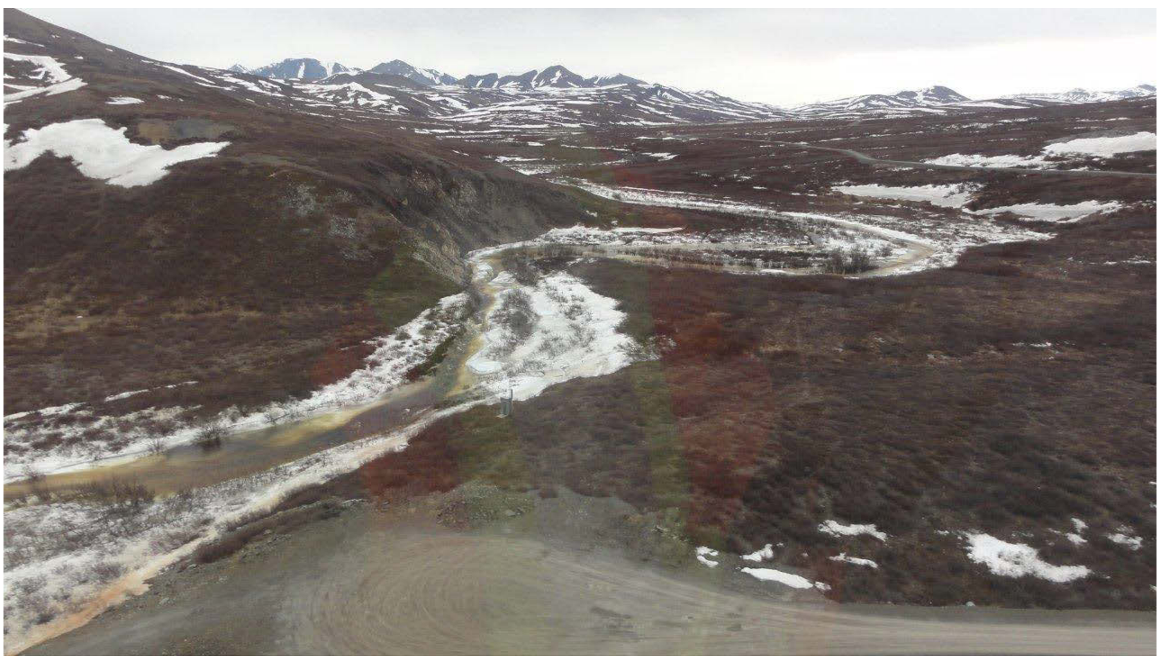
Technical Report No. 13-01

Aquatic Biomonitoring at Red Dog Mine, 2012
National Pollution Discharge Elimination System Permit No. AK-003865-2

by Alvin G. Ott and William A. Morris



North Fork Red Dog Creek (Prior to Setting Fyke Nets), May 23, 2012
Photograph by Teck

March 2013

Alaska Department of Fish and Game
Division of Habitat

The Alaska Department of Fish and Game (ADF&G) administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility please write:

●ADF&G ADA Coordinator, P.O. Box 115526, Juneau, AK 99811-5526

●U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, MS 2042, Arlington, VA 22203

●Office of Equal Opportunity, U.S. Department of Interior, 1849 C Street NW MS 5230, Washington DC 20240

The department's ADA Coordinator can be reached via phone at the following numbers:

●(VOICE) 907-465-6077

●(Statewide Telecommunication Device for the Deaf) 1-800-478-3648

●(Juneau TDD) 907-465-3646

●(FAX) 907-465-6078

For information on alternative formats and questions on this publication, please contact the following:

●ADF&G, Division of Habitat, 1300 College Road, Fairbanks, AK 99701 (907)459-7289.

Aquatic Biomonitoring at Red Dog Mine, 2012

National Pollution Discharge Elimination System
Permit No. AK-003865-2

Technical Report No. 13-01

By

Alvin G. Ott and William A. Morris

Randall W. Bates
Director
Division of Habitat
Alaska Department of Fish and Game

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in reports by the Divisions of Habitat, Sport Fish and of Commercial Fisheries. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

Table of Contents

List of Tables

List of Figures

List of Figures (concluded)

Acknowledgements

We thank Teck for their financial and logistical support for the 2012 aquatic biomonitoring work. We specifically acknowledge the assistance provided by Mr. Jeff Clark, Mr. Wayne Hall, Mr. John Martinisko, Mr. Chris Eckert, Mr. Andy Willman, Mr. Joseph Diehl III, Mr. Dennis Sheldon, Mr. Chris Menefee, Ms Karen Conitz, and Mr. Robert Napier.

Ms. Laura Jacobs and Mr. Brad Wendling with the Division of Habitat, Alaska Department of Fish and Game (ADF&G) and Mr. Brendan Scanlon with Sport Fish Division (ADF&G) provided assistance with laboratory work. Mr. Fred DeCicco (Fisheries Services and Supplies) conducted the fall Dolly Varden (*Salvelinus malma*) and chum salmon (*Oncorhynchus keta*) aerial surveys and collected the fall sample of adult Dolly Varden from the Wulik River. Mr. Parker Bradley (ADF&G) participated in the spring 2012 sampling event for adult Dolly Varden collection in the Wulik River and Arctic grayling sampling in the Red Dog Creek drainage and Bons Pond.

Dr. Phyllis Weber Scannell (Scannell Technical Services) updated our long-term water quality data base with 2012 data. Ms. Nora Foster (NRF Taxonomic Services) was responsible for sorting and identification of aquatic invertebrates. Mr. Jack Winters, Ms. Heather Scannell, and Mr. Robert Napier provided constructive review of our report.

Executive Summary

●Median metals concentrations (Pb, Zn, Al, Cd) in Mainstem Red Dog Creek are consistently lower when compared with pre-mining data. The pH and total dissolved solids (TDS) in Mainstem Red Dog Creek are higher than pre-mining. Median concentrations of Cd, Pb, and Zn are consistently higher in Mainstem Red Dog Creek as compared with Buddy and North Fork Red Dog creeks. We expected to see an increase in Pb, Zn, and Cd concentrations in 2012 without the treated water discharge; however, only Pb showed an increase.

●Algal biomass, as estimated by chlorophyll-a concentration, is sampled each year at Red Dog. In 2012, periphyton standing crops were highest in Buddy (below falls), Mainstem Red Dog, and Ikalukrok creeks (near Station 160). These results are not consistent with previous data where chlorophyll-a concentrations generally are highest in Buddy, North Fork Red Dog, and Bons creeks. Although low, chlorophyll-a concentrations were higher in Middle Fork Red Dog Creek in 2012 than in most years. The higher chlorophyll-a concentrations in Middle Fork Red Dog Creek likely are due to the low and warm water conditions during 2012. Results were similar to 2010 which also was unusually dry and warm.

●Aquatic invertebrate densities are used as a measure of stream productivity. In 2012, the highest aquatic invertebrate density was found in Buddy Creek upstream of the road. Densities were higher in North Fork Red Dog, Bons (upstream of Bons Pond), and Buddy creeks (above road and below falls). Overall, in 2012 EPT represented a higher proportion of the aquatic invertebrates. Taxa richness was similar in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks. Major changes in taxa richness have not been observed

●Juvenile Dolly Varden and Arctic grayling for whole body metals analyses were not collected in 2012.

●Kidney, liver, ovary, testes, and muscle from adult Dolly Varden captured in the Wulik River during spring and fall 2012 were sampled for Cd, Cu, Pb, Se, Zn, and Hg. None of the analytes measured have been found to concentrate in muscle tissue. Various metals do concentrate in specific tissues: Cd in kidney, Cu in liver, Se in kidney and ovary, Zn in ovary, and Hg in kidney. It is unlikely that tissue metals concentrations or changes can be related to events at the Red Dog Mine since Dolly Varden attain the majority of their growth in the marine environment.

●The number of overwintering Dolly Varden is estimated each fall in the Wulik River. From 2005 to 2012, the number of fish overwintering in the Wulik River has exhibited a decreasing trend. Aerial surveys prior to mine development found that over 90% of overwintering Dolly Varden in the Wulik River were located below the mouth of Ikalukrok Creek. Surveys post mining demonstrate the same distribution. Factors that may be related to the decreasing trend in the numbers of Dolly Varden in the Wulik River are unknown.

Executive Summary (concluded)

●Annual aerial surveys assess the distribution of chum salmon in Ikalukrok Creek. Aerial counts of adult chum salmon after mine development in 1990 and 1991 were much lower than those reported in baseline studies. The highest estimated number of chum salmon was 4,185 in 2006. In fall 2012, the estimated chum salmon return to Ikalukrok Creek was at least 1,198 fish. Returns of chum salmon to Ikalukrok Creek have been strong the last seven years.

●Juvenile Dolly Varden sampling was not conducted in fall 2012 due to high water events. Resident Dolly Varden were collected with fyke nets in North Fork Red Dog Creek in spring 2012.

●The Arctic grayling spring migration into North Fork Red Dog Creek was monitored in spring 2012. We caught 138 Arctic grayling in a fyke net in North Fork Red Dog Creek. Spawning was judged to be substantially complete by June 4 in Mainstem Red Dog Creek. Spawning success in North Fork Red Dog Creek was low, but fry were present along stream margins with schools of 15 to 20 individuals in Mainstem Red Dog Creek. Recruitment of juvenile Arctic grayling has been strong the past six years in North Fork Red Dog Creek.

●A seasonal migration/habitat use by Arctic grayling study, using radio telemetry, was initiated in spring 2011. Arctic grayling distributed throughout the Ikalukrok Creek drainage after spawning, then concentrated in lower Ikalukrok Creek in a reach used by chum salmon spawners in late summer/early fall, and by early winter most were in the Wulik River. Mortality rates for adult Arctic grayling were high (64%) from spring 2011 to spring 2012.

●The Arctic grayling population in Bons Pond in 2011 was an estimated 1,515 fish $\geq$ 200 mm long. The 2011 population was similar to 2008 to 2010, but lower than previous estimates and the peak estimate of 6,189 fish in 2004. Arctic grayling spawned in Bons Creek and in the outlet channel from Bons Pond in spring 2012. Arctic grayling fry were caught in drift nets in Bons Creek in July, 2012.

●Pre-mining slimy sculpin (*Cottus cognatus*) abundance is unknown. Baseline reports indicated that this species was numerous in the Ikalukrok Creek drainage, but uncommon in the Red Dog Creek drainage. In most years, we catch slimy sculpin in the spring in North Fork Red Dog Creek and in minnow buckets in Mainstem Red Dog Creek during the summer.

Introduction

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

Aquatic biomonitoring has occurred annually since 1995 and has included periphyton, aquatic invertebrate, and fish sampling, including tissue and whole body metals analyses for Dolly Varden (*Salvelinus malma*) and spawning season monitoring for Arctic grayling (*Thymallus arcticus*). On January 8, 2010, the US Environmental Protection Agency (EPA) issued National Pollution Discharge Elimination System Permit No. AK-003865-2 (NPDES Permit) to Teck Alaska Incorporated (Teck) to allow discharge of up to 2.418 billion gallons of treated effluent per year. The NPDES Permit required a bioassessment program that included periphyton, aquatic invertebrates, and fish in selected streams near the Red Dog Mine (Table 1). The bioassessment program became fully effective and enforceable on March 31, 2010.

Table 1. Location of NPDES Sample Sites and Factors Measured.

Sample Site	Factors Measured
North Fork Red Dog Creek	Periphyton (chlorophyll-a concentrations) Aquatic Invertebrates (taxonomic richness and abundance) Fish Presence and Use
Mainstem Red Dog Creek	Periphyton (chlorophyll-a concentrations) Aquatic Invertebrates (taxonomic richness and abundance) Fish Presence and Use
Ikalukrok Creek	Periphyton (chlorophyll-a concentrations) Aquatic Invertebrates (taxonomic richness and abundance) Fish Presence and Use

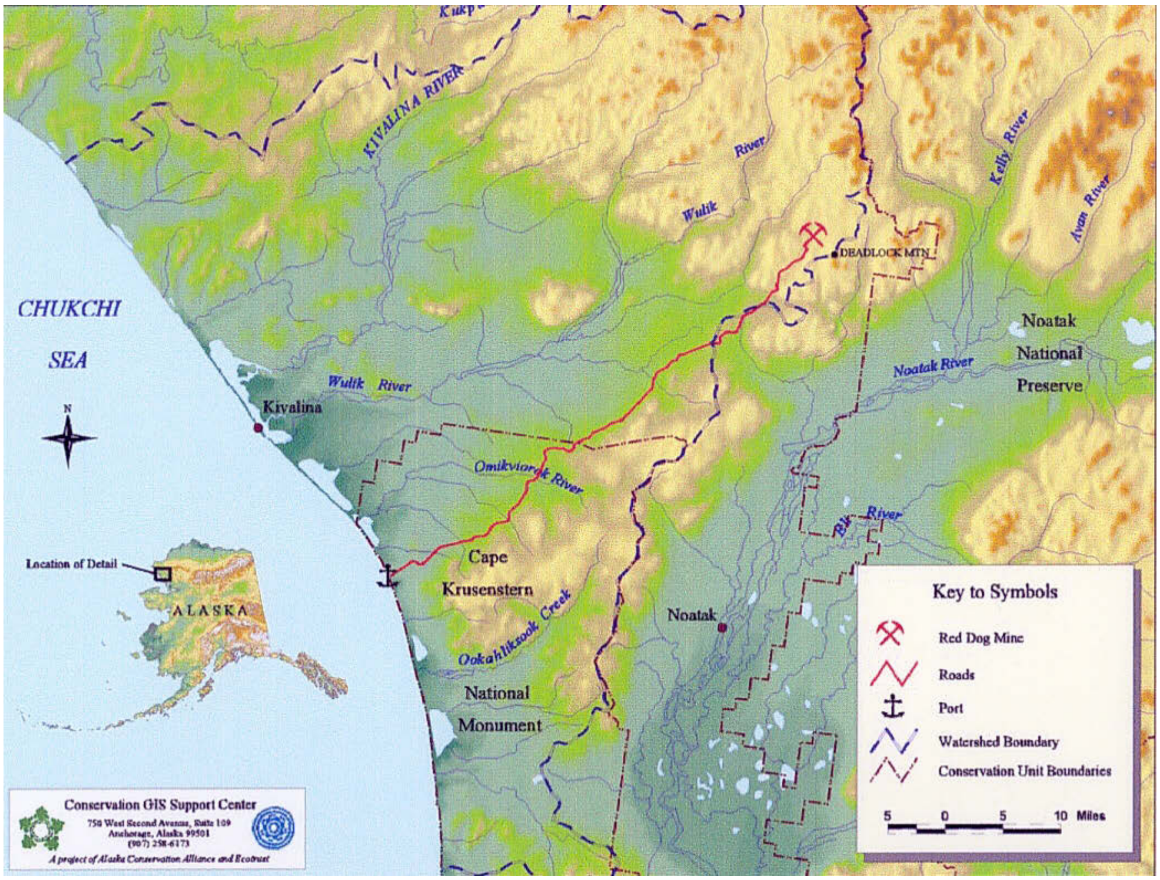


Figure 1. Location of the Red Dog Mine in northwestern Alaska. Map used with permission of Conservation GIS Support Center, Anchorage, Alaska.

On December 2, 2009, the Alaska Department of Environmental Conservation (ADEC) issued Waste Management Permit No. 0132-BA002 for the Red Dog Mine that included a condition that Teck adhere to the requirements of the monitoring plan submitted by Teck in May 2009. In April 2010 to satisfy conditions in the EPA and ADEC permits, the Alaska Department of Fish and Game (ADF&G) submitted Technical Report #10-04 titled "Methods for Aquatic Life Monitoring to Satisfy Requirements of 2010 NPDES Permit, Red Dog Mine Site (Revision #1)". Teck's May 2009 monitoring plan includes sample sites, sampling frequency, and parameters for all aquatic sites, including those required by the NPDES Permit (Table 2).

Table 2. Location of Sample Sites and Factors Measured.

Location	NPDES/ADEC	Location Description	Sampling Frequency	Parameters
Wulik River	ADEC	Kivalina Lagoon upstream to about 10 km upstream of the mouth of Ikalukrok Creek (where the canyon starts)	1/year	Fall aerial surveys for overwintering Dolly Varden
Ikalukrok Creek	ADEC	Lower Ikalukrok Creek to mouth of Dudd Creek	1/year	Fall aerial surveys for adult chum salmon
Station 9	NPDES/ADEC	Ikalukrok Creek upstream of confluence with Red Dog Creek	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
Station 160	ADEC	Lower Ikalukrok Creek	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
Station 20	ADEC	Middle Fork Red Dog Creek upstream on confluence wit	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
Station 10	NPDES/ADEC	Mouth of Red Dog Creek	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
			1/year	Juvenile Dolly Varden metals in tissue (Zn, Pb, Se, Hg, and Cd)
Station 12	NPDES/ADEC	North Fork Red Dog Creek	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
			1/year	Record of spawning activity (Arctic grayling)
			Periodic	Capture/mark Arctic grayling
Buddy Creek	ADEC	Below falls, about 1.5 km downstream of Haul Road	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
			1/year	Juvenile Dolly Varden metals in tissue (Zn, Pb, Se, Hg, and Cd)
Buddy 221	ADEC	Buddy Creek, above road	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
Bons 220	ADEC	Bons Creek, below pond	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
Bons Above Pond	ADEC	Above pond	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
Anxiety Ridge Creek	ADEC	below DMTS road	1/year	Fish presence and use
			1/year	Juvenile Dolly Varden metals in tissue (Zn, Pb, Se, Hg, and Cd)
Evaingiknuk Creek	ADEC	East of DMTS road	1/year	Fish presence and use
Bons Reservoir	ADEC	Above reservoir spillway	1/year	Juvenile Arctic grayling metals in tissue (Zn, Pb, Se, Hg, and Cd)
			1/year	Arctic grayling population estimate

Teck's monitoring plan is incorporated by reference into the Alaska Department of Natural Resources Reclamation Plan Approval (F20099958) dated December 2, 2009. On March 10, 2010, the U.S. Department of Army issued permit POA-1984-12-M45 to Teck which authorized development of the Aqqaluk Pit. Active mining in the Aqqaluk Pit occurred during 2012. In addition to mine drainage, certain waste rock from Aqqaluk and treated water were placed in the mined out main pit. Our report presents data collected during summer 2012 and where applicable, we compare these data with previous years.

Structure of Report

Water quality, periphyton standing crop, and aquatic invertebrate data are presented in the first three sections of our report. Metals concentration data for juvenile Dolly Varden and Arctic grayling collected from small streams and Bons Pond, and adult Dolly Varden collected from the Wulik River are then presented. Aerial survey estimates of overwintering Dolly Varden in the Wulik River and chum salmon (*Oncorhynchus keta*) spawners in Ikalukrok Creek are covered next. Finally, biological monitoring data for Dolly Varden juveniles, Arctic grayling, and slimy sculpin (*Cottus cognatus*) are presented.

Location of Sample Sites

Biomonitoring is conducted in streams adjacent to and downstream from the Red Dog Mine as required under the EPA NPDES Permit No. AK-003865-2 (Tables 1 and 2 and Figures 2 and 3), and by condition in the ADEC Waste Management Permit and the ADNR Reclamation Plan Approval. Monitoring sites include the Red Dog Creek drainage, Ikalukrok Creek, Bons and Buddy Creek drainage, Anxiety Ridge Creek, and Evaingiknuk Creek.

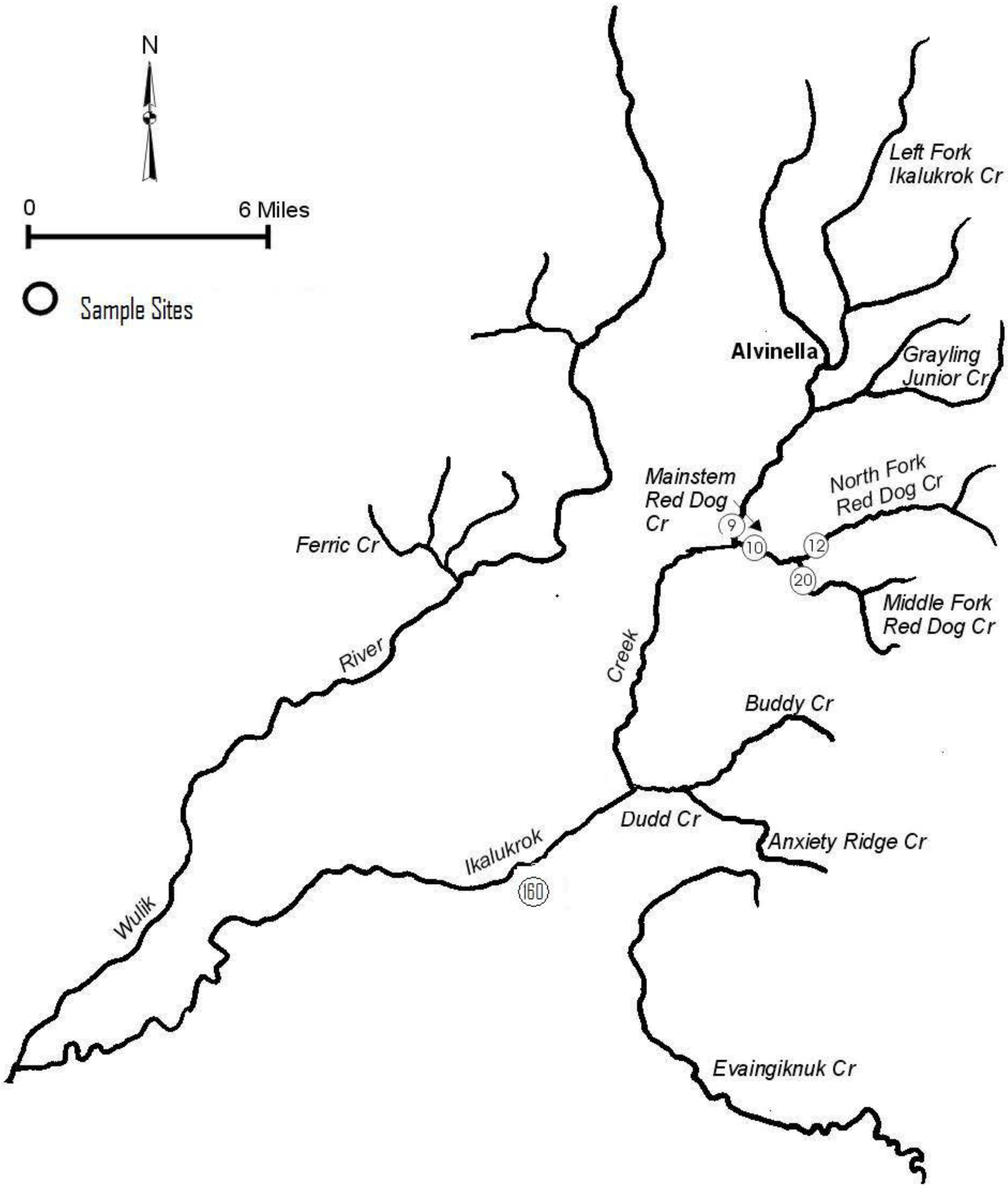


Figure 2. Location of sample sites (Station # on Figure) in the Ikalukrok Creek and Evaingiknuk Creek (a tributary of the Noatak River) drainages.

