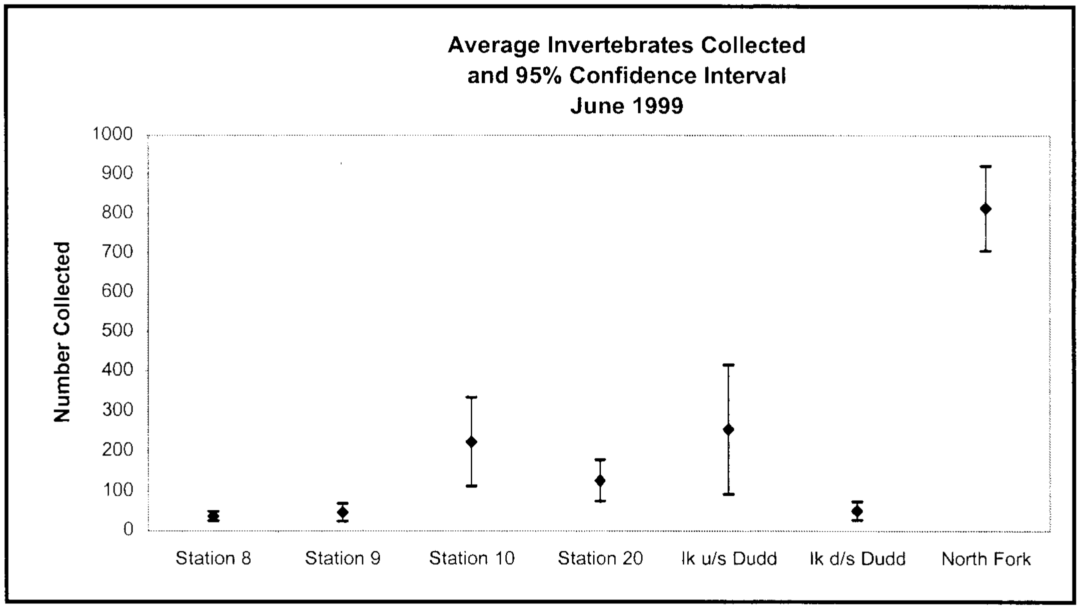


Figure 43. The abundance of aquatic invertebrates collected from sites downstream and adjacent to the Red Dog Mine.

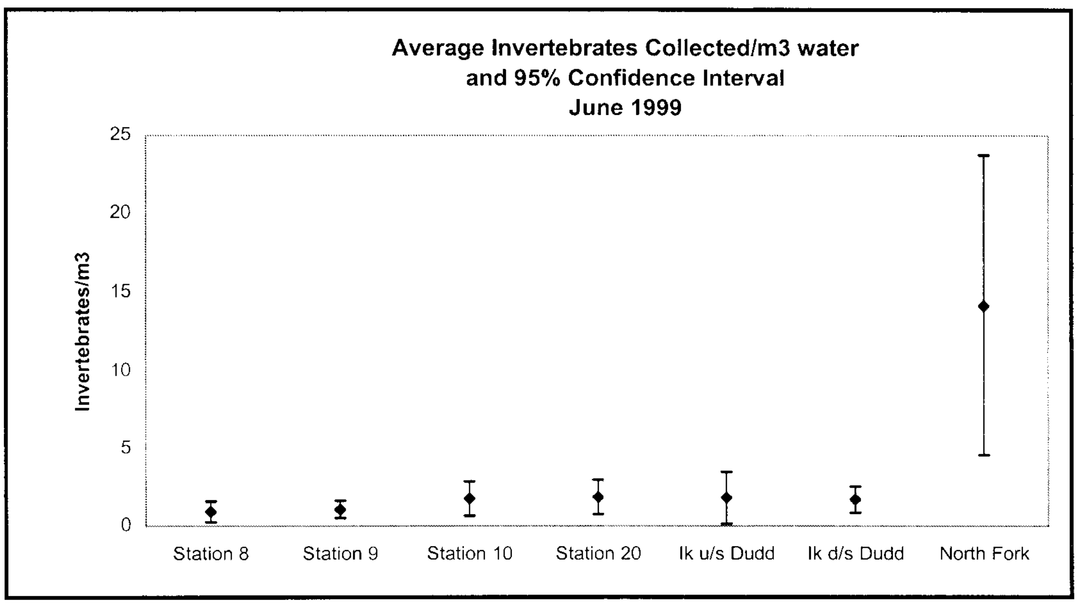


Figure 44. The density of aquatic invertebrates (as invertebrates per m^3 of water flowing through each drift net) collected from sites downstream and adjacent to the Red Dog Mine.

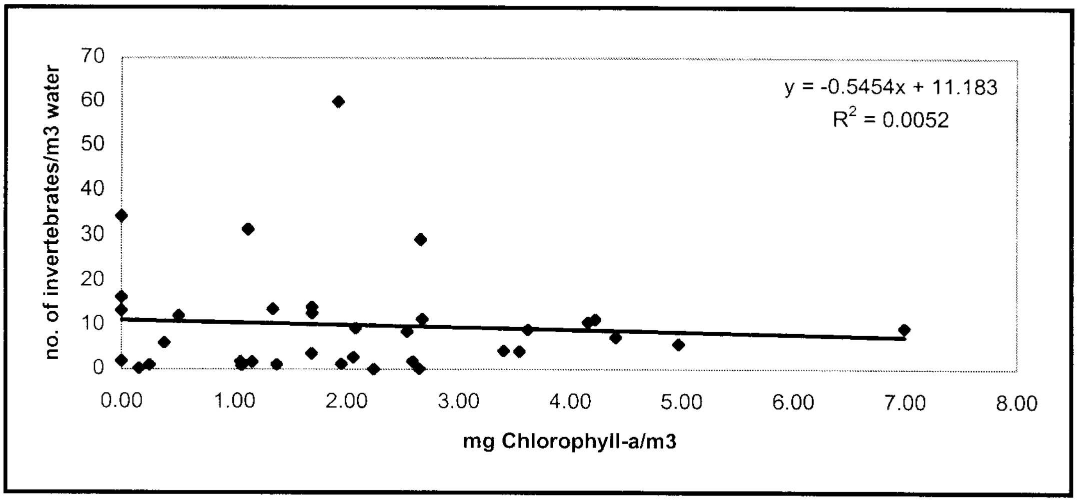


Figure 45. Comparison of invertebrate density with periphyton standing crop at each sample site.

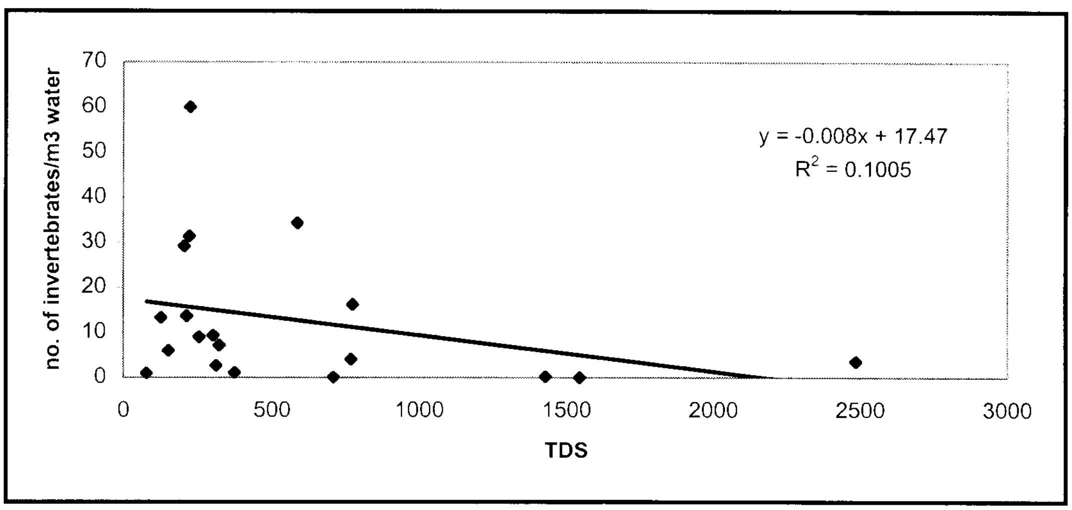


Figure 46. Comparison of invertebrate density with TDS solids at each sample site.

Structure of Aquatic Invertebrate Communities

Taxonomic richness, measured by the number of distinct taxa collected, provides an indirect measure of community diversity and complexity. The total number of aquatic taxa (usually genus) was compared among sites (Figure 47). We found no significant difference in the total numbers of taxa collected among the sites (ANOVA, $p<0.001$, Figure 47).

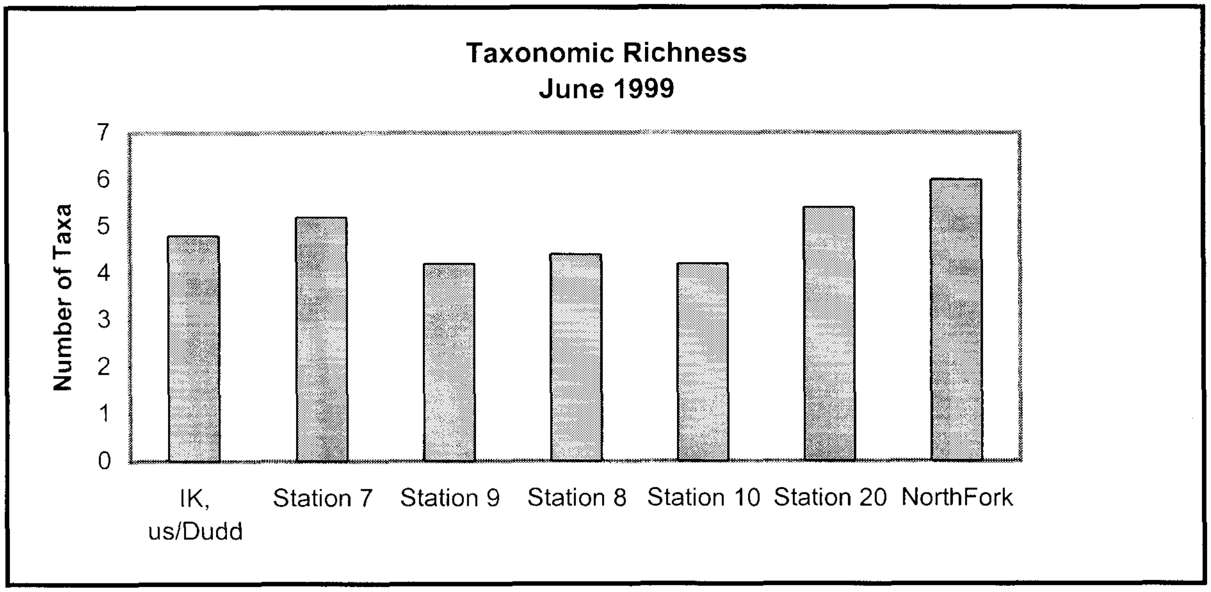


Figure 47. The taxonomic richness (as number of invertebrate taxa) collected in drift nets from sites downstream and adjacent to the Red Dog Mine.

Although taxonomic richness was similar among sites, the contribution of different groups varied. The aquatic invertebrate community (excluding terrestrial forms) was dominated by Diptera, primarily Chironomidae, with a few Simulidae and Tipulidae (Figure 48). Sites in Ikalukrok Creek (both upstream and downstream of Dudd Creek), and Stations 8 and 9 and 10 contained from 15 to 25% Plecoptera, almost exclusively Capniidae. Few Plecoptera were collected from Station 20 or North Fork Red Dog Creek.

Stations 9, 20 and North Fork Red Dog Creek contained the highest proportions of Ephemeroptera, primarily Baetidae: *Baetis* with a few Heptageniidae: *Cinygmula*. Less than 1% of samples from any of the sites were Trichoptera (Brachycentridae: *Micrasema* and *Brachycentrus*). Several Limnephiloidea were found in Mainstem Red Dog Creek; however, they were too immature to identify to genus.

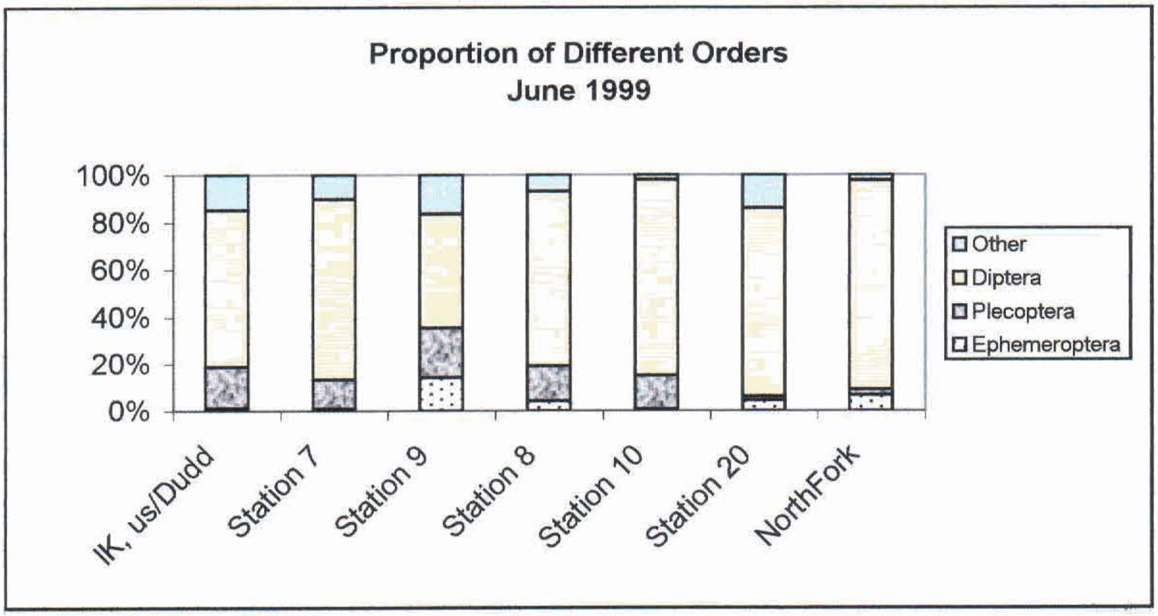


Figure 48. The community structure (proportions of invertebrates of each major taxonomic group) collected in drift nets from sites downstream and adjacent to the Red Dog Mine.

Trophic Organization

Most species of freshwater aquatic insects are omnivorous, especially in the early instars (Merritt and Cummins 1996). For example, detrital feeders also consume attached fungi, algae, and microarthropods. An alternative approach to dividing aquatic communities by food resource is to consider the methods for gathering food, based upon the morphological and behavioral adaptations of each species. This distinction was refined into functional feeding groups by Merritt and Cummins (1996) and others.

Using the functional feeding group paradigm described by Merritt and Cummins, we grouped the aquatic insect samples by feeding categories. Aquatic communities from all sites in the Red Dog Mine area were dominated by collectors/scrapers, with shredders forming a smaller, but important component (Figure 49). Both of these groups are considered to be a combination of detritivores and herbivores. Collectors filter or collect fine particles from the water column, scrapers graze from the substrate, and shredders chew larger detrital particles. Less than one percent of the communities at each of the sites was represented by carnivores.

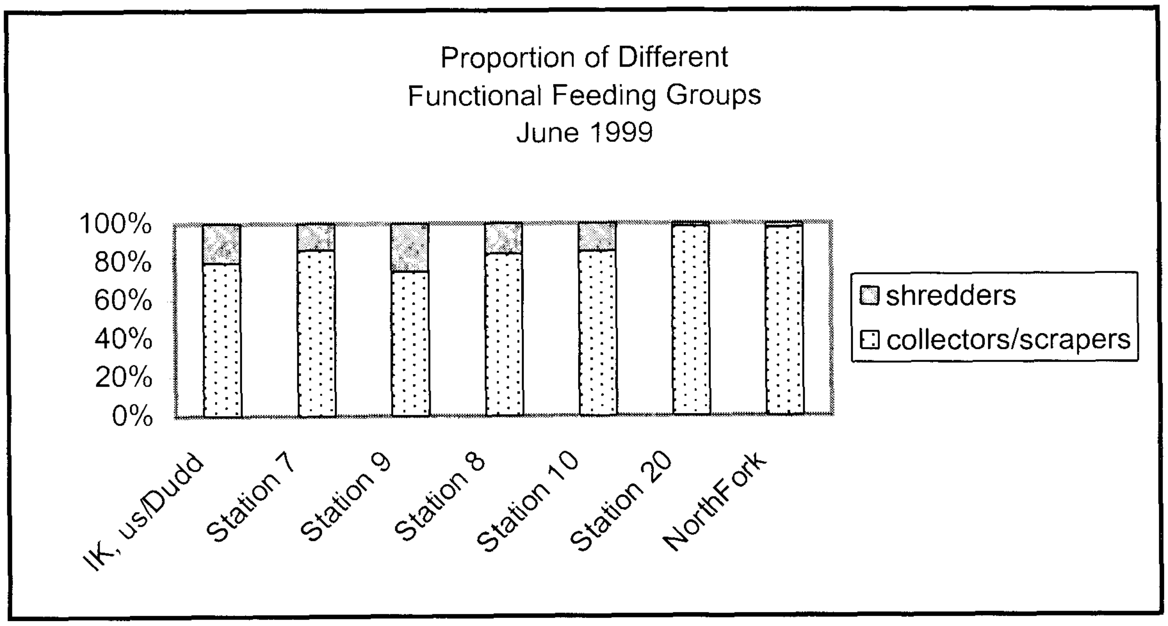


Figure 49. The trophic organization of insect communities collected in drift nets from sites downstream and adjacent to the Red Dog Mine.

Contribution of Terrestrial Species

Terrestrial insects often fall into streams where they are an important food source for drift feeding fish, such as Arctic grayling. The amount of terrestrial input depends on the abundance and type of riparian vegetation, stream flow, and the life history of individual species. Terrestrial forms of aquatic species are abundant in drift samples when the species emerge or when they collect over the water to deposit eggs.

In June 1999 the terrestrial component of the drift samples was highest in Ikalukrok Creek upstream of Dudd Creek. More than 50% of these samples were of terrestrial origin (Figure 50). (Note that in the discussion of insect abundance and densities above, the terrestrial forms were excluded.) The terrestrial input was lowest at Station 10.

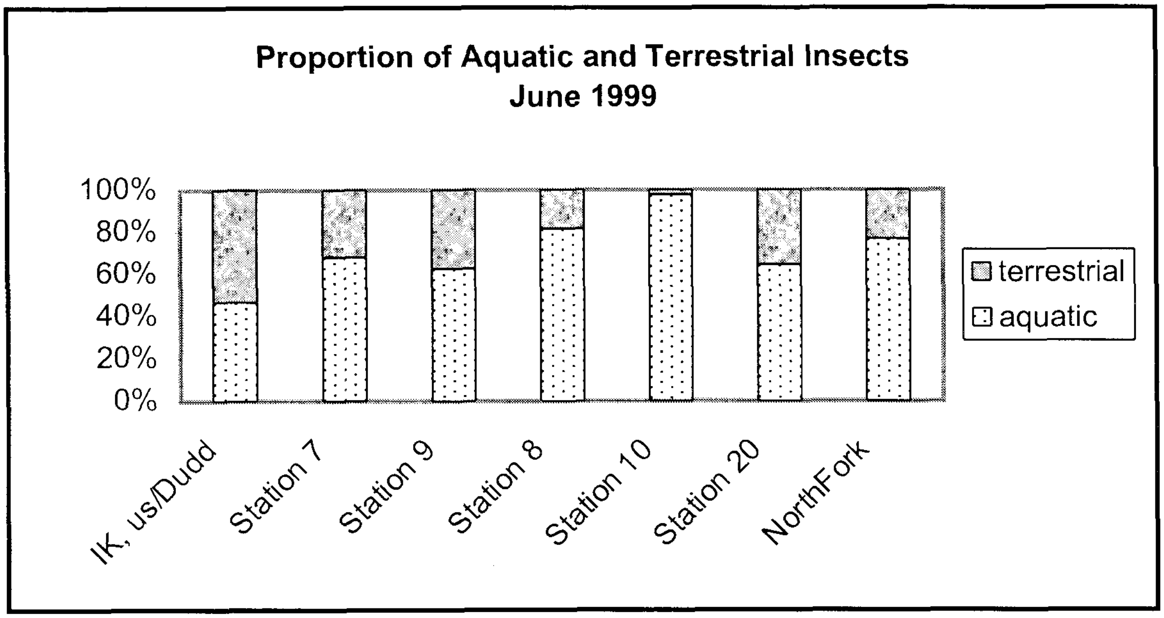


Figure 50. The proportion of terrestrial and aquatic forms in drift samples from sites downstream and adjacent to the Red Dog Mine.

METALS CONCENTRATIONS IN JUVENILE DOLLY VARDEN

Most of the streams sampled (e.g., Mainstem Red Dog Creek, North Fork Red Dog Creek, Ikalukrok Creek upstream of Dudd Creek) during the ice-free season contain little, if any, water in winter. Juvenile Dolly Varden likely overwinter in springs (e.g., Anxiety Ridge Creek), in Ikalukrok Creek below Dudd Creek, and in the Wulik River. Most juvenile fish that reside in the study area in summer probably overwinter in the Wulik River or Ikalukrok Creek. Juveniles disperse upstream to small tributaries after breakup to feed for the summer, with use peaking in late-July to mid-August. We collected juvenile Dolly Varden in early August to sample for tissues metals content. Differences in the concentrations of metals in these fish likely represent differences in the amount of metals accumulated from the summer rearing areas. In 1993, we sampled juvenile fish for whole body concentrations of Cd and Pb in Anxiety Ridge and North Fork Red Dog creeks and in 1998 in Mainstem Red Dog and Anxiety Ridge creeks. Juvenile fish collected in 1998 also were analyzed for selenium. Metals concentrations are in mg/Kg dry weight for whole body (Appendix 2).

In August 1999, we collected 10 juvenile Dolly Varden each from North Fork Red Dog, Anxiety Ridge, and Mainstem Red Dog creeks and nine from Ferric Creek. Fish selected for metals analyses were between 110 and 145 mm long (Figure 51) to constrain the sample to a similar size and age group.

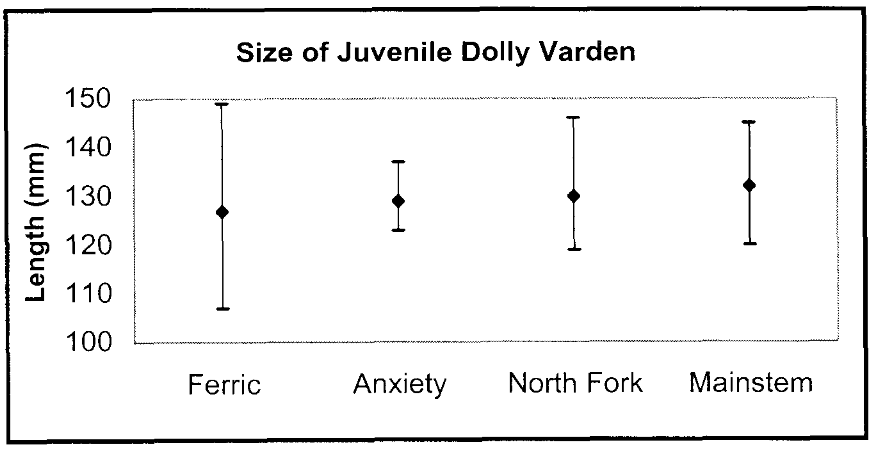


Figure 51. Maximum, minimum, and average size (mm) of juvenile Dolly Varden collected for metals analysis in summer 1999.

We compared the concentrations of Cd, Pb, and Se in juvenile fish tissues among the years sampled and among the different creeks. Juvenile Dolly Varden from Mainstem Red Dog Creek contained the highest concentrations of Cd and Pb (Figures 52 and 53). Concentrations of Se, although somewhat higher in Mainstem Red Dog Creek, were similar for all sample sites in the Red Dog Mine area (Figure 54).

Although the median concentrations of Cd were low in North Fork Red Dog Creek, one fish contained higher concentrations in 1993 (2.37 mg/Kg) and in 1999 (1.15 mg/kg). All fish collected from Anxiety Ridge and Ferric creeks had low Cd concentrations.

Concentrations of Pb in juvenile Dolly Varden were similar in the North Fork Red Dog Creek in both 1993 and 1999 and decreased slightly from 1993 to 1998 to 1999 in Anxiety Ridge Creek. Lead concentrations in fish from Ferric, North Fork Red Dog, and Anxiety Ridge creeks were lower than in fish from Mainstem Red Dog Creek.

Whole body concentrations of Se were only slightly higher in Mainstem Red Dog Creek, followed by samples from Ferric Creek. Selenium concentrations were similar in Dolly Varden collected in 1999 from North Fork Red Dog and Anxiety Ridge creeks.

We compared whole body Cd, Pb, and Se concentrations in fish collected in 1999 from streams in the vicinity of the Red Dog Mine area to juvenile salmonids collected from sites in interior Alaska. Juvenile chinook salmon (n = 20) (*Oncorhynchus tshawytscha*) from the Goodpaster River (Morsell 1999) and juvenile Arctic grayling (n = 24) from Last Chance Creek (Ott and Weber Scannell 1995) were used in the comparison. Metals concentrations for all fish were for whole body, on a dry weight basis.

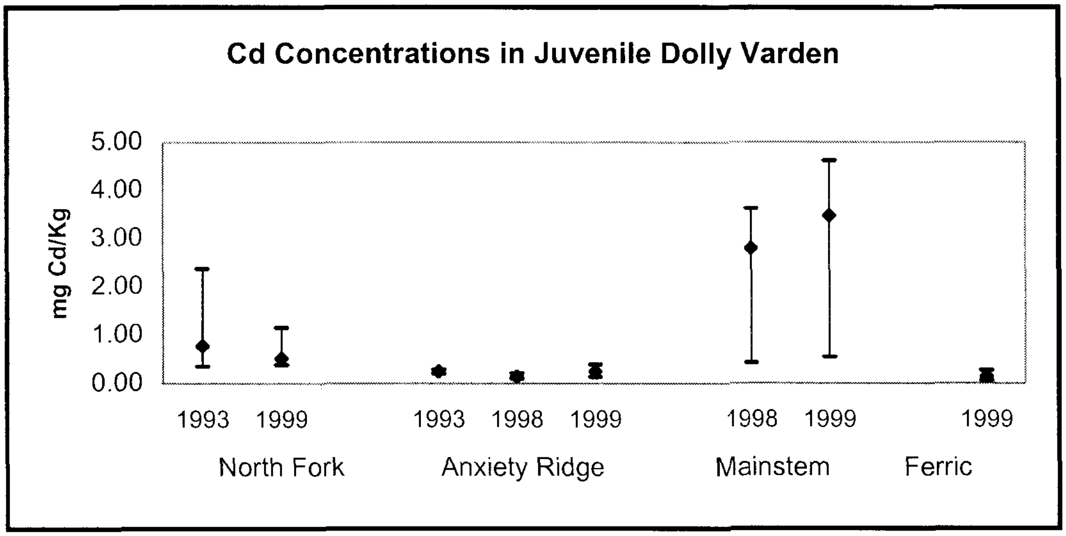


Figure 52. Median, maximum, and minimum concentrations of Cd (mg/Kg dry weight, whole body) in juvenile Dolly Varden from the Red Dog Mine area.

