# Comparison of Mainstem Red Dog Creek Pre-Mining and Current Conditions

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# Comparison of Mainstem Red Dog Creek
# Pre-Mining and Current Conditions

## *Pre-Mining Conditions*

Middle Fork Red Dog Creek flows through the main Red Dog ore body containing substantial amounts of Al, Ba, Cd, Cu, Fe, Pb, Zn, Ag, and Se. Erosion and oxidation from exposed mineralization and seepage through the ore body contributed dissolved metals to Middle Fork Red Dog Creek, resulting in periodic high concentrations of metals in both Mainstem Red Dog and Ikalukrok creeks. Neither fish spawning nor fish rearing was documented in Mainstem Red Dog Creek. The primary use of Mainstem Red Dog Creek by fish was as a migration corridor to North Fork Red Dog Creek. Periodic fish kills were documented. Few aquatic invertebrates were observed (sampling was limited to visual observations). No pre-mining sampling was done for periphyton.

### WATER QUALITY

Pre-mining water quality studied in Mainstem Red Dog Creek found:

| | |
|---|---|
| Cadmium | 100% of the samples exceeded the Chronic WQS For Aquatic Life, 95% exceeded the acute WQS, and 92% exceeded 5 times the acute WQS. |
| Lead | Most of the pre-mining water samples were reported at the detection limit, which was nearly equal to the acute limit for aquatic life; |
| Zinc | 100% of the samples exceeded the Chronic WQS For Aquatic Life, 100% exceeded the acute WQS, and 95% exceeded 5 times the acute WQS. |

Water quality in Mainstem Red Dog Creek was considered to be “degraded by metals” (EVS and Ott Water Engineers 1983), with low pH and high metal concentrations, especially cadmium and zinc.

Causes of periodic increases in metals were not investigated, but may have been related to high rainfall remobilizing metals in the soils (Dames and Moore 1983), because the highest metals concentrations occurred as stream flows declined after a storm event. Analysis of the pre-mining data (excluding samples that were reported as less than the

Method Detection Limit or collected when the creek was frozen[1]) found concentrations of all metals in Mainstem Red Dog Creek were high (Table 1), and often many times higher than the Water Quality Standards for Aquatic Life.

Table 1. Pre-mining water quality in Mainstem Red Dog Creek and the acute and chronic Water Quality Criteria for Aquatic Life (USEPA 1983), assuming hardness of 100 mg/L for hardness dependent criteria. Data from Dames and Moore (1983).

| | Chronic Limit, µg/L | Acute Limit, µg/L | Median Concentration µg/L | Maximum Concentration µg/L | Minimum Concentration µg/L | Number of Samples |
|---|---|---|---|---|---|---|
| Al, µg/L | | | 150 | 1190 | 20 | 38 |
| Cd, µg/L | 1.1 | 3.9 | 28 | 98 | 2 | 43 |
| SpCond, µSi/cm | | | 328 | 1090 | 154 | 8 |
| Cu, µg/L | 12 | 18 | 4 | 19 | 2 | 15 |
| Hardness, mg/L | | | 127 | 227 | 21 | 21 |
| Pb, µg/L | 3.2 | 82 | 80* | 100 | 0.8 | 43 |
| pH | | | 6.65 | 7.3 | 6.1 | 10 |
| SO4, mg/L | | | 69.6 | 440 | 7.9 | 11 |
| TDS, mg/L | | | 198 | 876 | 8.8 | 11 |
| Zn, µg/L | 47 | 320 | 3700 | 13000 | 567 | 43 |

*The detection limit in pre-mining samples.

## FISH IN MAINSTEM RED DOG CREEK

According to Ward and Olson (1980), EVS and Ott Water Engineers (1983) and Dames and Moore (1983):

- Fish use of Red Dog Creek was limited to migration to North Fork Red Dog Creek during spring high flows;
- Rearing Arctic grayling (age 1+ and 2+) frequently were excluded from North Fork Red Dog Creek by high concentrations of metals in Red Dog Creek;
- Few rearing Arctic grayling and Dolly Varden were found;
- Fish experienced high mortalities in Red Dog Creek during downstream migrations;
- Periodic fish kills occurred in Mainstem Red Dog Creek; and
- There was no evidence of spawning in Mainstem Red Dog Creek.

[1] Pre-mining water sample analysis by EVS and Ott Water Engineers used method detection limits (e.g. 25 ug/L for Cd) that were higher than EPA Water Quality Standards and the data were not included in Table 1.

Pre-mining studies suggest that fish use of Red Dog Creek was restricted to migration to North Fork Red Dog Creek during high water events, especially during break-up. The historic evidence for fish kills in Red Dog Creek is strong. As early as 1978, Ward and Olson (1980) conducted a baseline aquatic investigation of fishes and water quality in the Kivalina and Wulik River drainages. The purpose of their study was to conduct a detailed investigation intended to identify potential environmental problems related to mineral exploration and extraction. No specific mineral deposit had been targeted at this time. Ward and Olson reported:

> During the course of field investigations, we observed six individual fish kills in Red Dog Creek between 21 June and 29 August 1978. During these kills, a total of about 800 to 1000 juvenile and adult grayling and lesser numbers of juvenile arctic char died. Of the streams we examined, fish kills occurred only in Red Dog Creek and they often occurred five to ten days after precipitation began, i.e. when precipitation was sufficient enough to cause a 10 to 20 cm increase (100 – 300 cfs) in the water level.