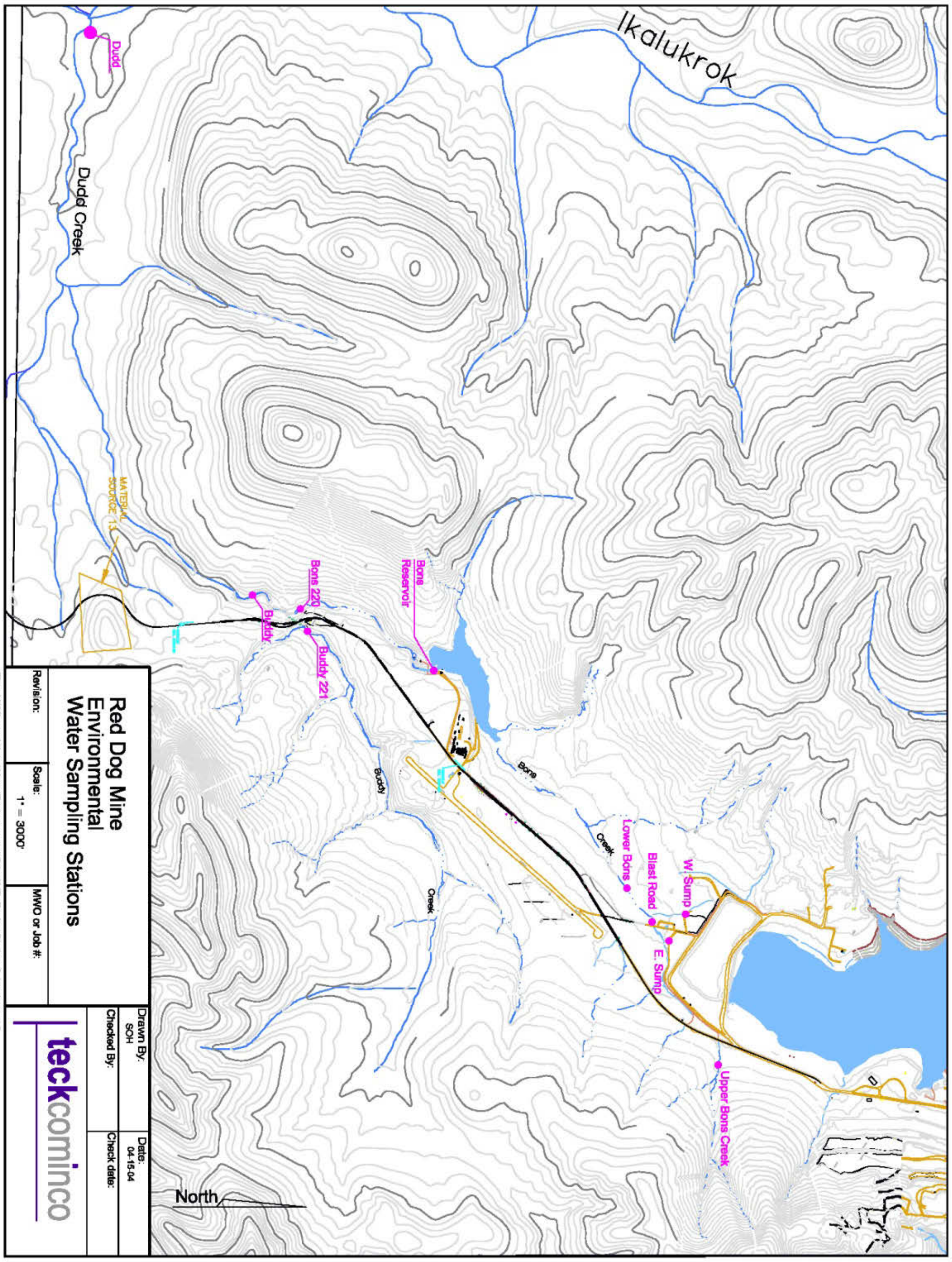


Figure 3. Bons and Buddy creeks and Bons Pond (map provided by Teck).

Description of Streams

All streams in the study area are in the Wulik River drainage, except for Evaingiknuk Creek, which is in the Noatak River drainage. Station numbers correspond either to those used by Dames and Moore (1983) during baseline work or to the current water quality program being conducted by Teck. Water quality and fish data collected during baseline studies (1979 to 1982) represent pre-mining conditions. Comparisons of existing conditions relative to baseline data should take into account that we have many years of data during mining and only a short time frame of baseline data.

Methods

All methods used for the Red Dog Mine aquatic biomonitoring study are described by ADF&G (2010) in Technical Report No. 10-04 titled "Methods for Aquatic Life Monitoring to Satisfy Requirements of 2010 NPDES Permit, Red Dog Mine Site (Revision #1)."

The method detection limit (MDL) in 2000 for copper (Cu), lead (Pb), and selenium (Se) was 50, 20, and 50 *u*g/L, respectively, for a portion of the samples early in the ice-free season. MDL's were changed part way through summer 2000 for Cu, Pb, and Se to 1, 2, and 1 *u*g/L respectively. Because of the high MDLs used in early 2000, water quality data for these samples are not presented. Water quality data presented in our report are for "total recoverable." All water quality data are provided by Teck. The number of water quality samples taken each year varies with the permit condition requirements, but for most analytes, samples are collected twice each month with a sample size of 9 to 13 per year per site. Baseline water quality pre-mining presented in the report were collected from 1979 to 1982.

The abundance of Arctic grayling was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951),

$$\hat{N}_c = \left\{ \frac{(n_1+1)(n_2+1)}{(m_2+1)} \right\} - 1,$$

where $\hat{N}_c$ = estimated population, n_1=fish marked in first capture event, n_2=fish captured during recapture event, and m_2=fish captured during recapture event that were marked in the capture event. Variance was calculated as: (Seber 1982)

$$\text{var}(\hat{N}_c) = \left\{ \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \right\}.$$

95% CI for the population estimate was calculated as

$$95\% C.I. = N_c \pm (1.960)\sqrt{\hat{\text{var}}(\hat{N}_c)}.$$

Radio tags (15) were implanted into adult Arctic grayling in North Fork Red Dog Creek in spring 2011. A description of the methods used was presented by Ott and Morris (2012). Radio tagged fish were radio-located during summer 2012 using a R22 helicopter.

Results and Discussion

Water Quality

Water quality data collected in Mainstem Red Dog Creek prior to 2010 are from Station 10, located near the mouth of the creek. Data from 2010 to 2012 were collected at Station 151 located about 2 km upstream from Station 10. Station 151 is at the downstream end of the mixing zone in Mainstem Red Dog Creek. There are no defined drainages entering Mainstem Red Dog Creek between these two water quality stations. Station 151 replaced Station 10 effective spring 2010. Mainstem Red Dog Creek is directly affected by the mine wastewater effluent and by water from the clean water bypass. North Fork Red Dog Creek is a reference site with no direct effects from the mine.

Teck continued to maintain the mine's clean water bypass system which picks up non-mining impacted water from Sulfur, Shelly, Connie, Rachael, and Middle Fork Red Dog creeks. This water is moved through the active mine area, including Aqqaluk, to its original channel via a combination of culverts and lined open ditch. These bypass conveyance structures also serve to isolate the clean water from mining impacts as it is routed back to its original channel. Pb and Zn concentrations at Station 151/10, downstream of the clean water bypass system, indicate that both of these elements are lower now than pre-mining, with the exception of several maximum Pb concentrations in some years (Figures 4 and 5).

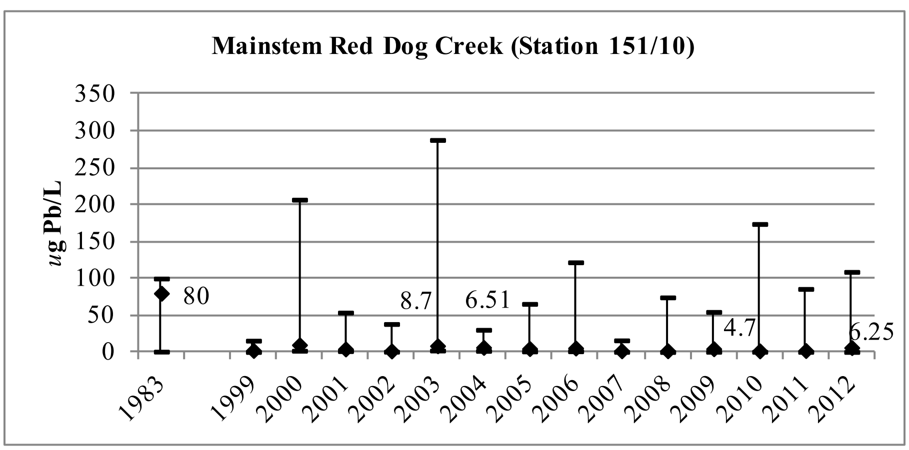


Figure 4. Median, maximum, and minimum Pb concentrations at Station 151/10 (selected median values shown).

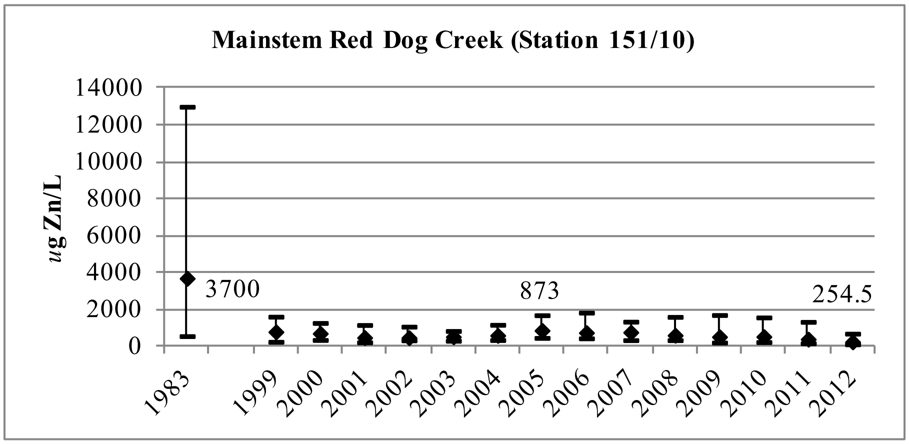


Figure 5. Median, maximum, and minimum Zn concentrations at Station 151/10 (selected median values shown).

We continue to evaluate water quality data collected in Mainstem Red Dog Creek as part of the ongoing aquatic biomonitoring program. Median Al concentrations at Station 10/151 continue to be lower than pre-mining (Figure 6). Cd concentrations also are lower than pre-mining conditions (Figure 7). The median Cd concentration in 1983 was 28 *u*g/L and in summer 2012 it was 1.65 *u*g/L (Figure 8). In most years (1999 to 2012), the maximum Cd concentration is below the 1983 median value.

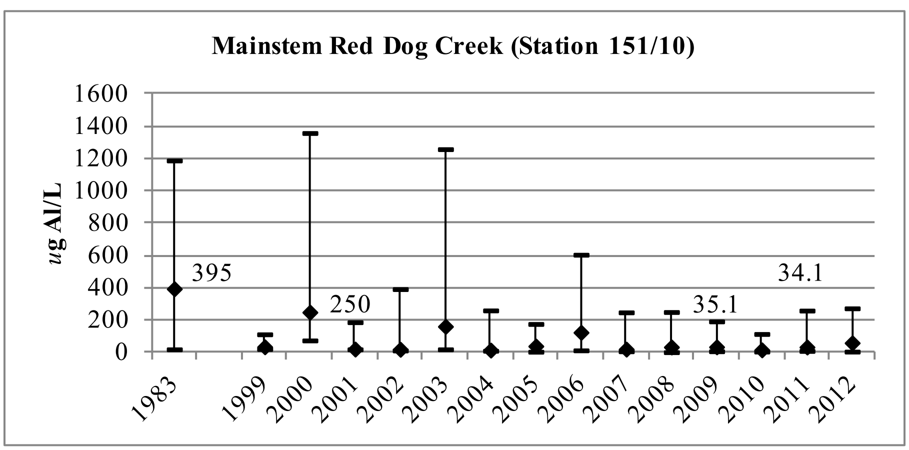


Figure 6. Median, maximum, and minimum Al concentrations at Station 151/10 (selected median values shown).

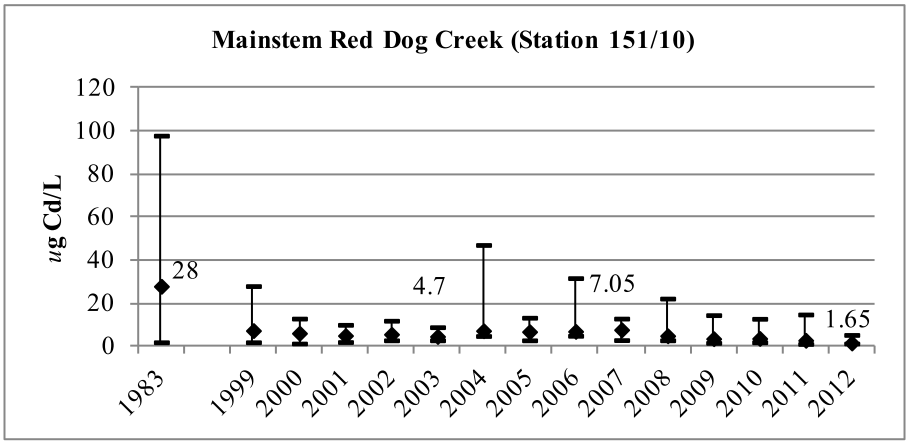


Figure 7. Median, maximum, and minimum Cd concentrations at Station 151/10 (selected median values shown).

Pre-mining data for Se are not available. Se concentrations in Mainstem Red Dog Creek have remained similar from 2001 to 2007, but have been higher in recent years (2008 to 2011) (Figure 8). The median Se concentration was 2.0 *u*g/L in 2012, but discharge of treated water was discontinued in summer 2012 due to elevated concentrations of Se.

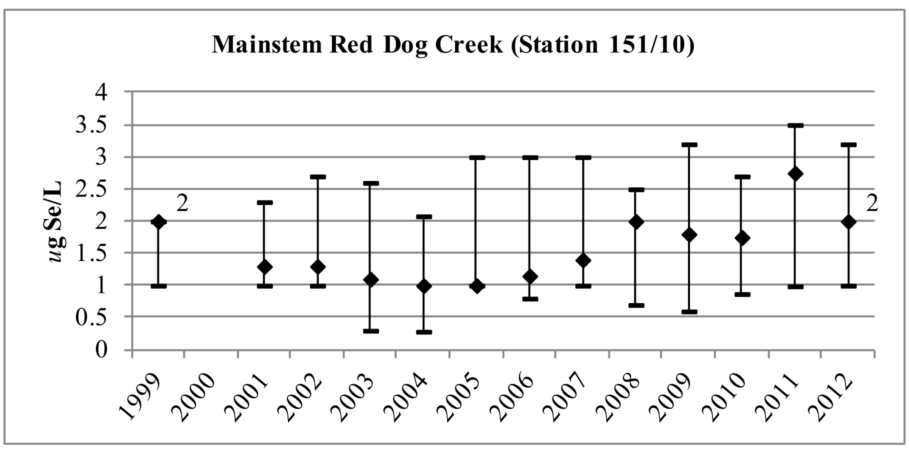


Figure 8. Median, maximum, and minimum Se concentrations at Station 151/10 (selected median values shown).

Pre-mining data for Ni are not available. Median Ni concentrations at Station 151/10 were higher from 2006 through 2011, but decreased in 2012 (Figure 9). Higher median

Ni concentrations were observed first in 2006 (19.5 *u*g/L). The primary source of Ni to the clean water bypass system has been Rachael Creek (Ott and Morris 2010). Median Ni concentrations decreased to 8.3 *u*g/L in 2012.

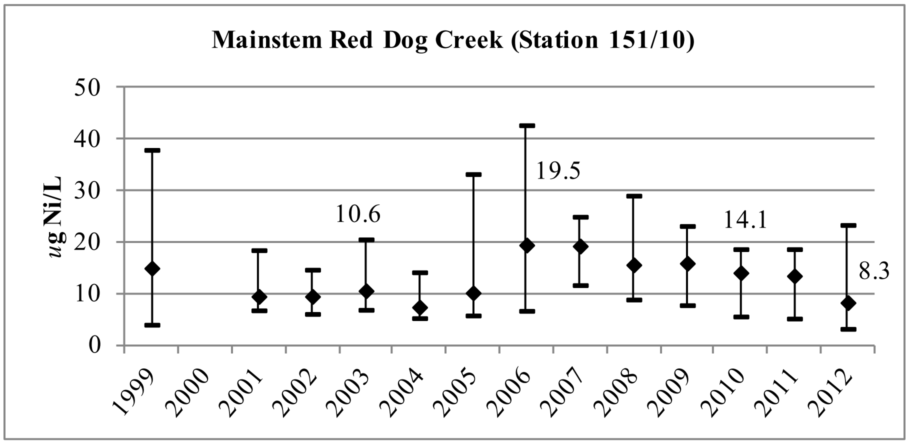


Figure 9. Median, maximum, and minimum Ni concentrations at Station 151/10 (selected median values shown).

The pH at Station 151/10 is higher than pre-mining (Figure 10). The pH is slightly more basic and has only dropped below 6 once in 2011. The 1990 data set is during mining, but prior to construction of the clean water bypass system. The clean water bypass system was built prior to spring breakup in 1991.

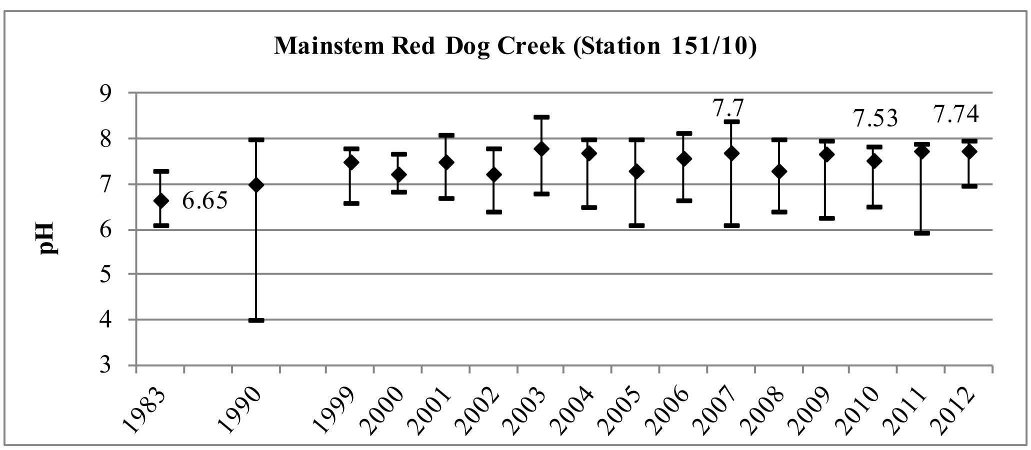


Figure 10. Median, maximum, and minimum pH values at Station 151/10 (selected median values shown).

Total dissolved solids (TDS) in Mainstem Red Dog Creek are higher than pre-mining (Figure 11). TDS is directly related to high concentrations in the treated wastewater discharge at Outfall 001. $Ca(OH)_2$ is added to precipitate and collect metals from the tailing water as metal hydroxides prior to discharge. Sulfates released in this process along with the Ca result in the elevated TDS concentrations. TDS concentrations in Mainstem Red Dog Creek in summer 2012 never exceeded the 1,500 mg/L standard applied at Station 151 and the median TDS concentration was substantially lower due to treated water being diverted back into the tailings pond or to the main pit (i.e., no discharge to Red Dog Creek occurred in 2012 after June 8^{th}).