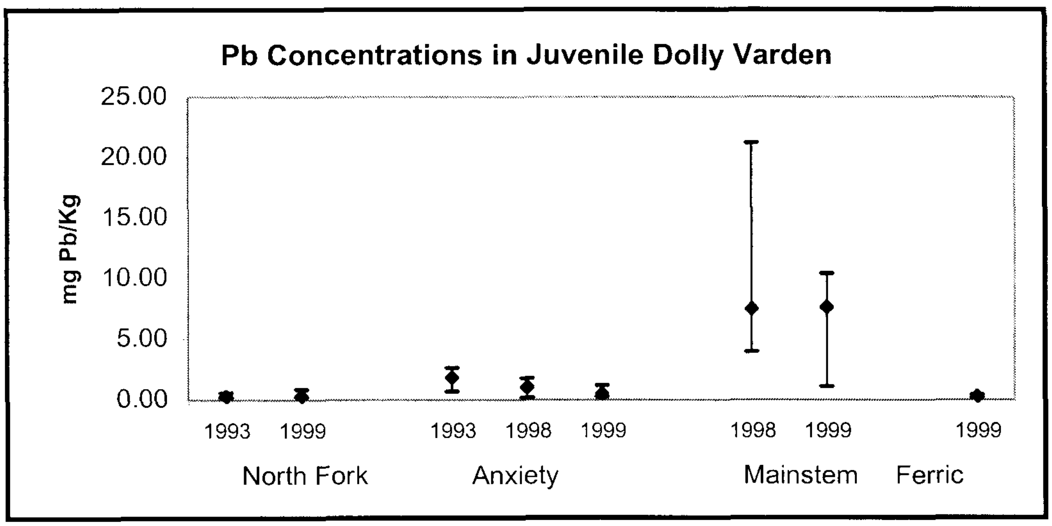


Figure 53. Median, maximum, and minimum concentrations of Pb (mg/Kg dry weight, whole body) in juvenile Dolly Varden from the Red Dog Mine area.

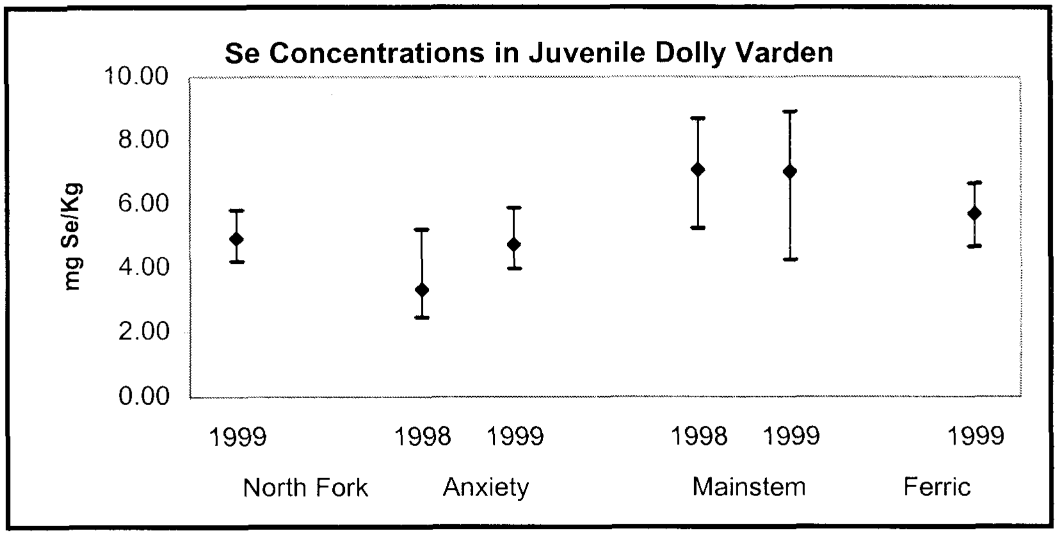


Figure 54. Median, maximum, and minimum concentrations of Se (mg/Kg dry weight, whole body) in juvenile Dolly Varden from the Red Dog Mine area.

Juvenile Dolly Varden from Anxiety Ridge and Ferric creeks had whole body concentrations of Cd that were similar to those reported for chinook salmon from the Goodpaster River and Arctic grayling from Last Chance Creek (Figure 55). Concentrations of Cd in juvenile Dolly Varden from Mainstem Red Dog Creek were higher than those recorded in the other streams examined. Whole body concentrations of Pb in Dolly Varden from North Fork Red Dog, Ferric, and Anxiety Ridge creeks were similar to Pb concentrations found in juvenile chinook salmon from the Goodpaster River and juvenile Arctic grayling from Last Chance Creek (Figure 56). The highest Pb concentrations in juvenile Dolly Varden were from fish collected in Mainstem Red Dog Creek. Whole body Se concentrations in juvenile Dolly Varden from all creeks in the Red Dog Mine area were higher than Se concentrations in juvenile chinook salmon from the Goodpaster River (Figure 57). Selenium concentrations for juvenile chinook salmon from the Goodpaster River were at or below the detection limit (1.0 mg/Kg).

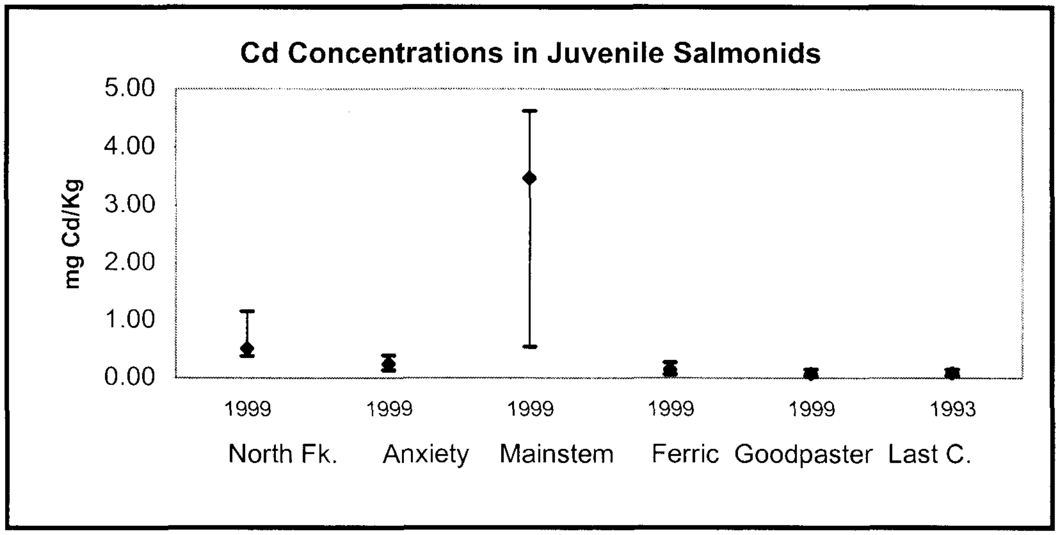


Figure 55. Median, maximum, and minimum Cd concentrations (mg/Kg) in juvenile Dolly Varden from the Red Dog Mine area compared with juvenile chinook salmon (Goodpaster River) and juvenile Arctic grayling (Last Chance Creek).

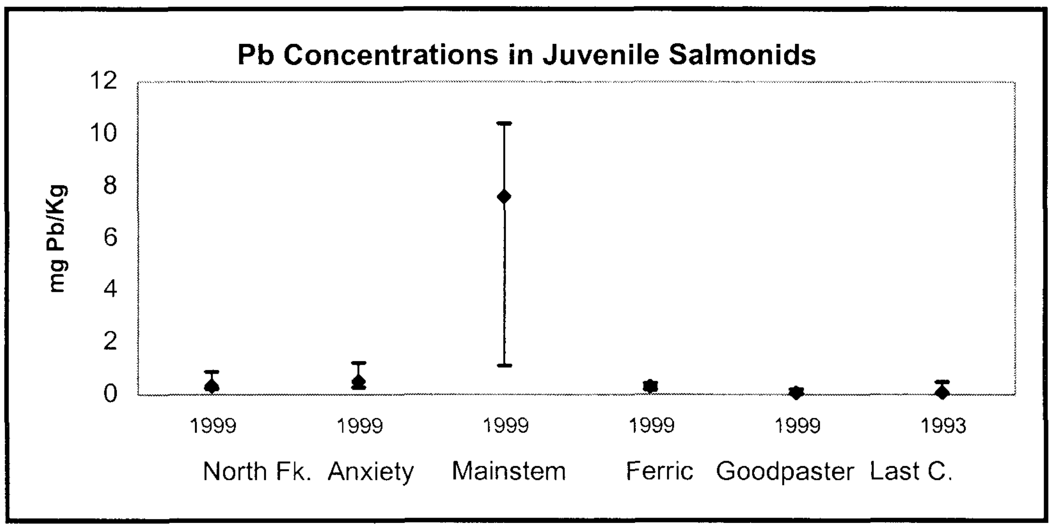


Figure 56. Median, maximum, and minimum Pb concentrations (mg/Kg) in juvenile Dolly Varden from the Red Dog Mine area compared with juvenile chinook salmon (Goodpaster River) and juvenile Arctic grayling (Last Chance Creek).

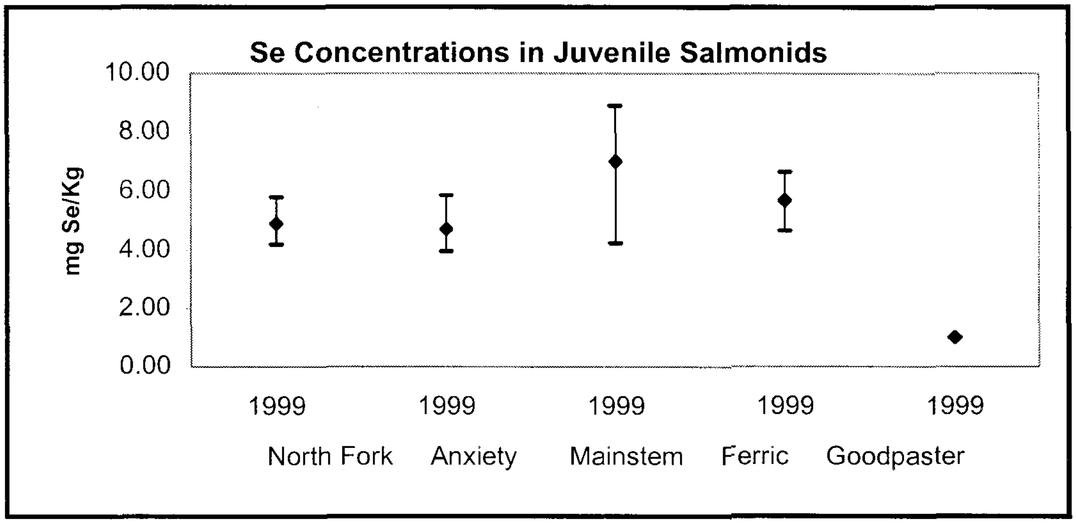


Figure 57. Median, maximum, and minimum Se concentrations (mg/Kg) in juvenile Dolly Varden from the Red Dog Mine area compared with juvenile chinook salmon (Goodpaster River).

Median concentrations of Cd in 1998 (0.12 *u*g/L) and 1999 (0.13 *u*g/L) in waters of North Fork Red Dog Creek were substantially lower than in Mainstem Red Dog Creek (7.19 *u*g/L in 1998 and 6.41 *u*g/L in 1999) (Figure 58). The Cd concentrations in whole body juvenile Dolly Varden also showed a similar pattern in these creeks (Figure 55).

Concentrations of Pb in waters from Mainstem and North Fork Red Dog creeks show a pattern similar to Cd (Figure 59). Concentrations of Pb in fish tissues displayed a similar pattern (Figure 56).

Median Se concentrations in Mainstem Red Dog Creek summer 1998 and 1999 were 2 *u*g/L. In Upper North Fork Red Dog Creek, Se was measured at 1.25 and 2.58 *u*g/L in 1999. In Ferric Creek, Se was 1.64 and 2.26 *u*g/L in 1999. Whole body concentrations of Se in juvenile Dolly Varden in Mainstem Red Dog Creek were higher than those found in fish from Ferric, Anxiety, or North Fork Red Dog creeks (Figure 54).

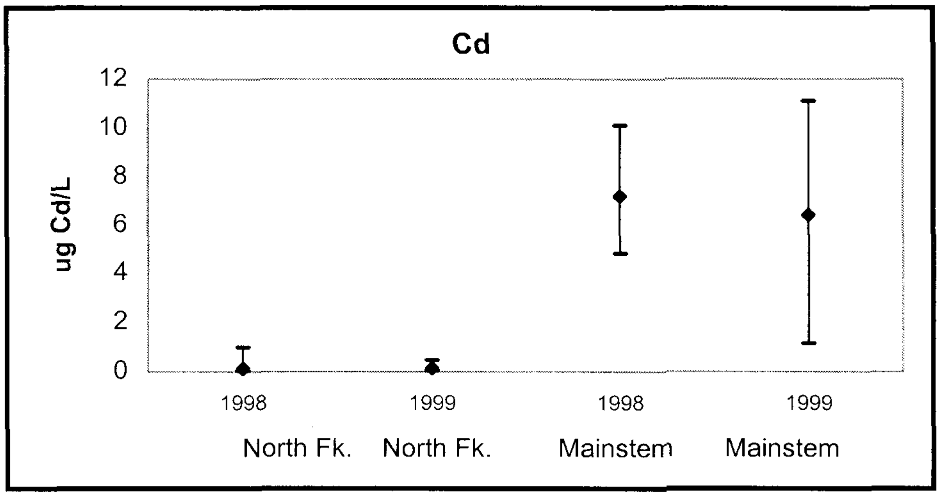


Figure 58. Median, maximum, and minimum Cd concentrations in 1998 and 1999 in North Fork and Mainstem Red Dog creeks.

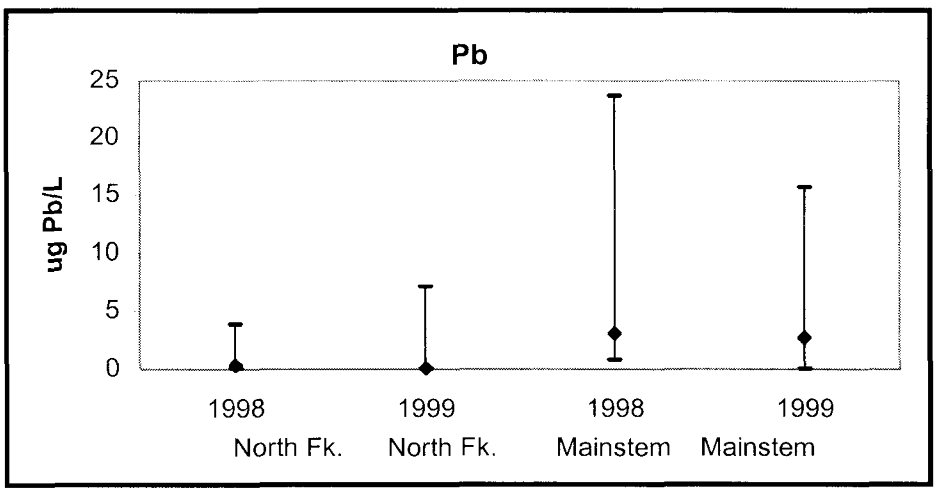


Figure 59. Median, maximum, and minimum Pb concentrations in 1998 and 1999 in North Fork and Mainstem Red Dog creeks.

Metal concentrations of Cd and Pb in juvenile Dolly Varden in the Red Dog Mine area are higher in fish collected in Mainstem Red Dog Creek. Based on available water quality data, concentrations of Cd and Pb also are higher in Mainstem Red Dog Creek. Concentrations of Cd and Pb at Station 140 (Middle Fork Red Dog Creek below the clean water bypass, but upstream of effluent outfall) were substantially higher than either the waters in the effluent outfall or North Fork Red Dog Creek (Station 12) (Figures 60 and 61). The major source of Cd and Pb in Mainstem Red Dog Creek appears to be from the clean water bypass.

Juvenile Dolly Varden in North Fork Red Dog Creek must pass through Mainstem Red Dog Creek to access the upper portion of the drainage for summer rearing; however, their Cd and Pb concentrations are lower than in Mainstem Red Dog Creek. We also see higher variability of Cd and Pb in Dolly Varden collected from Mainstem Red Dog Creek. Higher variability might be associated with the length of time these fish spent in Mainstem Red Dog Creek before entering North Fork Red Dog Creek.

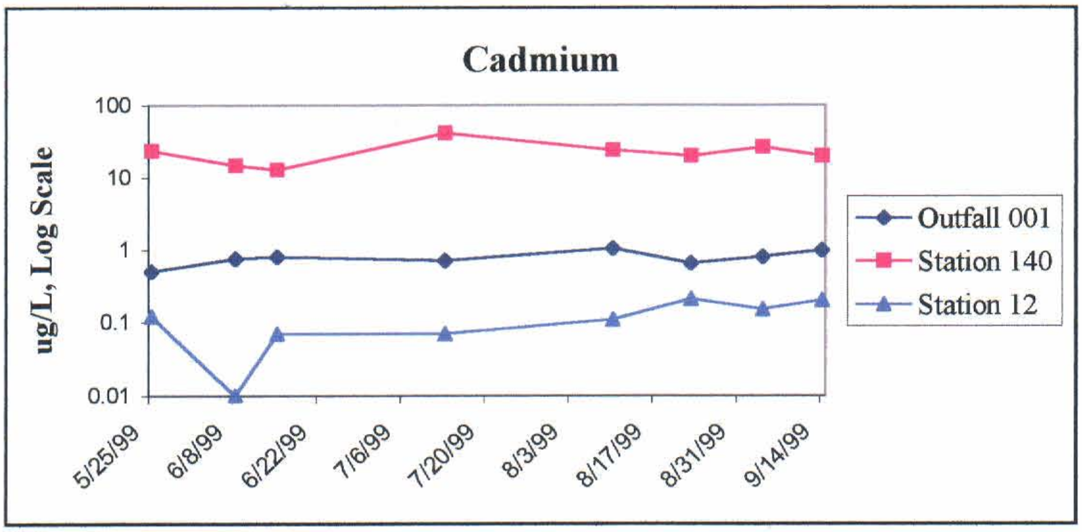


Figure 60. Concentration (*u*g/L) of Cd in water from the effluent outfall, Station 140, and North Fork Red Dog Creek (Station 12) in 1999. Data from Cominco.

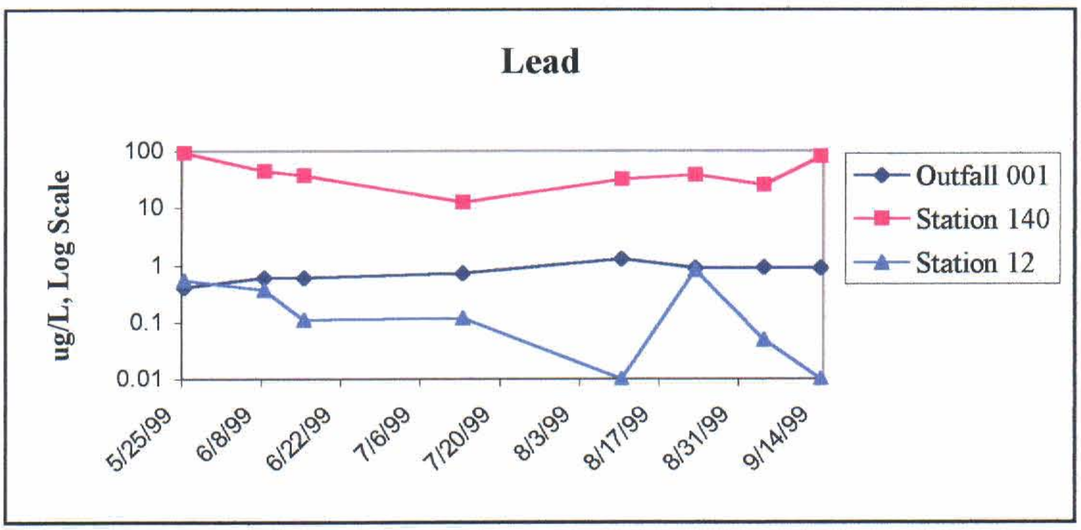


Figure 61. Concentration (*u*g/L) of Pb in water from the effluent outfall, Station 140, and North Fork Red Dog Creek (Station 12) in 1999. Data from Cominco.

Metals Concentrations in Adult Dolly Varden

Since 1990, ADF&G has sampled adult Dolly Varden from the Wulik River for metals concentrations (Al, Cd, Cu, Pb, and Zn) in gill, kidney, liver, and muscle tissue (Weber Scannell and Ott 1995, Weber Scannell and Ott 1998). We have compared metal concentrations in adult Dolly Varden tissues with baseline data collected by Dames and Moore (1983) and EVS and Ott Water Engineers (1983) with water quality conditions in the Wulik River to show long-term trends and to identify any changes in metal concentrations that may be related to operation of the Red Dog Mine. Metals monitored in Dolly Varden tend to concentrate in specific tissues: Al, Se, and Zn are most prevalent in gill tissue, Cd and Cu in liver, and Pb in both liver and kidney. Although certain tissues may have the highest concentrations, especially during periods when metals concentrations are high in the stream water, they are not necessarily the best indicators of metals accumulation for long-term monitoring. Fish sample groups are shown in Appendix 3 and data for concentrations of Al, Cd, Cu, Pb, Se, and Zn for all tissues monitored are presented in Appendix 4.

Gill Tissue

In 1998 and 1999, Cd and Pb concentrations in gill tissues were similar. Lead concentrations, although low, were slightly higher than pre-mining (Figures 62 and 63). Median Cd concentrations have remained lower than baseline data with the exception of fall 1990 to fall 1991. The higher median concentrations for both Cd and Pb in gill tissue in 1990/1991 and 1994/1995 coincide with changes in water quality at the mine. In spring 1991, the bypass and mine sump drainage ditches were constructed and in late fall 1995 the system was extended upstream to intercept water from Hilltop Creek. These improvements in water management were followed by lower Cd and Pb concentrations in gill tissues.

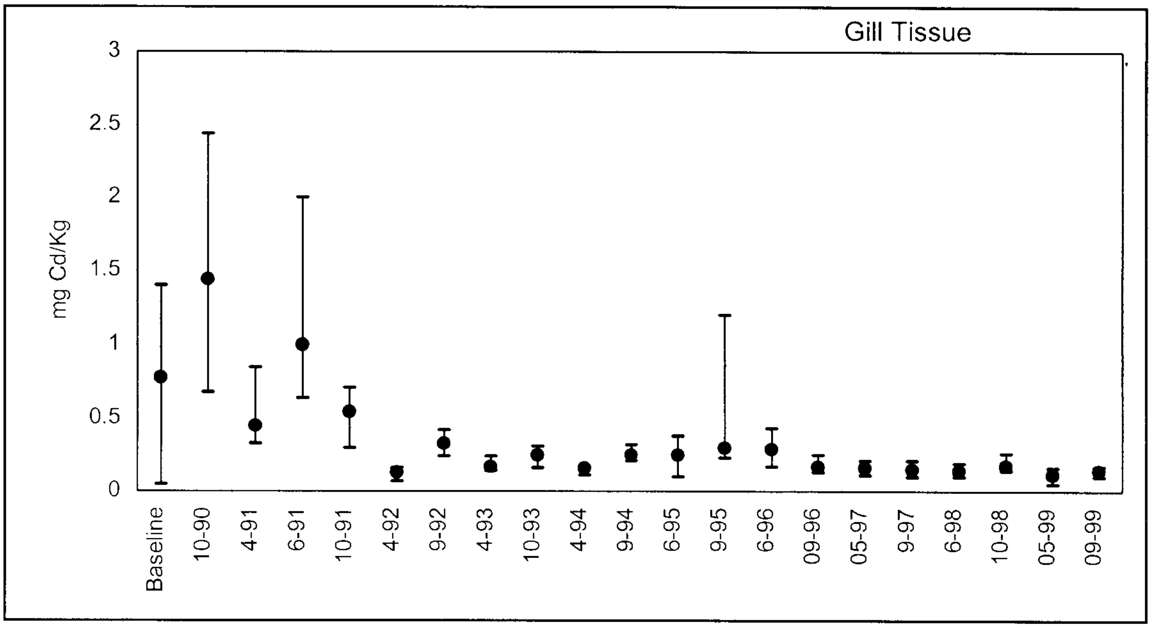


Figure 62. Median, maximum, and minimum concentrations of Cd (dry weight basis) in adult Dolly Varden gill tissue, Wulik River, baseline and 1990-1999.