The frequency and extent of these kills was documented as follows.

> Red Dog Creek was visited at least once a day throughout the entire field season. This visit included some form of visual inspection or sample collection. In addition, the largest, deepest, and quietest pool in Red Dog Creek was located next to camp [located near the mouth of Red Dog Creek]. Two smaller, quiet pools were located within 1.6 km upstream. The remainder of RDC is characterized by shallow, fast water riffles extending from the headwaters to the mouth. Each time a kill occurred, dead fish would begin accumulating in each of the three pools. When fish began appearing, the field crew counted and collected all possible. At the time of each kill, RDC was surveyed both from low-level helicopter and on foot to at least 4.8 km upstream of the mouth. During these surveys, an occasional dead or dying fish was found floating downstream. Village Creek, Sir Creek, Ikalukrok Creek, and GC [Grayling Junior Creek] were similarly surveyed

during each kill to determine if kills were occurring, but no dead fish were sighted in these streams at any time.

Houghton and Hilgert (1983) reported that Arctic grayling were rarely seen in Mainstem Red Dog Creek and were not reported as present in Middle Fork Red Dog Creek. Fish were observed in Mainstem Red Dog Creek within the influence of North Fork Red Dog Creek (Dames and Moore 1983). Arctic grayling adults were assumed to migrate through Mainstem Red Dog Creek in early spring when discharges were high and metals concentrations low. Outmigration of adults was believed to occur during high-water events. Young-of-the-year Arctic grayling migrated downstream as water temperatures cooled in the fall or they were displaced by high-water events.

EVS and Ott Water Engineers (1983) also reported limited use of Red Dog Creek by fish. They found abundant post-spawning Arctic grayling throughout Ikalukrok Creek in the vicinity of the Red Dog Creek confluence, but no evidence of Arctic grayling spawning in Red Dog Creek. The abundance of Arctic grayling was low in Red Dog Creek, compared to Ikalukrok Creek: "The abundance of spent and non-spawning sub-adult Arctic grayling (>200 mm) was estimated at 100 [fish]/river km in [Ikalukrok Creek in the] vicinity of the Red Dog Creek confluence. By comparison, Arctic grayling abundance in lower Red Dog Creek at this time was approximately 10 [fish] / river km, and 3-5 [fish] /river km in the upper reaches, downstream of North Fork Red Dog Creek. Approximately 200 Arctic grayling (range 100-400), comprised of spawners, non-spawning sub-adults and post-fry were observed earlier in the season in North Fork Red Dog Creek." EVS noted that Arctic grayling abundance in Red Dog Creek was only 1 to 2 fish per river km during periods of mid-summer low flows.

EVS reported young-of-the-year Arctic grayling in North Fork Red Dog Creek by July 10 and in Ikalukrok Creek near the confluence of Red Dog Creek by July 15. Young of-the-year and age 2+ Arctic grayling were "represented among natural fish kills in Red Dog Creek."

EVS electrofished Ikalukrok Creek in the vicinity of Red Dog Creek to document the presence of juvenile Dolly Varden. They reported "Despite extensive electrofishing effort within a 3 km length of Ikalukrok Creek in the Red Dog Creek area, only one 1+ Arctic char was found (75 mm; June 27). Relative abundance compared with Tutak, Rabbit and Five Fingered Creeks (known areas of char reproduction), was virtually nil (0.01 char/river km). However, 37 Arctic char ranging from 55-113 mm were found dead in Red Dog Creek at various times throughout the study."

EVS described the dead fish found in Red Dog Creek: "Natural mortalities from Red Dog Creek displayed considerable amounts of brown precipitates and mucus on gill surfaces; the occasional occurrence of gill hemorrhaging and eye opaqueness was noted. Fish collected from Ikalukrok Creek were free of precipitates, mucus or hemorrhaging."

Dames and Moore (1983) summarized the use of Red Dog Creek by Arctic grayling:

> Information gathered over the past 2 years suggests the following pattern of use of the Upper Ikalukrok / Red Dog Creek system by Arctic grayling. Adult spawners enter the stream as stream temperature begins to rise above 2 to 3 C in the spring. This probably occurs soon after the majority of in-channel ice has melted. Spawning occurs for perhaps 1 to 2 weeks with the major activity usually completed by late June. Fry hatch by the first or second week in July and remain in very low velocity backwaters and pockets until late July or early August when they are also found among cobbles and boulders in shallow areas with moderate current. During the early summer, many fry from North Fork Red Dog Creek are displaced downstream by current and enter the main stem of Red Dog Creek. Many, if not the majority, of these fish perish due to high metals levels in Red Dog Creek.
>
> Following breakup, age 1+ and 2+ subadult grayling also move upstream into most of the medium-sized tributaries in the area. Since no age 1+ and few (if any) age 2+ grayling have been found in North Fork Red Dog Creek, it may be hypothesized that they lack the swimming abilities to move through the toxic lower main stem to reach the "safe" area of North Fork Red Dog Creek.

> Later in the summer and fall there is a natural downstream movement of fry to overwintering areas in Ikalukrok Creek, which again takes them into the Mainstem Red Dog Creek where many succumb.

AQUATIC INVERTEBRATE AND PERIPHYTON COMMUNITIES

Dames and Moore (1983) and EVS and Ott Water Engineers (1983) summarized the aquatic communities of Mainstem Red Dog Creek:

- An absence or near-absence of algal growth on the stream bottom;
- An absence of aquatic macrophytes; and
- An absence of aquatic invertebrates.