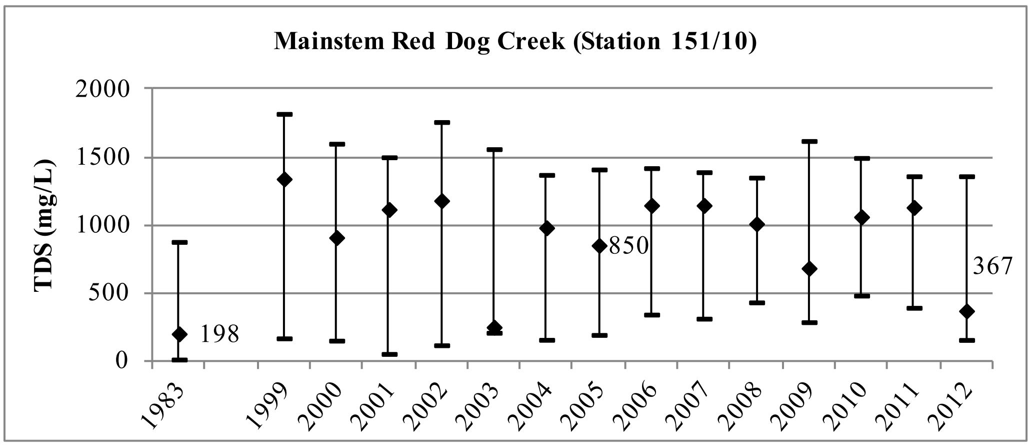


Figure 11. Median, maximum, and minimum TDS concentrations at Station 151/10 (selected median values shown).

Treated water was not discharged to Red Dog Creek after June 8, 2012, but was rerouted to the main pit or the tailing impoundment. We assumed that Pb, Zn, and Cd would increase and TDS and pH would decrease in Mainstem Red Dog Creek at Station 151. However, in summer 2012, Pb and pH increased while Zn, Cd, and TDS decreased. The effluent at Outfall 001 contains low concentrations of Pb, Zn, and Cd and higher concentrations of TDS and a higher pH than the receiving waters of Middle Fork Red Dog Creek.

Cadmium, Pb, Se, and Zn concentrations in Mainstem Red Dog Creek (Station 151/10) were compared with those found in North Fork Red Dog Creek (Station 12) and in Buddy

Creek (below the confluence of Bons and Buddy creeks). Sites in North Fork Red Dog and Buddy creeks were selected because they are reference sites with no direct effects from the mine process or discharge. Mainstem Red Dog Creek is directly downstream of the mine clean water bypass and wastewater effluent discharge at Outfall 001. Buddy Creek also is a reference site, but with the potential to be affected by the road, airport, waste rock dump, and Bons Pond, and is down gradient from the backdam on the south end of the tailing pond. Cadmium, Pb, Se, and Zn were selected for comparison because they are analyzed for whole body concentrations in juvenile Arctic grayling and Dolly Varden.

Cadmium, Pb, and Zn median concentrations are highest in Mainstem Red Dog Creek (Figures 12, 13, and 14). In the two reference sites, Cd and Zn concentrations are stable over the sampling period from 2000 to 2012. Pb concentrations demonstrate more variability, but still are consistently lower in North Fork Red Dog and Buddy creeks. Since 2007, median Cd and Zn concentrations in Mainstem Red Dog Creek have exhibited a decrease while Pb has remained the same or increased.

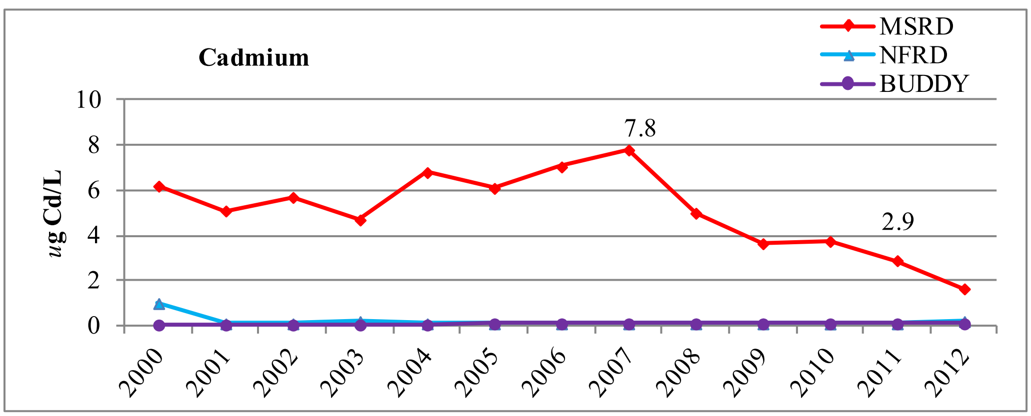


Figure 12. Median Cd concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy Creeks (2000 to 2012).

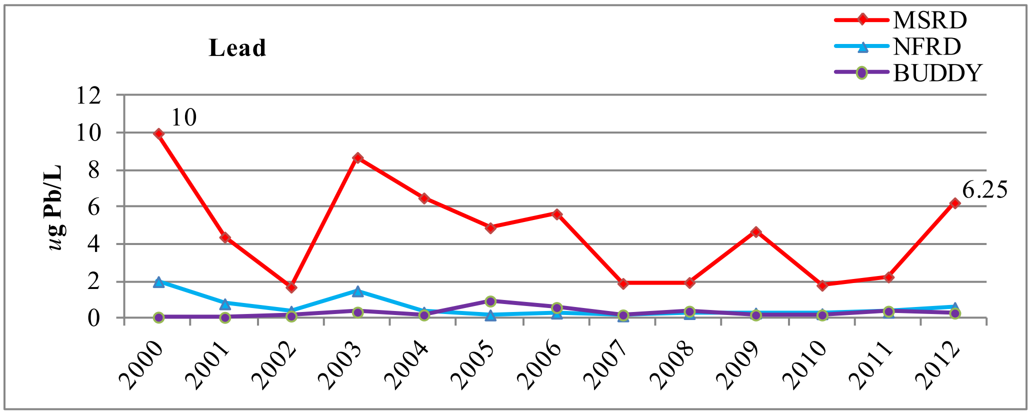


Figure 13. Median Pb concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy Creeks (2000 to 2012).

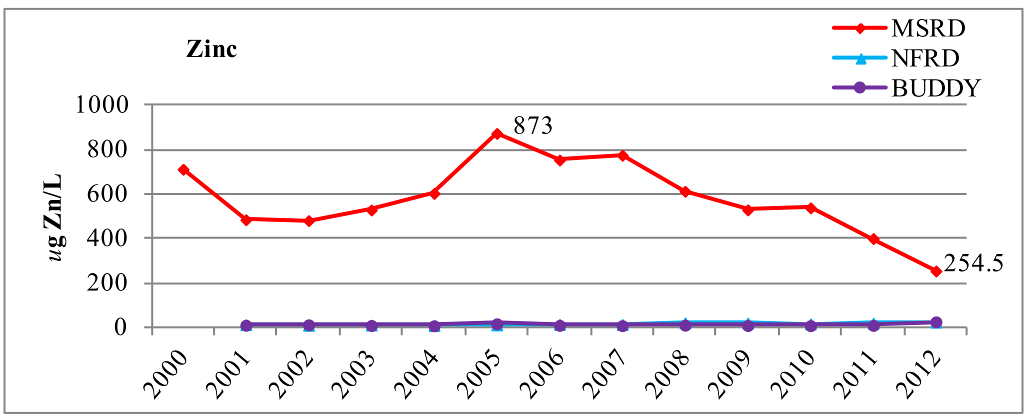


Figure 14. Median Zn concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy Creeks (2000 to 2012).

Median Se concentrations in Mainstem Red Dog Creek are lower than in Buddy Creek but the same or slightly higher than in North Fork Red Dog Creek (Figure 15). The differences among these sites are not substantial as most median Se concentrations range from 1 *u*g/L (the detection limit) to 3.0 *u*g/L.

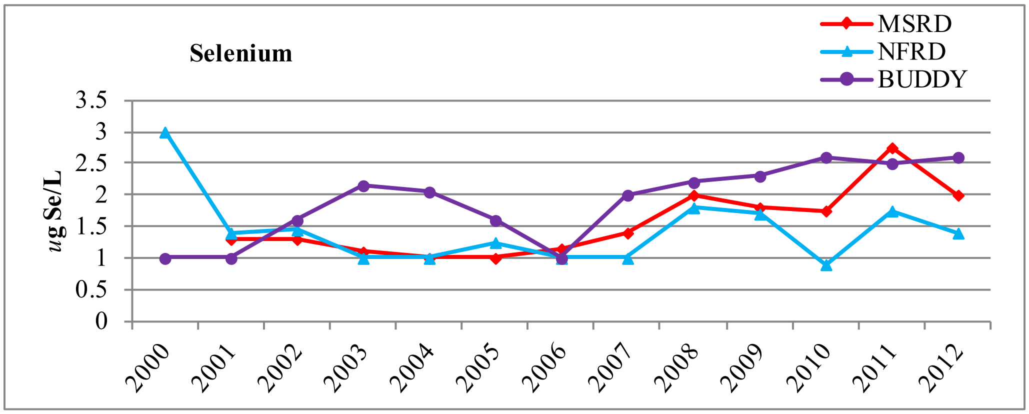


Figure 15. Median Se concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy Creeks (2000 to 2012).

Periphyton Standing Crop

Periphyton attached microalgae biomass samples are collected each year (2012 data, Appendix 2). Under the new program initiated in 2010, sampling occurred at nine sites (Table 2). In 2012, samples were collected at all sites except Bons Creek below Bons Pond because surface flow was not present at the site. Periphyton samples are processed in the laboratory and standing crop determined as mg/m^2 chlorophyll-a.

Chlorophyll-a concentrations in 2012 were highest in Buddy Creek (12.4 mg/m^2) below the falls and lowest in Bons Creek (1.2 mg/m^2) above Bons Pond (Figure 16). Periphyton standing crops were highest in Buddy (below falls), Mainstem Red Dog, and Ikalukrok creeks (near Station 160). These results are not consistent with data from previous years. Chlorophyll-a concentrations generally are highest in Buddy, Bons, and North Fork Red Dog Creek drainages.

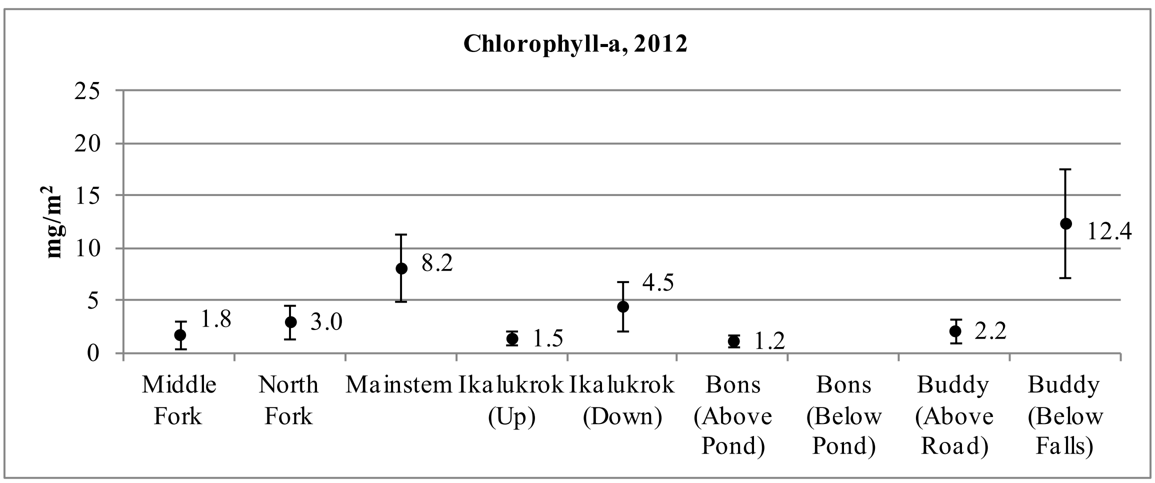


Figure 16. Average concentration of chlorophyll-a (plus and minus one SD).

Average chlorophyll-a concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy creeks (below falls) are presented in Figures 17, 18, and 19. Generally, average chlorophyll-a concentrations are higher in Buddy Creek (below falls). In North Fork Red Dog and Mainstem Red Dog creeks, chlorophyll-a concentrations are highly variable.

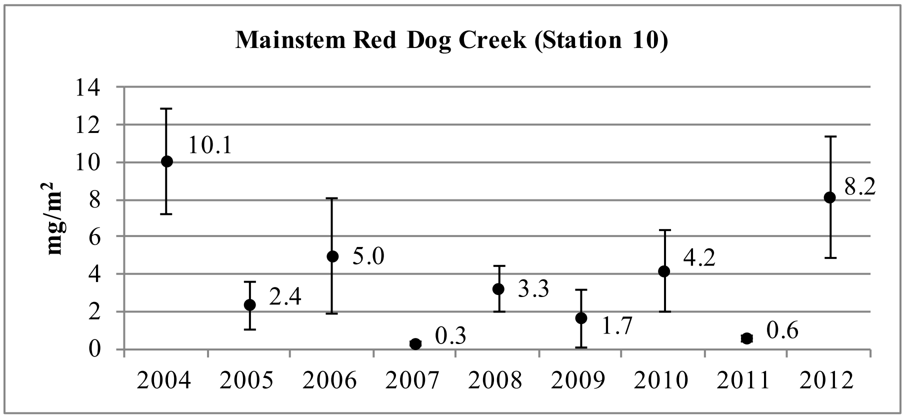


Figure 17. Average concentration of chlorophyll-a (plus and minus one SD).

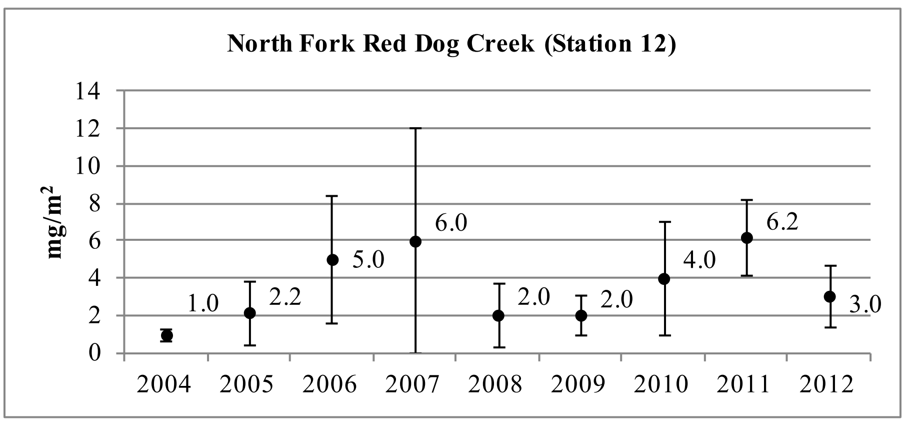


Figure 18. Average concentration of chlorophyll-a (plus and minus one SD)

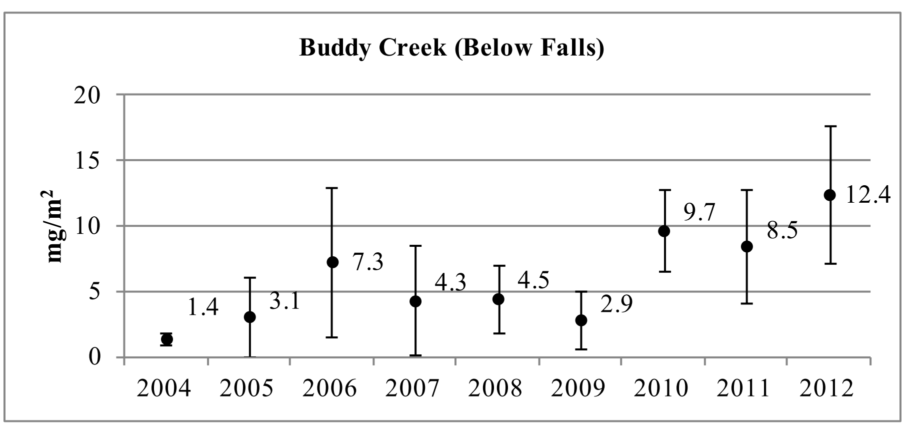


Figure 19. Average concentration of chlorophyll-a (plus and minus one SD).

In most sample years, periphyton standing crop is lowest in Middle Fork Red Dog Creek. However, in 2010 and 2012 we saw higher average concentrations of periphyton. (Figure 20). In 2012, average concentration of chlorophyll-a was 1.8 mg/m^2 in Middle Fork Red Dog Creek. Higher chlorophyll-a concentrations in Middle Fork Red Dog Creek may be related to the fact that the wastewater effluent from the Outfall 001 was rerouted from the Red Dog Creek drainage during most of the summer of 2012. This resulted in a decrease in TDS, Zn, and Cd in Middle Fork Red Dog Creek. It also should be noted that stream flows were extremely low in both 2010 and 2012 during and prior to the sample event and that also might explain the higher average chlorophyll-a concentrations.

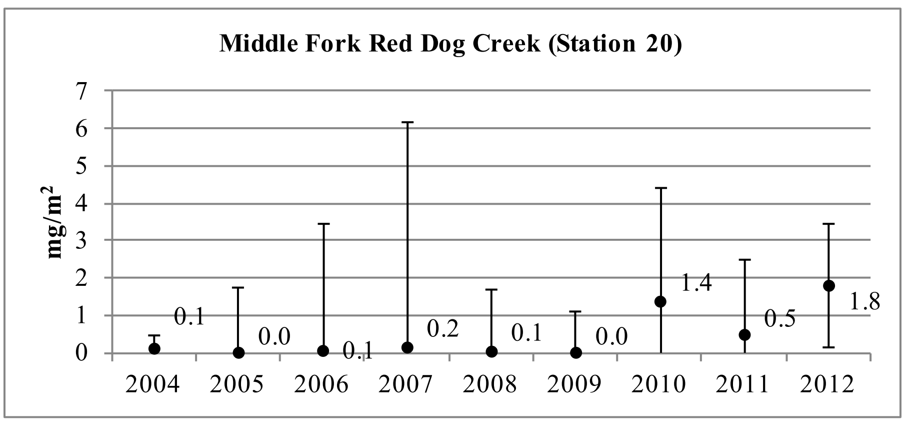


Figure 20. Average concentration of chlorophyll-a (plus and minus one SD).

Periphyton standing crop tracks closely with elevated Zn and Cd in Ikalukrok Creek at Station 9 which is just upstream of the mouth of Mainstem Red Dog Creek. Water quality at this site is not affected by water from the Red Dog Mine facility, but is affected by natural mineral seeps located upstream and along Ikalukrok Creek (Ott and Morris, 2007). Chlorophyll-a concentrations are higher when the Zn and Cd concentrations are lower (Figures 21 and 22). The variability seen from 2002 to 2012 may simply be natural as both Cd and Zn concentrations remained low and consistent during this time frame. The major source of Zn and Cd to Ikalukrok Creek is the Cub Creek seep (Figure 23).

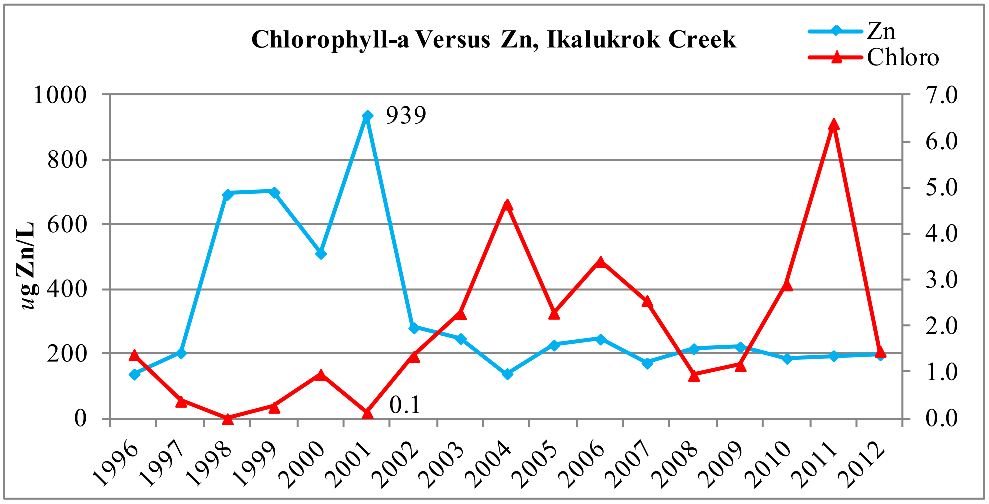


Figure 21. Chlorophyll-a concentrations versus Zn in Ikalukrok Creek (red line is chlorophyll and blue line is metal).

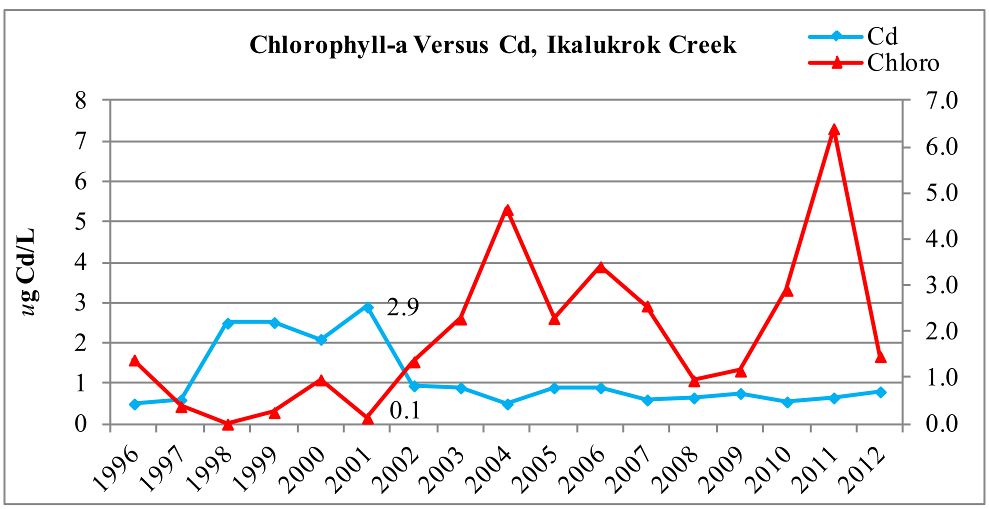


Figure 22. Chlorophyll-a concentrations versus Cd in Ikalukrok Creek (red line is chlorophyll and blue line is metal).