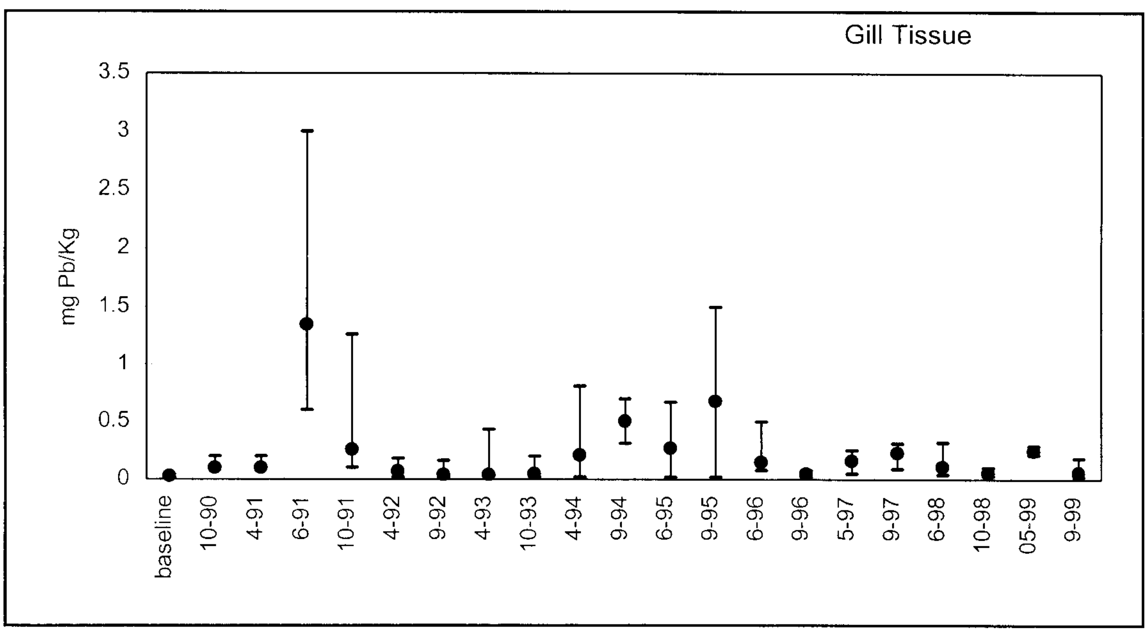


Figure 63. Median, maximum, and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden gill tissue, Wulik River, baseline and 1990-1999.

Kidney Tissue

Cd concentrations in kidney tissue of Dolly Varden have varied considerably since opening of the Red Dog Mine. However, median concentrations of Cd continue to be below values found during baseline data collection (Figure 64) with one exception, the June 1991 sample. After 1991, median concentrations of Cd in kidney were higher from fall 1995 through spring 1997, and fall 1998 through spring 1999 (Figure 64).

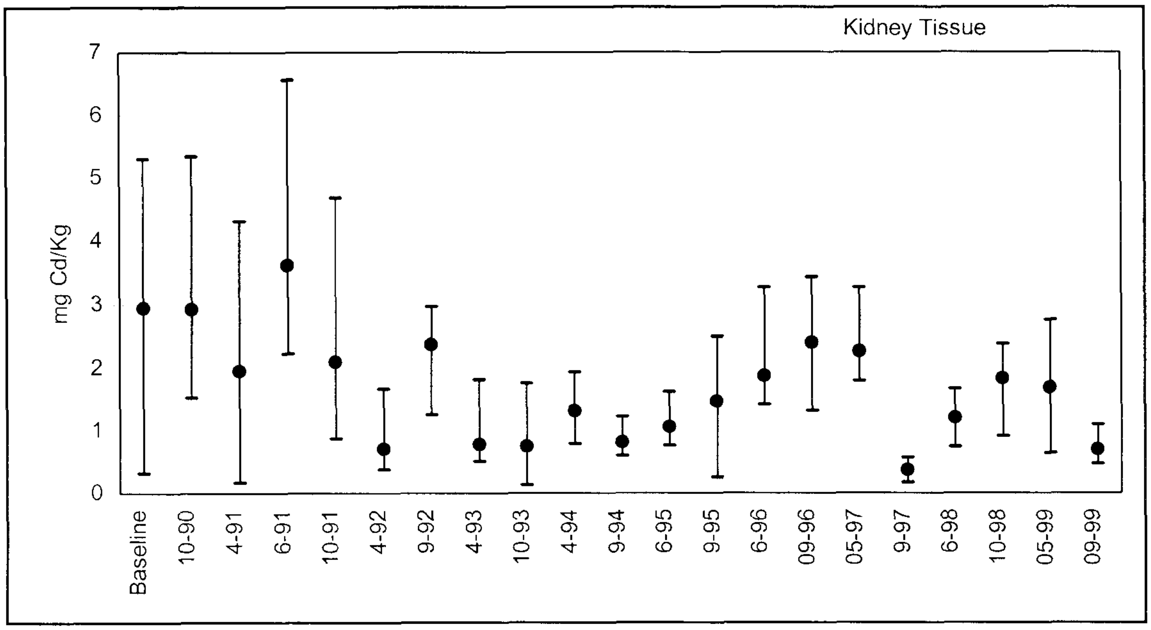


Figure 64. Median, maximum, and minimum concentrations of Cd (dry weight basis) in adult Dolly Varden kidney tissue, Wulik River, baseline and 1990-1999.

Pb concentrations in kidney tissue have remained low with a slight increase in median concentrations in 1991 and for the spring 1999 Dolly Varden sample (Figure 65). Median concentrations of Pb reported for most sample events were nearly identical to values found during baseline sampling.

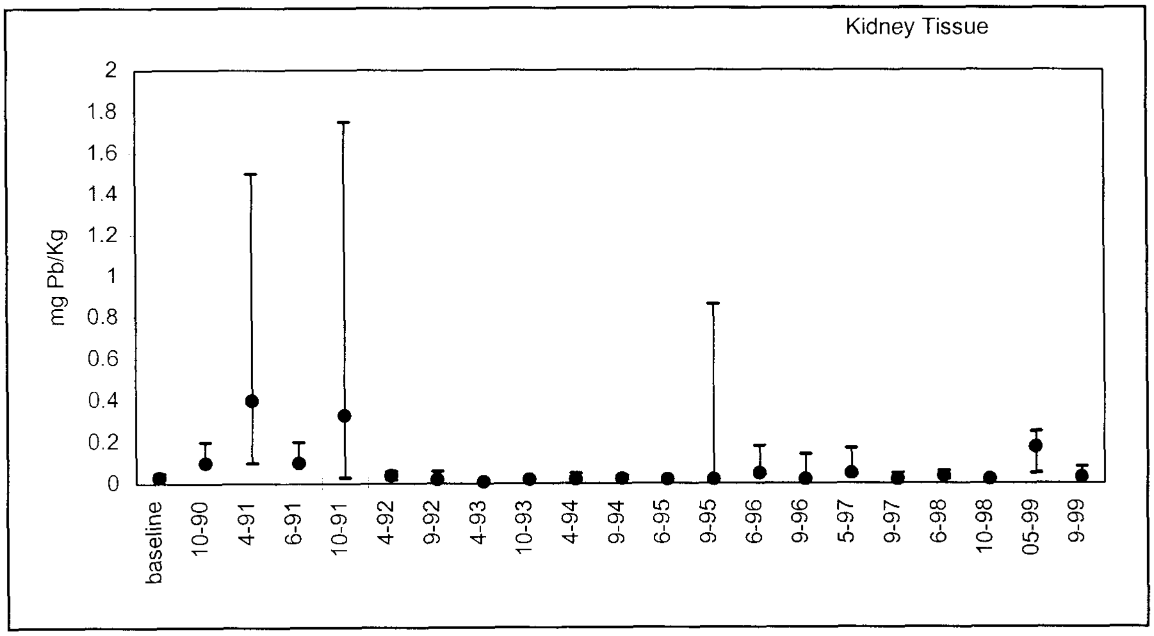


Figure 65. Median, maximum, and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden kidney tissue, Wulik River, baseline and 1990-1999.

Liver Tissue

In 1998 and 1999, the median Cu concentrations in Dolly Varden liver were higher than those reported in baseline data (Figure 66). With one exception (fall 1997), the median Cu concentrations have remained higher than baseline. Trends in concentrations of Cu in liver appear to parallel events at the Red Dog Mine and in Ikalukrok Creek drainage upstream of the mine. Higher values are reported in the 1990/1991 (before construction of the bypass), 1995 (before extension to capture Hilltop Creek), and from 1998 to 1999. Visual effects (iron stained streambed, discolored water) from Alvinella located on Left Fork Ikalukrok Creek were seen first in summer 1997.

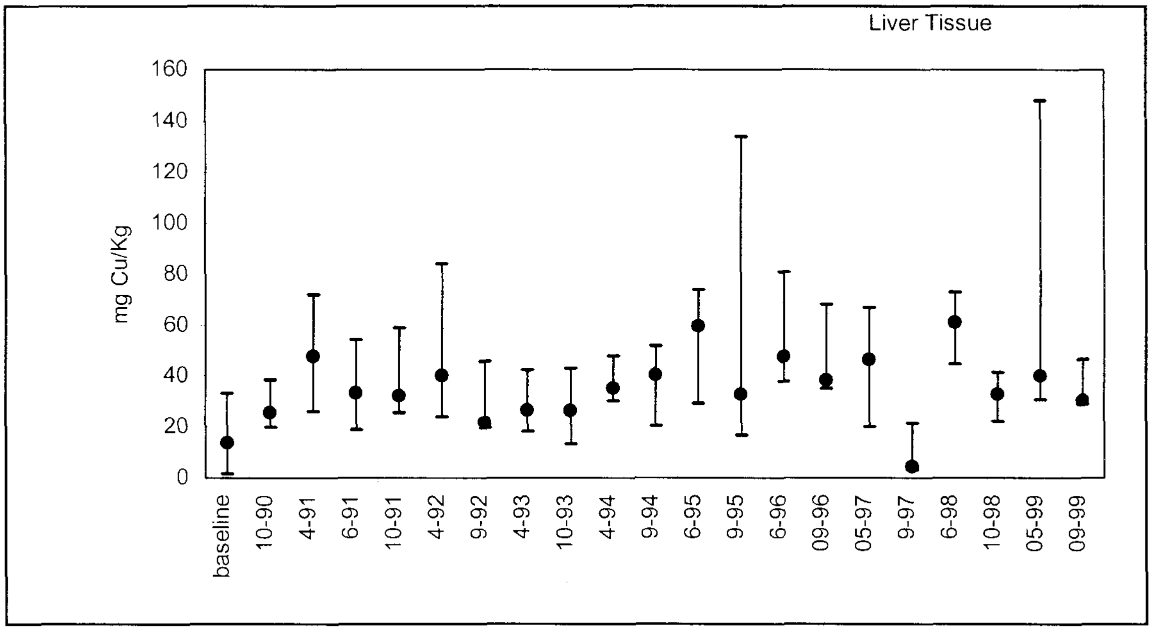


Figure 66. Median, maximum, and minimum concentrations of Cu (dry weight basis) in adult Dolly Varden liver tissue, Wulik River, baseline and 1990-1999.

Muscle

Not one of the metals being monitored tends to accumulate in muscle tissue (Figures 67 and 68). Median concentrations of Cd in muscle tissue have been stable since monitoring began in 1990 (Figure 67) and were lower than baseline. Generally, Pb median concentrations in muscle were similar to baseline data with median concentrations elevated slightly in 1990/1991, fall 1995, and spring 1999 (Figure 68).

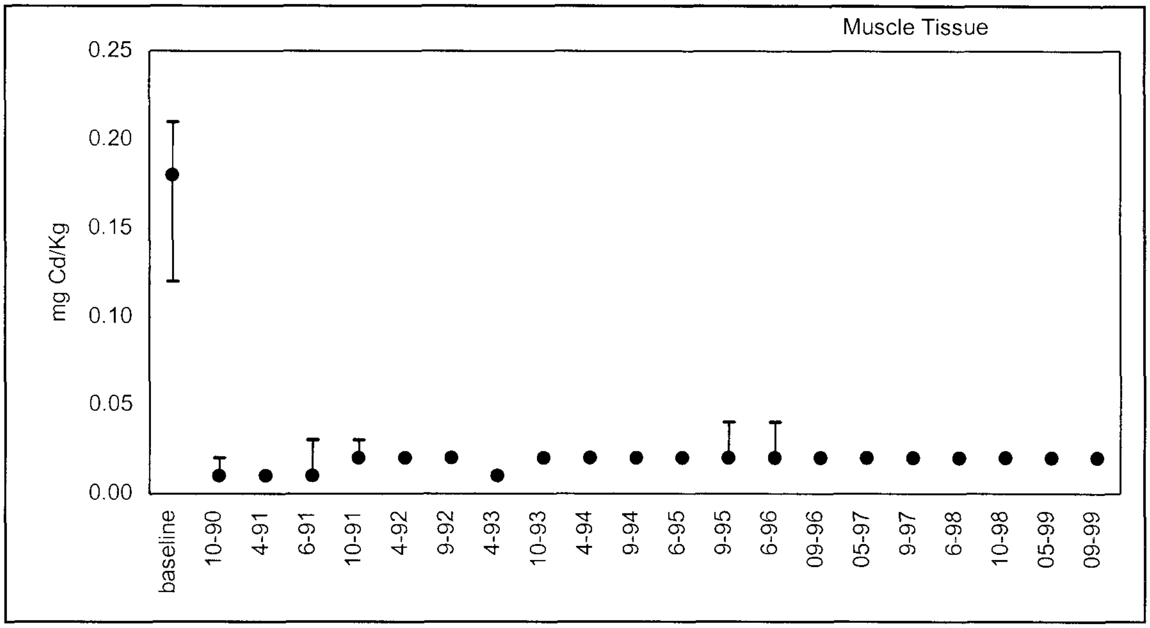


Figure 67. Median, maximum, and minimum concentrations of Cd (dry weight basis) in adult Dolly Varden muscle tissue, Wulik River, baseline and 1990-1999.

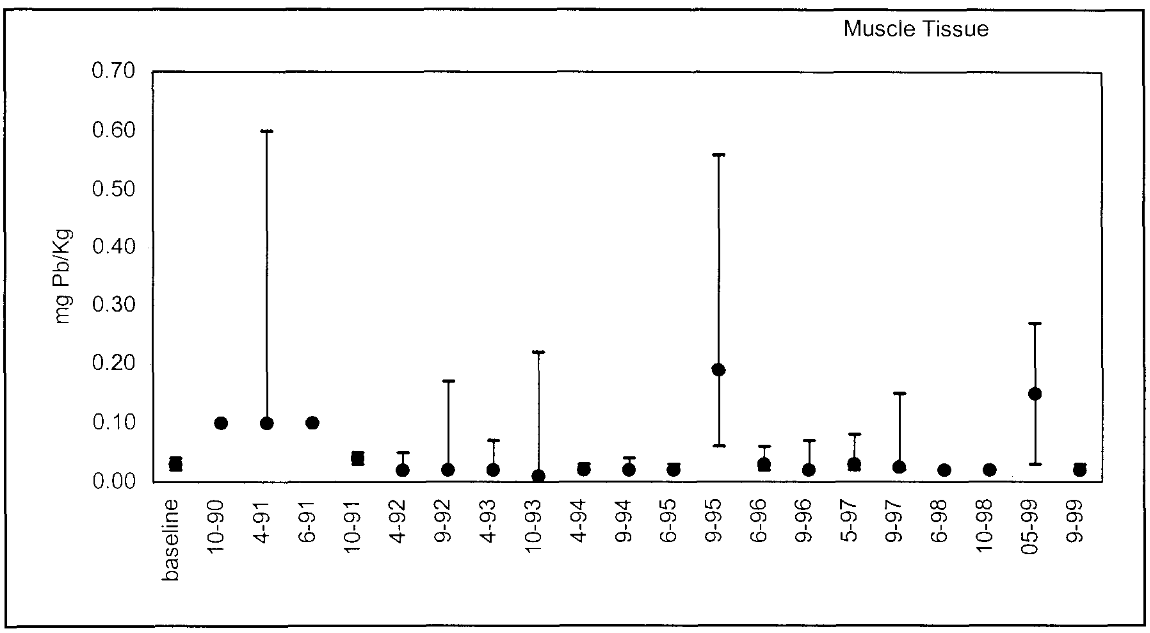


Figure 68. Median, maximum, and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden muscle liver tissue, Wulik River, baseline and 1990-1999.

Reproductive Tissue

In spring 1997, we began analyzing Dolly Varden tissues for Se. Median, maximum, and minimum Se concentrations in reproductive tissues were higher in fall-caught fish than in fish caught after spending the winter in fresh water (Figure 69). This suggests that Se is being incorporated into reproductive tissue as these tissues develop in the marine environment.

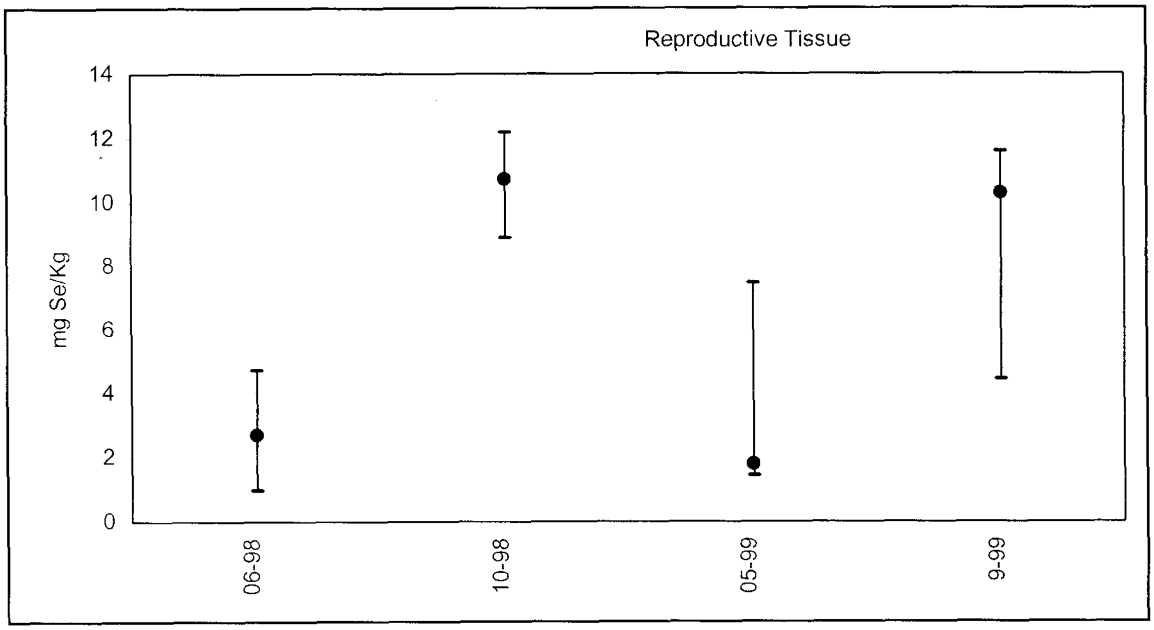


Figure 69. Median, maximum, and minimum concentrations of Se (dry weight basis) in adult Dolly Varden reproductive tissue, Wulik River, 1997-1999

Overwintering Dolly Varden

The number of Dolly Varden counted in fall 1998 and 1999 was 104,043 and 70,704 (DeCicco 1998, 1999) (Figure 70, Table 12). Numbers of Dolly Varden counted in the Wulik River during fall surveys have ranged from a low of 30,853 in 1984 to a high of 144,138 in 1993. Fluctuations in numbers appear to be related to weather conditions during the survey and to the time these fish enter the Wulik River for overwintering. In some years, most of the fish appear to enter the river late in the fall and may be missed during the annual survey. We found no increase or decrease in numbers of Dolly Varden that correspond to development and production at the Red Dog Mine. Over 90% of Dolly Varden continue to occur in the Wulik River below the mouth of Ikalukrok Creek in late September and early October (Table 12).

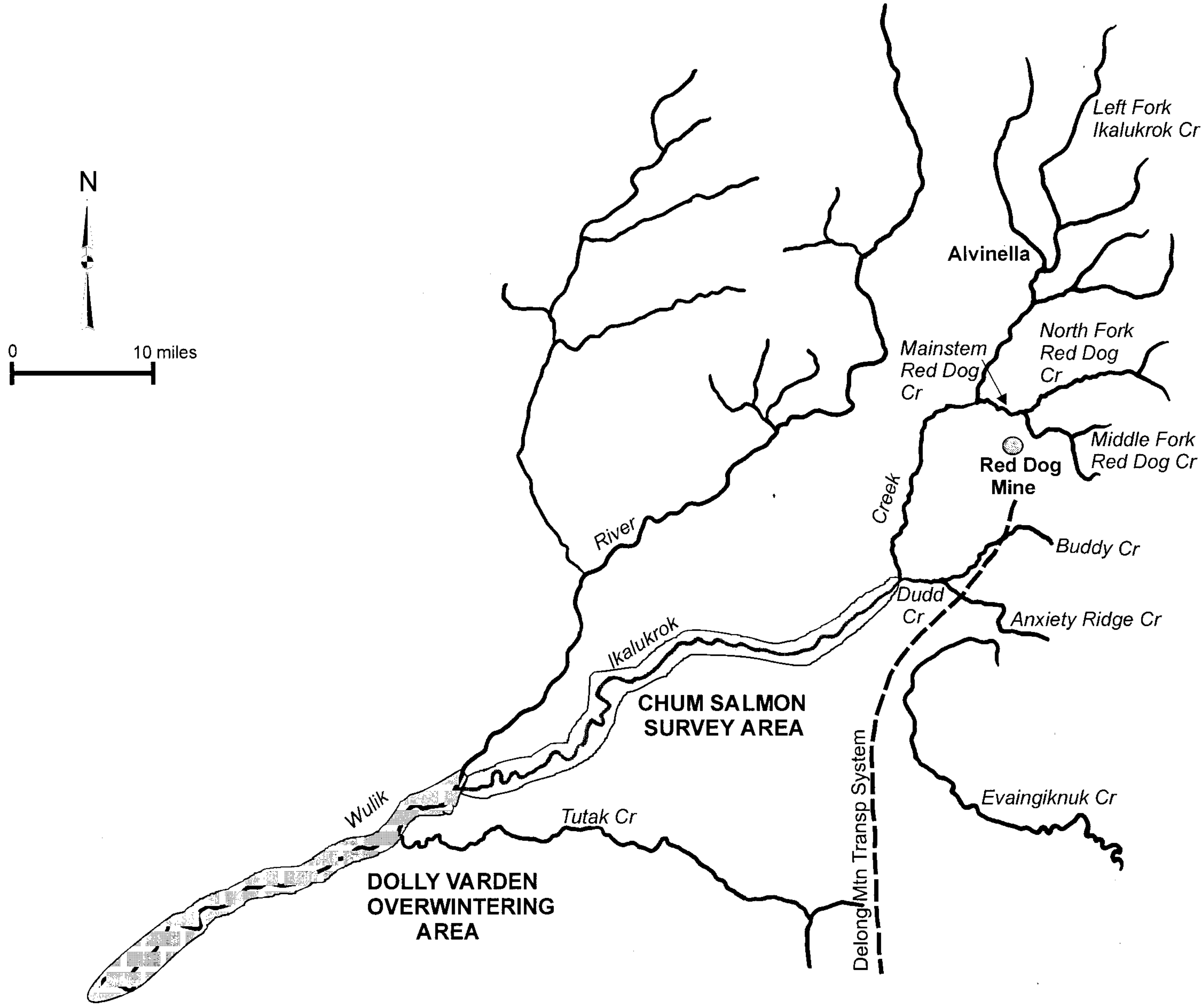


Figure 70. Aerial survey areas for overwintering Dolly Varden in Wulik River and chum salmon spawning in Ikalukrok Creek.

Table 12. Number of overwintering adult Dolly Varden in the Wulik River before freezeup. Surveys conducted by ADF&G (DeCicco 1989 and 1991-1999).

Year	Wulik River upstream of Ikalukrok Creek	Wulik River downstream of Ikalukrok Creek	Total Fish	Percent of Fish downstream of Ikalukrok Creek
Pre-Mining, including Mine Construction				
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	[1]80,144	98
Mine Production				
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	[2]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

[1]The population estimate (mark/recapture) for winter 1988/1989 for fish >400 mm was 76,892 (DeCicco 1990a).

[2]The population estimate (mark/recapture) for winter 1994/1995 for fish >400 mm was 361,599 (DeCicco 1996b).

Chum Salmon Spawning

Our objective was to count and assess distribution of adult chum salmon in Ikalukrok Creek downstream of Dudd Creek (Figure 70). Aerial surveys in fall 1998 could not be done due to high and turbid water in Ikalukrok Creek. In 1999, a helicopter survey was done on August 9 and 75 chum salmon were observed in lower Ikalukrok Creek. Visibility in August 1999 was poor and numbers of chum salmon probably were substantially higher than reported. DeCicco (1999) conducted a fixed-wing survey of Ikalukrok Creek on September 28, 1999, and reported seeing 145 chum salmon. DeCicco's 1999 survey was conducted after the peak spawning period for chum salmon and our August 9 survey results were limited due to poor visibility, thus numbers of chum salmon in Ikalukrok Creek in fall 1999 probably were higher than reported.

Numbers of chum salmon observed in Ikalukrok Creek in 1995, 1996, 1997, and 1999 were higher than in 1990 and 1992, although in 1996 we counted only 50% of the chum salmon observed in 1995 (Table 13). Our highest count since the opening of Red Dog Mine was in August 1997 (730 - 780 fish). During the August 1997 flight, we also observed ten sockeye salmon in Ikalukrok Creek.

Counts of chum salmon made after mine development are lower than during baseline fisheries work conducted by ADF&G and by Dames and Moore (1983). Chum salmon in 1996 and 1999 were actively spawning with all redds observed in the lower 8 km of Ikalukrok Creek. In 1997, chum salmon, while concentrated in the lower portion of Ikalukrok Creek, were seen spawning in Ikalukrok Creek from the Wulik River to the mouth of Dudd Creek. Most chum salmon observed in 1996 and 1997 were spawning adjacent to cut banks. Although numbers of chum salmon spawning in Ikalukrok Creek remain lower than before mining, the chum salmon spawning population appears to be increasing.

Table 13. Number of adult chum salmon in Ikalukrok Creek downstream of Dudd Creek.

Survey Time	Number of Chum Salmon	Reference
September 1981	3,520 to 6,960	Houghton and Hilgert 1983
August/September 1982	353 and 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 1995	49	Townsend and Lunderstadt 1995
August 1995	300 to 400	DeCicco 1995
August 1996	180	Townsend and Hemming 1996
August 1997	730 to 780	Ott and Simpers 1997
August 1999	75	Ott and Morris 1999
September 1999	145	DeCicco 1999

Fish Distribution

All streams identified in the EPA NPDES permit for fish presence and use were sampled at least twice during summer 1999. Data on number of species, estimated age, size, type of species, external abnormality, and fish condition were recorded. Information is reported by species. We recorded fish presence and use of North Fork Red Dog, Mainstem Red Dog, Anxiety Ridge, Buddy, Evaingiknuk, and Ikalukrok creeks for the purpose of detecting possible aquatic community changes related to the Red Dog Mine effluent or to other natural environmental factors. Emphasis was placed on Arctic grayling and Dolly Varden, and incidental data was gathered on slimy sculpin (*Cottus cognatus*). Minnow traps were the most effective sample gear for juvenile Dolly Varden and slimy sculpin; and fyke-nets, angling, and visual observations were the most productive sampling tool for assessing Arctic grayling use.