Dames and Moore (1983) summarized the ecology of Red Dog Creek:

> The Red Dog mineralization has been shown to have a profound effect on the water quality and, hence, the aquatic ecology of not only Red Dog Creek itself but also Ikalukrok Creek for some distance downstream. Within much of the Mainstem Red Dog Creek, this influence is graphically demonstrated by the absence or near absence of periphyton, macrophyton, insects and fish. Fish from the Ikalukrok [Creek] are completely cut off from the relatively good habitat in the South Fork of Red Dog Creek [presently dammed for the tailings impoundment] by the acutely toxic conditions in 5 kilometers of the mainstem. The spawning population in North Fork Red Dog Creek apparently persists by migrating swiftly through the 3 kilometers of the lower mainstem during the spring runoff when water metals levels (cadmium, zinc) are at their seasonal lows. Furthermore, this spawning population persists despite heavy mortalities of downstream migrating fry and the apparent lack of access to North Fork Red Dog Creek for rearing by age1+ and 2+ grayling.

*Current Conditions in Mainstem Red Dog*

A number of construction projects and changes in operational procedures at the Red Dog Mine resulted in changes to water quality in the Red Dog Creek drainage; these projects are discussed in greater detail by Ott (2004), Weber Scannell and Andersen (2000) and Weber Scannell and Ott (1998). The significant events, as summarized by Ott (2004), are presented below. Following are discussions of changes in water quality and aquatic populations that have been observed by ADF&G and ADNR.

| | |
|---|---|
| 1987-89 | Construction of the mine facility, including the tailing dam. Tailing dam cut off flow from South Fork Red Dog Creek |
| 1990 | Installation of sumps and pumps by Teck-Cominco partially minimized metals-laden water from entering Red Dog Creek |
| 1991 | Clean water bypass system designed, built, and modified |
| 1992 | Water treatment plant modified |
| 1993 | Sand filters installed to remove particulate zinc |
| 1994 | Water treatment capacity increased by thickening tank conversion<br>Wastewater discharge increased from 7.5 cfs to 23 cfs |
| 1995 | Clean water bypass system extended to intercept Hilltop Creek |
| 1998 | NPDES Permit reissued by USEPA<br>Additional treatment installed to meet reduced cadmium limits |
| 2001 | Catch-box and pipeline (about 430 m) placed in Shelley Creek to move water past disturbance due to expansion of the pit |
| 2002 | A bypass was installed in Connie Creek during Winter 2001-2002. The bypass captures the upstream creek and carries the water through a pipe to the clean-water bypass system and across areas disturbed by expansion of the pit<br>The bypass system for Shelly Creek was modified by adding a lined ditch to contain clean-water overflow and direct it to the clean-water bypass system |

## Water Quality

Biomonitoring studies in Mainstem Red Dog Creek found substantial changes in water quality as compared to pre-mining conditions: Although many of the water samples collected from 1998 through 2003 exceeded the US EPA Water Quality Criteria, overall concentrations were lower than pre-mining (Table 2).

Table 2. Percent of water samples from Station 10, Mainstem Red Dog Creek (collected during ice-free season) that exceeded the US EPA chronic and acute criteria for aquatic life and that exceed 5 times the acute criteria.

| | % of Samples Exceeding Chronic Criteria | | % of Samples Exceeding Acute Criteria | | % of Samples Exceeding 5 times Acute Criteria | |
|---|---|---|---|---|---|---|
| | Pre-mining | Current Conditions | Pre-mining | Current Conditions | Pre-mining | Current Conditions |
| Cd | 100 | 100 | 95 | 75 | 92 | 0 |
| Pb | * | 51 | * | 5 | 0 | 0 |
| Zn | 100 | 100 | 100 | 91 | 95 | 0 |

*Method Reporting Limit for lead in pre-mining data was too high to provide meaningful analysis.

Loehr (pers. comm. to Mark Thompson, TeckCominco, 2004) compared pre-mining and current water quality data for Red Dog Creek and Ikalukrok Creek. He limited the data to samples collected in the month of July to eliminate seasonal variations. Loehr suggested comparisons among sites based on the "exceedance factor," which he defined as the amount of metal in a water sample divided by the hardness-based standard. An exceedance factor of 1 means that the sample equals the standard, and factors less than 1 mean the sample is lower than the standard. Loehr used hardness concentrations measured at the same time the samples were taken, when they were available, or estimated hardness concentrations based on samples collected at about the same time. Data were limited to samples analyzed as total recoverable and compared with a water quality standard based on total recoverable analysis (ADEC 2003).

According to Loehr's method of comparison, the average July concentrations of Cd measured at Station 10 exceeded the Chronic Limit for Aquatic Life by 91 times before development of the mine and by a factor of 13.3 after mine development (Figure 1). Similar, although not as substantial, differences were found when Cd concentrations were compared to the Acute Limit for Aquatic Life: July water samples exceeded the acute limit for Cd by 11 times before mine development and by 1.2 times after mine development (Figure 2). His analysis demonstrates that, while Cd concentrations at Station 10 often exceed water quality standards for aquatic life, the concentrations are lower after mine development than before mining. Considerable reductions in cadmium from historic conditions are also evident at Stations 20 and 140.