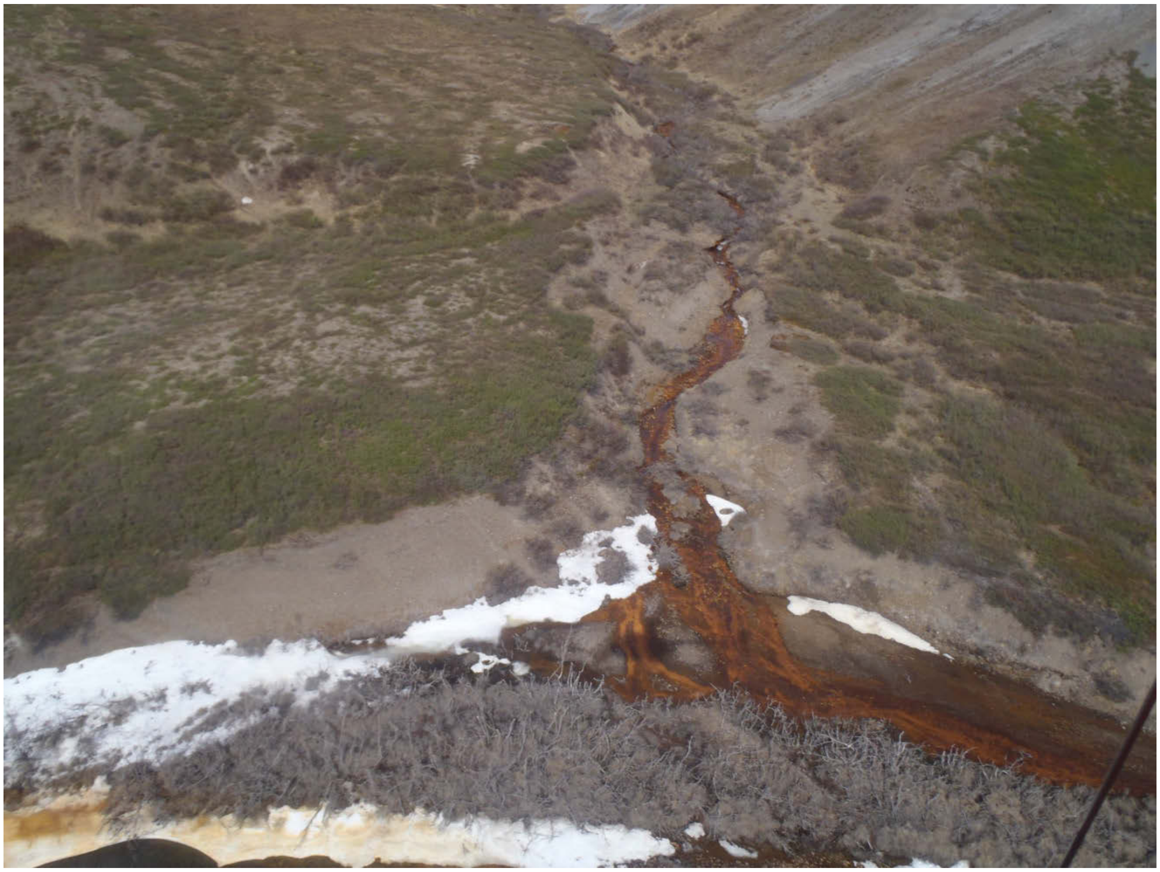


Figure 23. Ikalukrok Creek at the Cub Creek seep about 10 km upstream of the mouth of Mainstem Red Dog Creek – note iron staining in and along the edge of Cub Creek. Photograph by W. Morris, ADF&G, spring 2012.

Aquatic Invertebrates

Aquatic invertebrate samples are collected annually using drift nets (Appendix 3). In 2012, eight of nine sites were sampled in early July (July 8 to 10). Flows were low and there was no surface flow present at the Bons Creek site just upstream of Buddy Creek.

In 2012, the density of aquatic invertebrates was highest (164.5/m^3) in Buddy Creek upstream of the road and was lowest (2.1/m^3) in Middle Fork Red Dog Creek (Figure 24) (Appendix 3). These data continue to follow the same general pattern with higher densities occurring in the Bons and Buddy Creek drainages and in North Fork Red Dog Creek. Densities are lower in Middle Fork Red Dog, Mainstem Red Dog, and Ikalukrok creeks.

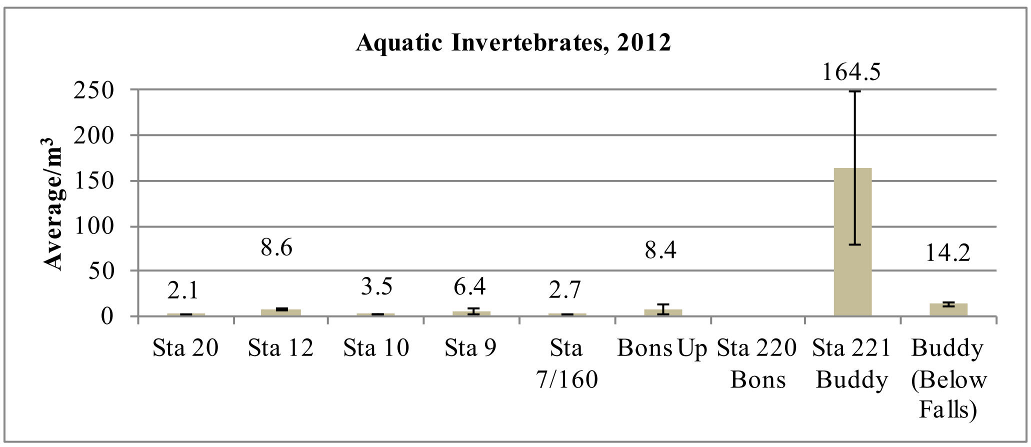


Figure 24. Aquatic invertebrate densities (average plus and minus one SD). Average values shown.

Average aquatic invertebrate densities vary among sample years. Densities in North Fork Red Dog Creek generally are higher than in Mainstem Red Dog Creek (Figures 25 and 26). In most years, the highest densities are found in Buddy Creek below the falls (Figure 27). There appears to be an increase in aquatic invertebrate densities since 2005 in North Fork Red Dog Creek and, though less consistently, in Mainstem Red Dog Creek.

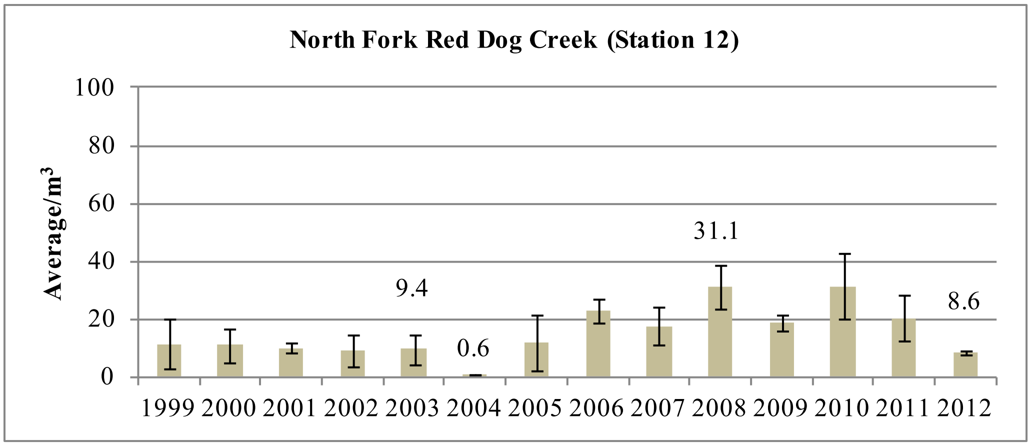


Figure 25. North Fork Red Dog Creek aquatic invertebrate densities (average plus and minus one SD). Selected average values shown.

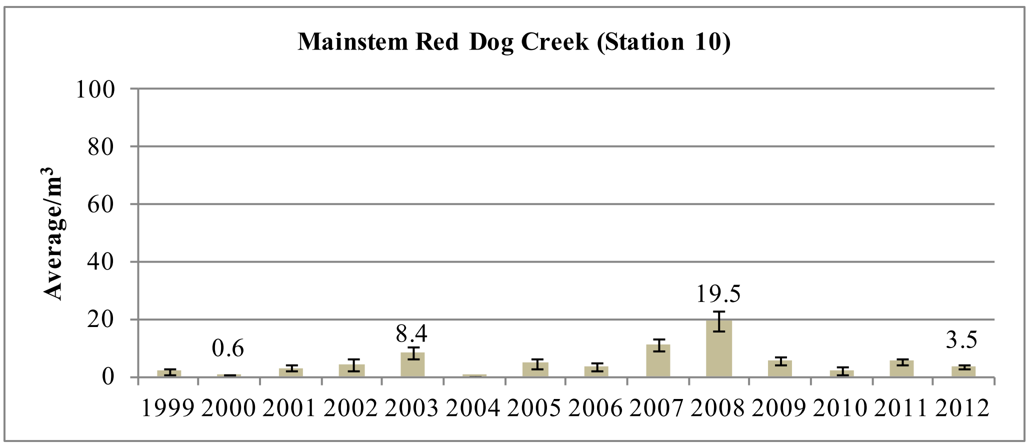


Figure 26. Mainstem Red Dog Creek aquatic invertebrate densities (average plus and minus one SD). Selected average values shown.

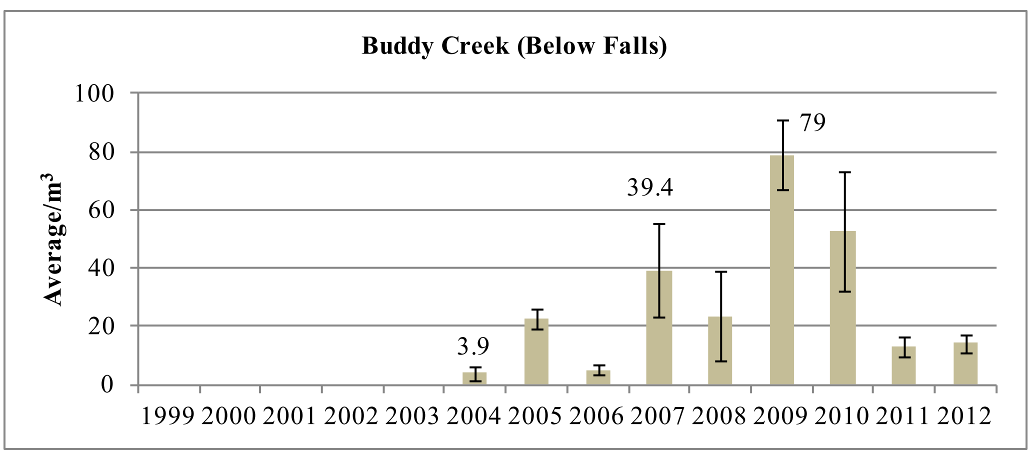


Figure 27. Buddy Creek aquatic invertebrate densities (average plus and minus one SD). Selected average values shown.

The percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) and the percent Chironomidae for all sample sites in 2012 are presented in Figure 28. All sites, except for Buddy Creek above the road contained a higher percentage of Chironomidae in 2012. Trichoptera are not common in our samples and are not a substantial contributor to EPT. Generally, the aquatic systems in the Red Dog Mine area are dominated by Chironomidae which is one of the primary food items of the fish species using these creeks.

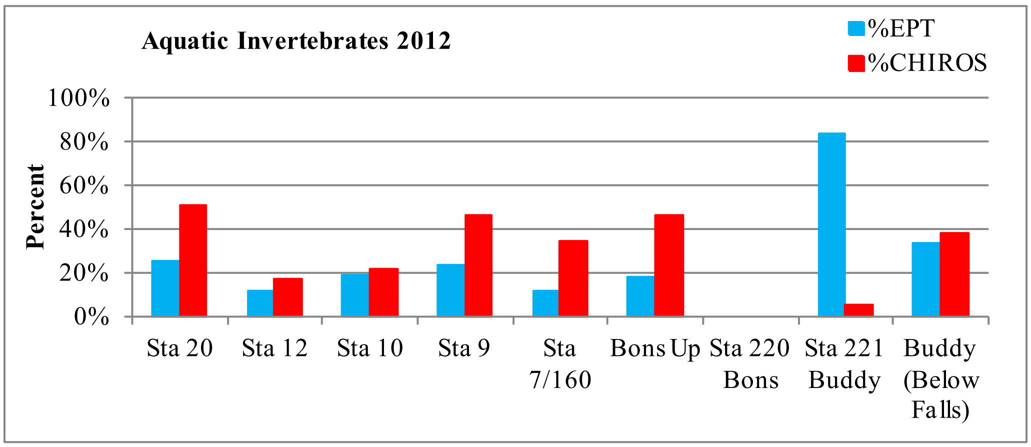


Figure 28. Percent Chironomidae and EPT in the aquatic invertebrate sample sites in July 2012.

The percent EPT in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks was lower from 2008 to 2011, but comparable in 2012 with data collected from 2004 to 2007 (Figure 29). Ott and Morris (2012) stated that a trend for decreasing EPT had been seen; however, this trend was reversed with data collected in summer 2012. North Fork Red Dog and Buddy creeks are considered reference sites whereas Mainstem Red Dog Creek at Station 10 is directly affected by waters from the clean water bypass system. Overall, EPT represented a higher proportion in 2012 than it had in previous years. It should be noted that in summer 2012, treated water was not discharged to the Red Dog Creek drainage after June 8.

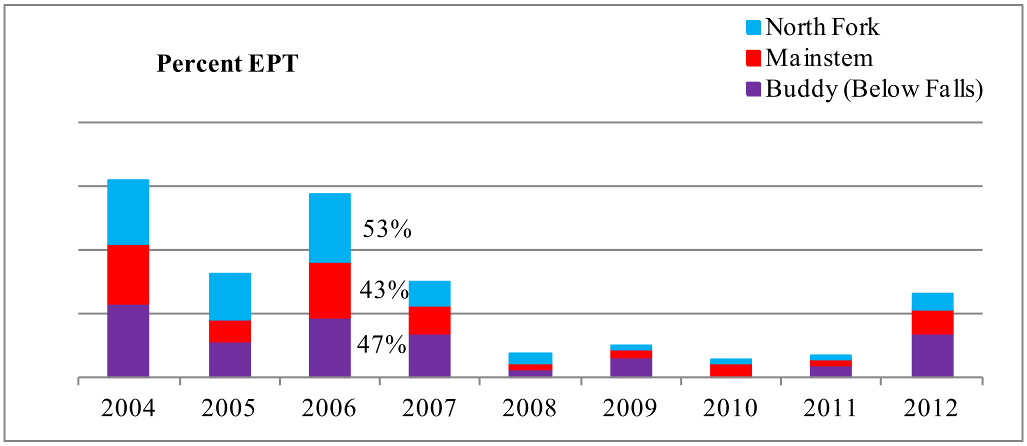


Figure 29. Percent EPT from 2004 to 2012. Values shown for 2006.

The percent Chironomidae in the aquatic invertebrate samples was higher from 2007 to 2011 than in 2004 to 2006 and 2012 (Figure 30).

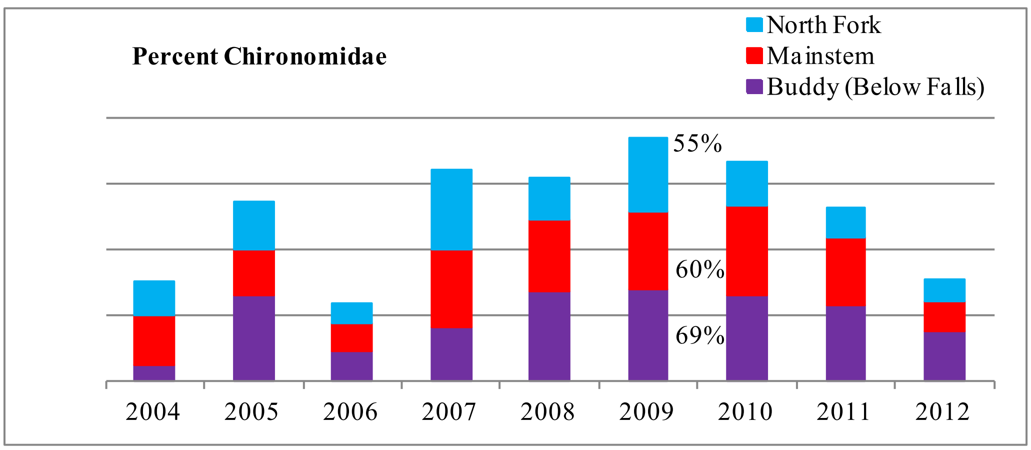


Figure 30. Percent Chironomidae from 2004 to 2011. Values shown for 2009.

We looked at the density of EPT in Mainstem Red Dog, North Fork Red Dog, and Buddy creeks (below falls) to determine if there has been an actual decrease in the numbers of EPT (Figure 31). Densities of EPT generally are higher in North Fork Red Dog Creek than in Mainstem Red Dog Creek and they are highly variable in Buddy Creek (below falls). The highest densities observed in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks were 12.18, 11.89, and 2.39/m^3, respectively. During the period of apparent decreasing EPT, there has not been a reduction in EPT densities rather there has been an increase in chironomidae density.

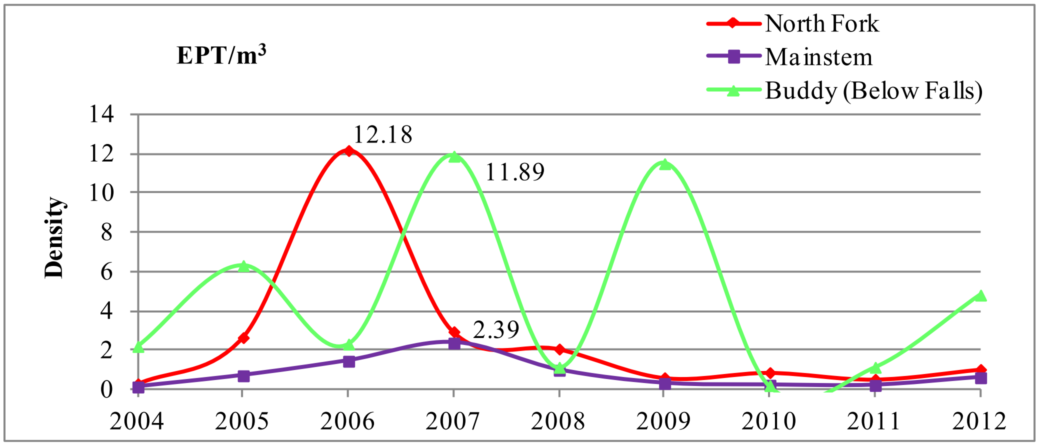


Figure 31. EPT/m3 in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks from 2004 to 2011 (peak density for each sample site is shown).

We compared taxa richness for the three sites in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks (Figure 32). Taxa richness was highest in 2011 and was the lowest in 2010. Overall taxa richness is similar in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks.

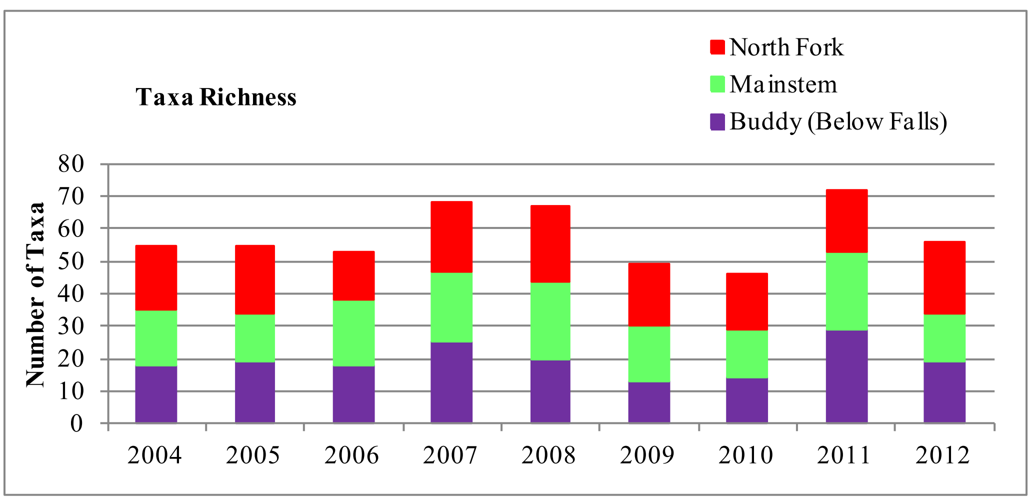


Figure 32. Aquatic invertebrate taxa richness in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks.