Juvenile Dolly Varden

Limited pre-mining data for juvenile Dolly Varden distribution and use were available for Evaingiknuk, Buddy, and Ikalukrok creeks. Highest use by juvenile Dolly Varden was found in Anxiety Ridge Creek, also identified as the most productive stream system in the project area by Houghton and Hilgert (1983). Houghton and Hilgert (1983) found only one juvenile Dolly Varden, assumed to be a resident fish, in the headwaters of North Fork Red Dog Creek. Fish were observed in Mainstem Red Dog Creek within the influence of the North Fork Red Dog Creek (Dames and Moore 1983) and fish mortalities were documented in Mainstem Red Dog Creek (EVS and Ott Water Engineers 1983, Ward and Olson 1980).

Patterns of juvenile Dolly Varden use of Evaingiknuk, Anxiety Ridge, Buddy, and Ikalukrok creeks have been studied by the ADF&G annually since summer 1990. Relative numbers vary considerably among years, due in large part, to natural environmental variables (Weber Scannell and Ott 1998; Ott and Weber Scannell

1996; Weber Scannell and Ott, 1995; Ott and Weber Scannell 1994; Ott and Weber Scannell 1993, Ott et al 1992). Peak use of tributary streams (i.e., Anxiety Ridge, Buddy, North Fork Red Dog, and Mainstem Red Dog creeks) by juvenile Dolly Varden occurs from late July to mid-August.

In summer 1999, ten minnow traps were fished for juvenile Dolly Varden during two sampling events (July and August) in Evaingiknuk, Anxiety Ridge, Buddy, Upper Mainstem Red Dog, Lower Mainstem Red Dog, Ikalukrok below Dudd, Ikalukrok above Dudd, Ikalukrok below Mainstem Red Dog, and Ikalukrok above Mainstem Red Dog creeks (Figure 71). Additional sampling was conducted in Upper Mainstem Red Dog Creek, immediately below North Fork Red Dog Creek, where traps were fished for five periods. We also sampled the headwaters of North Fork Red Dog, Left Fork Ikalukrok, and Ikalukrok creeks (above Alvinella) and Ferric Creek, a Wulik River tributary.

In July and August 1999, catches of juvenile Dolly Varden were highest in Anxiety Ridge and Buddy creeks. Most juvenile Dolly Varden handled were in good to excellent condition; one deformed (probably broken spinal column, appeared to be an old injury) juvenile Dolly Varden was caught in Buddy Creek in July and August. We caught 945 juvenile Dolly Varden (55 - 162 mm) in 100 minnow traps fished for about 24 hours in early August (Figure 72, length frequency August 1992 through 1999). Length at age work done by DeCicco (ADF&G) indicates most of these Dolly Varden are age 1 and 2 with some older fish and a few young-of-the-year starting to show in the catch (i.e., 59 mm fish). Overall abundance of juvenile Dolly Varden increased substantially from 1997 to 1998 and again from 1998 to 1999 - essentially doubling each year with strong young-of-the-year recruitment in both 1997 and 1998, but less in 1999.

We sampled Mainstem Red Dog Creek with ten minnow traps, just below North Fork Red Dog Creek, on June 29, July 9, July 13, July 24, and August 10. We caught 11, 19, 45, 23, and 86 juvenile Dolly Varden. Larger Dolly Varden were present in late June with young-of-the-year found first in late July (Figure 73).

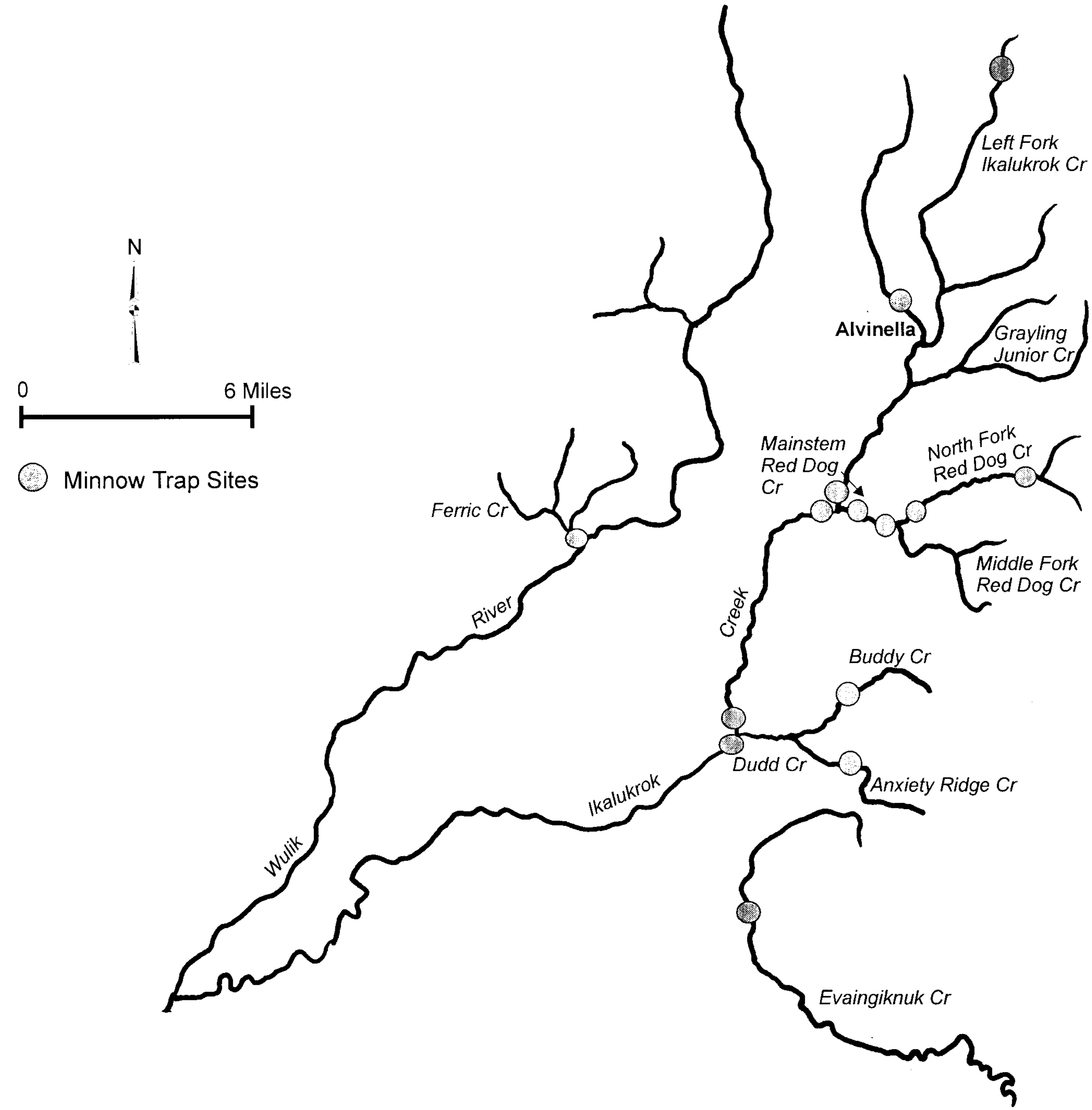


Figure 71. Minnow trap sample sites in the vicinity of the Red Dog Mine.

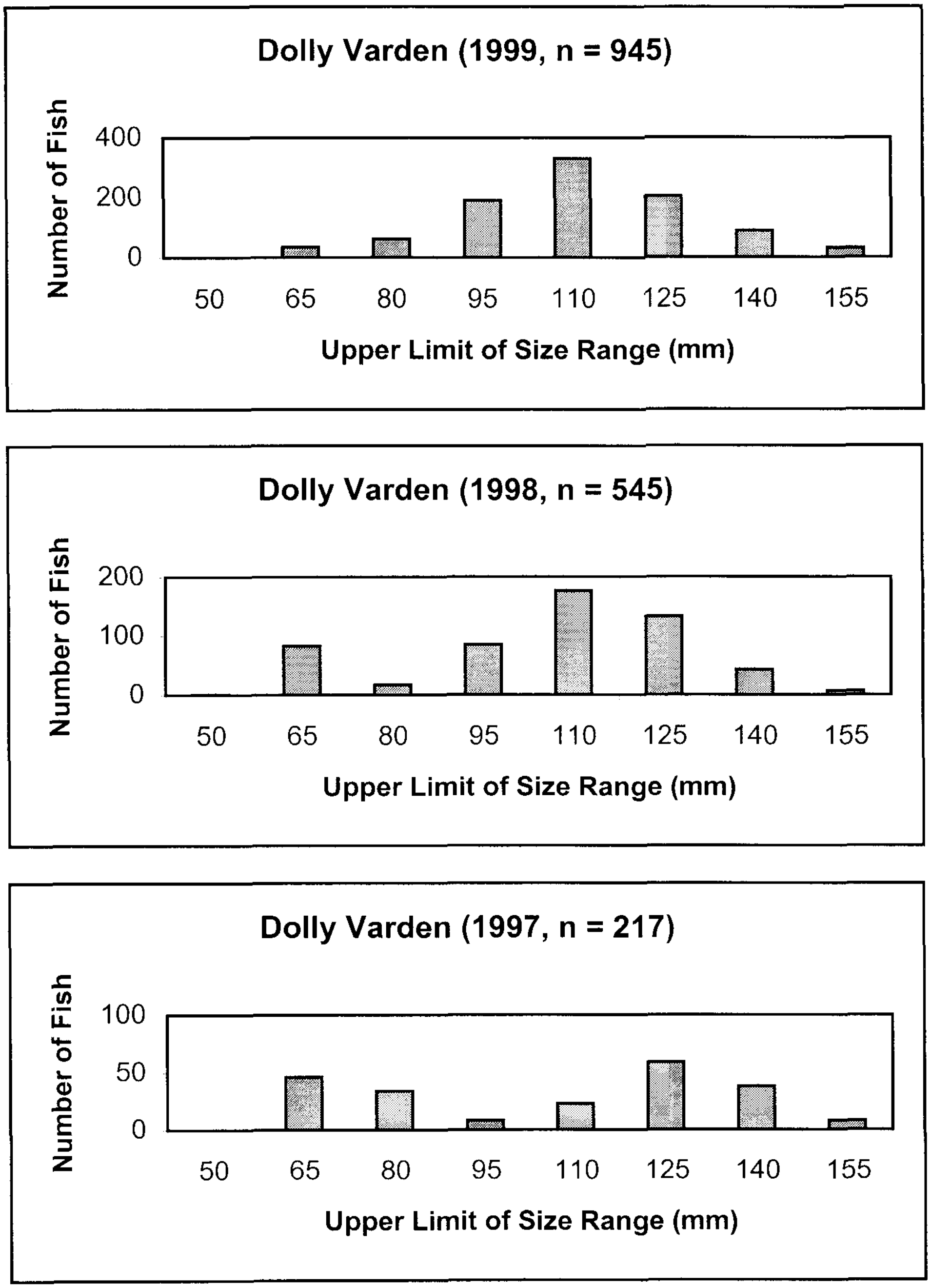


Figure 72. Length-frequency distribution of juvenile Dolly Varden in August, 1992-1999.

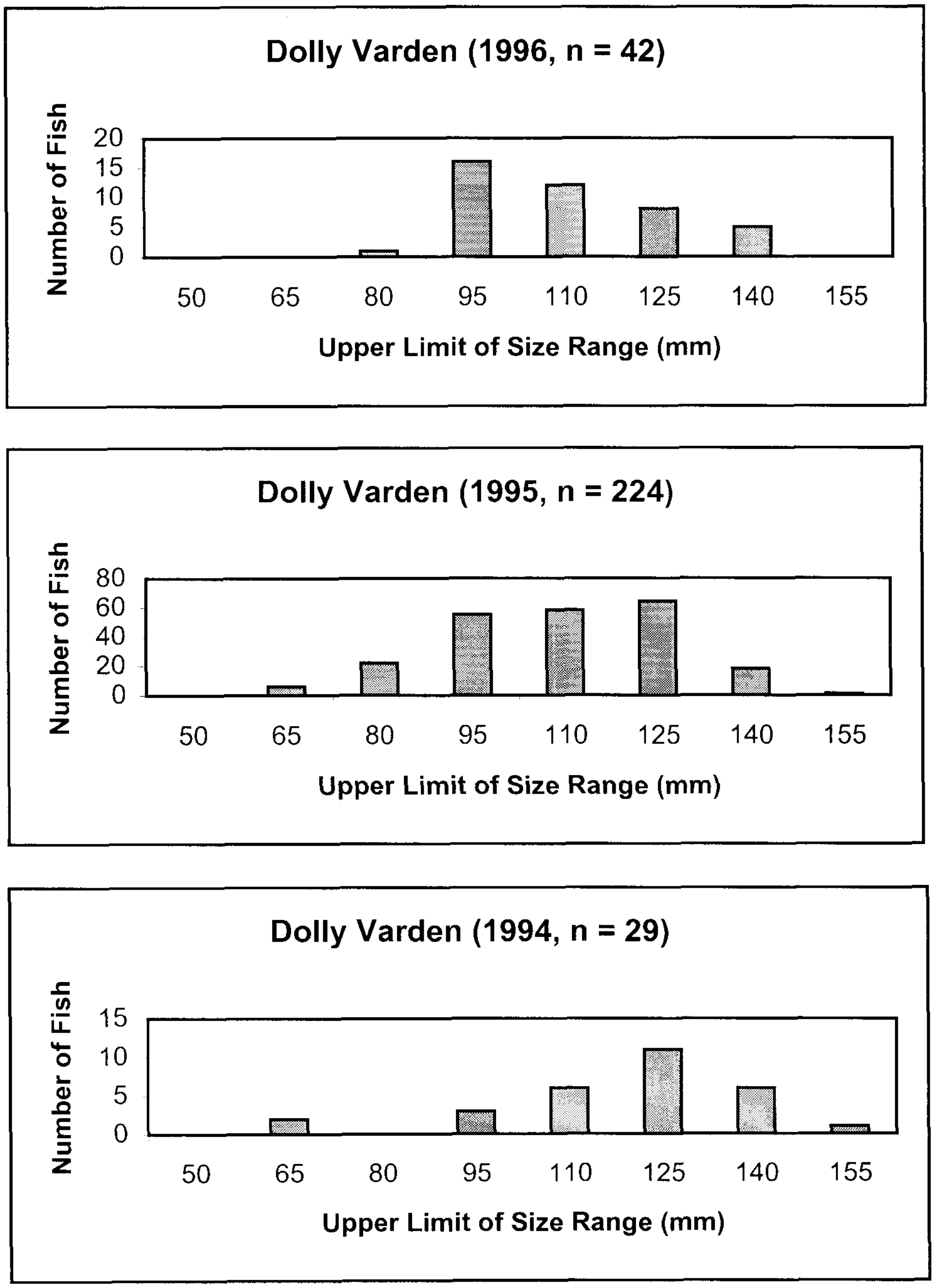
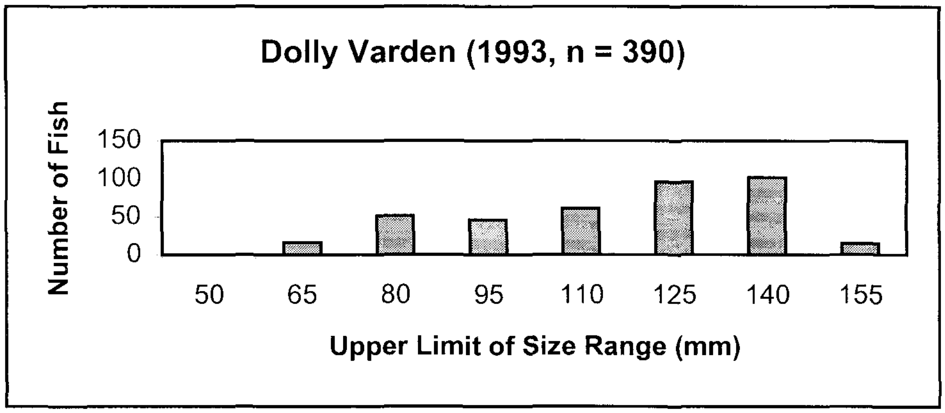


Figure 72. (continued).



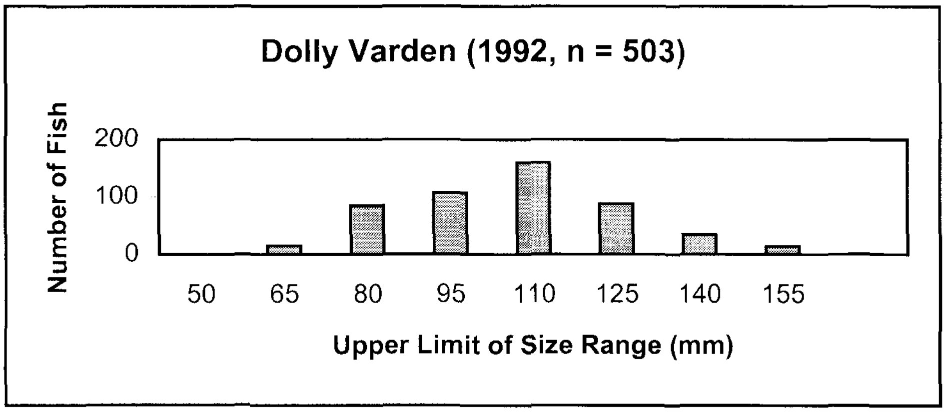


Figure 72. (concluded).

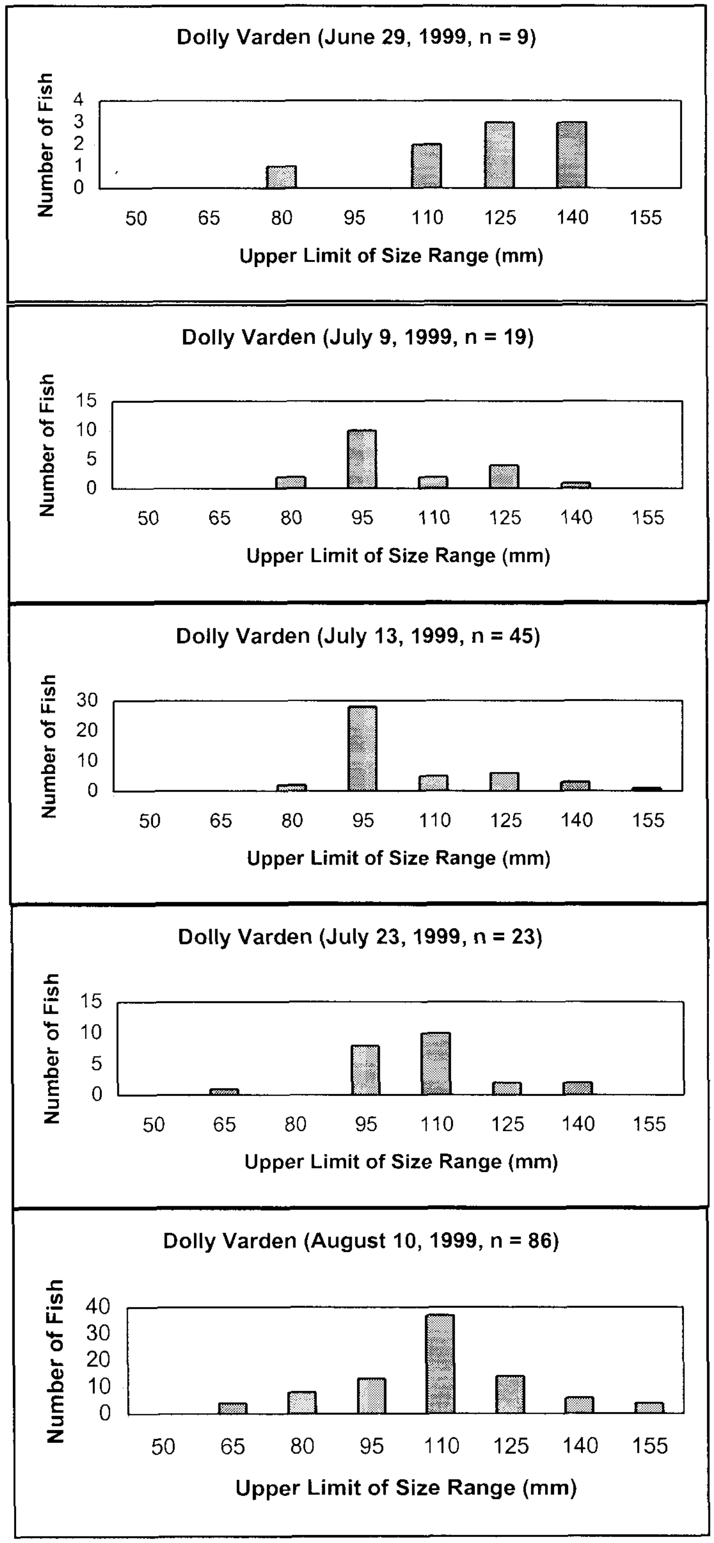


Figure 73. Length-frequency distribution of juvenile Dolly Varden in Mainstem Red Dog Creek from late June to early August, 1999.

Distribution of juvenile Dolly Varden in August was dominated by fish from 95 to 110 mm. In 1997, 1998, and 1999, the catch of juvenile Dolly Varden in Mainstem Red Dog Creek, just below North Fork Red Dog Creek, was 14, 70, and 86.

The length-frequency distributions for juvenile Dolly Varden collected in August 1999 from Anxiety Ridge, Buddy, and Mainstem Red Dog creeks are shown in Figure 74. Young-of-the-year Dolly Varden (fish < 80 mm) were more abundant in Anxiety Ridge and Buddy creeks, but also were present in Mainstem Red Dog Creek. Proximity to known Dolly Varden spawning areas in Anxiety Ridge Creek below the confluence with Buddy Creek, and in Buddy Creek explains the higher number of young-of-the-year fish. Even though the number of fish caught is lower in the two Mainstem Red Dog Creek sample sites, the general size distribution is very similar among these creeks.

Opaque water was visible in the Right Fork of Ikalukrok Creek below the Alvinella seep. Rocks were stained red in Ikalukrok Creek and the discolored water continued down Ikalukrok Creek to about 3.2 km (2.0 miles) below the mouth of Mainstem Red Dog Creek. The visual effects, discolored water and rocks stained red, have been observed in summers 1998 and 1999. In July 1999, we sampled Ikalukrok Creek above the Alvinella seep and the upper portion of the Left Fork of Ikalukrok Creek just below a waterfall. The Left Fork of Ikalukrok Creek is clear, without noticeable staining. We fished five traps at each site for 24 hours, but did not catch any fish. We did not observe any fish in Right Fork Ikalukrok Creek, but Arctic grayling adults were abundant in the Left Fork in deep scour pools within a narrow-width portion of the river.

On July 13, 1999, we caught 10 juvenile Dolly Varden (93-137 mm) in five minnow traps in the headwaters of North Fork Red Dog Creek about 7.2 km (4.5 mi) upstream from the mouth. We fished 10 minnow traps in upper North Fork Red Dog Creek in early August 1999 catching 26 juvenile Dolly Varden.

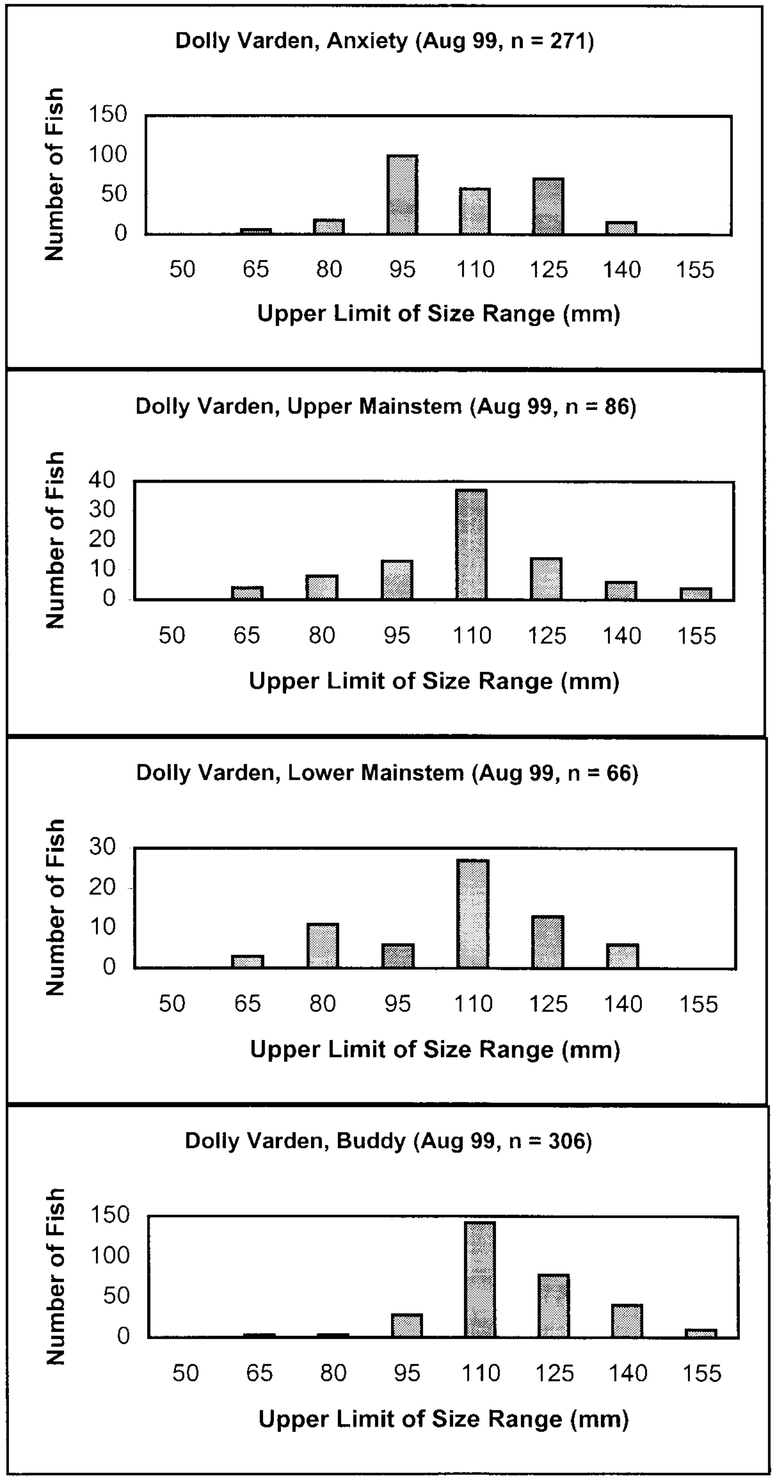


Figure 74. Length-frequency distribution of juvenile Dolly Varden collected with minnow traps in August 1999 in Anxiety Ridge, Buddy, and Mainstem Red Dog creeks.