Similar comparisons were made with concentrations of lead at Station 10; however reductions in lead concentrations are not as apparent. Pre-mining water analysis for lead used a high (80 ug/L) detection limit, which is nearly equal to the acute limit for aquatic life. Most of the pre-mining water samples collected at Station 10 were reported at the detection limit for lead. Lead concentrations at Stations 20 and 140 (where pre-mining data were substantially higher than the detection limits) show improvements in water quality when compared to both the Acute (Figure 3) and Chronic (Figure 4) limits for aquatic life.

Reductions in both Cd and Pb at Station 140 result from measures taken by TCAK to control drainage water in the region of the ore body. These measures include construction of the clean water bypass system, construction of the mine sump pump back system, and the more recent clean water bypass systems in Connie and Shelley Creeks. Reductions in metals at Station 20 are due to both a combination of the drainage control measures and dilution by the mine effluent. Metals in the mine effluent remain low (Figures 1 through 4).

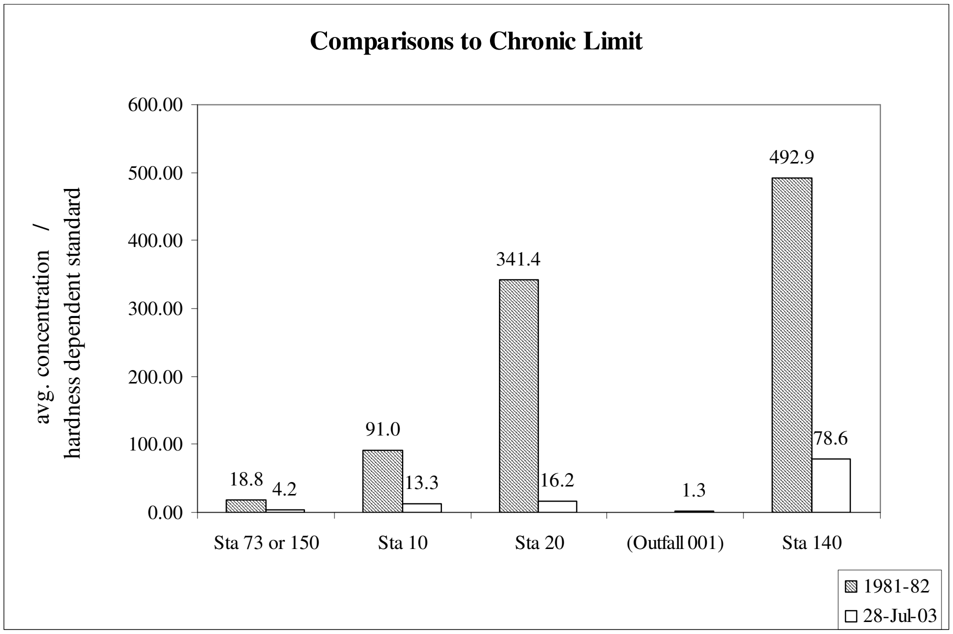


Figure 1. The amount that July water samples exceeded the Cd chronic limit for aquatic life (based on total recoverable analysis) at various stations, pre-mining and current conditions.

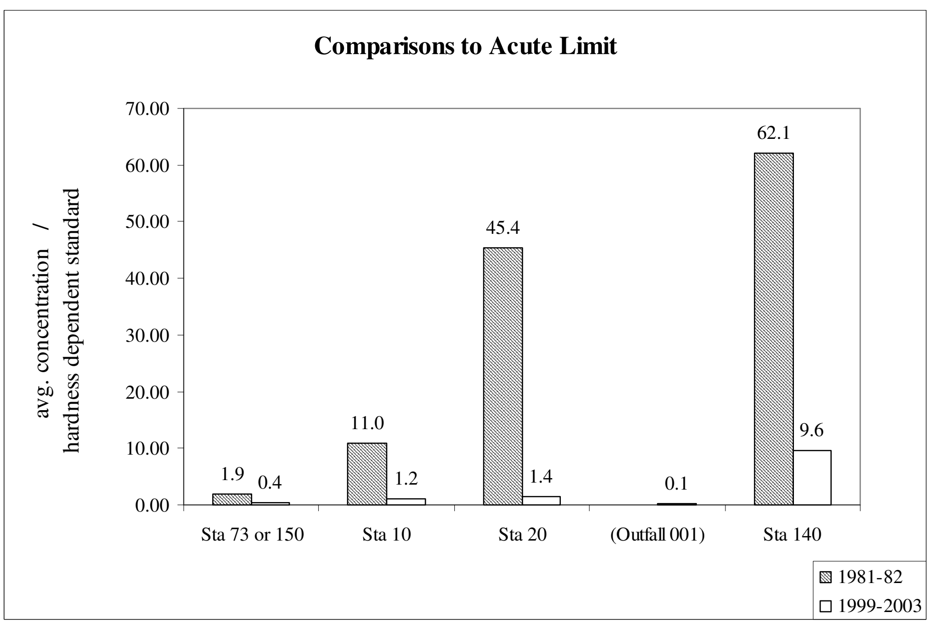


Figure 2. The amount that July water samples exceeded the Cd acute limit for aquatic life (based on total recoverable analysis) at various stations, pre-mining and current conditions.