Metals Concentrations in Juvenile Dolly Varden and Arctic Grayling

We sample juvenile Dolly Varden and Arctic grayling to determine whole body concentrations of selected metals. The purpose of this effort is: (1) to determine if differences exist in metals concentrations in fish among the sample sites that can be linked with background water quality; and (2) to track change over time. Juvenile Dolly Varden were selected as the target species because of their wide distribution in the Red Dog area streams, their presence in Mainstem Red Dog Creek, their residence in freshwater for two to four years before smolting, and their rearing in the sample sites only during the ice-free season. Juvenile Arctic grayling were added after we successfully established a self-sustaining population in Bons Pond. Arctic grayling captured in Bons Pond have been in the pond upstream of the freshwater dam their entire life and therefore serve as a good indicator of year round water quality conditions and change over time.

In spring 2012, we were not able to collect a sufficient number of small Arctic grayling from appropriate size classes from Bons Creek and Bons Pond to meet our sample objective of 15 fish. We also did not collect juvenile Dolly Varden in August, 2012, due to a substantial high rainfall event that led to region wide record flooding. Therefore, our report does not contain metals data on these fish for summer 2012. The most recent data for whole body metals for juvenile Arctic grayling and Dolly Varden are presented in our 2012 report (Ott and Morris, 2012).

Metals Concentrations in Adult Dolly Varden

Since 1990, we have sampled adult Dolly Varden from the Wulik River (Station 2) near Tutak Creek for metals concentrations (Al, Cd, Cu, Pb, and Zn) in gill, kidney, liver, and muscle tissue (Weber Scannell et al. 2000). In 1997, we added Se and in 1998 we started sampling reproductive tissue, when available in adequate mass. In 2003, we added Hg and Ca to the analytes being tested. From 2004 through 2009, Dolly Varden tissues were analyzed for Al, Cd, Cu, Pb, Se, Zn, and Hg. In 2010, we made several modifications based on previous results, including deleting Al from the analytes and eliminating gill tissue. The extreme variability of Al in gill tissue and the potential for gill sample contamination during sampling was the reason for the change. The sample size for each spring and fall sample period has been six fish, except for the fall 2002 sample, when only five fish were caught.

The purpose of sampling adult Dolly Varden for metals concentrations is to monitor the long-term condition of fish over the life of the mine, to identify changes in tissue metals concentrations that may be related to mine activities and to provide a database for use by other professionals. The most likely benefits of this sampling program are long-term monitoring and use of these data by other professionals. It is unlikely that tissue metals concentrations or changes in adult fish could be related to events at the Red Dog Mine, since Dolly Varden attain the majority of their growth while in the marine environment. All laboratory work has been done with Level III Quality Assurance. Metals data for 2012 are presented in Appendix 5.

Metals are known to concentrate preferentially in certain organs; however, the relationship of organ concentration to ambient environmental concentrations is unknown. Concentrations of metals vary with season, age, size, weight, and feeding habits of fish (Jenkins 1980) and in the case of anadromous Dolly Varden, the metals concentrations vary with exposure to freshwater and marine environments. None of the analytes we measure appear to concentrate in muscle tissue.

Analyte concentration in various tissues is summarized below and in Figures 33 through 45: Two figures are presented for each analyte – one for all fish handled from 1999 to 2012 and the second for fish caught in spring and fall, 2012.

- ●Cd concentrates in kidney tissue (Figures 33 and 34)
- ●Cu concentrates in liver tissue and eggs (Figure 35 and 36);
- ●Pb does not concentrate in any specific tissue (Figures 37 and 38);
- ●Se concentrates in kidney and eggs (Figures 39 and 40);
- ●Zn concentrates in eggs (Figures 41 and 42); and
- ●Hg concentrates in kidney tissue (Figures 43 and 44).

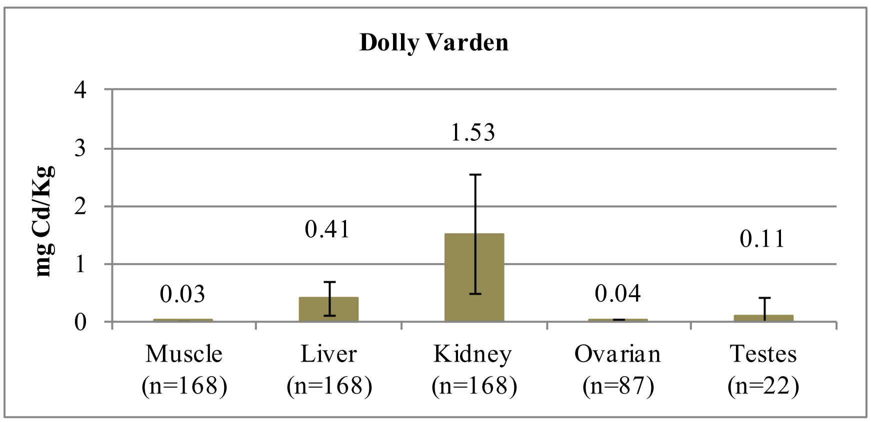


Figure 33. Average Cd concentrations (plus and minus 1 SD) in Dolly Varden (1999-2012).

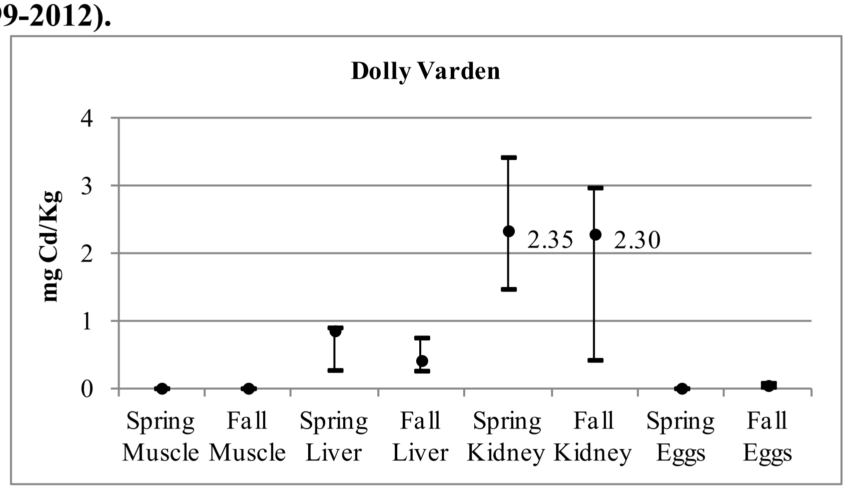


Figure 34. Median, maximum, and minimum Cd concentrations in Dolly Varden caught in spring and fall, 2012.

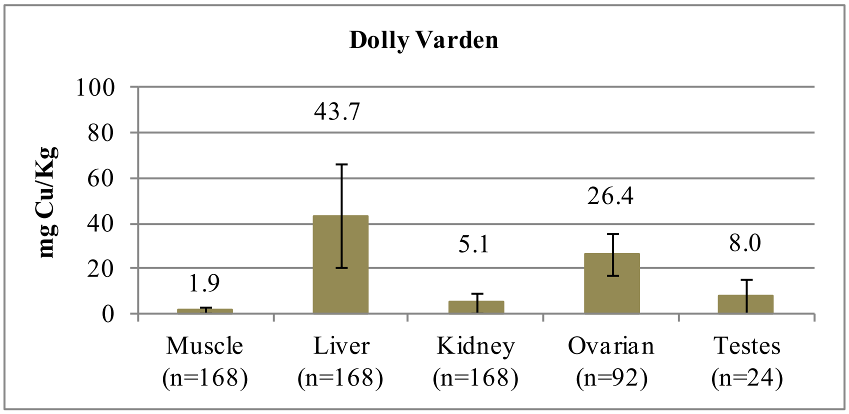


Figure 35. Average Cu concentrations (plus and minus 1 SD) in Dolly Varden (1999-2012).

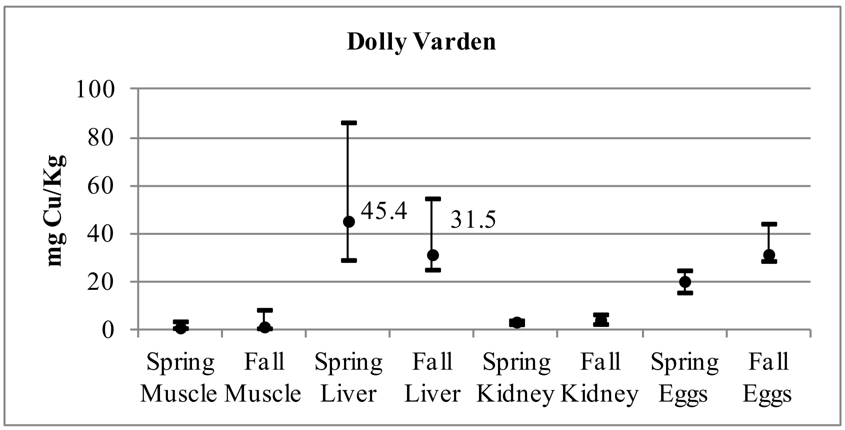


Figure 36. Median, maximum, and minimum Cu concentrations in Dolly Varden caught in spring and fall, 2012.

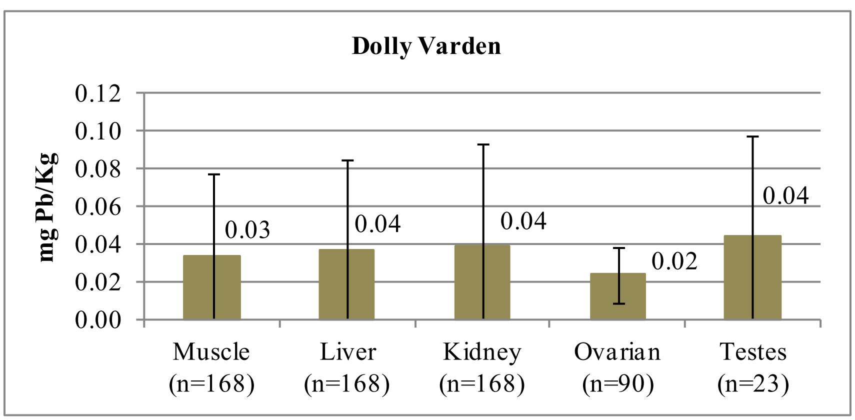


Figure 37. Average Pb concentrations (plus and minus 1 SD) in Dolly Varden (1999-2012).

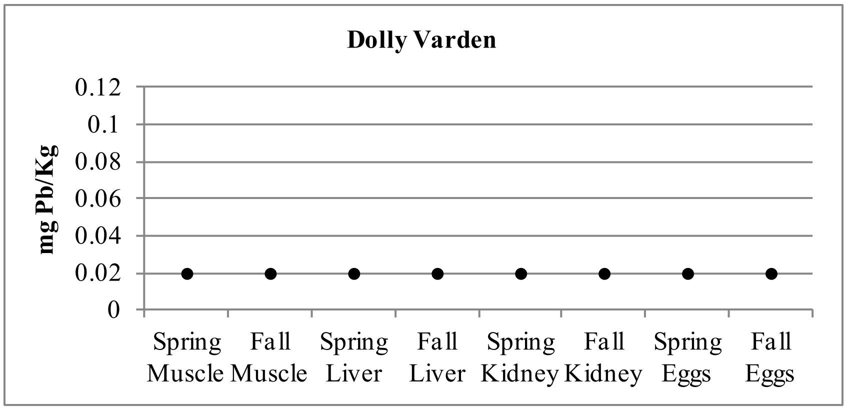


Figure 38. Median, maximum, and minimum Pb concentrations in Dolly Varden caught in spring and fall, 2012 (all were at the detection limit).

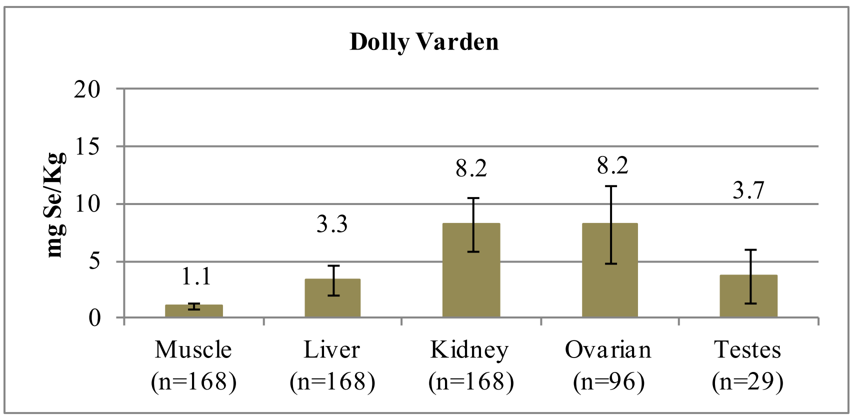


Figure 39. Average Se concentrations (plus and minus 1 SD) in Dolly Varden (1999-2012).

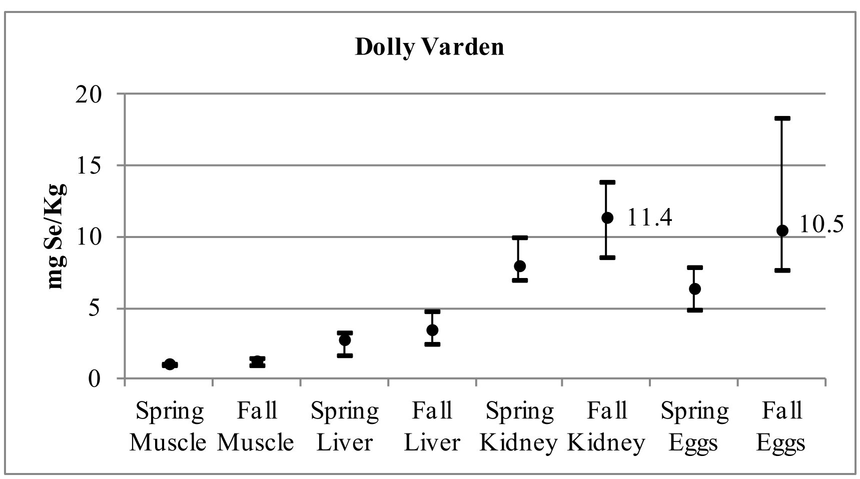


Figure 40. Median, maximum, and minimum Se concentrations in Dolly Varden caught in spring and fall, 2012.

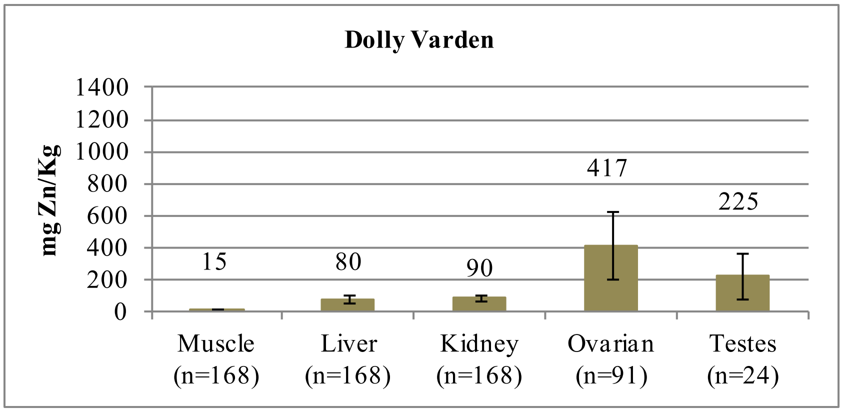


Figure 41. Average Zn concentrations (plus and minus 1 SD) in Dolly Varden (1999-2012).

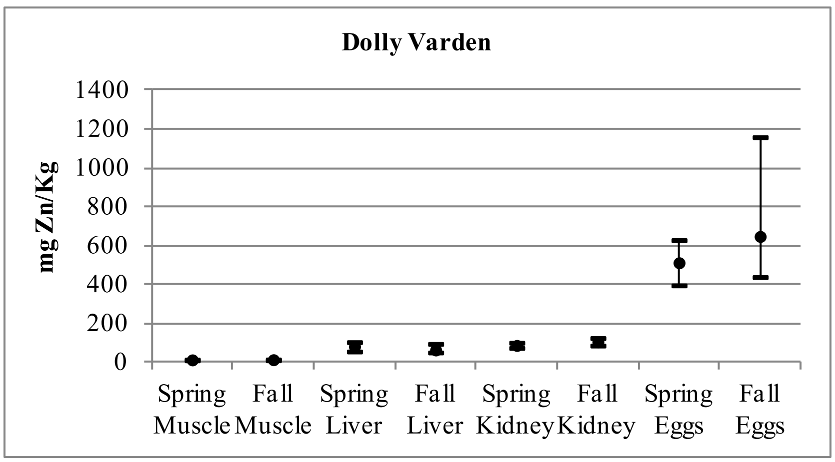


Figure 42. Median, maximum, and minimum Zn concentrations in Dolly Varden caught in spring and fall, 2012.

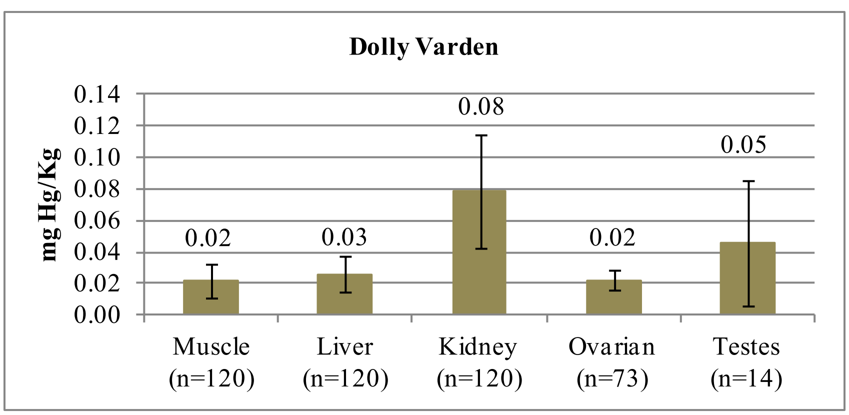


Figure 43. Average Hg concentrations (plus and minus 1 SD) in Dolly Varden (1999-2012).

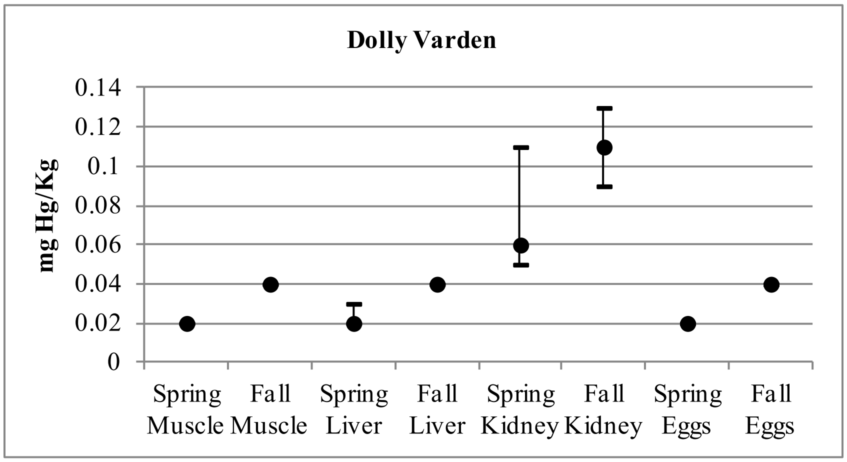


Figure 44. Median, maximum, and minimum Hg concentrations in Dolly Varden caught in spring and fall, 2012. Note, for spring/fall muscle and eggs the detection limit was changed from 0.02 to 0.04.

None of the analytes sampled concentrate in the muscle tissue of the Dolly Varden (Figure 45). Cd, Pb, Se, and Hg are at or very near the detection limit and many of the individual sample points are less than the detection limit. Sample sizes for each analyte are 168 fish, except for Hg where the sample size was 120.

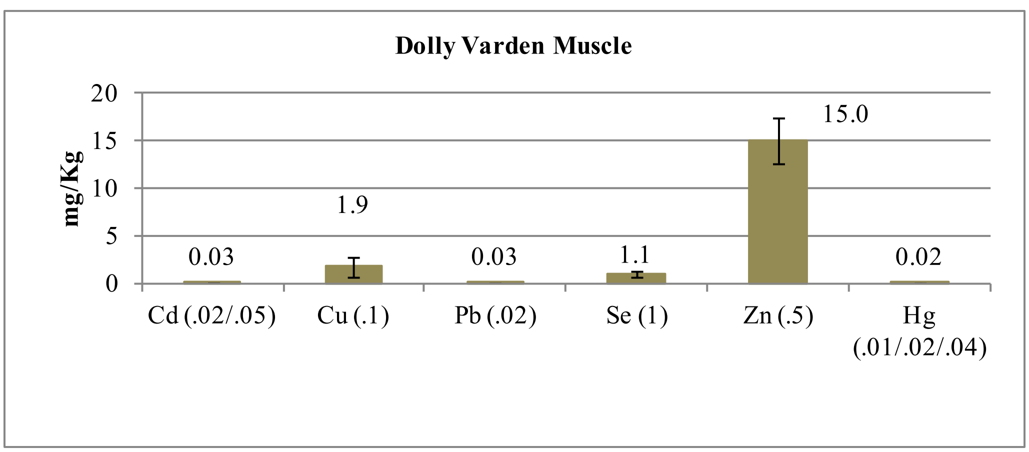


Figure 45. Average concentrations (plus and minus 1 SD) in Dolly Varden muscle (1999-2012). Note, detection limits shown in parenthesis.

Dolly Varden, Overwintering

Three aerial surveys to estimate the number of overwintering Dolly Varden in the Wulik River were conducted in 2012, two in late September (27 and 29) and one on October 10. Surveys were conducted with a R-44 helicopter provided by Teck (DeCicco 2012). The September 29 survey yielded the highest counts and was conducted under the best survey conditions for the year. Turbidity from a tundra slump located several km downstream of Ikalukrok Creek affected survey results. Counts began slightly upstream of Kivalina Lagoon.