This is the first year we sampled near the headwaters of North Fork Red Dog Creek. In August 1997 we did not catch fish in lower North Fork Red Dog Creek; however, in late September 1997, seven juvenile Dolly Varden were captured (Dusenbury 1997). We believe these Dolly Varden caught in lower North Fork Red Dog Creek were outmigrating from summer rearing areas in the headwaters.

Based on our sampling since 1990, it appears that juvenile Dolly Varden tend to migrate upstream to the headwaters for summer rearing. Generally, headwaters have higher invertebrate densities and typically, these areas rarely have adult Arctic grayling except during spring for spawning.

In August, we sampled Ferric Creek, a Wulik River tributary. Ferric Creek has a mineralized seep about 0.4 km above its confluence with the Wulik River. The mineralized seep affects water clarity turning Ferric Creek an orange-red color. We placed 10 minnow traps in Ferric Creek, just upstream of the mineralized seep, and caught 14 juvenile Dolly Varden from 57 to 149 mm.

Arctic grayling

Baseline studies reported abundant spawned-out Arctic grayling in North Fork Red Dog Creek in June 1982, and numerous young-of-the-year Arctic grayling in July 1982 (Dames and Moore 1983). Age 1 and 2 Arctic grayling were rarely found (Houghton and Hilgert 1983). Ward and Olson (1980) reported some use of the lower 1.6 km of Red Dog Creek by Arctic grayling but numbers were less than in adjacent study streams. Arctic grayling were rarely seen in Mainstem Red Dog Creek and were not reported in Middle Fork Red Dog Creek by Houghton and Hilgert (1983). Fish were observed in Mainstem Red Dog Creek within the influence of the North Fork Red Dog Creek (Dames and Moore 1983) and dead fish (Arctic grayling and Dolly Varden) were seen in Mainstem Red Dog Creek (EVS and Ott Water Engineers 1983, Ward and Olson 1980).

Prior to mine development, Arctic grayling adults were thought to migrate through Mainstem Red Dog Creek in early spring when discharges were high and metals concentrations low. Outmigration of adults probably occurred during high-water events and the young-of-the-year Arctic grayling left as water temperatures cooled in the fall or were displaced by high-water events. In some years, young-of-the-year Arctic grayling probably were exposed to low flow events with high metals concentrations. These conditions would likely have resulted in the death of young Arctic grayling.

In 1999 sampling for fish presence and use of North Fork Red Dog and Mainstem Red Dog creeks began in late May and continued with sampling events in July and August. On May 25, 1999, we checked the upper portion of Mainstem Red Dog Creek immediately below North Fork Red Dog Creek for fish presence and use. Arctic grayling were first observed on May 29 when water temperatures in Mainstem and North Fork Red Dog creeks were 3.0 and 1.5°C. Three male Arctic grayling were caught by angling in Mainstem Red Dog Creek on the evening of May 29, 1999. A fyke-net was set in a run in Mainstem Red Dog Creek along a rock bluff about 100 m below the mouth of North Fork Red Dog Creek. On May 30, 1999, we caught 32 Arctic grayling (22 males and 10 females). All fish captured were mature adults in pre-spawning condition.

Eighty-four Arctic grayling were captured and marked with Floy-tags (fish >200 mm were tagged) in Mainstem Red Dog, North Fork Red Dog, and Ikalukrok creeks (Appendix 5). Seventy-two Arctic grayling were handled in North Fork Red Dog Creek between July 7 and 13, 1999. The length-frequency distributions for Arctic grayling from North Fork Red Dog Creek (1999 to 1993) is presented in Figure 75. Recruitment of Arctic grayling to the population (i.e., fish less than 250 mm) was extremely strong in 1999; the strongest recruitment seen since our sampling began in 1993. Small Arctic grayling also were abundant in Ikalukrok Creek below Mainstem Red Dog, Anxiety Ridge, and Buddy creeks. All Arctic grayling handled were in good to excellent condition, although some of the larger males were still recovering from spawning.

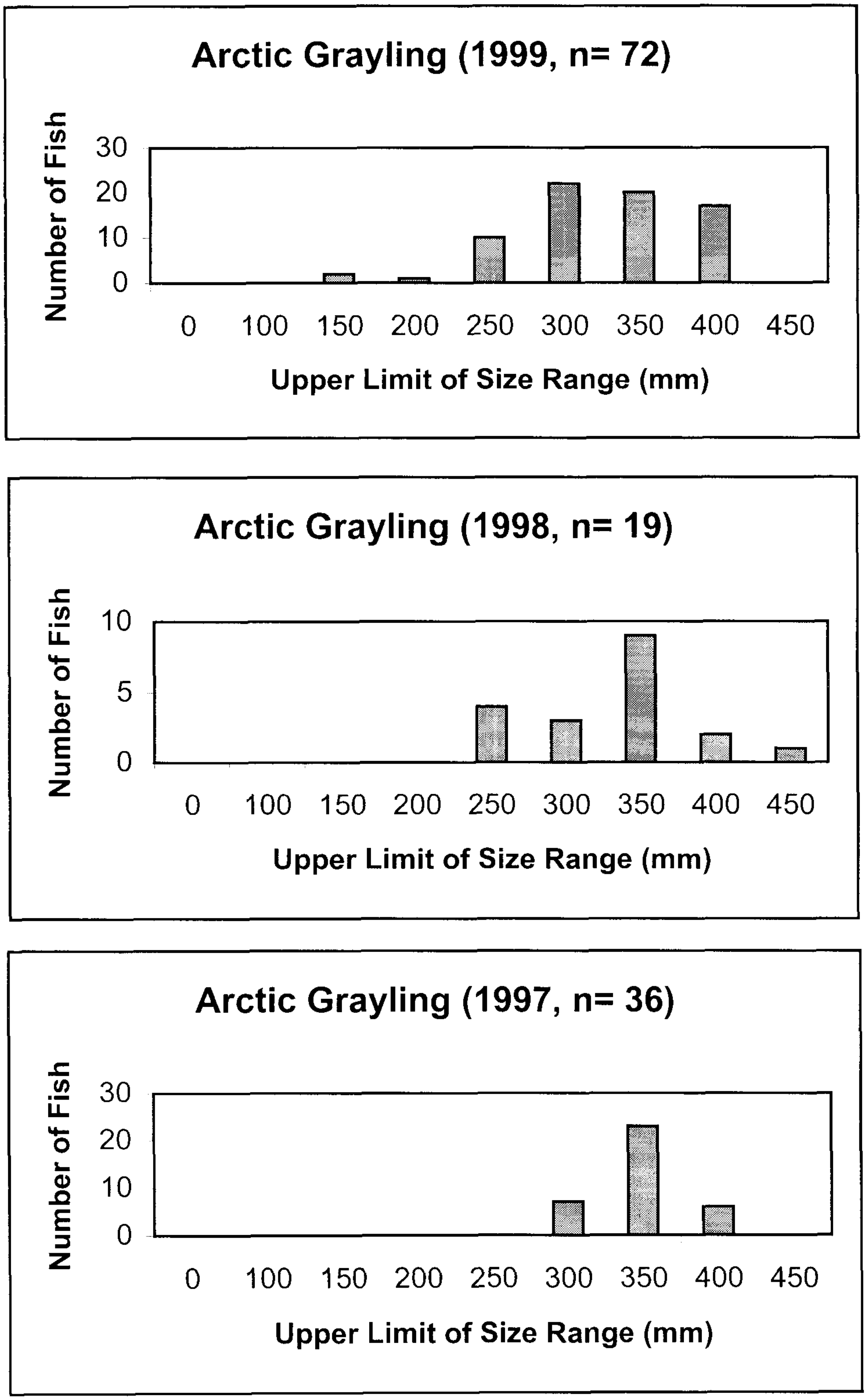
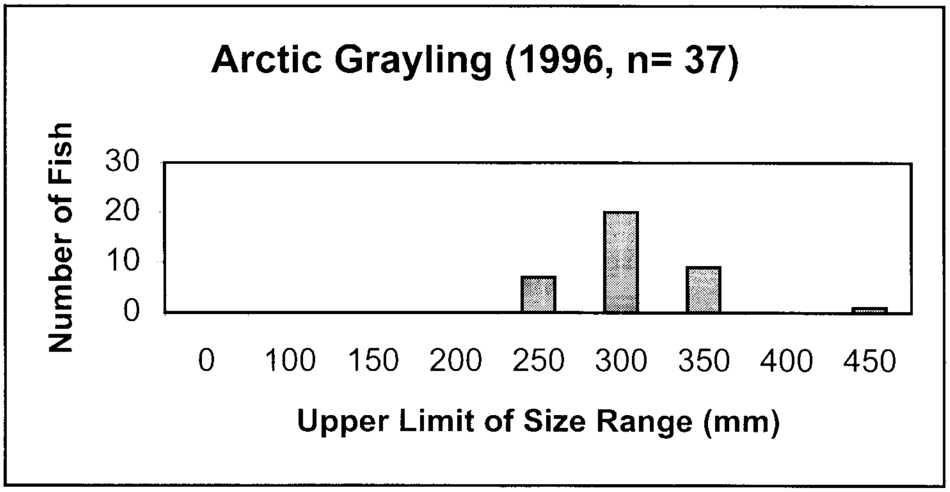
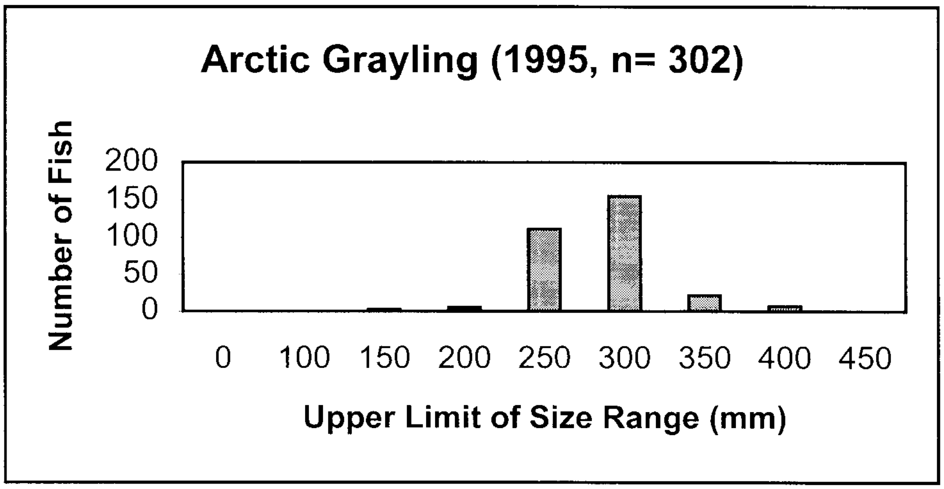


Figure 75. Length frequency distribution of Arctic grayling from North Fork Red Dog Creek, 1993-1999.





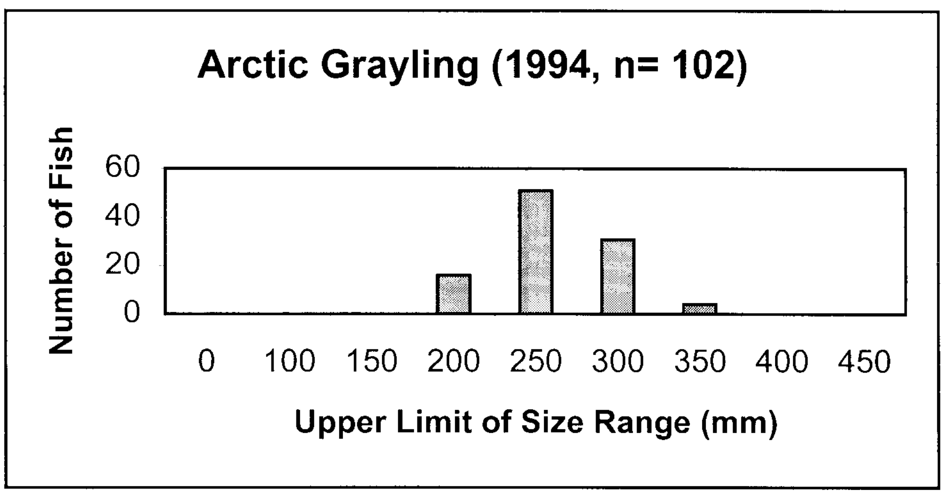


Figure 75. (continued).

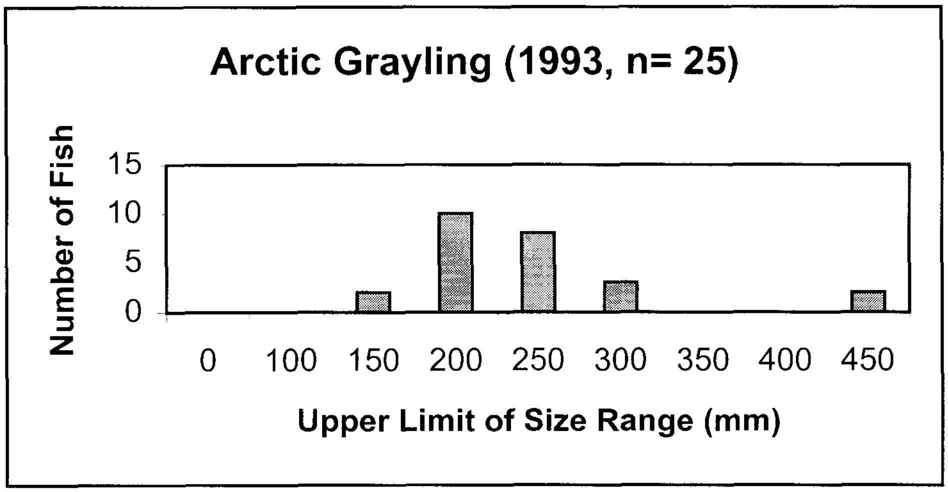


Figure 75. (concluded).

Arctic grayling young-of-the-year were abundant and seen throughout North Fork Red Dog Creek in early July 1999 and small numbers were found in Mainstem Red Dog and Ikalukrok creeks. Fry were observed along the lower 4.8 km (3.0 mi) of North Fork Red Dog Creek. Low flows, low precipitation, and high water temperature contribute to good fry survival and growth. Schools of 50 to 100 young-of-the-year Arctic grayling were common in North Fork Red Dog Creek.

Arctic grayling adults and juveniles seen during July in North Fork Red Dog, Anxiety, and Buddy creeks had outmigrated by early August 1999. In early August, relative numbers of young-of-the-year Arctic grayling had decreased substantially in North Fork Red Dog Creek, but young-of-the-year fish were abundant in Mainstem Red Dog Creek in shallow waters, backwaters, and along the stream margins (Table 14). All Arctic grayling observed in early August 1999 appeared to be in excellent condition.

Arctic grayling adults were seen and several were captured and marked in Ikalukrok Creek below the mouth of Mainstem Red Dog Creek in early July 1999. During an aerial survey of Ikalukrok Creek in early July, 1999 we observed several hundred Arctic grayling at three locations: the mouth of Dudd Creek; the mouth of Grayling Junior Creek; and in the headwaters of the Left Fork of Ikalukrok Creek. In August 1999, we again observed large concentrations of adult Arctic grayling in Ikalukrok Creek at the mouth of Dudd and Grayling Junior creeks - we did not fly the left fork in August. A summary of Arctic grayling visual observations made since 1994 in Mainstem Red Dog Creek is presented in Table 14.

Table 14. Arctic grayling visual observations and captures in Mainstem Red Dog Creek below confluence of North Fork and Middle Fork Red Dog creeks since 1994. Note, surveys limited until 1994 when minnow trap sample areas were established.

Sample Date	Sample Method	Comments on Arctic grayling (YOY = young-of-the-year Arctic grayling)
5/29/99	angling	three adult Arctic grayling caught just below North Fork mouth
5/30/99	fyke-net	32 adult grayling, about 100 m below North Fork mouth
7/8-9/99	angling	two Arctic grayling marked in lower Mainstem Red Dog
7/8-9/99	visual	12 grayling and some fry in lower Mainstem
7/8-9/99	visual	two adult grayling at rock bluff (0.8 km below North Fork)
7/8-9/99	visual	two adult grayling at rock bluff (0.1 km below North Fork)
8/9-10/99	visual	numerous YOY in backwaters and along stream margins in Mainstem Red Dog Creek
6/10/98	visual	no fish seen in Mainstem, North Fork mouth to rock bluff
6/28/98	visual	one adult feeding (rock bluff 0.8 km below North Fork)
6/25/97	drift net	YOY present near Station 10, 13-15 mm long
6/25/97	visual	two adults near rock bluff about 0.8 km below North Fork
6/26/97	angling	15 tagged fish (range 300-416 mm, average 364 mm) in scour pool at mouth of Mainstem, eight were spawned out
6/27/97	visual	YOY numerous near Station 10
8/10/97	visual	YOY present in backwater areas
9/29/97	traps	seven YOY caught near Station 10
6/19/96	visual	one adult near Station 10
7/15/96	angling	seven tagged fish (range 274-382 mm, average 330 mm), 2 km above mouth
8/11/96	visual	YOY in shallow eddies at mouth
8/12/96	visual	YOY near rock bluff about 0.8 km below North Fork

Table 14. (concluded).

Sample Date	Sample Method	Comments on Arctic grayling (YOY = young-of-the-year Arctic grayling)
6/29/95	angling	one adult (368 mm) just below North Fork
7/17/95	angling	two adults (296, 323 mm) near rock bluff about 0.8 km below North Fork
7/20/95	visual	one adult near rock bluff about 0.8 km below North Fork
8/11/95	visual	YOY (about 30) below North Fork
8/11/95	visual	one adult near rock bluff about 0.8 km below North Fork
8/14/95	angling	11 tagged/recaptured (range 290-340 mm, average 319 mm), near rock bluff about 0.8 km below North Fork
7/27/94	visual	two adults just below North Fork

Seven Arctic grayling tagged with Floy-tags during previous sampling events in the Ikalukrok Creek drainage were recaptured (Table 15). Five fish were recaptured in North Fork Red Dog Creek and two in Mainstem Red Dog Creek. One of the larger Arctic grayling (i.e., #1599-White) tagged in 1995 at 377 mm did not exhibit any growth in length over the last four years.

Table 15. Arctic grayling recaptures during summer 1999.

Tag Number	Color	Length (mm)	Date Captured	Site Captured	Recapture Date	Recapture Site	Length (mm)
3137	Yellow	203	7/27/94	North Fork	8/15/95	North Fork	272
					5/30/99	Mainstem	376
1599	White	377	7/17/95	North Fork	8/11/95	North Fork	383
					6/27/97	North Fork	385
					7/9/99	North Fork	378
1745	White	238	7/20/95	North Fork	7/13/96	North Fork	272
					7/13/99	North Fork	348
1762	White	277	7/20/95	North Fork	7/13/99	North Fork	370
10926	Orange	321	6/26/97	Ikalukrok (Red)	5/30/99	Mainstem	346
10935	Orange	304	6/27/97	North Fork	7/8/99	North Fork	341
1607	White	355	7/1/98	North Fork	7/13/99	North Fork	368

Slimy Sculpin

Houghton and Hilgert (1983) found slimy sculpin in all of the regularly sampled stations on Ikalukrok Creek and in Dudd Creek, but none were collected in the Red Dog Creek drainage. We started sampling with minnow traps in North Fork Red Dog Creek in 1992 and in Middle Fork and Mainstem Red Dog creeks in 1994. Slimy sculpin were never caught in Middle Fork Red Dog Creek, but were captured in Mainstem and North Fork Red Dog creeks in 1995 (Weber Scannell and Ott 1998). The number of slimy sculpin using the Red Dog Creek drainage is extremely low and similar to Anxiety Ridge Creek (Weber Scannell and Ott 1998). The largest catches of slimy sculpin have occurred in Ikalukrok Creek just above and below the mouth of Dudd Creek (Table 16). It is generally accepted that slimy sculpin do not distribute long distances from suitable overwintering habitats. We believe slimy sculpin overwinter in lower Ikalukrok Creek and the Wulik River, and probably do not migrate long distances to spring spawning or summer rearing habitats.

Table 16. Slimy sculpin collected in Ikalukrok Creek at the mouth of Dudd and Mainstem Red Dog Creeks.

Creek	Year	No. Sample Periods	No. Traps Deployed	No. Slimy Sculpin
Ikalukrok (at Dudd Cr.)	1999	2	20	18
	1998	2	20	5
	1997	2	20	11
	1996	2	20	2
	1995	3	20	8
	1994	1	20	8
	1993	2	10	2
	1992	3	10	3
	1991	4	5	3
	1990	3	5	0
Ikalukrok (at Red Dog)	1999	2	20	8
	1998	2	20	1
	1997	2	20	1
	1996	2	20	0

CONCLUSIONS

We conclude that during 1998 and 1999, Cominco Alaska Inc. operated the Red Dog Mine with no apparent adverse effect on fish migration to and use of North Fork Red Dog Creek. We did not observe fish kills in Mainstem Red Dog or Ikalukrok Creeks. Catches of juvenile Dolly Varden were high in all sample areas and recruitment of small Arctic grayling was the highest seen since sampling began in the early 1990s. Metals concentrations in 1996 through 1999 in Mainstem Red Dog Creek were lower than any concentrations reported during baseline studies. Median Se concentrations in water have fallen each year since 1996 when measurement first began. These water quality changes occurred following construction of the clean water bypass and mine sump drainage ditch in 1991 and the extension of the mine sump ditch to collect water from Hilltop Creek.

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APPENDIX 1 - INVERTEBRATE SPECIES LIST

Invertebrate Species List			
1998-1999			
Species listed in order of abundance			
Class	Order	Family	Genus
Insecta			
	Ephemeroptera		
		Baetidae	Baetis
		Heptageniidae	Cingymula
		Ephemerellidae	
		Ameletidae	
	Plecoptera		
		Perlodidae	Alloperla
			Perlomyia
		Nemouridae	Paranemouridae
			Podmosta
		Capniidae	Capnia
			Allocapnia
			Paracapnia
			Isocapnia
			Eucapnopsis
		Chloroperlidae	Utaperla
	Trichoptera		
		Brachiocentridae	Brachycentrus
		Limnephilidae	
		Glossosmatidae	
	Diptera	Chironomidae	
			Orthocladiini
			Tabanidae
		Tipulidae	Tipula
		Simuliidae	Simulium
		Psychodidae	
	Coleoptera	Staphylinidae	
		Hydrophilidae (larvae)	
		Dyticidae	
		Curculionidae	
		Chrysomelidae	
		Hydroscaphidae	

Appendix 1. (concluded).

Invertebrate Species List			
1998-1999			
Species listed in order of abundance			
Class	Order	Family	Genus
Miscellaneous			
	Collembola	Poduridae	Podura
		Sminthuridae	Sminthides
			Sminthurus
		Onchyiuridae	Lophognathella
		Hypogasturidae	
		Isotomidae	
	Homoptera	Veliidae	
		Macroveliidae	
		Saldidae	
	Hymenoptera	Eulophidae	
		Mymaridae	
		Braconidae	
		Ichneumonidae	Mymaridae
		Scelonidae	
		Pteromalidae	
		Trichogrammatidae	
		Apis	
	Nematoda		
	Thysanoptera		
	Neuroptera	Sialidae	
	Lepidoptera		
	Psocoptera		
Arachnida			
	Acari	Acarina	
Oligochaeta			
Fish larvae	Pisces	Salmonidae	Thymallus

APPENDIX 2 - JUVENILE DOLLY VARDEN - METALS DATA

Matrix	Collector	Sample Name	Location	Length (mm)	Cd (mg/Kg) (dry wt.)	Pb (mg/Kg) (dry wt.)	Se (mg/Kg) (dry wt.)
Whole Body	ADF&G	080798MSDVJ01	Mainstem Red Dog	132	1.97	5.04	6.46
Whole Body	ADF&G	080798MSDVJ02	Mainstem Red Dog	145	3.62	15.00	7.27
Whole Body	ADF&G	080798MSDVJ03	Mainstem Red Dog	124	3.62	16.20	6.40
Whole Body	ADF&G	080798MSDVJ04	Mainstem Red Dog	124	3.04	10.60	5.23
Whole Body	ADF&G	080798MSDVJ05	Mainstem Red Dog	110	3.07	6.97	5.73
Whole Body	ADF&G	080798MSDVJ06	Mainstem Red Dog	130	1.89	4.17	7.29
Whole Body	ADF&G	080798MSDVJ07	Mainstem Red Dog	143	0.42	3.95	6.88
Whole Body	ADF&G	080798MSDVJ08	Mainstem Red Dog	130	2.54	21.20	8.68
Whole Body	ADF&G	080798MSDVJ09	Mainstem Red Dog	115	3.08	6.48	7.26
Whole Body	ADF&G	080798MSDVJ10	Mainstem Red Dog	132	1.04	7.97	7.62
Whole Body	ADF&G	081098AXDVJ11	Anxiety	120	0.14	1.03	2.89
Whole Body	ADF&G	081098AXDVJ12	Anxiety	120	0.10	0.72	2.45
Whole Body	ADF&G	081098AXDVJ13	Anxiety	118	0.18	1.33	5.19
Whole Body	ADF&G	081098AXDVJ14	Anxiety	133	0.21	1.45	2.83
Whole Body	ADF&G	081098AXDVJ15	Anxiety	142	0.15	1.77	3.12
Whole Body	ADF&G	081098AXDVJ16	Anxiety	126	0.16	0.62	3.03
Whole Body	ADF&G	081098AXDVJ17	Anxiety	140	0.11	0.17	5.12
Whole Body	ADF&G	081098AXDVJ18	Anxiety	128	0.11	1.07	3.51
Whole Body	ADF&G	081098AXDVJ19	Anxiety	132	0.15	0.41	3.64
Whole Body	ADF&G	081098AXDVJ20	Anxiety	111	0.13	1.15	4.26
Whole Body	ADF&G	081299AXDVJ01	Anxiety	125	0.22	0.42	5.63
Whole Body	ADF&G	081299AXDVJ02	Anxiety	134	0.39	0.51	5.87
Whole Body	ADF&G	081299AXDVJ03	Anxiety	135	0.18	0.48	4.55
Whole Body	ADF&G	081299AXDVJ04	Anxiety	131	0.37	1.20	4.17
Whole Body	ADF&G	081299AXDVJ05	Anxiety	137	0.13	0.27	3.96
Whole Body	ADF&G	081299AXDVJ06	Anxiety	130	0.26	0.36	4.31
Whole Body	ADF&G	081299AXDVJ07	Anxiety	123	0.34	1.10	5.24
Whole Body	ADF&G	081299AXDVJ08	Anxiety	127	0.14	0.43	4.89
Whole Body	ADF&G	081299AXDVJ09	Anxiety	123	0.23	0.68	4.48
Whole Body	ADF&G	081299AXDVJ10	Anxiety	126	0.27	0.56	5.46
Whole Body	ADF&G	081299FEDVJ01	Ferric	123	0.09	0.36	5.27
Whole Body	ADF&G	081299FEDVJ02	Ferric	125	0.21	0.37	5.20
Whole Body	ADF&G	081299FEDVJ03	Ferric	149	0.06	0.22	6.32
Whole Body	ADF&G	081299FEDVJ04	Ferric	141	0.06	0.33	5.58
Whole Body	ADF&G	081299FEDVJ05	Ferric	123	0.26	0.42	6.19
Whole Body	ADF&G	081299FEDVJ06	Ferric	141	0.11	0.18	6.46
Whole Body	ADF&G	081299FEDVJ07	Ferric	115	0.27	0.30	6.64
Whole Body	ADF&G	081299FEDVJ08	Ferric	116	0.16	0.22	5.69

Appendix 2. (concluded).