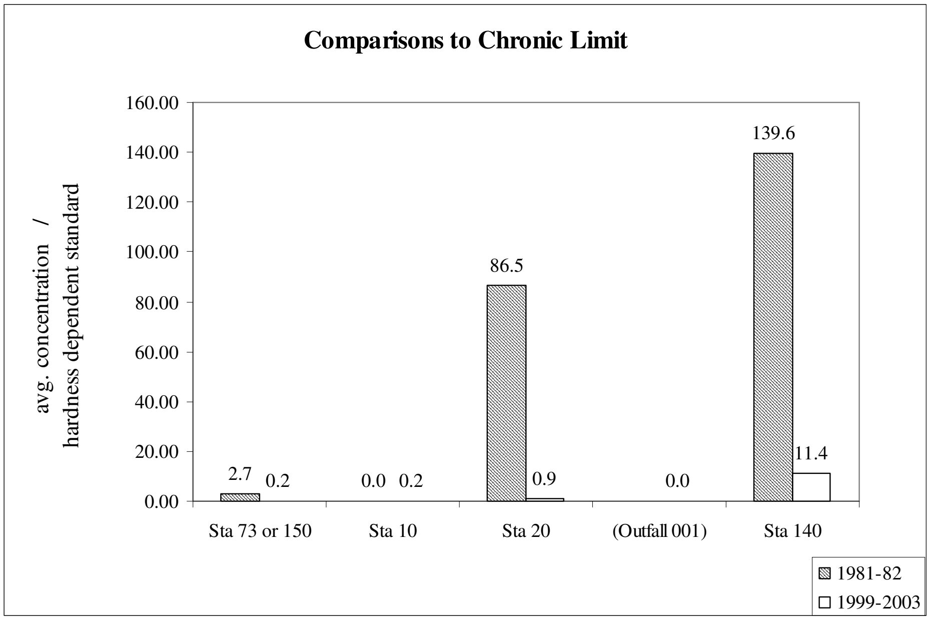


Figure 3. The amount that July water samples exceeded the Pb chronic limit for aquatic life (based on total recoverable analysis) at various stations, pre-mining and current conditions.

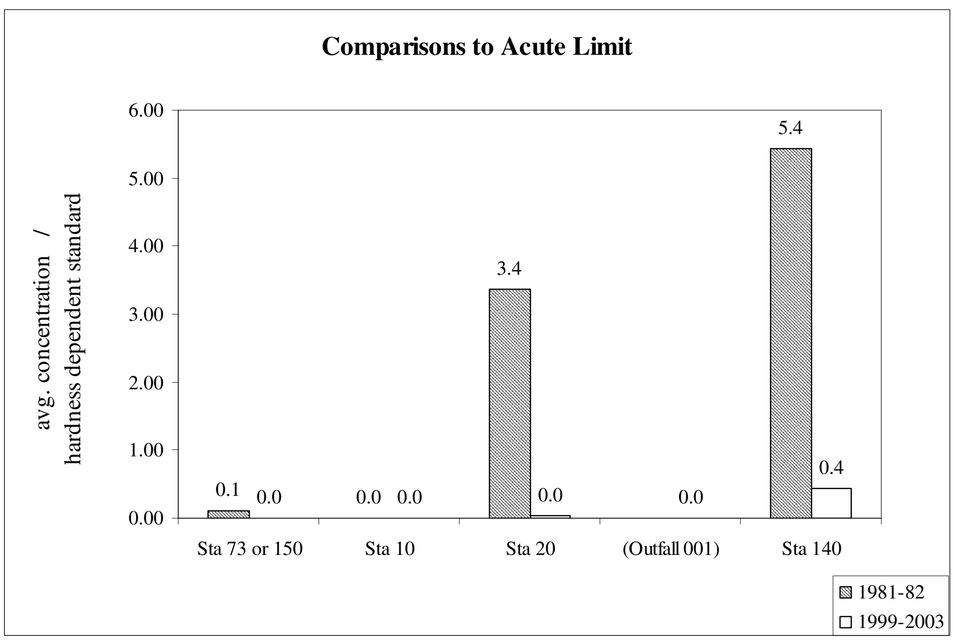


Figure 4. The amount that July water samples exceeded the Pb acute limit for aquatic life (based on total recoverable analysis) at various stations, pre-mining and current conditions.

Water quality data presented by Ott (2004) show that although there were occasional spikes in Cd (Figure 5) and Zn (Figure 6), the median concentrations during mine operation were substantially lower than pre-mining concentrations. Median concentrations of Pb (Figure 7) also appear lower than during baseline; however, the high detection limits used for pre-mining metals analysis limit the value of this comparison. Samples from 2000, 2003, and 2004 show occasional peaks in lead concentrations that are above both chronic and acute limits for aquatic life.