Late September estimates of Dolly Varden have decreased annually since 2005 and reached their lowest (21,084) in recent years (Figure 46, Table 3, and Appendix 6). We hypothesized that, similar to some recent salmon migrations in the Arctic, Dolly Varden may be delaying their migration until later in the fall and that the aerial survey may need to be conducted later in the season. In 2011, DeCicco was successful in counting a larger number of fish during a late survey on October 6. The late survey in 2012 was conducted on October 10, but counts of Dolly Varden were low (2,648) due to slightly turbid water and floating slush ice. We will continue to attempt these later surveys, but results will be largely dependent upon weather and survey conditions.

The number of Dolly Varden estimated in the fall in the Wulik River varies annually. Survey results in 2012 found that 100% of the fish observed were downstream of the mouth of Ikalukrok Creek. Only in 2004 has the percentage of fish below Ikalukrok Creek been less than 90%. Continued use of this section of the Wulik River by the majority of overwintering Dolly Varden suggests that conditions have not changed to alter the distribution of these fish.

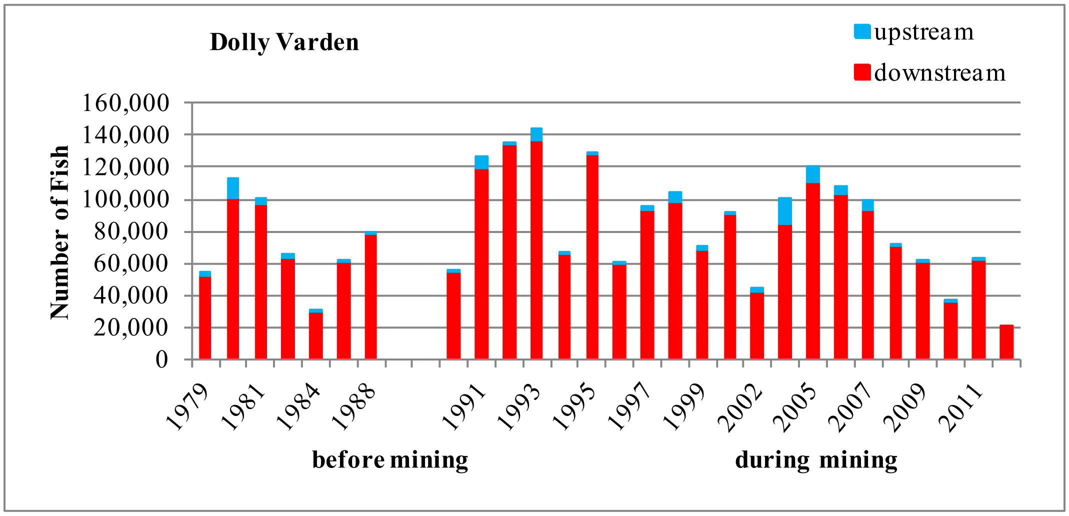


Figure 46. Estimated Dolly Varden in the Wulik River just prior to freezeup.

Table 3. Estimated number of Dolly Varden in the Wulik River.

Year	Wulik River upstream of alukrok Creek	Wulik River ownstream of lukrok Creek	Total Fish	Percent of Fish downstream of kalukrok Creek
Before Mining				
1979	3,305	51,725	55,030	94
1980	12,486	101,067	113,553	89
1981	4,125	97,136	101,261	96
1982	2,300	63,197	65,497	97
1984	370	30,483	30,853	99
1987	893	60,397	61,290	99
1988	1,500	78,644	80,144	98
During Mining				
1989	2,110	54,274	56,384	96
1991	7,930	119,055	126,985	94
1992	750	134,385	135,135	99
1993	7,650	136,488	144,138	95
1994	415	66,337	66,752	99
1995	240	128,465	128,705	99
1996	1,010	59,995	61,005	98
1997	2,295	93,117	95,412	98
1998	6,350	97,693	104,043	94
1999	2,750	67,954	70,704	96
2001	2,020	90,594	92,614	98
2002	1,675	42,582	44,257	96
2004	16,486	84,320	100,806	84
2005	10,645	110,203	120,848	91
2006	4,758	103,594	108,352	96
2007	5,503	93,808	99,311	94
2008	271	71,222	71,493	99
2009	122	60,876	60,998	99
2010	70	36,248	36,318	99
2011	637	62,612	63,249	99
2012	0	21,084	21,084	100

The population estimate (mark/recapture) for winter 1988/1989 for fish >400 mm was 76,892 (DeCicco 1990b)

The population estimate (mark/recapture) for winter 1994/1995 for fish >400 mm was 361,599 (DeCicco 1996c)

Fall 2000 aerial survey was not made due to weather.

Fall 2003 aerial survey was not made due to weather.

Chum Salmon, Spawning

ADF&G conducts annual aerial surveys to assess the distribution of adult chum salmon in Ikalukrok Creek from its confluence with the Wulik River upstream to Dudd Creek (Table 4 and Appendix 7). In fall 2012, we flew a survey using a R-44 helicopter. An estimated 1,198 chum salmon were observed in Ikalukrok Creek (DeCicco 2012).

Our estimated chum salmon return to Ikalukrok Creek in 2012 was at least 1,198 fish. We have observed returns of chum salmon similar to pre-mining for the last seven years, with the exception of the highest counts reported in 1981 by Houghton and Hilgert (1983). Our highest count since mining began at Red Dog was in 2006, when we estimated 4,185 chum salmon in Ikalukrok Creek.

All chum salmon observed were below Station 160 on Ikalukrok Creek, the furthest downstream location at which instream TDS limits apply (from July 25 through the end of the discharge season). Counts of chum salmon in Ikalukrok Creek in 1990 and 1991 (mine discharge began in 1989) were lower than reported in baseline studies. Surveys began again in 1995, with the highest count made in fall 2006. The numbers of returning chum salmon in recent years suggest that the population has recovered from the early 1990s.

Table 4. Number of chum salmon adults in Ikalukrok Creek.

Survey Date	Number of Chum Salmon	Reference
September 1981	3,520 to 6,960	Houghton and Hilgert 1983
August September 1982	353 to 1,400	Houghton and Hilgert 1983
August 1984	994	DeCicco 1990c
August 1986	1,985	DeCicco 1990c
August 1990	<70	Ott et al. 1992
August 1991	<70	Ott et al. 1992
August 16, 1995	49	Townsend and Lunderstadt 1995
August 1995	300 to 400	DeCicco 1995
August 11, 1996	180	Townsend and Hemming 1996
August 12, 1997	730 to 780	Ott and Simpers 1997
1998	no survey	
August 9, 1999	75	Ott and Morris 1999
2000	no survey	
August 7, 2001	850	Morris and Ott 2001
August 28, 2001	2,250	DeCicco 2001b
August 29, 2001	1,836	DeCicco 2001b
September 23, 2001	500	DeCicco 2001c
October 8, 2001	232	DeCicco 2001a
August 5, 2002	890	Ott and Townsend 2002
August 11, 2003	218	Townsend and Ingalls 2003
August 26, 2004	405	Townsend and Conley 2004
August 29, 2005	350	Thompson 2005
August 14, 2006	4,185	Ott and Timothy 2006
August 11, 2007	1,408 and 1,998	Ott and Townsend 2007
August 6, 2008	3,820	Ott and Jacobs 2008
July 31, 2009	100	Ott and Benkert 2009
September 25, 2009	2,051	DeCicco 2009
September 24, 2010	1,358	DeCicco 2010
September 26, 2011	1,507	DeCicco 2011
September 29, 2012	1,198	DeCicco 2012

Dolly Varden, Juveniles

Limited pre-mining juvenile Dolly Varden distribution data are available for streams in the Red Dog Mine area. Houghton and Hilgert (1983) identified Anxiety Ridge Creek as the most productive system in the project area. They also reported finding only one Dolly Varden in the North Fork Red Dog Creek drainage and presumed that it was a resident fish. Surveys along Mainstem Red Dog Creek reported either few fish or no fish, and in some cases mortalities of small juvenile Dolly Varden and Arctic grayling fry (EVS Consultants Ltd and Ott Water Engineers 1983, Ward and Olson 1980).

We have sampled for juvenile Dolly Varden in streams within the Red Dog Mine area since 1990. We added new sample sites and increased the number of minnow traps (10) per sample reach in 1992. Under the modified program that began in 2010, we sample eight sites with 10 minnow traps per sample reach with about 24 hrs of effort in early-to-mid August (Table 5, Appendix 8). Seven of these sites are unchanged since 1992 and the new Station 160 corresponds to Station 7 – instead of being immediately downstream of Dudd Creek, it is now located about 7 km downstream.

Table 5. Location of juvenile Dolly Varden sample sites.

Site Name	Station No.	Year Sampling Started
Evaingiknuk Creek		1990
Anxiety Ridge Creek		1990
Buddy Creek		1996
North Fork Red Dog Creek	12	1993
Mainstem Red Dog Creek	151	1995
Mainstem Red Dog Creek	10	1996
Ikalukrok Creek above Mainstem	9	1996
Ikalukrok Creek below Dudd	7/160	1990

Minnow traps are the preferred sampling gear for juvenile Dolly Varden because they are very effective for the species and age classes present in the Red Dog Mine area, the gear is suitable for sample areas in large to small streams, the effort is uniform across sample sites, variability due to sampler-induced bias is reduced, and there is seldom fish mortality. Juvenile Dolly Varden generally are the most numerous fish species present and are distributed most widely in the sample area. Our objective is to assess numbers of fish using streams over time and to sample juvenile Dolly Varden for whole body metal analyses from selected streams. Data relevant to whole body metal analyses of juvenile Dolly Varden were presented in a previous section of this report.

Dolly Varden Catches and Metrics

Sampling of juvenile Dolly Varden was not conducted in fall 2012 due to extremely high water which lasted most of the month of August (Appendix 9). However, during spring breakup we fish fyke nets in North Fork Red Dog Creek to capture Arctic grayling, but we also catch resident Dolly Varden and slimy sculpin. In spring 2012, we caught 5 Dolly Varden that averaged 158 mm long (Figure 47). Most of these fish were presumed to be freshwater resident (non-anadromous) fish due to size (larger than smolts), obvious parr marks, and distinct orange/pink dots. Use of North Fork Red Dog Creek by resident Dolly Varden varies among the sample years.

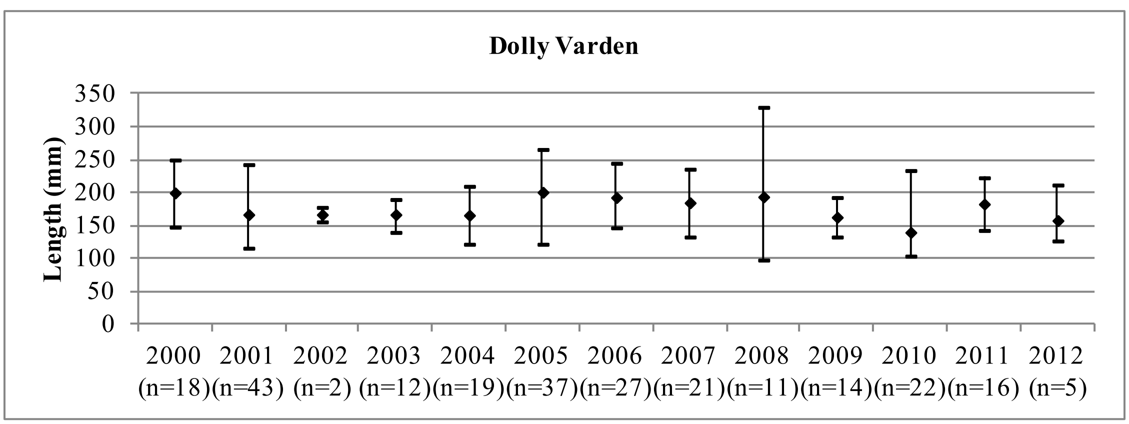


Figure 47. Dolly Varden caught in fyke nets fished in North Fork Red Dog Creek in spring during the Arctic grayling spawning run.

Arctic Grayling, Red Dog Creek Drainage

Before mine development, Arctic grayling adults migrated through Mainstem Red Dog Creek in spring when flows were high and metals concentrations were low (Ward and Olsen 1980, EVS and Ott Water Engineers 1983, and Houghton and Hilgert 1983). Arctic grayling moved through Mainstem Red Dog Creek to spawn in North Fork Red Dog Creek. None of these reports indicated that Arctic grayling spawned in Mainstem Red Dog Creek. Arctic grayling fry reared in North Fork Red Dog Creek and were displaced downstream by high-water events or outmigrated as water temperatures cooled in the fall. A few juvenile Arctic grayling were observed in North Fork Red Dog Creek prior to mine development. Dolly Varden and Arctic grayling fry mortality was reported in Mainstem Red Dog Creek by EVS Consultants and Ott Water Engineers (1983) and Ward and Olsen (1980). Since 1994, we have documented Arctic grayling use of Mainstem Red Dog Creek and have not observed any fish mortalities (Appendix 10).

Arctic Grayling Spawning

We have monitored Arctic grayling spawning during the spring in North Fork Red Dog and Mainstem Red Dog creeks since 2001. The purposes of this sampling effort are to document when spawning has been substantially completed in Mainstem Red Dog Creek and to assess the return of Arctic grayling to North Fork Red Dog Creek. Spring water temperatures and timing of warming appears to be the key variable determining spawning success, determining spawning time, emergence of fry, first year growth, and likely survival. High flows during or immediately following spawning can have a negative effect on fry survival (Clark 1991).

Discharge volume and quality from the wastewater treatment facility at the Red Dog Mine are regulated to meet permit conditions. From 2001 to 2007, TDS concentrations were regulated to be less than 500 mg/L at Station 151 (Station 10) during Arctic grayling spawning. During that time frame, monitoring of Arctic grayling spawning was performed to determine when spawning was substantially completed, thus allowing Teck to increase the TDS concentrations to 1,500 mg/L for the remainder of the ice-free season.

A TDS site-specific criterion (SSC) of 1,500 mg/L during Arctic grayling spawning was issued by ADEC and became effective on February 15, 2006. The US Environmental Protection Agency (EPA) approved the 1,500 mg/L TDS SSC on April 21, 2006. The SSC developed by ADEC was based on field and laboratory studies conducted with Arctic grayling at the Red Dog Mine site (Brix and Grosell 2005). Teck regulates the wastewater discharge to ensure that TDS concentrations do not exceed the ADEC and EPA approved TDS limit of 1,500 mg/L at Station 151.

We used fyke nets and angling to capture Arctic grayling in Mainstem Red Dog and North Fork Red Dog creeks from June 3 to 6, 2012. Flows were low and the water was clear (Figure 48). We set a fyke net on June 3 in North Fork Red Dog Creek and a second fyke net on June 5, upstream of the main net. The upstream fyke net catches Arctic grayling (post-spawning) as they move downstream. Arctic grayling tend to mill upstream of the main net which is set to completely block the channel.

Figure 48. Fyke net site in North Fork Red Dog Creek in spring 2012 at Station 12.

We caught 138 Arctic grayling in North Fork Red Dog Creek in the main net. Catches declined towards the end of the sampling event (Figure 49). Generally, catches early in the spring spawning migration consist predominantly of large mature fish. This was not the case in spring 2012, when juvenile Arctic grayling dominated the catch (Figure 50). Sampling in 2012 began after most adult Arctic grayling already had entered North Fork Red Dog Creek.

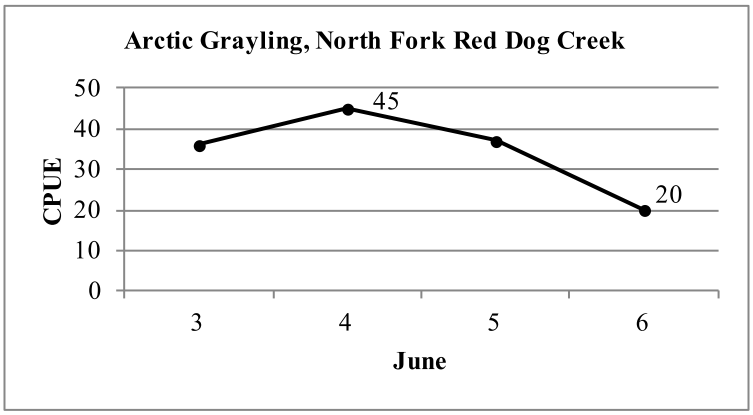


Figure 49. Catch per unit of effort (fish/day) in North Fork Red Dog Creek in June 2012.

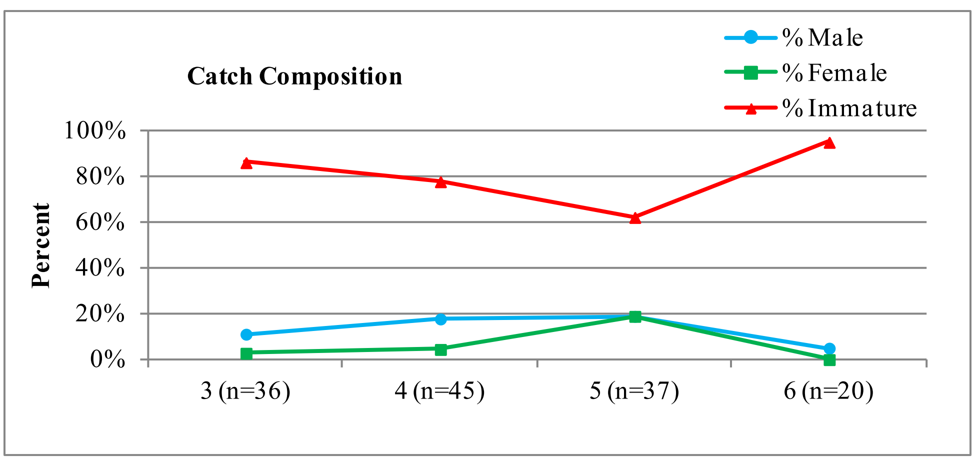


Figure 50. Percent male, female, and immature Arctic grayling in North Fork Red Dog Creek in June 2012.

On June 2, 2012, two partially spent females were captured. On June 5, 2012, all seven females caught were spent. Based on these data, it appears that spawning was substantially complete in Mainstem Red Dog Creek by June 4. Spawning probably started in North Fork Red Dog Creek on June 2 as peak water temperatures reached 5.1°C (Figure 51). Water temperatures were consistently higher in Mainstem Red Dog Creek than in North Fork Red Dog Creek.

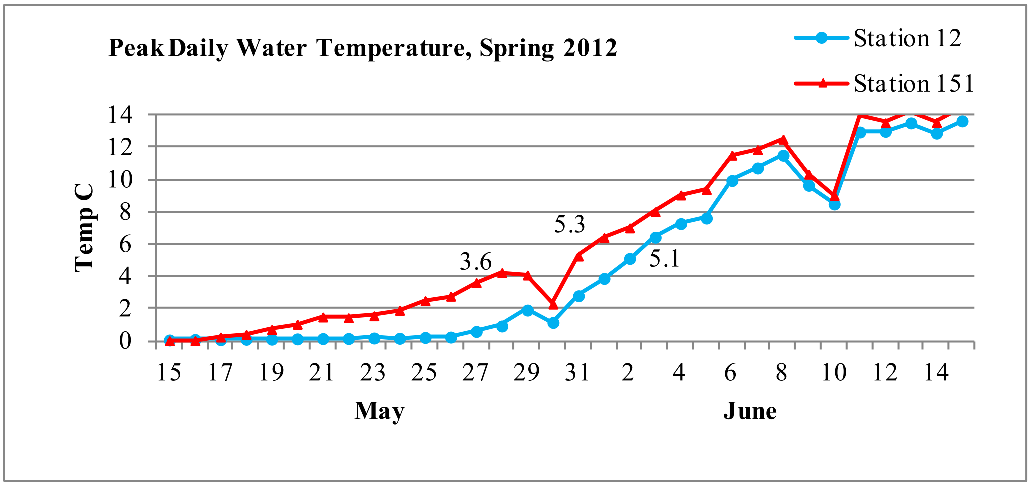


Figure 51. Peak daily water temperatures in North Fork Red Dog (Station 12) and Mainstem Red Dog (Station 151) creeks in spring 2012.

The Middle Fork and North Fork of Red Dog Creek join to form Mainstem Red Dog Creek downstream of the fish barrier in Middle Fork Red Dog Creek. Substantial aufeis exists in North Fork Red Dog Creek, but not in Middle Fork Red Dog Creek. The increased water temperatures in Mainstem Red Dog Creek as compared with North Fork Red Dog Creek appear to be related to the lack of aufeis in Middle Fork Red Dog Creek. The absence of aufeis in Middle Fork Red Dog Creek may be due to the fact that potential winter surface and ground water contributions are collected in the mine sump drainage and moved to the tailing impoundment (rather than contributing to formation of aufeis). This change results in a temperature increase in Mainstem Red Dog Creek in early spring, this increase in temperature likely is the key factor that led to use of this reach by Arctic grayling for spawning.

The earliest spawning was judged to be substantially complete was May 29 in 2010 (Table 6). In both 2001 and 2006, spawning was not completed until June 15 (Table 6). Limited spawning could start at 3°C, but most likely does not start until temperatures reach 4°C. For comparison, data collected at Ft. Knox in spring 2010 did confirm that some Arctic grayling spawned before peak temperatures reached 4°C (Ott and Morris 2010).

Table 6. Summary of Arctic grayling spawning in Mainstem Red Dog Creek.