					Cd	Pb	Se
		Sample		Length	(mg/Kg)	(mg/Kg)	(mg/Kg)
Matrix	Collector	Name	Location	(mm)	(dry wt.)	(dry wt.)	(dry wt.)
Whole Body	ADF&G	081299FEDVJ09	Ferric	107	0.07	0.21	4.66
Whole Body	ADF&G	081299MSDVJ01	Mainstem	140	4.62	8.91	6.89
Whole Body	ADF&G	081299MSDVJ02	Mainstem	121	3.90	8.78	7.13
Whole Body	ADF&G	081299MSDVJ03	Mainstem	125	3.75	8.68	8.90
Whole Body	ADF&G	081299MSDVJ04	Mainstem	127	4.14	3.11	7.26
Whole Body	ADF&G	081299MSDVJ05	Mainstem	130	3.19	4.97	6.87
Whole Body	ADF&G	081299MSDVJ06	Mainstem	134	1.28	3.18	7.30
Whole Body	ADF&G	081299MSDVJ07	Mainstem	139	3.84	6.52	8.89
Whole Body	ADF&G	081299MSDVJ08	Mainstem	145	3.17	10.40	6.30
Whole Body	ADF&G	081299MSDVJ09	Mainstem	143	0.54	1.09	5.66
Whole Body	ADF&G	081299MSDVJ10	Mainstem	120	2.47	9.94	4.24
Whole Body	ADF&G	081299NFDVJ01	North Fork	140	0.42	0.52	4.71
Whole Body	ADF&G	081299NFDVJ02	North Fork	123	0.88	0.86	5.22
Whole Body	ADF&G	081299NFDVJ03	North Fork	128	0.56	0.22	4.40
Whole Body	ADF&G	081299NFDVJ04	North Fork	128	0.58	0.57	4.20
Whole Body	ADF&G	081299NFDVJ05	North Fork	125	0.43	0.31	5.46
Whole Body	ADF&G	081299NFDVJ06	North Fork	134	0.42	0.28	5.81
Whole Body	ADF&G	081299NFDVJ07	North Fork	146	0.52	0.57	4.28
Whole Body	ADF&G	081299NFDVJ08	North Fork	119	0.50	0.30	4.61
Whole Body	ADF&G	081299NFDVJ09	North Fork	126	1.15	0.29	5.72
Whole Body	ADF&G	081299NFDVJ10	North Fork	126	0.38	0.32	5.13

Sample Name 080798MSDVJ01 represents the date of collection (August 8, 1998), location (MS = Mainstem Red Dog Creek), species (DV = Dolly Varden), age (J = juvenile), and individual sample number (01).

APPENDIX 3 - ADULT DOLLY VARDEN SAMPLE GROUPS

Fall 1990. Six adult Dolly Varden collected from the Wulik River (downstream of the mouth of Ikalukrok Creek) by Fred DeCicco (ADF&G) on October 3, 1990, before freezeup.

Late Winter, 1991. Nine adult Dolly Varden collected from the Wulik River (three by Cominco on 3/9/91, five by Kivalina on 4/6/91, one by Cominco on 4/26/91) between Driver's Camp (Station 2) and Umiivaq (lower Wulik River) during late winter before breakup.

Winter 1990-1991. Five adult Dolly Varden collected from the Noatak River by local residents during winter 1990/1991. Date and exact location in the Noatak River are unknown.

Spring 1991. Eight adult Dolly Varden collected from the Wulik River (lower Wulik River immediately upstream of Kivalina) by Cominco and local residents from Kivalina on 6/16/91, immediately following breakup.

Fall 1991. Six adult Dolly Varden collected from the Wulik River (Station 2) by Matt Robus (ADF&G) and Hank Brown and John Martinisko (Cominco) on 10/5/91, before freezeup.

Spring 1992. Eight adult Dolly Varden collected from the Wulik River (about five miles upstream of Kivalina) between 4/28 and 4/30/92, by Al Townsend (ADF&G) and Hank Brown (Cominco) during late winter before breakup.

Fall 1992. Six adult Dolly Varden collected from the Wulik River (Station 2) by Al Townsend (ADF&G) on 9/29/92, before freezeup.

Spring 1993. Six adult Dolly Varden collected from the Wulik River (about five miles upstream of Kivalina) between 4/19 and 4/23/93, by Al Townsend (ADF&G) and Jake Wells (Cominco) during late winter before breakup.

Fall 1993. Six adult Dolly Varden collected from the Wulik River (Station 2) by Al Townsend (ADF&G) on 10/23/93, before freezeup.

Spring 1994. Six adult Dolly Varden collected from the Wulik River (Station 2) by Al Townsend (ADF&G) on 4/7/94, during late winter before breakup.

Fall 1994. Six adult Dolly Varden collected from the Wulik River (Station 2) by Fred DeCicco (ADF&G) on 9/23/94, before freezeup.

Spring 1995. Six adult Dolly Varden collected from the Wulik River (lower Wulik River near Kivalina) by Fred DeCicco (ADF&G) on 6/10/95, after breakup.

Fall 1995. Six adult Dolly Varden collected from the Wulik River (Station 2) by Randy Zarnke (ADF&G) on 9/9/95, before freezeup.

Appendix 3. (concluded).

Spring 1996. Five adult Dolly Varden collected from the Wulik River (Station 2) by Al Townsend on 6/16/96, after breakup.

Fall 1996. Six adult Dolly Varden collected from the Wulik River (upstream of Kivalina) by Fred DeCicco on 9/19/96, before freezeup. Tissue from fish #5 was split into two samples, to constitute a blind duplicate for the analytical laboratory. The duplicate sample is listed as fish #7. Tissues from these fish also were sent to Washington state for histological analysis.

Spring 1997. Six adult Dolly Varden collected from the Wulik River (Station 2) by Fred DeCicco on 5/22/97, after breakup.

Fall 1997. Six adult Dolly Varden collected from the Wulik River (Station 2) by Fred DeCicco on 9/27/97, before freezeup. Samples 6 and 7 are duplicates of the same fish.

Spring 1998. Six adult Dolly Varden collected from the Wulik River (Station 2) by Phil Driver on 6/1/98, after breakup.

Fall 1998. Six adult Dolly Varden collected from the Wulik River (Station 2) by Fred DeCicco on 10/6/98, before freezeup.

Spring 1999. Six adult Dolly Varden collected from the Wulik River (Station 2) by Bill Morris and Al Ott (ADF&G) on 5/25-26/99, after breakup.

Fall 1999. Six adult Dolly Varden collected from the Wulik River (Station 2) by Fred DeCicco on 9/18/99, before freezeup.

APPENDIX 4 - ADULT DOLLY VARDEN - METALS DATA

Gill Tissue																			
Collector	Date Collected	Location	Sex	Weight grams	Length mm	Age fresh	Age salt	Total age	Al mg/kg		Cd mg/kg		Cu mg/kg		Pb mg/kg		Se mg/kg		Zn mg/kg
D&M	6/1/81	Sta 1									0.770		3.00	<	0.03				67.20
D&M	6/1/81	Sta 2									1.200		3.20	<	0.02				68.60
D&M	8/1/81	Sta 1									0.360		3.20	<	0.04				34.10
D&M	9/1/81	Sta 1									0.790		3.10	<	0.04				67.40
D&M	9/1/81	Mid-Ikaluk									1.400		3.10	<	0.03				52.70
D&M	6/1/82										5.750		0.75		3.18				0.03
EVS	7/3/82	Wulik			559				35.30		0.050		0.68		n.d.				23.30
ADF&G	8/30/90	Wulik	F		500				13.70		0.160		3.10		0.30				94.10
ADF&G	10/5/90	Wulik	F		538				1.80		1.630		2.20		0.20				90.40
ADF&G	10/5/90	Wulik	F		615				1.30		0.680		3.10	<	0.10				70.90
ADF&G	10/5/90	Wulik	M		608				1.40		1.440		2.60	<	0.10				68.70
ADF&G	10/5/90	Wulik	F		430				2.00		1.200		3.30		0.10				70.50
ADF&G	10/5/90	Wulik	F		452				0.60		1.220		2.10	<	0.10				70.20
ADF&G	10/5/90	Wulik	F		528				2.20		2.440		2.60		0.20				96.60
KIVALINA	10/19/90	Wulik	F	1680	535				6.60		2.280		3.70	<	0.10				84.00
Cominco	6/16/91	Wulik	M	962	489				36.60		1.510		3.10		1.00				75.60
Cominco	6/16/91	Wulik	F	1426	538				56.30		0.780		3.00		3.00				79.30
Cominco	6/16/91	Wulik	M	1361	541				21.20		1.150		2.70		0.60				75.50
Cominco	6/16/91	Wulik	F	762	461				18.40		2.000		3.10		1.50				89.60
Cominco	6/16/91	Wulik	F	672	417				20.50		0.640		2.10		0.80				64.70
Cominco	6/16/91	Wulik	F	745	430				33.30		0.830		2.80		1.50				75.30
Cominco	6/16/91	Wulik	F	680	443				60.20		0.850		2.90		2.40				67.70
Cominco	6/16/91	Wulik	F	654	430				1.20		1.820		3.10		1.20				78.50
Cominco	10/5/91	Wulik	F	1162	480				1.61		0.550		3.39		0.10				70.80
Cominco	10/5/91	Wulik	M	1262	480				23.40		0.300		2.92		0.16				75.20
Cominco	10/5/91	Wulik	M	2551	614				10.60		0.630		2.82		0.29				71.40
Cominco	10/5/91	Wulik	F	2188	589				2.08		0.540		3.64		0.23				72.30
Cominco	10/5/91	Wulik	F	1616	525				22.10		0.500		4.23		1.26				73.60
Cominco	10/5/91	Wulik	M	2233	563				31.70		0.710		5.10		0.33				84.10
ADF&G	4/29/92	Wulik	F	180	291				3.10		0.130		3.34		0.18				93.30
ADF&G	4/29/92	Wulik	F	670	424	2	2	4	2.10		0.160		1.780		0.07				65.50
ADF&G	4/29/92	Wulik	F	1420	530	2	3	5	9.00		0.070		1.79		0.11				65.70
ADF&G	4/29/92	Wulik	U	180	294	2	1	3	2.30		0.130		1.92		0.07				84.20
ADF&G	4/29/92	Wulik	F	140	275	3	1	4	2.70		0.120		3.73		0.04				93.70
ADF&G	4/29/92	Wulik	M	160	276				4.40		0.140		2.21		0.02				81.30
ADF&G	4/29/92	Wulik	M	140	264	4	1	5	5.90		0.080		2.24		0.06				80.20
ADF&G	4/29/92	Wulik	F	150	259	3	1	4	1.70		0.090		2.13		0.03				77.70
ADF&G	9/30/92	Wulik	F	4120	706			9	2.79		0.240		3.22		0.04				76.00
ADF&G	9/30/92	Wulik	M	2820	620	3	4	7	2.29		0.420		8.50		0.16				90.00
ADF&G	9/30/92	Wulik	F	3410	674	3	5	8	1.25		0.410		2.92	<	0.02				86.00
ADF&G	9/30/92	Wulik	M	2630	600	4	4	8	1.28		0.330		2.90		0.04				91.00
ADF&G	9/30/92	Wulik	F	2110	564	3	4	7	1.39		0.330		2.92	<	0.02				94.00
ADF&G	9/30/92	Wulik	M	2920	595	2	4	6	1.02		0.360		2.34		0.04				73.00
ADF&G	4/21/93	Wulik		673	407				1.80		0.240		2.420		0.36				87.00
ADF&G	4/21/93	Wulik		1032	480	2	3	5	1.60		0.150		2.500		0.03				97.00

Appendix 4. (Gill Tissue continued).

Gill Tissue																			
	Date			Weight	Length	Age	Age	Total	Al		Cd		Cu		Pb		Se		Zn
Collector	Collected	Location	Sex	grams	mm	fresh	salt	age	mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg
ADF&G	4/21/93	Wulik		717	414	4	2	6	2.50		0.180		2.350		0.43				84.00
ADF&G	4/21/93	Wulik		701	421	3	2	5	3.70		0.140		2.330		0.04				74.00
ADF&G	4/21/93	Wulik		685	398			6	3.10		0.160		2.190		0.04				75.00
ADF&G	4/21/93	Wulik		611	407	2	3	5	1.40		0.170		2.310		0.03				77.00
ADF&G	10/20/93	Wulik	F	2168	575	3	3	6	42.40		0.180		2.680		0.06				101.00
ADF&G	10/20/93	Wulik	M	1352	491	4	3	7	3.90		0.260		12.800		0.20				88.50
ADF&G	10/20/93	Wulik	M	1551	498	3	3	6	3.70		0.310		3.930	<	0.02				80.10
ADF&G	10/20/93	Wulik	F	1188	456	3	3	6	66.70		0.280		2.900		0.08				88.50
ADF&G	10/20/93	Wulik	M	1324	473	3	3	6	2.90		0.160		2.640		0.03				81.20
ADF&G	10/20/93	Wulik	M	2204	556	3	4	7	4.30		0.230		2.020		0.02				64.70
ADF&G	4/7/94	Wulik	M	245	297				15.90		0.110		2.150		0.04				83.10
ADF&G	4/7/94	Wulik	F	572	380				14.50		0.160		16.300		0.81				78.30
ADF&G	4/7/94	Wulik	M	526	390				5.20		0.170		23.100		0.43				66.00
ADF&G	4/7/94	Wulik	M	499	385				3.50		0.120		2.910		0.04				111.00
ADF&G	4/7/94	Wulik	M	590	386				3.90		0.160		3.640	<	0.02				103.00
ADF&G	4/7/94	Wulik	F	1651	521				5.50		0.150		27.400		0.38				88.50
ADF&G	9/23/94	Wulik	F	844	420				487.0		0.25		3.41		0.65				99.10
ADF&G	9/23/94	Wulik	M	690	420				379.0		0.21		2.95		0.55				99.40
ADF&G	9/23/94	Wulik	M	826	425				452.0		0.25		2.52		0.70				94.60
ADF&G	9/23/94	Wulik	M	890	435				184.0		0.25		2.09		0.32				83.5
ADF&G	9/23/94	Wulik	F	681	405				308.0		0.26		25		0.46				87.2
ADF&G	9/23/94	Wulik	F	726	420				212.0		0.32		2.35		0.31				91.4
ADF&G	6/14/95	Wulik	M	916	443	3	3	6	4.4		0.26		2.37		0.04				68.8
ADF&G	6/14/95	Wulik	F	1007	454	3	3	6	2.3		0.1		2.3	<	0.02				53
ADF&G	6/14/95	Wulik	M	762	419	3	2	5	441		0.23		3.26		0.67				70.3
ADF&G	6/14/95	Wulik	F	907	455	3	3	6	5.4		0.24		3.05	<	0.02				83.5
ADF&G	6/14/95	Wulik	F	925	462	3	3	6	294		0.29		7.51		0.5				74.7
ADF&G	6/14/95	Wulik	F	916	448	3	3	6	388		0.38		2.95		0.56				78.9
ADF&G	9/9/95	Wulik	F	816	434	3	3	6	11.8		0.43		3.71		1.5				362
ADF&G	9/9/95	Wulik	M	1170	482	3	3	6	7.1		0.3		2.47		1.08				527
ADF&G	9/9/95	Wulik	F	1451	475	4	3	7	11.1		0.23		2.43		0.63				351
ADF&G	9/9/95	Wulik	M	1098	457	2	3	5	0.9		1.2		3.29		0.02				70.3
ADF&G	9/9/95	Wulik	F	1978	530	2	3	5	24.6		0.25		2.34		0.73				375
ADF&G	9/9/95	Wulik	U	1778	555			7	12.1		0.3		2.25		0.58				315
ADF&G	6/16/96	Wulik	F	699	424	4	3	7	25.5		0.17		3.23		0.15				56.4
ADF&G	6/16/96	Wulik	F	808	450	2	3	5	18.8		0.43		2.1		0.37				52.7
ADF&G	6/16/96	Wulik	M	799	432	2	4	6	14.8		0.24		2.32		0.08				61.2
ADF&G	6/16/96	Wulik	M	962	468	2	4	6	26.2		0.29		1.78		0.1				61.1
ADF&G	6/16/96	Wulik	F	1416	505	3	5	8	38.9		0.41		2.52		0.5				62
ADF&G	9/19/96	Wulik	F	826	430	4	3	7	21		0.17		1.99		0.05				54.2
ADF&G	9/19/96	Wulik	F	1044	455			5	22.9		0.15		2.55		0.03				49.9
ADF&G	9/19/96	Wulik	F	1471	475	2	5	7	14.9		0.18		4.07		0.06				58.4
ADF&G	9/19/96	Wulik	F	1416	485	2	4	6	31.8		0.25		2.43		0.08				64.8
ADF&G	9/19/96	Wulik	F	1734	520	2	4	6	9.4		0.13		2.06		0.03				59.2
ADF&G	9/19/96	Wulik	F	1571	525	2	5	7	64		0.18		2.02		0.08				55.1

Appendix 4. (Gill Tissue concluded).

Gill Tissue														
	Date			Weight	Length	Age	Age	Total	Al	Cd	Cu	Pb	Se	Zn
Collector	Collected	Location	Sex	grams	mm	fresh	salt	age	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
ADF&G	9/19/96	Wulik	duplicate fish of #5						11.3	0.17	1.81	0.02		61.6
ADF&G	5/22/97	Wulik	F	1207	499				104	0.2	2.91	0.25	2	58.6
ADF&G	5/22/97	Wulik	F	1061	478				45.7	0.14	2.58	0.17	3	55.5
ADF&G	5/22/97	Wulik	F	1279	488				58.4	0.14	2.16	0.15	2	56.3
ADF&G	5/22/97	Wulik	M	1325	485				88.9	0.11	2.76	0.19	3	56.9
ADF&G	5/22/97	Wulik	M	1488	531				12.7	0.21	2.25	0.05	2	61.4
ADF&G	5/22/97	Wulik	F	771	450				17.5	0.18	2.27	0.05	2	59
ADF&G	9/27/97	Wulik	F	572	383			4	72.7	0.13	2.06	0.2	2.7	54.6
ADF&G	9/27/97	Wulik	M	536	392	3	3	6	136	0.21	2.4	0.27	2.4	68.4
ADF&G	9/27/97	Wulik	M	572	397	2	2	4	7.8	0.1	1.62	0.09	2.3	46.3
ADF&G	9/27/97	Wulik	F	263	299	2	1	3	66.4	0.16	2.16	0.18	2.8	58.4
ADF&G	9/27/97	Wulik	F	1653	555	3	6	9	90	0.21	2.6	0.26	2.9	73.4
ADF&G	9/27/97	Wulik	M	1507	520	3	5	8	112	0.14	2.28	0.31	2.1	79.5
ADF&G	6/1/98	Wulik	F	1889	530	3	4	7	24	0.16	2.79	0.04	2.23	68.1
ADF&G	6/1/98	Wulik	M	2334	575	4	5	9	39.7	0.16	2.42	0.08	1.73	62.8
ADF&G	6/1/98	Wulik	M	1880	553	2	5	7	125	0.19	3.08	0.32	1.65	64.1
ADF&G	6/1/98	Wulik	F	1961	550	3	5	8	115	0.12	2.34	0.19	1.6	56.9
ADF&G	6/1/98	Wulik	F	1471	514	3	4	7	14.7	0.1	1.79	0.04	1.21	52.8
ADF&G	6/1/98	Wulik	M	1244	500	5	5	10	73.9	0.11	1.74	0.14	1.97	48.6
ADF&G	10/6/98	Wulik	F	2830	626	2	8	10	4.8	0.17	5.97	0.06	3.2	65.8
ADF&G	10/6/98	Wulik	M	2304	560	2	4	6	7.5	0.18	8.38	0.08	3.71	83.1
ADF&G	10/6/98	Wulik	F	2713	578	3	6	9	31.7	0.14	6.82	0.1	1.98	62.2
ADF&G	10/6/98	Wulik	F	1914	528	3	5	8	21.5	0.26	4.36	0.04	2.05	72.2
ADF&G	10/6/98	Wulik	M	1343	475	3	3	6	7.7	0.2	5.15	0.03	3.54	62.4
ADF&G	10/6/98	Wulik	F	1161	467	3	3	6	7	0.16	5.09	0.05	2.97	75.6
ADF&G	5/15/99	Wulik	M	1235	491	3	3	6	44.3	0.16	2.46	0.21	2.89	76.4
ADF&G	5/15/99	Wulik	F	1943	625	3	6	9	30.4	0.05	1.83	0.29	0.36	66.7
ADF&G	5/15/99	Wulik	M	1898	605	3	7	10	51	0.12	2.99	0.22	0.63	94.8
ADF&G	5/15/99	Wulik	M	2225	595	4	4	8	34.4	0.13	2.86	0.27	2.45	59.2
ADF&G	5/15/99	Wulik	F	2760	620	3	7	10	66.4	0.1	1.71	0.29	1.74	66.2
ADF&G	5/15/99	Wulik	M	4831	720	3	6	9	21.9	0.11	1.87	0.21	2.12	65.1
ADF&G	9/8/99	Wulik	M	681	392	2	3	5	34.3	0.15	2.16	0.05	4.54	81.5
ADF&G	9/8/99	Wulik	F	1344	490	3	4	7	10.1	0.13	1.92	0.05	2.67	73.6
ADF&G	9/8/99	Wulik	F	1616	510	2	4	6	32.3	0.17	2.36	0.07	1.54	73.5
ADF&G	9/8/99	Wulik	F	1144	455	3	3	6	45	0.1	1.37	0.11	6.5	51.4
ADF&G	9/8/99	Wulik	M	1734	540	3	1	4	164	0.15	1.76	0.18	3.53	67.9
ADF&G	9/8/99	Wulik	M	1752	520	3	4	7	9.2	0.13	1.27	0.02	3.09	52.5

Appendix 4. (Kidney Tissue).