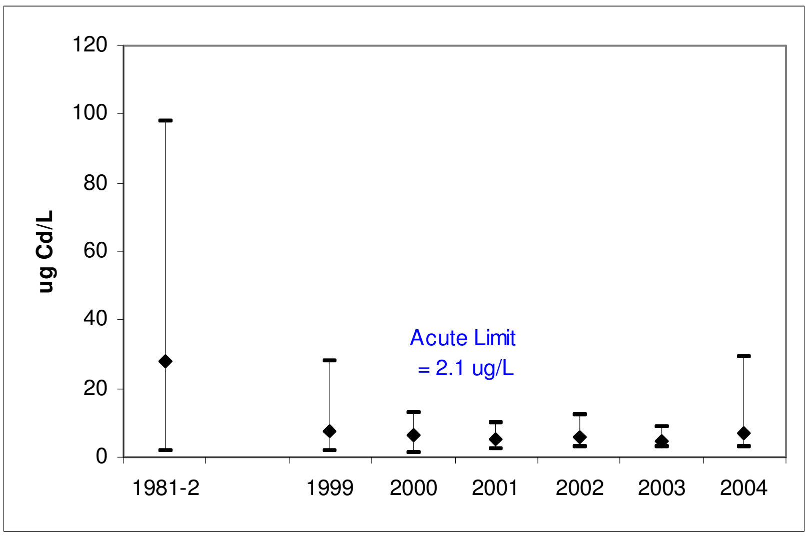


Figure 5. Median, maximum, and minimum concentrations of Cd at Station 10. Data from Alaska Department of Natural Resources, used with permission. The acute limit for aquatic life is based on the pre-discharge median hardness of 100 mg/L.

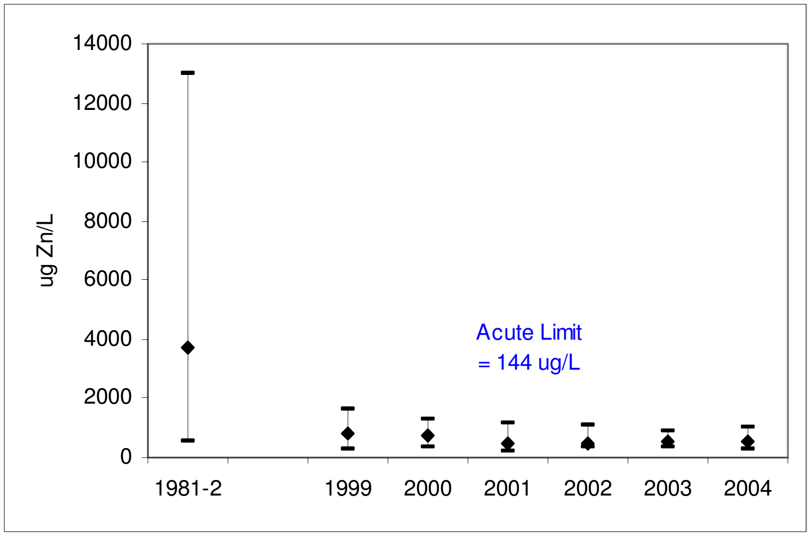


Figure 6. Median, maximum, and minimum concentrations of Zn at Station 10. Data from Alaska Department of Natural Resources, used with permission. The acute limit is based on the pre-discharge median hardness of 100 mg/L.

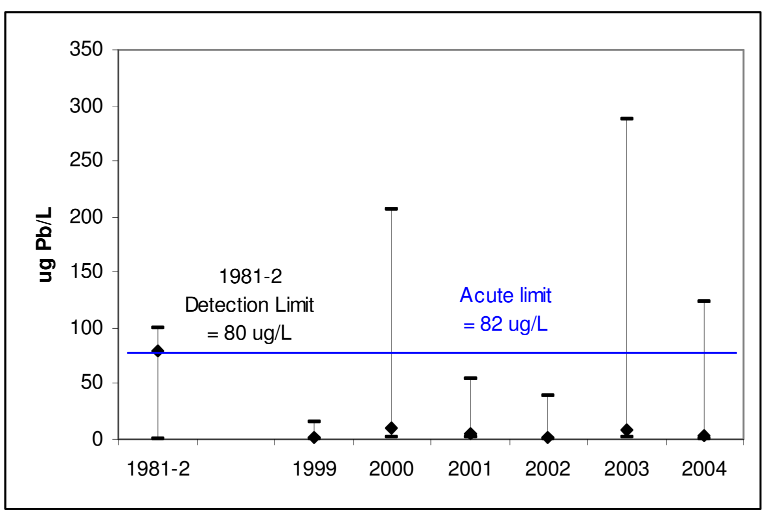


Figure 7. Median, maximum, and minimum concentrations of Pb at Station 10. Data from Alaska Department of Natural Resources, used with permission. The acute limit is based on the pre-discharge median hardness of 100 mg/L.

## FISH IN MAINSTEM RED DOG CREEK

- The Alaska Department of Fish and Game first observed adult Arctic grayling in Mainstem Red Dog Creek in 1994.
- In 1995, both young-of-the-year Arctic grayling and adult fish were observed in Mainstem Red Dog Creek.
- Young-of-the-year Arctic grayling 13-15 mm long were caught in drift nets in late June 1997 near Station 10 and they were still present in August and September of 1997, indicating that both spawning and rearing was occurring.

Ott (2004) describes the Arctic grayling populations in Mainstem Red Dog Creek:

> Visual surveys of Mainstem Red Dog Creek have been conducted annually from 1994 to 2003. The purpose of these surveys is to document use of Mainstem Red Dog Creek by Arctic grayling and compare it with information available from the baseline studies. Use of Mainstem Red Dog Creek prior to development of the mine was limited to migration, with some adult use of the lower portion of the creek. Arctic grayling use (adults and age 0 fish) of Mainstem Red Dog Creek currently is higher than that described in the baseline studies. Changes in use are likely related to overall improvement in water quality as compared with pre-mining conditions.
>
> Beginning in 1995 and continuing through 2004, juvenile Dolly Varden were caught with minnow traps in Mainstem Red Dog Creek below North Fork Red Dog Creek. Dolly Varden use of tributary creeks is substantial and highly variable [Table 3]. Depending on environmental conditions (stream flows and water temperature), peak use of these creeks occurs from late July through mid-August with few fish caught early in the spring and late in the fall. Juvenile Dolly Varden use of Mainstem Red Dog Creek was first found in 1995 and presence and use continued to be documented in summers 1996 through 2004.