Year	Date When Limited Spawning Started (3°C)	Date When Spawning Complete (Condition of Females)	Number of Days Peak Temperatures Exceeded 4°C[1]
2001	June 6	June 15	6
2002	May 29	June 8	8
2003	June 7	June 14	6
2004	May 25	May 31	4
2005	May 27	June 6	9
2006	May 30	June 15	10
2007	May 26	June 3	8
2008	June 1	June 9	9
2009	June 8	June 13	4
2010[2]	May 21	May 29	6
2011	June 6	June 9	4
2012	May 27	June 4	7

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

[2]The date spawning was judged to be substantially complete was based solely on the water temperature data collected in spring 2010.

Arctic Grayling Fry

In 2012, spawning success in North Fork Red Dog Creek was low. However, Arctic grayling fry were present along the stream margins and several schools of 15 to 20 were observed in the vicinity of Station 10 (lower Mainstem Red Dog Creek).

Arctic Grayling Catches and Metrics

In spring 2012, we handled 177 Arctic grayling in North Fork Red Dog Creek caught by angling and with fyke nets. Recruitment of immature fish was strong in spring 2012 (Figure 52). For the last six years, numbers of immature Arctic grayling have been high in our catches.

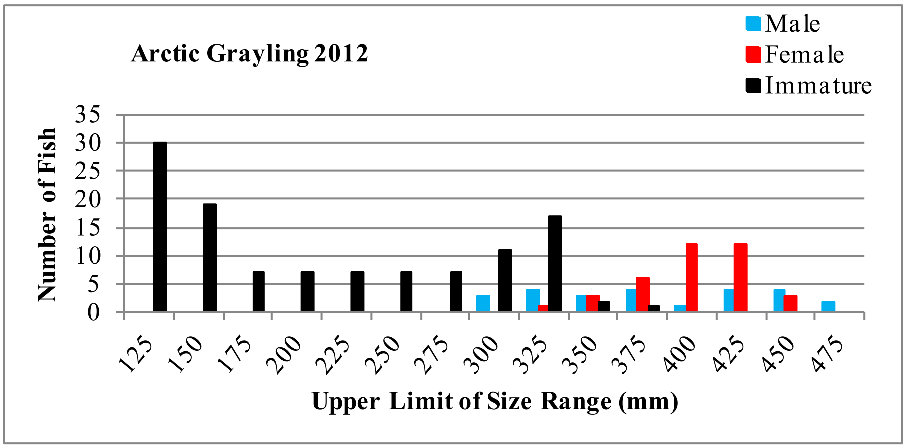


Figure 52. Length frequency distribution of Arctic grayling in June 2011.

A portion of the Arctic grayling in the North Fork Red Dog Creek catch is attributable to fish leaving Bons Pond, entering the Ikalukrok Creek drainage, and returning to North Fork Red Dog Creek. The percentage of marked fish coming from Bons Pond in our 2012 sample was 7% (Figure 53). In 2008, 18% of the catch in North Fork Red Dog Creek was from Bons Pond.

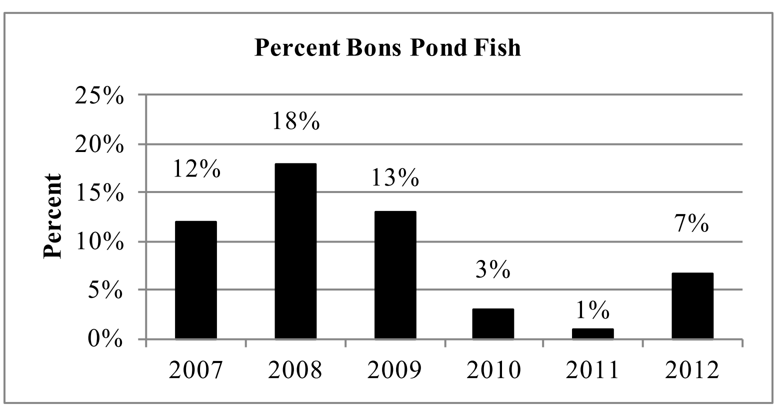


Figure 53. Percent of recaptured and marked fish that came from Bons Pond.

The catch per unit of effort (CPUE) for immature Arctic grayling in North Fork Red Dog Creek has ranged from 3.4 in 2002 to 41.1 in 2012 (Figure 54). Our highest CPUE was in 2012, but the higher catch was influenced by the fact that we did not get the fyke nets set until most of the larger fish had already moved upstream. The CPUE has been increasing since 2007.

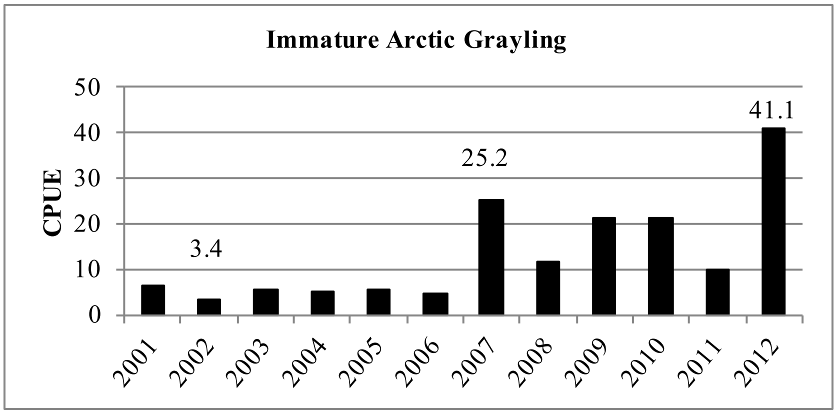


Figure 54. Catch per unit of effort (fish per day) of immature Arctic grayling in North Fork Red Dog Creek in spring 2001 to 2012.

Catches of mature Arctic grayling in North Fork Red Dog Creek have remained stable since 2001 (Figure 55). Our highest CPUE was 37.6 fish/day in 2007. If you exclude 2006 and 2007, the CPUE for adult Arctic grayling averaged 10.1 fish/day (SD = 2.6). That consistency is characteristic of a stable northern population of long lived fish where, for the most part, only natural mortality is affecting the adult population.

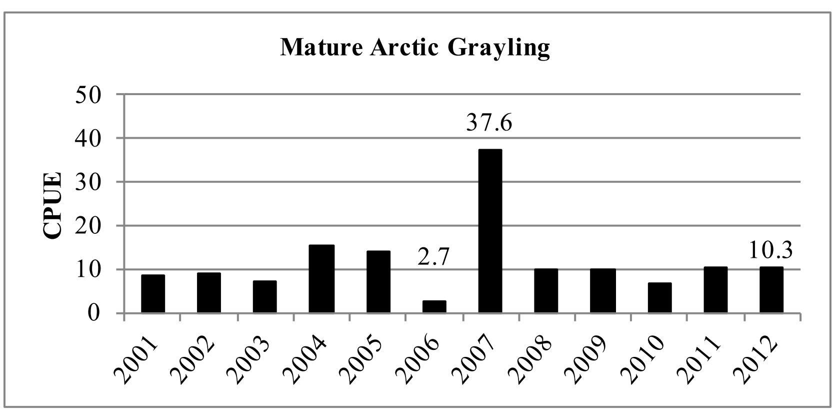


Figure 55. Catch per unit of effort (fish per day) of mature Arctic grayling in North Fork Red Dog Creek in spring 2001 to 2012.

The average growth rate for Arctic grayling between 250 and < 300 mm long when marked and at large for one year is presented in Figure 56. Recapture numbers for this size group are low (1 to 7 fish per year). Average growth rates from 2002 to 2011 have remained stable.

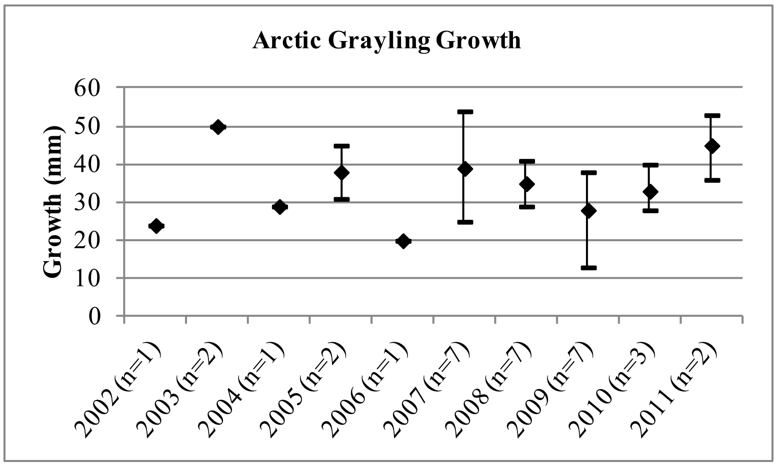


Figure 56. Average, maximum, and minimum growth of Arctic grayling in North Fork Red Dog Creek for fish between 250 and < 300 mm long when marked.

The population of Arctic grayling in North Fork Red Dog Creek, pre-mining, is not known. We try to make population estimates each year, but in some years the number of recaptures is insufficient. In 2011, we saw 139 marked Arctic grayling ≥ 200 mm long. In spring 2012, we caught 100 Arctic grayling ≥ 250 mm long of which 14 were recaptures. Based on a comparison of the 2011 and 2012 length frequency distributions we determined that fish < 250 mm in 2012 would not have been large enough to mark in spring 2011. The estimated 2011 North Fork Red Dog Creek Arctic grayling population was 942 fish (SD = 402) (Figure 57).

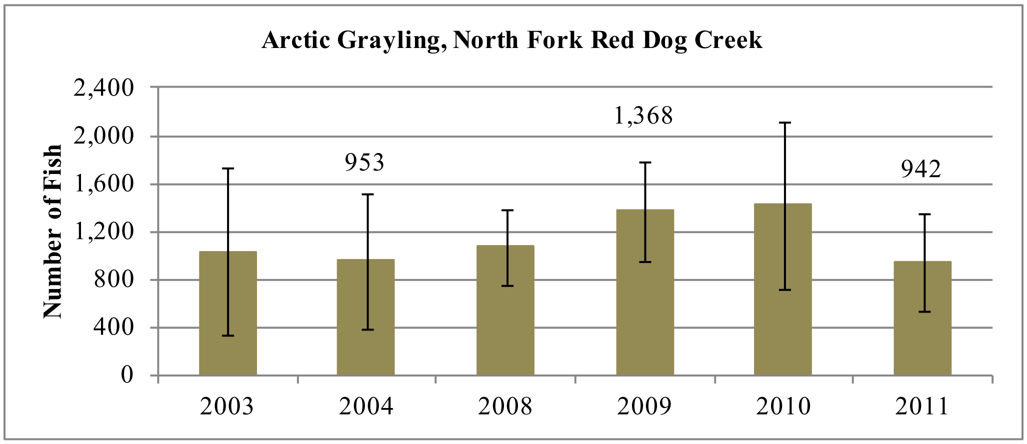


Figure 57. The estimated Arctic grayling population (± SD) in North Fork Red Dog Creek for fish ≥ 200 mm long.

Arctic Grayling Seasonal Migration

We initiated an Arctic grayling seasonal migration and habitat use study using radio telemetry in spring 2011. The goal of the study was primarily to identify overwintering areas used by the North Fork Red Dog Creek Arctic grayling spawning population. Secondary goals of the project were to monitor movement and migration patterns of the radio tagged population during summer and also during the spring migration. The radio tagged Arctic grayling averaged 404 mm long (370 to 442 mm, SD = 27). Three were females and the rest were males. Radio tracking surveys were flown in June, July, September, October, and November, 2011 and on June 2 and 5, 2012.

After spawning, adult Arctic grayling distributed throughout the Ikalukrok Creek drainage, but by fall most were in lower Ikalukrok Creek in the same reach used by spawning chum salmon (Ott and Morris 2012). By early winter all the radio tagged Arctic grayling were in the Wulik River in a 3 km reach below the mouth of Ikalukrok Creek. Analysis of radio-located sites for each fish from November 1, 2011 to June 2 and 5, 2012, indicates a high mortality rate. Fish that exhibited little or no movement between November 2011 and June 2 and 5, 2012 were assumed to have died. The apparent mortality rate is about 64% overall.

Radio-locating of the surviving fish in spring 2012, one female and four males, indicate that radio tagged males were already in Mainstem Red Dog and North Fork Red Dog creeks near spawning areas on June 2, 2012 and that by June 5, some were out-migrating from the system. These observations track well with fyke net catches in North Fork Red Dog Creek which by June 5, clearly indicated that spawning in North Fork Red Dog Creek had occurred. The only surviving radio tagged female was still in Ikalukrok Creek on June 2 and had moved into known spawning areas in North Fork Red Dog Creek by June 5. These observations are consistent with catches from previous years where males typically arrive in spawning areas well in advance of females and remain on the spawning grounds for an extended period of time. Because of the high mortality rate and the knowledge we gained from the study, we do not plan on radio tagging more large adult Arctic grayling. We had hypothesized that the Arctic grayling overwinter in lower Ikalukrok Creek and Wulik River and we found that most of the fish overwintered in the Wulik River just below the mouth of Ikalukrok Creek.

Arctic Grayling, Bons Pond

Bons Pond, is an impoundment created by construction of an earthen dam. The dam was built in 1987/1988 to provide potable and make-up water for operational activities. Prior to construction of the dam, there were no fish present in Bons Creek due to a series of impassable waterfalls and chutes in bedrock about 1 km downstream of the dam. Bons Creek flows into Buddy Creek and eventually into Ikalukrok Creek.

The Arctic grayling population in Bons Pond is the result of a fish transplant conducted in 1994 and 1995 (Ott and Townsend 2003). The 1994 transplant fish from North Fork Red Dog Creek ranged in size from 158 to 325 mm long (n=102, average 235, SD = 34) and included 5 large Arctic grayling from Ikalukrok Creek (350 to 425 mm long, average 376, SD =32). In 1995, about 200 fry were caught in North Fork Red Dog Creek and transported to Bons Pond. Bons Creek flows out of the pond via a channel excavated in bedrock. Bons Creek flows over a 20 m high falls – there is no upstream fish passage (Figure 58).

Figure 58. Outlet of Bons Pond into Bons Creek – Arctic grayling leaving Bons Pond go over the falls and into Bons Creek.

Sampling conducted in 1996 and 1997 indicated that the transplant was not successful as we were unable to catch or observe any fish in Bons Pond. In summers 1995 to 1997, 12 of the marked Arctic grayling from Bons Pond were recaptured in North Fork Red Dog Creek. However, in 2001 and 2002, Arctic grayling juveniles were observed in Bons Creek immediately downstream of the blast road. In summer 2003, fish sampling was initiated in Bons Pond to determine the extent of fish use. The estimated Arctic grayling population in 2003 was 6,773 fish $\geq$ 200 mm long (Ott and Townsend 2003).

Since 2003, we have sampled Bons Pond and Bons Creek in the spring, with additional sampling later in the ice-free season to increase the number of marked fish. Spawning has been observed in Bons Creek and in the outlet of Bons Pond. Our current program in Bons Pond includes a mark/recapture study to estimate the population size and the collection of 15 juvenile Arctic grayling for whole body metals analysis.

Bons Creek, upstream of Bons Pond, is about 1 to 2 m wide with depths from 0.3 to 1 m. In our sample reach, located about 200 m upstream of Bons Pond, the substrate consists of gravel in riffles, with fine sediments and organics in the pools. Bons Creek is incised with streambanks vegetated with willows and sedges.

A diversion ditch was constructed to carry surface water around the waste rock stockpile. Thermal and hydraulic erosion in diversion ditch contributes seasonally to the sediment and organic load in Bons Creek. Most of the Bons Creek drainage area is in ice-rich permafrost with thermal erosion and sediment/organic input that varies with seasonal conditions. Generally, there is a high input of sediments and organics to Bons Creek, particularly during rainfall events.

Arctic Grayling Fry

In 2012, Arctic grayling successfully spawned in Bons Creek based on observations and collection of fry in drift nets fished in early July. Drift nets have been used to sample aquatic invertebrates in Bons Creek upstream of Bons Pond since 2004. In addition to aquatic invertebrates, we have been successful in catching Arctic grayling fry in drift nets. In 5 of 9 years, catches of fry in Bons Creek have been zero. The highest number of Arctic grayling fry caught was 78 in 5 drift nets in 2007 (Figures 59 and 60). The Arctic grayling fry in early July were about 15 to 20 mm long.

Figure 59. Drift nets in Bons Creek upstream of Bons Pond.

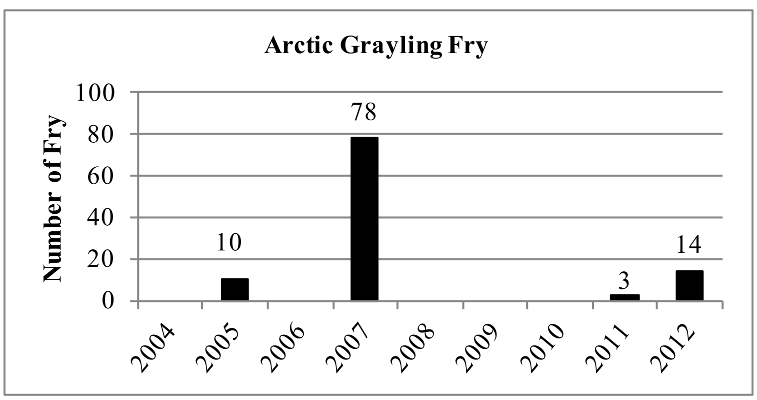


Figure 60. Number of Arctic grayling fry caught in drift nets.

Arctic Grayling Catches and Metrics

On June 4, 2012, we set a fyke net in Bons Creek, about 200 m upstream of Bons Pond. We fished the fyke net until the morning of June 6. We caught 167 Arctic grayling in Bons Creek and Bons Pond. Most of the Arctic grayling were caught in the fyke net; however, some fish were captured by angling in the outlet of Bons Pond. Our catch/fyke net per day in 2012 was 95 (Figure 61). The catch/fyke net day for Arctic grayling < 200 mm has ranged from 1 to 38 (Figure 62) and was the highest in 2012 at 95 fish since the 2006 sample event.

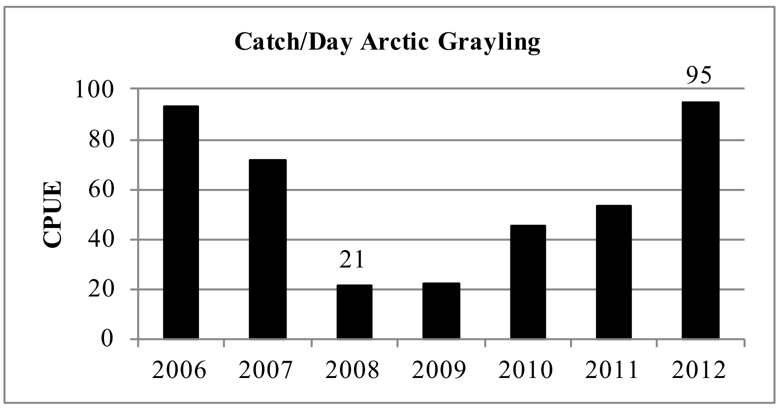


Figure 61. Fyke net catch/day for all Arctic grayling in Bons Creek.

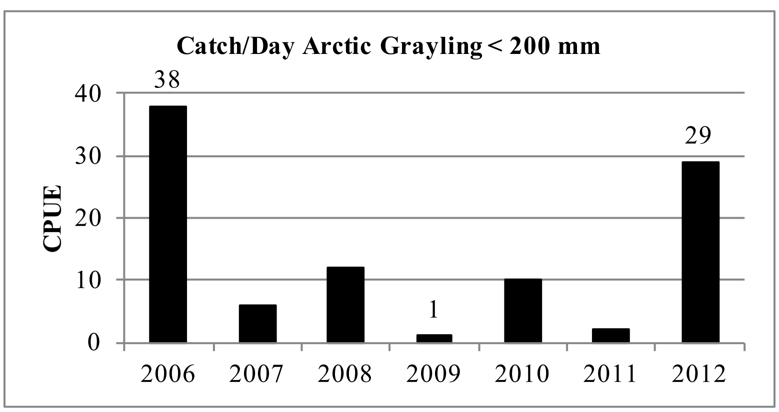


Figure 62. Fyke net catch/day for Arctic grayling < 200 mm in Bons Creek.

The length frequency distribution for Arctic grayling caught in fyke nets and by angling in spring 2012 is presented in Figure 63. The current population in Bons Pond consists of mature fish with limited numbers of juveniles suggesting limited spawning success and/or survival and low recruitment. However, in spring 2012, we did catch 29 Arctic grayling less than 100 mm long – most of these fish are age 1+.

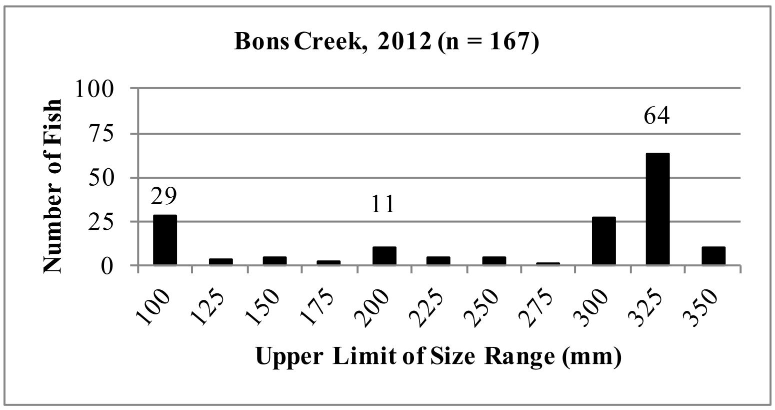


Figure 63. Length frequency distribution of Arctic grayling in Bons Pond in spring 2012.