Kidney Tissue																			
	Date		Sex	Weight	Length	Age	Age	Total	Al		Cd		Cu		Pb		Se		Zn
Collector	Collected	Location		grams	mm	fresh	salt	age	mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg
D&M	6/1/81	Sta 1									0.320		4.90		0.02				80.10
D&M	6/1/81	Sta 2									5.300		4.00	<	0.02				75.90
D&M	8/1/81	Sta 1									2.900		5.20	<	0.05				74.60
D&M	9/1/81	Sta 1									3.000		5.80	<	0.03				109.00
D&M	6/1/82								3.00		2.530		5.28		0.03				94.43
ADF&G	8/30/90	Wulik	F		500				0.70		1.200		5.00		0.20				108.00
ADF&G	10/5/90	Wulik	F		538				1.50		5.340		3.30		0.20				117.00
ADF&G	10/5/90	Wulik	F		615				1.10		2.220		4.80	<	0.10				96.40
ADF&G	10/5/90	Wulik	M		608				0.70		1.530		4.80	<	0.10				79.30
ADF&G	10/5/90	Wulik	F		430				3.00		2.930		5.20	<	0.10				100.00
ADF&G	10/5/90	Wulik	F		452				0.90		3.300		5.00	<	0.10				106.00
ADF&G	10/5/90	Wulik	F		528				1.10		2.630		5.30	<	0.10				103.00
KIVALINA	10/19/90	Wulik	F	1680	535				3.90		3.050		8.40	<	0.10				105.00
Cominco	6/16/91	Wulik	M	962	489				6.00		6.560		6.00		0.10				83.30
Cominco	6/16/91	Wulik	F	1426	538				2.40		4.870		4.10	<	0.10				89.20
Cominco	6/16/91	Wulik	M	1361	541				1.70		4.140		4.00		0.20				76.60
Cominco	6/16/91	Wulik	F	762	461				2.10		3.090		4.50	<	0.10				94.50
Cominco	6/16/91	Wulik	F	672	417				1.50		2.470		3.50	<	0.10				208.00
Cominco	6/16/91	Wulik	F	745	430				1.60		2.230		4.20	<	0.10				71.10
Cominco	6/16/91	Wulik	F	680	443				1.90		4.010		4.90	<	0.10				108.00
Cominco	6/16/91	Wulik	F	654	430				1.30		3.230		4.10	<	0.10				95.90
Cominco	10/5/91	Wulik	F	1162	480				0.96		1.270		4.54		0.06				87.10
Cominco	10/5/91	Wulik	M	1262	480				1.86		1.660		4.89		0.62				92.40
Cominco	10/5/91	Wulik	M	2551	614				3.93		0.870		17.70		1.75				51.20
Cominco	10/5/91	Wulik	F	2188	589				1.30		2.540		6.18		0.03				104.00
Cominco	10/5/91	Wulik	F	1616	525				1.86		4.680		5.94		0.04				107.00
Cominco	10/5/91	Wulik	M	2233	563				0.75		2.810		4.37		0.06				86.40
ADF&G	4/29/92	Wulik	F	180	291				6.60		0.620		5.04		0.04				114.00
ADF&G	4/29/92	Wulik	F	670	424	2	2	4	5.00		1.510		3.570		0.04				78.10
ADF&G	4/29/92	Wulik	F	1420	530	2	3	5	5.70		1.280		3.43		0.02				86.60
ADF&G	4/29/92	Wulik	U	180	294	2	1	3	4.70		0.530		3.83		0.04				91.70
ADF&G	4/29/92	Wulik	F	140	275	3	1	4	4.30		0.380		6.43		0.06				99.70
ADF&G	4/29/92	Wulik	M	160	276				8.10		1.670		3.88		0.05				95.50
ADF&G	4/29/92	Wulik	M	140	264	4	1	5	2.60		0.400		3.50		0.04				82.20
ADF&G	4/29/92	Wulik	F	150	259	3	1	4	5.90		0.800		4.22		0.03				114.00
ADF&G	9/30/92	Wulik	F	4120	706			9	3.08		2.740		4.49	<	0.02				85.00
ADF&G	9/30/92	Wulik	M	2820	620	3	4	7	2.30		2.970		5.00	<	0.02				110.00
ADF&G	9/30/92	Wulik	F	3410	674	3	5	8	1.13		2.370		4.09	<	0.02				74.00
ADF&G	9/30/92	Wulik	M	2630	600	4	4	8	0.97		1.260		5.64	<	0.02				93.00
ADF&G	9/30/92	Wulik	F	2110	564	3	4	7	1.00		2.140		5.24		0.06				105.00
ADF&G	9/30/92	Wulik	M	2920	595	2	4	6	1.66		1.640		3.69		0.24				81.00
ADF&G	4/21/93	Wulik		673	407				1.40		0.760		3.850		0.02				88.00
ADF&G	4/21/93	Wulik		1032	480	2	3	5	1.70		1.330		4.530		0.02				106.00
ADF&G	4/21/93	Wulik		717	414	4	2	6	1.50		1.820		4.440		0.01				112.00
ADF&G	4/21/93	Wulik		701	421	3	2	5	1.20		0.790		3.660		0.01				84.00

Appendix 4. (Kidney Tissue continued).

Kidney Tissue																			
	Date		Sex	Weight	Length	Age	Age	Total	Al		Cd		Cu		Pb		Se		Zn
Collector	Collected	Location		grams	mm	fresh	salt	age	mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg
ADF&G	4/21/93	Wulik		685	398			6	2.10		0.510		4.050	<	0.01				100.00
ADF&G	4/21/93	Wulik		611	407	2	3	5	4.10		0.530		3.610	<	0.01				99.00
ADF&G	10/20/93	Wulik		2168	575	3	3	6	2.3		1.37		4.67	<	0.02				103
ADF&G	10/20/93	Wulik		1352	491	4	3	7	1.1		0.13		0.54	<	0.02				13.8
ADF&G	10/20/93	Wulik		1551	498	3	3	6	2.3		0.77		4.51	<	0.02				110
ADF&G	10/20/93	Wulik		1188	456	3	3	6	2.6		0.73		4.01	<	0.02				95.5
ADF&G	10/20/93	Wulik		1324	473	3	3	6	2.6		0.71		3.93	<	0.02				116
ADF&G	10/20/93	Wulik		2204	556	3	4	7	2.5		1.76		5.45	<	0.02				98.9
ADF&G	4/7/94	Wulik	M	245	297				16.00		0.790		4.660		0.03				97.60
ADF&G	4/7/94	Wulik	F	572	380				10.20		0.880		3.280	<	0.02				88.50
ADF&G	4/7/94	Wulik	M	526	390				6.90		1.200		3.300	<	0.02				87.40
ADF&G	4/7/94	Wulik	M	499	385				9.60		1.940		4.190		0.05				102.00
ADF&G	4/7/94	Wulik	M	590	386				8.90		1.470		4.190		0.02				98.20
ADF&G	4/7/94	Wulik	F	1651	521				10.40		1.430		4.370	<	0.02				92.40
ADF&G	9/23/94	Wulik	F	844	420				5.7		0.92		4.34		0.04				106.00
ADF&G	9/23/94	Wulik	M	690	420				3.1		1.17		6.93		0.03				117.00
ADF&G	9/23/94	Wulik	M	826	425				2.9		0.60		3.70	<	0.02				101.00
ADF&G	9/23/94	Wulik	M	890	435				7.2		0.63		3.69		0.03				86.6
ADF&G	9/23/94	Wulik	F	681	405				2.6		0.71		4.37	<	0.02				114
ADF&G	9/23/94	Wulik	F	726	420				2.0		1.23		3.83		0.02				91.3
ADF&G	6/14/95	Wulik	M	916	443	3	3	6	3.5		1.18		4.58	<	0.02				88
ADF&G	6/14/95	Wulik	F	1007	454	3	3	6	5.4		1.62		4.31	<	0.02				71.8
ADF&G	6/14/95	Wulik	M	762	419	3	2	5	2.5		1.22		4.59	<	0.02				83.5
ADF&G	6/14/95	Wulik	F	907	455	3	3	6	1.2		0.95		4.28	<	0.02				74.3
ADF&G	6/14/95	Wulik	F	925	462	3	3	6	1.9		0.8		3.59	<	0.02				61.2
ADF&G	6/14/95	Wulik	F	916	448	3	3	6	1.3		0.76		3.58	<	0.02				65.9
ADF&G	9/9/95	Wulik	F	816	434	3	3	6	1.3		2.36		4.94	<	0.02				89.4
ADF&G	9/9/95	Wulik	M	1170	482	3	3	6	1		2.5		13.4	<	0.02				89.6
ADF&G	9/9/95	Wulik	F	1451	475	4	3	7	1.6		1.86		4.47	<	0.02				75.1
ADF&G	9/9/95	Wulik	M	1098	457	2	3	5	11.8		0.25		2.27		0.86				444
ADF&G	9/9/95	Wulik	F	1978	530	2	3	5	3.4		1.08		3.88	<	0.02				80.5
ADF&G	9/9/95	Wulik	U	1778	555			7	0.9		0.85		3.98		0.06				61.4
ADF&G	6/16/96	Wulik	F	699	424	4	3	7	4.7		1.76		4.55		0.09				64.6
ADF&G	6/16/96	Wulik	F	808	450	2	3	5	3.4		1.42		3.56		0.04				74.5
ADF&G	6/16/96	Wulik	M	799	432	2	4	6	8.8		3.27		3.6		0.18				85.3
ADF&G	6/16/96	Wulik	M	962	468	2	4	6	2.2		1.88		3.95		0.05				71.1
ADF&G	6/16/96	Wulik	F	1416	505	3	5	8	3.1		2.1		4.68		0.05				83.7
ADF&G	9/19/96	Wulik	F	826	430	4	3	7	3.3		3.43		7.83		0.02				88.1
ADF&G	9/19/96	Wulik	F	1044	455			5	5.6		2.4		5.62		0.02				81
ADF&G	9/19/96	Wulik	F	1471	475	2	5	7	3.1		2.34		6.56		0.04				88.8
ADF&G	9/19/96	Wulik	F	1416	485	2	4	6	3.4		3.18		6.01		0.04				84.5
ADF&G	9/19/96	Wulik	F	1734	520	2	4	6	2.3		1.32		3.92	<	0.02				84.1
ADF&G	9/19/96	Wulik	F	1571	525	2	5	7	2.4		2.64		6.75		0.14				81.2
ADF&G	5/22/97	Wulik	F	1207	499				4.1		3.27		5.15		0.17		7		89.9

Appendix 4. (Kidney Tissue concluded).

Kidney Tissue																			
	Date		Sex	Weight	Length	Age	Age	Total	Al		Cd		Cu		Pb		Se		Zn
Collector	Collected	Location		grams	mm	fresh	salt	age	mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg
ADF&G	5/22/97	Wulik	F	1061	478				4.4		2.08		3.7		0.04		7		76.2
ADF&G	5/22/97	Wulik	F	1279	488				2.2		2.45		4.2		0.08		7		74.4
ADF&G	5/22/97	Wulik	M	1325	485				3.3		1.97		6.49		0.04		7		66.7
ADF&G	5/22/97	Wulik	M	1488	531				7		1.8		7.88		0.06		6		73.5
ADF&G	5/22/97	Wulik	F	771	450				4.6		2.96		6.31		0.04		5		87.1
ADF&G	9/27/97	Wulik	F	572	383			4	5		0.57		3.82		0.05		6.8		87.4
ADF&G	9/27/97	Wulik	M	536	392	3	3	6	3.1		0.17		36.8		0.02		3.7		69.1
ADF&G	9/27/97	Wulik	M	572	397	2	2	4	2.7		0.36		60.8		0.03		3.8		122.0
ADF&G	9/27/97	Wulik	F	263	299	2	1	3	2.7		0.19		54.4	<	0.02		4.4		70.2
ADF&G	9/27/97	Wulik	F	1653	555	3	6	9	2.5		0.52		43.4		0.02		2.9		58.2
ADF&G	9/27/97	Wulik	M	1507	520	3	5	8	3.1		0.39		63.2	<	0.02		2.8		56.8
ADF&G	6/1/98	Wulik	F	1889	530	3	4	7	4.7		1.17		4.78	<	0.02		3.61		75.5
ADF&G	6/1/98	Wulik	M	2334	575	4	5	9	16.5		1.23		4.55		0.05		5.45		87.5
ADF&G	6/1/98	Wulik	M	1880	553	2	5	7	26.2		1.67		6.55		0.06		4.58		68.5
ADF&G	6/1/98	Wulik	F	1961	550	3	5	8	17.8		1.63		5.62		0.04		5.67		78.5
ADF&G	6/1/98	Wulik	F	1471	514	3	4	7	5.6		0.74		3.42	<	0.02		4.47		65.2
ADF&G	6/1/98	Wulik	M	1244	500	5	5	10	16.3		1.19		21.2	<	0.03		8.65		77
ADF&G	10/6/98	Wulik	F	2830	626	2	8	10	5.2		2.09		4.22	<	0.02		10.9		94.7
ADF&G	10/6/98	Wulik	M	2304	560	2	4	6	2.3		2.12		5.9	<	0.02		3.71		121
ADF&G	10/6/98	Wulik	F	2713	578	3	6	9	2.2		1.59		5.12	<	0.02		8.84		118
ADF&G	10/6/98	Wulik	F	1914	528	3	5	8	1.8		1.34		6.09	<	0.02		6.55		119
ADF&G	10/6/98	Wulik	M	1343	475	3	3	6	3.6		0.91		4.52	<	0.02		8.92		111
ADF&G	10/6/98	Wulik	F	1161	467	3	3	6	1.7		2.38		6.4	<	0.02		8.14		123
ADF&G	5/15/99	Wulik	M	1235	491	3	3	6	2.4		1.02		4.56		0.22		9.75		98.1
ADF&G	5/15/99	Wulik	F	1943	625	3	6	9	4.7		1.62		4.29		0.23		7.53		109
ADF&G	5/15/99	Wulik	M	1898	605	3	7	10	2.7		2.56		4.41		0.25		9.77		113
ADF&G	5/15/99	Wulik	M	2225	595	4	4	8	1.7		0.64		3.04		0.13		7.55		70.2
ADF&G	5/15/99	Wulik	F	2760	620	3	7	10	3.1		1.76		3.8		0.13		8.91		79.2
ADF&G	5/15/99	Wulik	M	4831	720	3	6	9	2.8		2.76		4.5		0.05		12.1		106
ADF&G	9/8/99	Wulik	M	681	392	2	3	5	1.3		1.1		4.61		0.02		9.01		91.4
ADF&G	9/8/99	Wulik	F	1344	490	3	4	7	1.2		0.6		3.01		0.03		5.03		88.3
ADF&G	9/8/99	Wulik	F	1616	510	2	4	6	1.3		0.79		4.07		0.02		9.35		88.2
ADF&G	9/8/99	Wulik	F	1144	455	3	3	6	1.6		0.47		3.67		0.04		8.46		95.5
ADF&G	9/8/99	Wulik	M	1734	540	3	1	4	1.2		1.06		4.61		0.08		10.2		96.9
ADF&G	9/8/99	Wulik	M	1752	520	3	4	7	0.7		0.57		4.71		0.02		9.52		92

Appendix 4. (Liver Tissue).

Liver Tissue Collector	Date Collected	Location	Sex	Weight grams	Length mm	Age fresh	Age salt	Total age	Al mg/kg	Cd mg/kg	Cu mg/kg		Pb mg/kg	Se mg/kg	Zn mg/kg
D&M	6/1/81	Sta 1								0.580	33.00	<	0.02		72.30
D&M	6/1/81	Sta 1								0.540	16.50	<	0.02		50.80
D&M	8/1/81	Sta 1								0.770	11.00	<	0.02		91.00
D&M	9/1/81	Sta 1								0.970	18.00		0.02		78.20
D&M	6/1/82	Wulik							2.50	0.670	27.75		0.03		69.63
EVS	7/3/82	Wulik			559				n.d.	0.120	1.58		n.d.		35.80
ADF&G	8/30/90	Wulik	F		500				0.40	0.320	43.70	<	0.10		105.00
ADF&G	10/5/90	Wulik	F		538				1.50	1.110	25.60		0.10		103.00
ADF&G	10/5/90	Wulik	F		615				0.70	0.250	19.70	<	0.10		46.60
ADF&G	10/5/90	Wulik	M		608				0.70	0.190	38.40	<	0.10		58.70
ADF&G	10/5/90	Wulik	F		430				0.80	0.460	22.60	<	0.10		79.30
ADF&G	10/5/90	Wulik	F		452				0.70	0.400	24.20	<	0.10		74.60
ADF&G	10/5/90	Wulik	F		528				0.40	0.370	29.90	<	0.10		61.80
KIVALINA	10/19/90	Wulik	F	1680	535				1.40	0.410	35.50	<	0.10		52.50
Cominco	6/16/91	Wulik	M	962	489				1.30	1.250	32.40	<	0.10		74.00
Cominco	6/16/91	Wulik	F	1426	538				1.80	0.710	18.70	<	0.10		75.20
Cominco	6/16/91	Wulik	M	1361	541				3.60	0.860	37.50	<	0.10		83.20
Cominco	6/16/91	Wulik	F	762	461				2.00	1.180	34.10	<	0.10		96.60
Cominco	6/16/91	Wulik	F	672	417				1.80	1.480	38.30		0.80		124.00
Cominco	6/16/91	Wulik	F	745	430				1.20	0.690	54.20	<	0.10		85.40
Cominco	6/16/91	Wulik	F	680	443				1.20	1.040	26.00	<	0.10		84.30
Cominco	6/16/91	Wulik	F	654	430				0.90	0.840	31.00	<	0.10		88.00
Kivalina	7/10/91	Wulik	F	2778	627				6.50	0.500	22.30		0.20		57.70
Kivalina	7/10/91	Wulik	F	1738	550				3.40	0.800	72.20		1.00		78.60
Kivalina	7/10/91	Wulik	F	280	280				7.80	1.200	27.30		0.30		141.00
Kivalina	8/6/91	Wulik	F	1434	480				2.03	0.160	20.30		0.07		78.20
Kivalina	8/6/91	Wulik	M	962	417				0.82	0.310	24.70		0.06		78.20
Kivalina	8/6/91	Wulik	F	863	405				0.44	0.280	11.10		0.03		66.60
Kivalina	8/6/91	Wulik	F	1780	512				0.56	0.300	15.80		0.03		76.20
Cominco	10/5/91	Wulik	F	1162	480				0.94	0.290	33.60		0.04		70.80
Cominco	10/5/91	Wulik	M	1262	480				0.34	0.210	27.40		0.02		50.20
Cominco	10/5/91	Wulik	M	2551	614				0.44	0.720	39.00		0.10		61.70
Cominco	10/5/91	Wulik	F	2188	589				0.87	0.320	59.00		0.05		65.60
Cominco	10/5/91	Wulik	F	1616	525				0.40	0.530	25.40		0.04		55.10
Cominco	10/5/91	Wulik	M	2233	563				0.70	0.210	30.60		0.04		33.80
ADF&G	4/29/92	Wulik	F	180	291				3.20	0.410	40.30	<	0.02		152.00
ADF&G	4/29/92	Wulik	F	670	424	2	2	4	7.20	0.310	23.800	<	0.02		62.80
ADF&G	4/29/92	Wulik	F	1420	530	2	3	5	4.70	0.260	47.80		0.02		66.20
ADF&G	4/29/92	Wulik	U	180	294	2	1	1	7.60	0.370	32.40		0.03		142.00
ADF&G	4/29/92	Wulik	F	140	275	3	1	4	7.80	0.210	71.80		0.07		222.00
ADF&G	4/29/92	Wulik	M	160	276				2.30	0.740	39.90	<	0.02		162.00
ADF&G	4/29/92	Wulik	M	140	264	4	1	5	5.50	0.450	84.10		0.04		176.00
ADF&G	4/29/92	Wulik	F	150	259	3	1	4	4.50	0.350	36.20		0.02		160.00
ADF&G	9/30/92	Wulik	F	4120	706			9	1.64	0.270	21.50		0.02		60.00
ADF&G	9/30/92	Wulik	M	2820	620	3	4	7	3.07	0.370	19.50		0.03		67.00

Appendix 4. (Liver Tissue continued).

Liver Tissue															
	Date			Weight	Length	Age	Age	Total	Al	Cd	Cu		Pb	Se	Zn
Collector	Collected	Location	Sex	grams	mm	fresh	salt	age	mg/kg	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg
ADF&G	9/30/92	Wulik	F	3410	674	3	5	8	0.92	0.240	19.70		0.02		56.00
ADF&G	9/30/92	Wulik	M	2630	600	4	4	8	0.51	0.160	40.20	<	0.02		60.00
ADF&G	9/30/92	Wulik	F	2110	564	3	4	7	0.61	0.320	45.60		0.02		74.00
ADF&G	9/30/92	Wulik	M	2920	595	2	4	6	0.55	0.150	20.00	<	0.02		59.00
ADF&G	4/21/93	Wulik		673	407				1.200	0.2400	29.800	<	0.01		75.000
ADF&G	4/21/93	Wulik		1032	480	2	3	5	1.400	0.1600	37.300		0.02		73.000
ADF&G	4/21/93	Wulik		717	414	4	2	6	1.400	0.1900	42.300	<	0.01		63.000
ADF&G	4/21/93	Wulik		701	421	3	2	5	1.400	0.1300	23.000		0.02		58.000
ADF&G	4/21/93	Wulik		685	398			6	1.400	0.1500	21.000		0.01		66.000
ADF&G	4/21/93	Wulik		611	407	2	3	5	1.100	0.1800	18.100		0.02		67.000
ADF&G	10/20/93	Wulik		2168	575	3	3	6	2.800	0.1800	23.600	<	0.02		46.500
ADF&G	10/20/93	Wulik		1352	491	4	3	7	2.800	0.2300	22.100		0.03		67.600
ADF&G	10/20/93	Wulik		1551	498	3	3	6	2.000	0.1200	13.200	<	0.02		51.000
ADF&G	10/20/93	Wulik		1188	456	3	3	6	2.300	0.2300	42.900	<	0.02		86.000
ADF&G	10/20/93	Wulik		1324	473	3	3	6	2.600	0.1400	28.900	<	0.02		60.900
ADF&G	10/20/93	Wulik		2204	556	3	4	7	2.400	0.2700	35.200	<	0.02		62.400
ADF&G	4/7/94	Wulik	M	245	297				24.40	0.270	34.500		0.21		88.50
ADF&G	4/7/94	Wulik	F	572	380				10.10	0.550	42.800	<	0.02		118.00
ADF&G	4/7/94	Wulik	M	526	390				4.70	0.630	47.800	<	0.02		93.30
ADF&G	4/7/94	Wulik	M	499	385				7.80	0.480	35.000	<	0.02		110.00
ADF&G	4/7/94	Wulik	M	590	386				2.20	0.400	35.200	<	0.02		86.00
ADF&G	4/7/94	Wulik	F	1651	521				10.20	0.270	30.000		0.02		56.50
ADF&G	9/23/94	Wulik	F	844	420				0.70	0.17	20.30	<	0.02		85.3
ADF&G	9/23/94	Wulik	M	690	420				0.80	0.20	41.10	<	0.02		87.0
ADF&G	9/23/94	Wulik	M	826	425				1.10	0.18	51.70	<	0.02		87.2
ADF&G	9/23/94	Wulik	M	890	435				0.9	0.18	39.60	<	0.02		81.4
ADF&G	9/23/94	Wulik	F	681	405				0.9	0.17	48.00	<	0.02		82.0
ADF&G	9/23/94	Wulik	F	726	420				0.9	0.34	28.90	<	0.02		89.9
ADF&G	6/14/95	Wulik	M	916	443	3	3	6	7.4	4.58	61.7	<	0.02		125
ADF&G	6/14/95	Wulik	F	1007	454	3	3	6	3.2	0.32	53	<	0.02		93.6
ADF&G	6/14/95	Wulik	M	762	419	3	2	5	0.8	0.52	57.6	<	0.02		124
ADF&G	6/14/95	Wulik	F	907	455	3	3	6	1.4	0.54	65.7	<	0.02		121
ADF&G	6/14/95	Wulik	F	925	462	3	3	6	2.8	0.44	73.9		0.04		126
ADF&G	6/14/95	Wulik	F	916	448	3	3	6	18.2	0.24	29		0.06		98.9
ADF&G	9/9/95	Wulik	F	816	434	3	3	6	2.1	0.62	34.5		0.02		103.0
ADF&G	9/9/95	Wulik	M	1170	482	3	3	6	4.5	0.65	134		0.44		366
ADF&G	9/9/95	Wulik	F	1451	475	4	3	7	0.6	0.4	16.6	<	0.02		61
ADF&G	9/9/95	Wulik	M	1098	457	2	3	5	1	0.4	27.3		0.03		65.8
ADF&G	9/9/95	Wulik	F	1978	530	2	3	5	0.6	0.21	31		0.08		54.6
ADF&G	9/9/95	Wulik	U	1778	555			7	0.9	0.19	39.4	<	0.02		55.4
ADF&G	6/16/96	Wulik	F	699	424	4	3	7	3	0.64	50.1		0.04		97.1
ADF&G	6/16/96	Wulik	F	808	450	2	3	5	1.9	0.61	37.7		0.02		85.7
ADF&G	6/16/96	Wulik	M	799	432	2	4	6	2.1	1.14	46.3		0.04		82.3
ADF&G	6/16/96	Wulik	M	962	468	2	4	6	1.9	0.67	80.9		0.07		87.2
ADF&G	6/16/96	Wulik	F	1416	505	3	5	8	4.1	0.51	47.6		0.03		65.6

Appendix 4. (Liver Tissue concluded).

Liver Tissue															
	Date			Weight	Length	Age	Age	Total	Al	Cd	Cu		Pb	Se	Zn
Collector	Collected	Location	Sex	grams	mm	fresh	salt	age	mg/kg	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg
ADF&G	9/19/96	Wulik	F	826	430	4	3	7	2.4	0.95	38.3		0.03		90.2
ADF&G	9/19/96	Wulik	F	1044	455			5	2.5	0.44	68.1	<	0.02		63.3
ADF&G	9/19/96	Wulik	F	1471	475	2	5	7	3.2	0.4	34.9	<	0.02		62.4
ADF&G	9/19/96	Wulik	F	1416	485	2	4	6	2.3	0.6	43.6		0.06		60.8
ADF&G	9/19/96	Wulik	F	1734	520	2	4	6	1.9	0.43	37.2	<	0.02		60
ADF&G	9/19/96	Wulik	F	1571	525	2	5	7	2.3	0.44	37.9	<	0.02		59.2
ADF&G	5/22/97	Wulik	F	1207	499				5.5	0.85	44.9		0.1	4	72.5
ADF&G	5/22/97	Wulik	F	1061	478				2.6	0.44	19.9		0.02	2	48.8
ADF&G	5/22/97	Wulik	F	1279	488				1.9	0.9	48		0.05	3	87.7
ADF&G	5/22/97	Wulik	M	1325	485				2.1	0.55	41.3	<	0.02	2	56.4
ADF&G	5/22/97	Wulik	M	1488	531				1.3	0.31	67		0.02	2	63.9
ADF&G	5/22/97	Wulik	F	771	450				2	0.83	57.8	<	0.02	3	93.9
ADF&G	9/27/97	Wulik	F	572	383			4	6.3	0.18	21.3		0.07	2.7	54.5
ADF&G	9/27/97	Wulik	M	536	392	3	3	6	4.2	2.2	4.61	<	0.02	6.6	86.9
ADF&G	9/27/97	Wulik	M	572	397	2	2	4	3.1	0.67	3.22		0.03	7.1	71.9
ADF&G	9/27/97	Wulik	F	263	299	2	1	3	4.6	0.47	4.37		0.02	5.9	73.2
ADF&G	9/27/97	Wulik	F	1653	555	3	6	9	3.5	3.09	4.48		0.02	7.6	76.5
ADF&G	9/27/97	Wulik	M	1507	520	3	5	8	4.5	1.61	4.04		0.03	6.6	74.7
ADF&G	6/1/98	Wulik	F	1889	530	3	4	7	2.3	0.25	44.6	<	0.02	1.67	65.9
ADF&G	6/1/98	Wulik	M	2334	575	4	5	9	2.2	0.5	73	<	0.02	2.25	59.5
ADF&G	6/1/98	Wulik	M	1880	553	2	5	7	4.1	0.32	72.4	<	0.02	1.48	60.2
ADF&G	6/1/98	Wulik	F	1961	550	3	5	8	3.2	0.41	67.5	<	0.02	1.88	73.9
ADF&G	6/1/98	Wulik	F	1471	514	3	4	7	2.4	0.41	53.1	<	0.02	2.03	88.4
ADF&G	6/1/98	Wulik	M	1244	500	5	5	10	8.6	0.41	54.9		0.02	1.81	69.6
ADF&G	10/6/98	Wulik	F	2830	626	2	8	10	2.6	0.32	25.9	<	0.02	3.17	63.5
ADF&G	10/6/98	Wulik	M	2304	560	2	4	6	1.3	0.17	22	<	0.02	2.39	60.7
ADF&G	10/6/98	Wulik	F	2713	578	3	6	9	2.8	0.2	41.2	<	0.02	2.14	65.9
ADF&G	10/6/98	Wulik	F	1914	528	3	5	8	2.2	0.13	39.7	<	0.02	2.84	70.1
ADF&G	10/6/98	Wulik	M	1343	475	3	3	6	1.3	0.12	24.2	<	0.02	1.89	54.3
ADF&G	10/6/98	Wulik	F	1161	467	3	3	6	1.5	0.29	40.4	<	0.02	2.26	74.7
ADF&G	5/15/99	Wulik	M	1235	491	3	3	6	1.3	0.1	30.5		0.15	2.42	60.6
ADF&G	5/15/99	Wulik	F	1943	625	3	6	9	1.4	0.96	148		0.24	2.14	168
ADF&G	5/15/99	Wulik	M	1898	605	3	7	10	2.1	0.9	104		0.26	2.26	141
ADF&G	5/15/99	Wulik	M	2225	595	4	4	8	1.4	0.17	45.4		0.08	3.79	97.6
ADF&G	5/15/99	Wulik	F	2760	620	3	7	10	1.3	0.23	31.3		0.13	3.24	76
ADF&G	5/15/99	Wulik	M	4831	720	3	6	9	1.2	0.31	34.5		0.36	2.83	56.7
ADF&G	9/8/99	Wulik	M	681	392	2	3	5	0.8	0.26	28.8	<	0.02	4.61	64.2
ADF&G	9/8/99	Wulik	F	1344	490	3	4	7	0.9	0.33	30.3	<	0.02	4.05	84.2
ADF&G	9/8/99	Wulik	F	1616	510	2	4	6	0.7	0.2	29.3		0.05	2.4	68
ADF&G	9/8/99	Wulik	F	1144	455	3	3	6	0.8	0.15	34.9		0.03	2.41	62.5
ADF&G	9/8/99	Wulik	M	1734	540	3	1	4	0.6	0.2	46.5		0.03	2.96	77.9
ADF&G	9/8/99	Wulik	M	1752	520	3	4	7	1.4	0.12	30.5	<	0.02	3.47	74.6

Appendix 4. (Muscle Tissue).