The mine effluent is warmer but does not appear to have a direct effect on the temperature of Mainstem Red Dog Creek at Station 10. In the spring, after the mine has commenced discharging, the creek reaches 4° C before North Fork Red Dog Creek warms. Arctic grayling key on temperatures around 4° C to begin spawning. Arctic grayling that historically migrate through Mainstem Red Dog Creek to spawn in North Fork Red Dog Creek are more likely to spawn upon reaching the warmer water of Mainstem Red Dog Creek. Therefore, at least part of the Arctic grayling population spawns earlier in Mainstem Red Dog Creek than before development of the mine. These changes in spawning habits are not necessarily positive or negative.

Table 3. Summary of total catch of Dolly Varden in Red Dog Creek, 1997-2003.

| Year | Mainstem Red Dog Creek Near Station 10 | Mainstem Red Dog Creek Below North Fork |
|---|---|---|
| 1997 (early August) | 10 | 14 |
| 1998 (early August) | 21 | 70 |
| 1999 (early August) | 66 | 86 |
| 2000 (late July) | 1 | 13 |
| 2001 (late July) | 3 | 9 |
| 2002 (late July) | 12 | 12 |
| 2003 (early August) | 12 | 2 |
| 2004 (mid July) | 9 | 7 |

Note: Middle Fork Red Dog Creek was sampled in 1995, 1996, and 1997 with five traps (two sample events per summer) and no Dolly Varden juveniles were captured.

## Invertebrate and Periphyton Communities

- Mainstem Red Dog Creek contains abundant and diverse aquatic invertebrate communities, compared to no or few invertebrates found in pre-mining;
- Mainstem Red Dog Creek contains abundant and diverse periphyton communities, compared to no or little periphyton pre-mining;

Ott (2004) summarized the biomonitoring studies conducted over the 1999-2003 NPDES Permit monitoring period and compared the results with pre-mining observations. In contrast to pre-mining, when no or few invertebrates were found, 1999 - 2003 sampling in Mainstem Red Dog Creek found high invertebrate densities (Figure 8) with many taxa

(Figure 9). Periphyton, estimated by concentrations of chlorophyll-a, also was abundant in Mainstem Red Dog Creek (Figure 10). Periphyton samples collected from 2001 through 2003 show a predominance of chlorophyll-a, with some chlorophyll-c and small amounts of chlorophyll-b (Figure 11). Samples collected in 1999 and 2000 were analyzed with a fluorometer and estimates of the different pigments were not made. The presence of chlorophylls a, b, and c is indicative of a complex and diverse algal community.

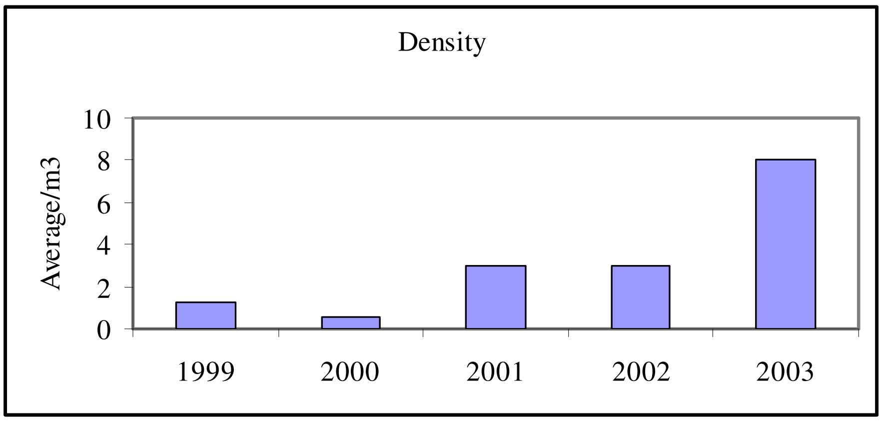


Figure 8. Density of aquatic invertebrates collected in Mainstem Red Dog Creek at Station 10.

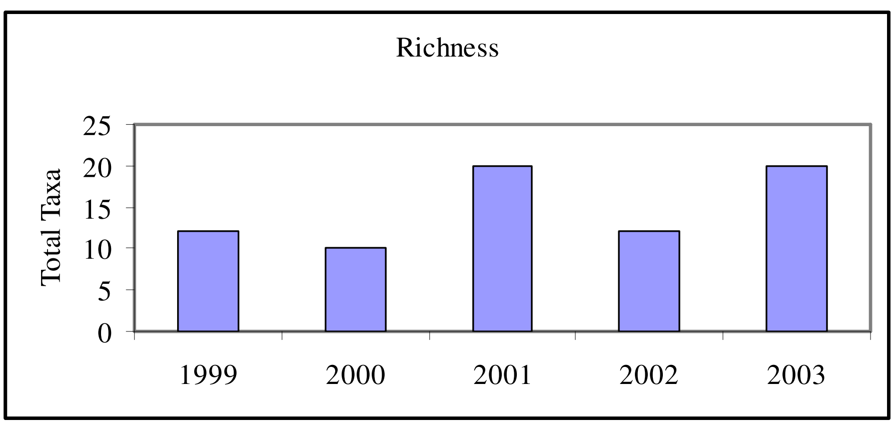


Figure 9. Taxa richness of aquatic invertebrates collected in Mainstem Red Dog Creek at Station 10.