Muscle Tissue																				
	Date			Weight	Length	Age	Age	Total	Al		Cd		Cu		Pb		Se		Zn
Collector	Collected	Location	Sex	grams	mm	fresh	salt	age	mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg
D&M	6/1/81	Sta 1									0.160		1.30	<	0.02				9.9
D&M	6/1/81	Sta 2									0.200		2.00	<	0.02				9.2
D&M	8/1/81	Sta 1									0.190		2.00		0.03				13.6
D&M	9/1/81	Sta 1									0.120		2.10	<	0.02				16.8
D&M	6/1/82	Sta 1							3.40		0.170		1.56		0.02				12.1
EVS	7/3/82	Wulik			559				n.d.		n.d.		1.75		n.d.				16.2
ADFG	8/30/90	Wulik	F		500				0.70		0.020		1.70	<	0.10				12.9
ADFG	10/5/90	Wulik	F		538				1.60	<	0.010		2.50	<	0.10				18.1
ADFG	10/5/90	Wulik	F		615				0.40	<	0.010		1.00	<	0.10				7.6
ADFG	10/5/90	Wulik	M		608				0.80	<	0.010		1.80	<	0.10				11.5
ADFG	10/5/90	Wulik	F		430				0.50	<	0.010		1.90	<	0.10				12.9
ADFG	10/5/90	Wulik	F		452				0.50	<	0.010		1.70	<	0.10				15.3
ADFG	10/5/90	Wulik	F		528				0.90	<	0.010		1.70	<	0.10				12.1
KIVALINA	10/19/90	Wulik	F	1680	535				2.30	<	0.010		2.40	<	0.10				12.9
Cominco	6/16/91	Wulik	M	962	489				1.40		0.010		3.30	<	0.10				16.0
Cominco	6/16/91	Wulik	F	1426	538				1.80	<	0.010		2.20		0.10				15.3
Cominco	6/16/91	Wulik	M	1361	541				3.00	<	0.010		2.60	<	0.10				15.6
Cominco	6/16/91	Wulik	F	762	461				0.80	<	0.010		2.40	<	0.10				16.0
Cominco	6/16/91	Wulik	F	672	417				0.90	<	0.010		1.20	<	0.10				16.4
Cominco	6/16/91	Wulik	F	745	430				1.10	<	0.010		1.50	<	0.10				15.1
Cominco	6/16/91	Wulik	F	680	443				1.20		0.030		1.50	<	0.10				18.9
Cominco	6/16/91	Wulik	F	654	430				1.20	<	0.010		2.00	<	0.10				16.6
Kivalina	7/10/91	Wulik	F	2778	627				11.20	<	0.010		3.70		0.10				13.8
Kivalina	7/10/91	Wulik	F	1738	550				2.50	<	0.010		5.00	<	0.10				13.4
Kivalina	7/10/91	Wulik	F	280	280				8.70		0.030		5.40		0.40				29.3
Kivalina	8/6/91	Wulik	F	1434	480				0.24	<	0.020		2.40		0.03				14.7
Kivalina	8/6/91	Wulik	M	962	417				1.08		0.020		4.70		1.38				17.6
Kivalina	8/6/91	Wulik	F	863	405				0.44	<	0.020		2.02	<	0.02				17.6
Kivalina	8/6/91	Wulik	F	1780	512				2.12	<	0.020		1.97		0.05				14.0
Cominco	10/5/91	Wulik	F	1162	480				0.55	<	0.020		2.55		0.03				14.9
Cominco	10/5/91	Wulik	M	1262	480				0.66	<	0.020		2.85		0.03				13.9
Cominco	10/5/91	Wulik	M	2551	614				0.43	<	0.020		2.02		0.04				14.5
Cominco	10/5/91	Wulik	F	2188	589				0.13		0.030		2.68		0.04				13.1
Cominco	10/5/91	Wulik	F	1616	525				0.22	<	0.020		2.03		0.03				12.8
Cominco	10/5/91	Wulik	M	2233	563				0.32	<	0.020		2.42		0.05				12.2
ADFG	4/29/92	Wulik	F	180	291				2.50	<	0.020		2.27	<	0.05				16.5
ADFG	4/29/92	Wulik	F	670	424	2	2	4	2.20	<	0.020		1.46		0.02				14.6
ADFG	4/29/92	Wulik	F	1420	530	2	3	5	1.80	<	0.020		1.35	<	0.02				14.1
ADFG	4/29/92	Wulik	U	180	294	2	1	1	2.60	<	0.020		2.12		0.03				25.9
ADFG	4/29/92	Wulik	F	140	275	3	1	4	1.50	<	0.020		2.08	<	0.02				28.7
ADFG	4/29/92	Wulik	M	160	276				2.60	<	0.020		2.38		0.02				22.9
ADFG	4/29/92	Wulik	M	140	264	4	1	5	3.00	<	0.020		2.57	<	0.02				24.3
ADFG	4/29/92	Wulik	F	150	259	3	1	4	3.90	<	0.020		1.99		0.02				26.1
ADFG	9/30/92	Wulik	F	2820	620			9	1.35	<	0.020		1.74	<	0.02				14.0
ADFG	9/30/92	Wulik	M	3410	674	3	4	7	0.47	<	0.020		1.27	<	0.02				11.0

Appendix 4. (Muscle Tissue continued).

Muscle Tissue																			
	Date			Weight	Length	Age	Age	Total	Al		Cd		Cu		Pb		Se		Zn
Collector	Collected	Location	Sex	grams	mm	fresh	salt	age	mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg
ADFG	9/30/92	Wulik	F	2630	600	3	5	8	0.72	<	0.020		1.27	<	0.02				13.0
ADFG	9/30/92	Wulik	M	2110	564	4	4	8	0.74	<	0.020		1.26		0.03				13.0
ADFG	9/30/92	Wulik	F	2920	595	3	4	7	0.42	<	0.020		1.59	<	0.02				14.0
ADFG	9/30/92	Wulik	M	673	407	2	4	6	1.26	<	0.020		2.08		0.17				14.0
ADFG	4/21/93	Wulik		1032	480				1.000	<	0.0100		1.38		0.02				16.0
ADFG	4/21/93	Wulik		717	414	2	3	5	1.400	<	0.0100		1.45		0.03				18.0
ADFG	4/21/93	Wulik		701	421	4	2	6	1.300	<	0.0100		1.49		0.02				20.0
ADFG	4/21/93	Wulik		685	398	3	2	5	1.300	<	0.0100		1.38		0.02				16.0
ADFG	4/21/93	Wulik		611	407	.		6	1.200	<	0.0100		1.23		0.02				18.0
ADFG	4/21/93	Wulik		2168	575	2	3	5	1.300	<	0.0100		1.27		0.07				15.0
ADFG	10/20/93	Wulik		2168	575	3	3	6	2.70	<	0.020		16.70		0.22				14.6
ADFG	10/20/93	Wulik		1352	491	4	3	7	2.60	<	0.020		1.57	<	0.01				14.5
ADFG	10/20/93	Wulik		1551	498	3	3	6	2.10	<	0.020		1.51	<	0.01				14.0
ADFG	10/20/93	Wulik		1188	456	3	3	6	1.90	<	0.020		1.91	<	0.01				16.1
ADFG	10/20/93	Wulik		1324	473	3	3	6	2.10	<	0.020		1.37	<	0.01				14.7
ADFG	10/20/93	Wulik		2204	556	3	4	7	1.80	<	0.020		1.00	<	0.01				11.7
ADFG	4/7/94	Wulik	M	245	297				7.80	<	0.020		1.38	<	0.02				16.7
ADFG	4/7/94	Wulik	F	572	380				8.80	<	0.020		1.35		0.02				15.8
ADFG	4/7/94	Wulik	M	526	390				6.60	<	0.020		1.48		0.03				16.5
ADFG	4/7/94	Wulik	M	499	385				5.70	<	0.020		1.09	<	0.02				17.0
ADFG	4/7/94	Wulik	M	590	386				8.20	<	0.020		1.39		0.02				16.4
ADFG	4/7/94	Wulik	F	1651	521				15.00	<	0.020		1.25		0.02				12.9
ADFG	9/23/94	Wulik	F	844	420				3.10	<	0.02		1.74		0.04				16.9
ADFG	9/23/94	Wulik	M	690	420				0.90	<	0.02		1.53	<	0.02				23.7
ADFG	9/23/94	Wulik	M	826	425				1.00	<	0.02		1.64	<	0.02				19.6
ADFG	9/23/94	Wulik	M	890	435				1.2	<	0.02		1.73	<	0.02				21.4
ADFG	9/23/94	Wulik	F	681	405				1.4	<	0.02		1.48	<	0.02				20.3
ADFG	9/23/94	Wulik	F	726	420				2.1	<	0.02		1.7	<	0.02				20.8
ADFG	6/14/95	Wulik	M	916	443	3	3	6	31.8	<	0.02		1.82		0.03				21.3
ADFG	6/14/95	Wulik	F	1007	454	3	3	6	12.8	<	0.02		1.49	<	0.02				16.4
ADFG	6/14/95	Wulik	M	762	419	3	2	5	2.2	<	0.02		1.9	<	0.02				20.5
ADFG	6/14/95	Wulik	F	907	455	3	3	6	2.2	<	0.02		1.21	<	0.02				14.6
ADFG	6/14/95	Wulik	F	925	462	3	3	6	2.4	<	0.02		1.76	<	0.02				19.5
ADFG	6/14/95	Wulik	F	916	448	3	3	6	3.3	<	0.02		1.44	<	0.02				17.4
ADFG	9/9/95	Wulik	F	816	434	3	3	6	5.9	<	0.04		2.43	<	0.56				264.0
ADFG	9/9/95	Wulik	M	1170.3	482	3	3	6	4.2	<	0.02		1.66	<	0.42				160.0
ADFG	9/9/95	Wulik	F	1451.5	475	4	3	7	1.8	<	0.02		1.23		0.18				88.5
ADFG	9/9/95	Wulik	M	1097.7	457	2	3	5	2.2	<	0.02		1.52		0.16				67.1
ADFG	9/9/95	Wulik	F	1977.7	530	2	3	5	2.3	<	0.02		1.34		0.19				64.7
ADFG	9/9/95	Wulik	U	1778.1	555			7	1.3	<	0.02		0.97		0.06				28.5
ADFG	6/16/96	Wulik	F	699	424	4	3	7	3.9		0.02		3.05		0.06				14.8
ADFG	6/16/96	Wulik	F	808	450	2	3	5	2.4		0.04		1.99		0.03				21.3
ADFG	6/16/96	Wulik	M	799.04	432	2	4	6	2	<	0.02		1.3		0.03				22.8
ADFG	6/16/96	Wulik	M	962	468	2	4	6	3.4	<	0.02		1.44	<	0.02				19.7
ADFG	6/16/96	Wulik	F	1416.5	505	3	5	8	2.1	<	0.02		0.99		0.02				12.5

Appendix 4. (Muscle Tissue concluded).

Muscle Tissue																			
	Date			Weight	Length	Age	Age	Total	Al		Cd		Cu		Pb		Se		Zn
Collector	Collected	Location	Sex	grams	mm	fresh	salt	age	mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg
ADFG	9/19/96	Wulik	F	826	430	4	3	7	4.1	<	0.02		1.49		0.07				13.9
ADFG	9/19/96	Wulik	F	1044	455			5	2.2	<	0.02		1.08	<	0.02				12.1
ADFG	9/19/96	Wulik	F	1471	475	2	5	7	2.4		0.02		1.26	<	0.02				17.9
ADFG	9/19/96	Wulik	F	1416	485	2	4	6	2.4	<	0.02		1.7	<	0.02				15.4
ADFG	9/19/96	Wulik	F	1734	520	2	4	6	2.9	<	0.02		0.88	<	0.02				12.2
ADFG	9/19/96	Wulik	F	1571	525	2	5	7	2.8	<	0.02		1.55		0.03				13.6
ADFG	5/22/97	Wulik	F	1207	499				2.7	<	0.02		1.43		0.08	<	1		14.3
ADFG	5/22/97	Wulik	F	1061	478				5.1	<	0.02		1.44		0.02	<	1		14.2
ADFG	5/22/97	Wulik	F	1279	488				7.7	<	0.02		1.36		0.04	<	1		12.6
ADFG	5/22/97	Wulik	M	1325	485				3.7	<	0.02		1.16		0.04	<	1		11.5
ADFG	5/22/97	Wulik	M	1488	531				1.4	<	0.02		1.41	<	0.02	<	1		10.7
ADFG	5/22/97	Wulik	F	772	450				1.2	<	0.02		1.87	<	0.02	<	1		15.8
ADFG	9/27/97	Wulik	F	572	383			4	3.6	<	0.02		1.21		0.03		0.9		12
ADFG	9/27/97	Wulik	M	536	392	3	3	6	3.3	<	0.02		1.36		0.15		1.6		12.9
ADFG	9/27/97	Wulik	M	572	397	2	2	4	4.5	<	0.02		2.38		0.04		0.9		16.5
ADFG	9/27/97	Wulik	F	263	299	2	1	3	2.7	<	0.02		2.32	<	0.02		1.1		18.9
ADFG	9/27/97	Wulik	F	1653	555	3	6	9	3.2	<	0.02		1.25		0.02		1.2		9.7
ADFG	9/27/97	Wulik	M	1507	520	3	5	8	3.8	<	0.02		1.03	<	0.02		0.9		12.1
ADF&G	6/1/98	Wulik	F	1889	530	3	4	7	2.4	<	0.02		2.25	<	0.02		0.738		15.1
ADF&G	6/1/98	Wulik	M	2334	575	4	5	9	2.4	<	0.02		2.11	<	0.02		0.596		13.2
ADF&G	6/1/98	Wulik	M	1880	553	2	5	7	2.7	<	0.02		2.67	<	0.02		0.742		13.7
ADF&G	6/1/98	Wulik	F	1961	550	3	5	8	2.9	<	0.02		2.57	<	0.02		0.46		14
ADF&G	6/1/98	Wulik	F	1471	514	3	4	7	2.5	<	0.02		1.87	<	0.02		0.518		14.2
ADF&G	6/1/98	Wulik	M	1244	500	5	5	10	2.3	<	0.02		2.18	<	0.02		0.546		13.8
ADF&G	10/6/98	Wulik	F	2830	626	2	8	10	5.2	<	0.02		2	<	0.02		0.7		12.4
ADF&G	10/6/98	Wulik	M	2304	560	2	4	6	1.1	<	0.02		1.48	<	0.02		0.7		10.9
ADF&G	10/6/98	Wulik	F	2713	578	3	6	9	2.5	<	0.02		2.34	<	0.02		0.5		12.3
ADF&G	10/6/98	Wulik	F	1914	528	3	5	8	2.8	<	0.02		1.81	<	0.02		0.4		12.4
ADF&G	10/6/98	Wulik	M	1343	475	3	3	6	1.7	<	0.02		1.73	<	0.02		0.8		11.9
ADF&G	10/6/98	Wulik	F	1161	467	3	3	6	1.2	<	0.02		1.76	<	0.02		0.8		13.6
ADF&G	5/15/99	Wulik	M	1235	491	3	3	6	1.2	<	0.02		1.61		0.2		0.4		12.5
ADF&G	5/15/99	Wulik	F	1943	625	3	6	9	2.2	<	0.02		2.26		0.2		0.5		20.8
ADF&G	5/15/99	Wulik	M	1898	605	3	7	10	1.1	<	0.02		2.87		0.04		0.7		21.2
ADF&G	5/15/99	Wulik	M	2225	595	4	4	8	1	<	0.02		2.28		0.27		0.6		15.5
ADF&G	5/15/99	Wulik	F	2760	620	3	7	10	0.9	<	0.02		1.63		0.03		0.5		12.3
ADF&G	5/15/99	Wulik	M	4831	720	3	6	9	2.4	<	0.02		1.53		0.1		0.6		15.5
ADF&G	9/8/99	Wulik	M	681	392	2	3	5	0.8	<	0.02		1.16	<	0.02		0.7		13.1
ADF&G	9/8/99	Wulik	F	1344	490	3	4	7	0.6	<	0.02		1.18	<	0.02		1.0		13.1
ADF&G	9/8/99	Wulik	F	1616	510	2	4	6	0.7	<	0.02		0.99		0.03		0.5		12.2
ADF&G	9/8/99	Wulik	F	1144	455	3	3	6	0.7	<	0.02		1.39	<	0.02		0.5		14.0
ADF&G	9/8/99	Wulik	M	1734	540	3	1	4	0.7	<	0.02		1.49	<	0.02		0.8		16.1
ADF&G	9/8/99	Wulik	M	1752	520	3	4	7	0.5	<	0.02		1.36	<	0.02		0.6		14.0

Appendix 4. (Reproductive Tissue).

Reproductive Tissue																			
	Date		Sex	Weight	Length	Age	Age	tota	Al		Cd		Cu		Pb		Se		Zn
Collector	Collected	Location		grams	mm	fresh	salt	age	mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg
ADF&G	6/1/98	Wulik	F	1888.6	530	3	4	7			0.01			<	0.034		4.72		
ADF&G	6/1/98	Wulik	M	2333.6	575	4	5	9			0.036				0.054		1.85		
ADF&G	6/1/98	Wulik	M	1879.6	553	2	5	7			0.026			<	0.034		2.02		
ADF&G	6/1/98	Wulik	F	1961.3	550	3	5	8			0.015			<	0.034		3.38		
ADF&G	6/1/98	Wulik	F	1471	514	3	4	7			0.01			<	0.034		3.61		
ADF&G	6/1/98	Wulik	M	1244	500	5	5	10			0.034				0.034		0.982		
ADF&G	10/6/98	Wulik	F	2830	626	2	8	10									8.91		
ADF&G	10/6/98	Wulik	F	2713	578	3	6	9									12.2		
ADF&G	10/6/98	Wulik	F	1161	467	3	3	6									10.2		
ADF&G	10/6/98	Wulik		duplicate of #3													11.3		
				no tissue from fish #1															
ADF&G	5/15/99	Wulik	M	duplicate of #6													2.74		
ADF&G	5/15/99	Wulik	F	1943.1	625	3	6	9									1.44		
ADF&G	5/15/99	Wulik	M	1897.7	605	3	7	10									1.47		
ADF&G	5/15/99	Wulik	M	2224.6	595	4	4	8									1.8		
ADF&G	5/15/99	Wulik	F	2760.3	620	3	7	10									7.48		
ADF&G	5/15/99	Wulik	M	4830.6	720	3	6	9									2.86		
ADF&G	9/8/99	Wulik	M	no tissue from fish #1															
ADF&G	9/8/99	Wulik	F	1343.8	490	3	4	7									7.68		
ADF&G	9/8/99	Wulik	F	1616.2	510	2	4	6									11		
ADF&G	9/8/99	Wulik	F	1144.1	455	3	3	6									10.3		
ADF&G	9/8/99	Wulik	M	1734.3	540	3	1	4									4.43		
ADF&G	9/8/99	Wulik	M	1752.4	520	3	4	7									11.6		

Sex (M = male, F = female, U = unknown)

mg/Kg dry weight

duplicate tissue samples are not included in calculations of medians, etc.

< (limit of detection)

APPENDIX 5 - ARCTIC GRAYLING - 1999 TAGS

Tag Number	Color	Length (mm)	Date Captured	Site Captured	Recapture Date	Recapture Site	Length (mm)
8075	OR	351	7/8/99	North Fork			
8076	OR	276	7/8/99	North Fork			
		266	7/8/99	North Fork			
10935	OR	341	7/8/99	North Fork			
		168	7/8/99	North Fork			
8077	OR	262	7/8/99	North Fork			
8078	OR	278	7/8/99	North Fork			
8079	OR	218	7/8/99	North Fork			
8080	OR	218	7/8/99	North Fork			
8081	OR	267	7/8/99	North Fork			
8082	OR	290	7/8/99	North Fork			
8083	OR	265	7/8/99	North Fork			
		140	7/8/99	North Fork			
		148	7/8/99	North Fork			
8084	OR	215	7/8/99	North Fork			
8085	OR	256	7/8/99	North Fork			
8086	OR	340	7/8/99	North Fork			
8087	OR	275	7/8/99	North Fork			
1599	W	378	7/9/99	North Fork			
8088	OR	275	7/9/99	North Fork			
8089	OR	270	7/9/99	North Fork			
8090	OR	275	7/9/99	North Fork			
8091	OR	276	7/9/99	North Fork			
8092	OR	385	7/9/99	North Fork			
8093	OR	325	7/9/99	Mainstem			
8094	OR	358	7/9/99	Mainstem			
8095	OR	290	7/9/99	North Fork			
8096	OR	400	7/10/99	Ikalukrok (Dudd)			
8097	OR	415	7/10/99	Ikalukrok (Dudd)			
8098	OR	405	7/10/99	Ikalukrok (Dudd)			
8099	OR	346	7/10/99	Ikalukrok (Dudd)			
8025	OR	395	7/11/99	Ikalukrok (Dudd)			
8026	OR	342	7/11/99	Ikalukrok (Dudd)			
8027	OR	361	7/11/99	Ikalukrok (Dudd)			
8028	OR	376	7/11/99	Ikalukrok (Dudd)			
8029	OR	369	7/11/99	Ikalukrok (Dudd)			
8030	OR	345	7/11/99	Ikalukrok (Dudd)			

Appendix 5. (continued).

Tag Number	Color	Length (mm)	Date Captured	Site Captured	Recapture Date	Recapture Site	Length (mm)
8031	OR	345	7/12/99	North Fork			
8032	OR	215	7/12/99	North Fork			
8033	OR	292	7/12/99	North Fork			
8034	OR	230	7/12/99	North Fork			
8035	OR	330	7/12/99	North Fork			
8037	OR	348	7/12/99	North Fork			
8038	OR	345	7/12/99	North Fork			
8039	OR	350	7/12/99	North Fork			
8040	OR	310	7/12/99	North Fork			
8041	OR	270	7/12/99	North Fork			
8042	OR	210	7/12/99	North Fork			
8043	OR	295	7/12/99	North Fork			
8044	OR	325	7/12/99	North Fork			
8045	OR	290	7/12/99	North Fork			
8046	OR	338	7/12/99	North Fork			
8036	OR	235	7/13/99	North Fork			
8047	OR	254	7/13/99	North Fork			
8048	OR	265	7/13/99	North Fork			
8049	OR	370	7/13/99	North Fork			
10950	OR	258	7/13/99	North Fork			
10951	OR	340	7/13/99	North Fork			
10952	OR	225	7/13/99	North Fork			
10953	OR	395	7/13/99	North Fork			
10954	OR	348	7/13/99	North Fork			
10955	OR	375	7/13/99	North Fork			
10956	OR	350	7/13/99	North Fork			
10957	OR	385	7/13/99	North Fork			
10958	OR	378	7/13/99	North Fork			
10959	OR	355	7/13/99	North Fork			
10960	OR	398	7/13/99	North Fork			
10961	OR	367	7/13/99	North Fork			
10962	OR	355	7/13/99	North Fork			
10963	OR	305	7/13/99	North Fork			
10964	OR	330	7/13/99	North Fork			
10965	OR	317	7/13/99	North Fork			
10966	OR	347	7/13/99	North Fork			
10967	OR	375	7/13/99	North Fork			
10968	OR	330	7/13/99	North Fork			

Appendix 5. (concluded).

Tag Number	Color	Length (mm)	Date Captured	Site Captured	Recapture Date	Recapture Site	Length (mm)
10969	OR	370	7/13/99	North Fork			
10970	OR	275	7/13/99	North Fork			
10971	OR	220	7/13/99	North Fork			
10972	OR	345	7/13/99	North Fork			
10973	OR	372	7/13/99	North Fork			
10974	OR	232	7/13/99	North Fork			
1762	W	370	7/13/99	North Fork			
1607	W	368	7/13/99	North Fork			
1745	W	348	7/13/99	North Fork			