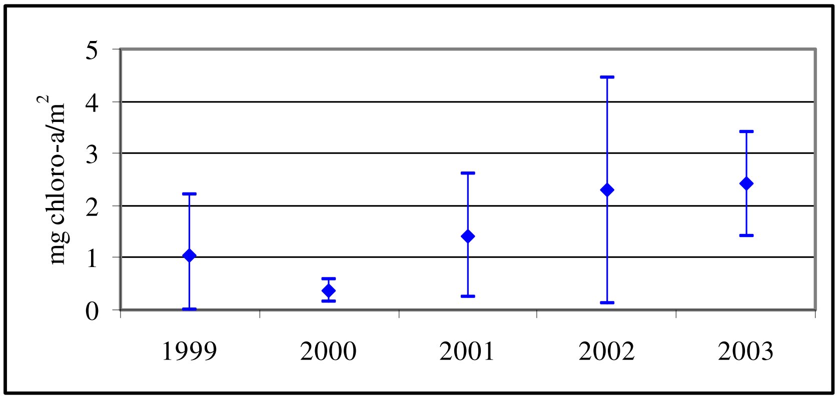


Figure 10. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Mainstem Red Dog Creek at Station 10.

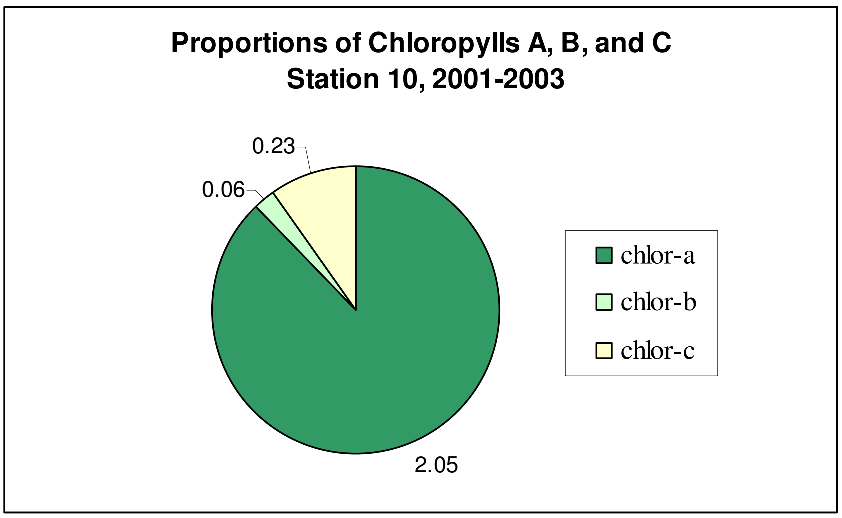


Figure 11. Concentrations and relative proportions of chlorophyll-a, b, and c ($mg/m^2$) in Mainstem Red Dog Creek at Station 10 in 2003.

Over the last six years (1998 through 2004) there has been a viable aquatic community in Mainstem Red Dog Creek with the current water quality and mine discharge. Analysis of the water quality data supports the finding that the mine discharge is a net benefit to the creek. The naturally occurring concentrations of metals (especially cadmium and zinc) are diluted, the pH is moderated, and the higher hardness of the discharge water moderates the toxicity of the metals.

*Summary of Comparisons of Pre-Mining and Current Conditions*

- Before development of the Red Dog Mine, (a) water quality was naturally degraded in Red Dog Creek; (b) fish use was limited to migration to North Fork of Red Dog Creek during high water events; (c) no fish spawning was documented in Red Dog Creek; and (d) natural fish kills commonly occurred in Red Dog Creek;
- Development of the Red Dog Mine included a number of water management practices that resulted in improved water quality in Red Dog Creek. These practices included collection, treatment and discharge of mineralized water; discharge of high volumes of water with low metals concentrations; and improvements in water treatment;
- High volumes of treated water are discharged to Middle Fork Red Dog Creek. This water dilutes the naturally occurring metals in Red Dog Creek, moderates the pH, and lessens the toxicity of metals by increasing the hardness;
- As a result of improved water quality, Arctic grayling began using Mainstem Red Dog Creek for spawning and rearing and Dolly Varden for rearing;
- Improved water quality was followed by development of abundant and diverse aquatic invertebrate and periphyton communities; and
- Over the last six years (1998 through 2004) there is a viable aquatic community in Mainstem Red Dog Creek with the current water quality and mine discharge.

Table 4. Summary of the characteristics of the aquatic communities and water quality between pre-mining and current conditions, Mainstem Red Dog Creek.

| | Pre-mining<br>1982 - 1983 | Current Conditions<br>1999 - 2003 |
|---|---|---|
| Water Quality | high metals, Most water samples (>90%) exceed 5 times the acute standard for Cd and Zn. | somewhat elevated metals. No samples exceeded 5 times acute standard for Cd and Zn. |
| Fish Populations | Few fish, migration only. | Arctic grayling spawning and rearing, Dolly Varden rearing |
| Invertebrate Communities | No or few invertebrates observed | Abundant community with high taxonomic richness. |
| Periphyton Communities | No periphyton observed | Abundant community, richness represented by all three major pigments. |

# References


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