Growth rates for Arctic grayling from Bons Pond are much less than for comparable sized fish from North Fork Red Dog Creek. Growth rates (spring to spring) have been low (less than 13 mm per year) from 2005 through 2010 with higher growth rates in 2003, 2004, and 2011 (Table 7). Growth rates increased in 2011 as compared with the previous five years. Growth rates by size group are presented in Figure 64. Higher growth rates were seen in 2003 and 2004 as the population increased and then remained low for the next six years. Higher growth rates in 2011 may be the result of having fewer fish in the population and thus an increased food supply for those fish present. Although, not measured specifically, we noted that the Arctic grayling caught in spring 2012 appeared to be in better condition (e.g., more robust) than in previous years.

Table 7. Average growth by size group for Arctic grayling in Bons Pond.

Length at Marking (mm)	2003 Average Growth (mm)	2004 Average Growth (mm)	2005 Average Growth (mm)	2006 Average Growth (mm)	2007 Average Growth (mm)	2008 Average Growth (mm)	2009 Average Growth (mm)	2010 Average Growth (mm)	2011 Average Growth (mm)
225	22	34						9	
250	12	28	10	11			13	13	
275	2	6	7	11	8	11	7	10	22
300	2	4	9	4	10	9	6	6	15
325	1	6				17	8	4	14
350									8
sample size	44	63	15	28	12	24	44	96	40

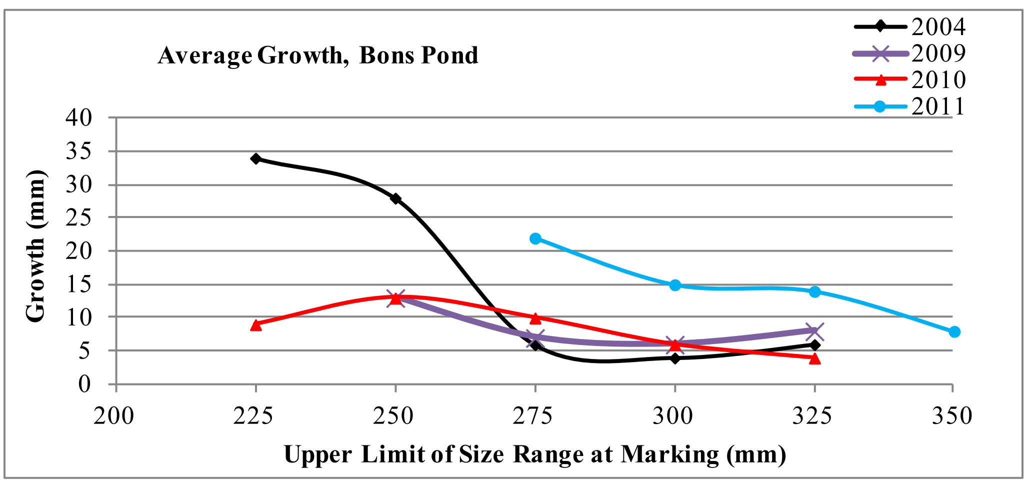


Figure 64. Individual growth of Arctic grayling from in summer 2004, 2009, 2010, and 2011 in Bons Pond.

We estimated the Arctic grayling population in Bons Pond using 2011 as the mark event and spring 2012 as the recapture event. We had 456 marked fish in summer 2011 that were either recaptures or new marks. In spring 2012, we caught 135 Arctic grayling of which 40 were recaptures (fish observed in summer 2011). Our estimated Arctic grayling population is 1,515 fish ≥ 200 mm long (SD = 365 fish). The population estimates show a substantial decrease in the population beginning in 2008 (Figure 65). Population estimates from 2008 to 2011 are similar, but still decreasing each year.

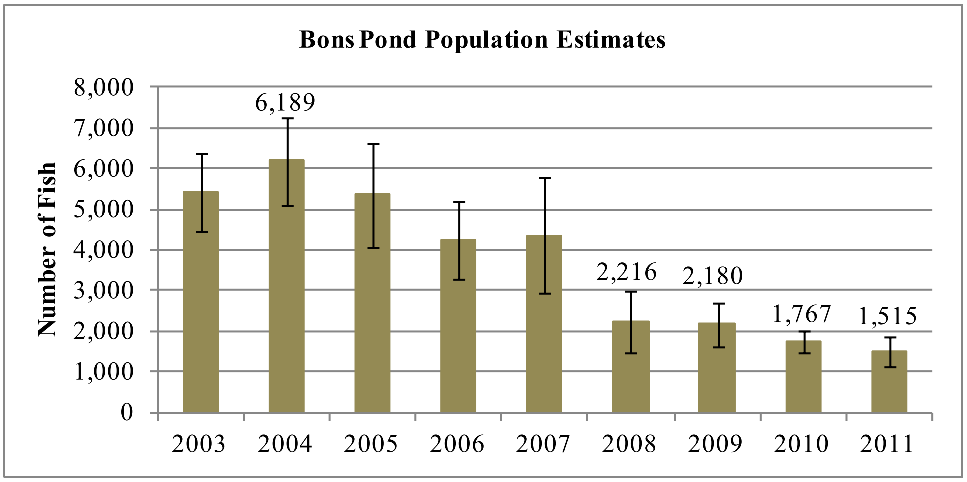


Figure 65. Estimated Arctic grayling population (± SD) in Bons Pond for fish ≥ 200 mm long.

Slimy Sculpin

Houghton and Hilgert (1983) found slimy sculpin in Ikalukrok and Dudd creeks, but none were observed or caught in the Red Dog Creek drainage. In 1995, we caught slimy sculpin in Mainstem Red Dog and North Fork Red Dog creeks (Weber Scannell and Ott 1998). Slimy sculpin are infrequently caught in the Red Dog Creek drainage; however, we did catch three large slimy sculpin (133, 129, and 132 mm) in spring 2008 and 4 large slimy sculpin (132, 134, 136, and 142 mm) in spring 2009 in the North Fork Red Dog Creek fyke net. In spring 2011 and 2012 we caught no slimy sculpin in North Fork Red Dog Creek.

Literature Cited

ADF&G. 1998. Methods for aquatic life monitoring to satisfy requirements under NPDES Permit. NPDES AK-003865-2, Red Dog Mine Site. AK Dept. of Fish and Game, Habitat and Restoration Division. 23 pp.

Brix, K.V. and M. Grosell. 2005. Report on the effects of total dissolved solids on Arctic grayling and Dolly Varden fertilization success. Prepared for Teck Cominco. 23 pp.

Dames and Moore. 1983. Environmental baseline studies Red Dog project.

Chapman, D.G. 1951. Some practices of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics. 1:131-60.

Clark, R.A. 1992. Influence of stream flows and stock size on recruitment of Arctic grayling (*Thymallus arcticus*) in the Chena River, Alaska. Can. J. Fish Aquat. Sci. 49:1027-1034.

DeCicco, A.L. 2012. Wulik River aerial surverys 2012. Letter to Division of Habitat dated October 12, 2012. Fisheries Services and Supplies. Fairbanks, AK. 2 pp.

DeCicco, A.L. 2011. Wulik River aerial surverys 2011. Letter to Division of Habitat dated October 11, 2011. Fisheries Services and Supplies. Fairbanks, AK. 2 pp.

DeCicco, A.L. 2010. Wulik River aerial survey 2010. Letter to Division of Habitat dated October 1, 2010. Fisheries Services and Supplies. Fairbanks, AK. 2 pp.

DeCicco, A.L. 2009. Wulik River aerial survey 2009. Letter to Division of Habitat dated September 30, 2009. Fisheries Services and Supplies. Fairbanks, AK. 2 pp.

DeCicco, A.L. 2008. Wulik River aerial survey 2008. Letter to Division of Habitat dated September 20, 2008. Fisheries Services and Supplies. Fairbanks, AK. 2 pp.

DeCicco, A.L. 2007. Wulik River aerial survey 2007. Letter to Office of Habitat Management and Permitting dated October 18, 2007. Fisheries Services and Supplies. Fairbanks, AK. 2 pp.

DeCicco, A.L. 2006. Wulik River aerial survey 2006. Letter to Office of Habitat Management and Permitting dated October 9, 2006. Fisheries Services and Supplies. Fairbanks, AK. 1 p.

DeCicco, A.L. 2005. Memorandum, 2005 Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 2004. Red Dog trip report, September 11 to 15, 2004. Memorandum, AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 2 pp.

DeCicco, A.L. 2002. 2002 Wulik River survey. October 14, 2002. Memorandum, AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

Literature Cited (continued)

DeCicco, A.L. 2001a. Wulik River survey and Ikalukrok Creek, October 8, 2001. Memorandum, AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 2001b. Ikalukrok Creek salmon, September 3, 2001. Memorandum, AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 2 p.

DeCicco, A.L. 2001c. Ikalukrok Creek salmon, September 28, 2001. Memorandum, AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 2 p.

DeCicco, A.L. 2000. Personal communication to Habitat and Restoration Division. November, 2000.

DeCicco, A.L. 1999. Memorandum, 1999 Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 1998. Memorandum, 1998 Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 1997. Memorandum, 1997 Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 1996a. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 1996b. Abundance of Dolly Varden overwintering in the Wulik River, Northwest Alaska during 1994/1995. AK Dept. of Fish and Game, Sport Fish Fishery Data Series No. 96-3. Anchorage, AK.

DeCicco, A.L. 1995. Personal communication. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK.

DeCicco, A.L. 1994. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 1993. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 1992. Memorandum, char surveys. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 2 pp.

DeCicco, A.L. 1991. Kotzebue trip report, August 16 to 27, 1991. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 5 pp.

DeCicco, A.L. 1990a. Life history of anadromous Dolly Varden (*S. malma*) in Northwestern Alaska. AK Dept. of Fish and Game, Sport Fish Division. Prepared for the 1990 meeting of the International Society of Arctic char fanatics in Murmansk, USSR. September 1990. 19 pp.

Literature Cited (continued)

DeCicco, A.L. 1990b. Northwest Alaska Dolly Varden study 1989. Federal Aid in Sport Fish Restoration Act. AK Dept. of Fish and Game, Fishery Data Series No. 90-8. Fairbanks, AK. 42 pp.

DeCicco, A.L. 1990c. Trip report, Red Dog October 3 to 6, 1990. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 2 pp.

DeCicco, A.L. 1989. Memorandum, Wulik River char distribution. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 3 pp.

DeCicco, A.L. 1985. Inventory and cataloging of sport fish and sport fish waters of Western Alaska with emphasis on Arctic char life history studies. AK Dept. of Fish and Game. Federal-Aid Fish Rest. Annual Performance Report, 1984-1985, Project F-9-17, Volume 26. 41-134.

EVS Consultants Ltd and Ott Water Engineers. 1983. Toxicological, biophysical and chemical assessment of Red Dog, Delong Mountains, Alaska, 1982. Prepared for the Alaska Department of Environmental Conservation, Juneau, by G. Vigers, J. Barrett, R. Hoffman, J. Humphrey, D. Kathman, D. Konasewich, R. Olmsted, and B. Reid. 245 pp.

Houghton, J.F. and P.J. Hilgert. 1983. In environmental baseline studies Red Dog project. Dames and Moore. 82 pp.

Jenkins, D.W. 1980. Biological monitoring of toxic trace metals. Vol. 1. Biological Monitoring and Surveillance. J EPA-600/3-80-089. 215 pp.

Morris, W.A. and A.G. Ott. 2001. Red Dog trip report (July 28 to August 9, 2001). AK. Dept. of Fish and Game. 9 pp.

Ott, A.G. and W.A. Morris. 2012. Aquatic biomonitoring at Red Dog Mine, 2011. Technical Report No. 12-02. AK Dept. of Fish and Game, Division of Habitat. Juneau, AK. 121 pp.

Ott, A.G. and W.A. Morris. 2011. Aquatic biomonitoring at Red Dog Mine, 2010. Technical Report No. 11-01. AK Dept. of Fish and Game, Division of Habitat. Juneau, AK. 108 pp.

Ott, A.G. and W.A. Morris. 2010. Aquatic biomonitoring at Red Dog Mine, 2009. Technical Report No. 10-02. AK Dept. of Fish and Game, Division of Habitat. Juneau, AK. 158 pp.

Ott, A.G. and W.A. Morris. 2009. Aquatic biomonitoring at Red Dog Mine, 2008. Technical Report No. 09-03. AK Dept. of Fish and Game, Division of Habitat. Juneau, AK. 168 pp.

Ott, A.G. and R.C. Benkert. 2009. Red Dog Mine, Biomonitoring Field Trip, July 29 to August 1, 2009. AK. Dept. of Fish and Game. Division of Habitat. Juneau, AK. 4 pp.

Literature Cited (continued)

Ott, A.G. and L. Jacobs. 2008. Red Dog trip report, August 2 to 9, 2008. AK. Dept. of Fish and Game. Division of Habitat. Juneau, AK. 4 pp.

Ott, A.G. and W.A. Morris. 2007. Aquatic biomonitoring in Bons Pond, and Bons and Buddy Creeks, 2004 to 2006, at Red Dog Mine. Technical Report No. 07-04. AK Dept. of Natural Resources, Office of Habitat Management and Permitting. Juneau, AK. 92 pp.

Ott, A.G. and A.H. Townsend. 2007. Red Dog trip report, August 8 to 15, 2007. AK Dept. of Natural Resources, Office of Habitat Management and Permitting. Juneau, AK. 4 pp.

Ott, A.G. and J.L. Timothy. 2006. Red Dog trip report, August 9 to 16, 2006. AK Dept. of Natural Resources, Office of Habitat Management and Permitting. Juneau, AK. 3 pp.

Ott, A.G. and W.A. Morris. 2004. Juvenile Dolly Varden whole body metals analyses, Red Dog Mine (2002). Technical Report No. 04-01. AK Dept. of Natural Resources, Office of Habitat Management and Permitting. Juneau, AK. 71 pp.

Ott, A.G. and P.W. Scannell. 2003. Aquatic biomonitoring at Red Dog Mine, 2002. Technical Report No. 03-03. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 116 pp.

Ott, A.G. and A.H. Townsend. 2003. A transplant of Arctic grayling to Bons Pond at the Red Dog Mine. AK Department of Natural Resources, Office of Habitat Management and Permitting. Juneau, AK. 36 pp.

Ott, A.G. and A.H. Townsend. 2002. Red Dog trip report (July 27 to August 7, 2002). AK Department of Fish and Game, Div. Habitat and Restoration, Fairbanks, AK. 7 pp.

Ott, A.G., P.K. Weber Scannell, and M.H. Robus. 1992. Fish monitoring study, Red Dog Mine in the Wulik River drainage, emphasis on Dolly Varden (*Salvelinus malma*). Technical Report No. 91-4. AK Dept. of Fish and Game, Habitat Division. Juneau, AK. 67 pp.

Ott, A.G. and W.A. Morris. 1999. Red Dog Mine Field Trip Report. August 7 - August 13, 1999. AK Department of Fish and Game, Div. Habitat and Restoration, Fairbanks, AK. 5 pp.

Ott, A.G. and S. Simpers. 1997. Red Dog Mine Field Trip Report. August 9 - August 15, 1997. AK Department of Fish and Game, Div. Habitat and Restoration, Fairbanks, AK. 9 pp.

Seber, G.A.F. 1982. The estimation of abundance. Charles Griffin & Company LTD.

Thompson, M. 2005. Electronic mail report to A.G. Ott on August 29, 2005. Teck-Cominco Alaska Inc. Red Dog Mine.

Literature Cited (concluded)

Townsend, A.H. and L. Conley. 2004. Red Dog field trip report, August 18 to 28, 2004. AK Dept. of Natural Resources, Office of Habitat Management and Permitting. Fairbanks, AK. 2 pp.

Townsend, A.H. and L. Ingalls. 2003. Red Dog Field Trip Report. August 6 to 13, 2003. Alaska Department of Natural Resources, Office of Habitat Management and Permitting, Fairbanks, AK. 3 pp.

Townsend, A.H. and C. Hemming. 1996. Red Dog Field Trip Report. August 9 - August 15, 1996. Alaska Department of Fish and Game, Habitat and Restoration Division, Fairbanks, AK.

Townsend, A.H. and C. Lunderstadt. 1995. Trip report, August 11 to 16, 1995. AK Dept. of Fish and Game, Habitat and Restoration Division. Fairbanks, AK. 7 pp.

Ward, D.L. and T.J. Olson. 1980. Baseline aquatic investigations of fishes and heavy metal concentrations in the Kivalina and Wulik Rivers, 1978-79. LGL Ecological Research Associates, Inc. Prepared for GCO Minerals Company. 89 pp.

Weber Scannell P., A.G. Ott, and W.A. Morris. 2000. Fish and aquatic taxa report at Red Dog Mine, 1998-1999. Technical Report No. 00-03. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 136 pp.

Weber Scannell P. and A.G. Ott. 1998. Fisheries resources and water quality, Red Dog Mine. Technical Report No. 98-02. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 136 pp.

Appendix 1. Summary of Mine Development and Operations

1982

- ●Baseline studies initiated, Cominco agreement with NANA finalized

1983

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

1984

- ●Stream surveys conducted along proposed road by private consultant

1985

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

1986

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

1987

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

1988

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

Appendix 1 (continued)

1989

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

1990

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

1991

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

Appendix 1 (continued)

1992

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

1993

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

1994

- ●Fish study continued
- ●Use attainability studies of several streams initiated for reclassification
- ●Water treatment capacity increased by thickening tank conversion
- ●Wastewater discharge increased from 7.5 cfs to 23 cfs
- ●Ore processing capability expanded by Cominco
- ●107 juvenile and adult Arctic grayling transplanted from North Fork Red Dog Creek to Bons Pond in late June
- ●79 juvenile Dolly Varden transplanted from Anxiety Ridge Creek to Bons Pond in late June

1995

- ●Fish study expanded to include other aquatic biota
- ●Work on stream reclassification and site-specific criteria continued by ADF&G
- ●Metals concentrations in the clean water bypass system increased; contributing sources were identified: Hilltop Creek (Zn), Shelly Creek (Cd), and Rachel Creek (Al)
- ●Clean water bypass system extended to collect water from Hilltop Creek
- ●Reserves were doubled after exploration drilling located more ore
- ●Possible metals contamination in Bons Creek identified by ADF&G
- ●About 200 Arctic grayling fry (40 to 45 mm) were moved from North Fork Red Dog Creek to Bons Pond in August

1996

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

Appendix 1 (continued)

1997

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

1998

●Wet fertilization studies to test effects of TDS on fish embryos continued
●Draft 401 certification for a new NPDES permit prepared by ADEC and reviewed by ADF&G
●Discussed extension of the clean water bypass system up Shelly and Connie Creeks to ensure bypass of clean water and collection of seepage water from newly disturbed areas
●Heavy red staining in headwaters of Ikalukrok Creek, originating from seep in headwaters of Ikalukrok Creek, upstream of mining activity, staining extends downstream about 30 km
●Site-specific criteria for Zn in Mainstem Red Dog and Ikalukrok Creeks approved by EPA
●Heavy rains cause an unanticipated release of water into Bons Creek from the Kivalina stockpile
●Plans to increase port site capacity for direct loading of ships released to public
●NPDES permit (AK-003865-2) issued by US EPA became effective August 28, 1998 and was certified by ADEC (Certificate of Reasonable Assurance)
●Two-year aquatic community study completed
●Biomonitoring, including studies of fish and aquatic biota, required under 1998 NPDES permit

Appendix 1 (continued)

1999

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

2000

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

Appendix 1 (continued)

2001

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

Appendix 1 (continued)

2002

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

Appendix 1 (continued)

2003

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

Appendix 1 (continued)

2004

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

2005

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

Appendix 1 (continued)

2005

- ●Red Dog Creek diversion (clean water ditch) mine engineering drawings (r4) were provided by TCAK showing the culverts and lined ditch that carry water from tributaries and Middle Fork Red Dog Creek through the pit area
- ●Recommendations for changes to the Red Dog biomonitoring program based on field data collection and analyses since 1999 were made for possible incorporation into the renewed NPDES permit or ADEC's solid waste permit for the tailing impoundment
- ●TCAK distributed the 2005 draft report on Arctic grayling fertilization studies that concluded TDS concentrations at or below 1,500 mg/L at Station 10 in Mainstem Red Dog Creek would provide for proper protection of Arctic grayling in the Red Dog Creek drainage, OHMP supported these findings in a letter to Pete McGee (ADEC) dated August 17, 2005
- ●Dr. Weber Scannell prepared comments on fish tissue data (Dolly Varden from Wulik and Kivalina rivers) collected by Maniilaq Association and compared these data with existing information from other sources in both Alaska and nationwide
- ●OHMP prepared a summary report (letter to Jim Kulas dated August 23, 2005) on temperature/spawning data collected for Arctic grayling in Mainstem Red Dog and North Fork Red Dog creeks from 2001 through 2005, a recommendation for determining start and completion of spawning based on temperature was developed for Mainstem Red Dog Creek
- ●State and TCAK continued to work on key issues associated with the solid waste permit and closure plan for the mine ADEC
- ●Wastewater Treatment Plant (WTP) #3 began operations in late summer 2005 to treat mine sump water and drainage from waste rock dumps prior to placement of these waters into the tailing impoundment; purpose is to improve water quality in tailing impoundment over time
- ●Exploratory drilling and flow testing for gas in North Fork Red Dog Creek basin was conducted, access road and pads inspected, corrugated pipes installed to provide cross drainage, no evidence of erosion noted along road to and connecting the drill pads
- ●A road was constructed to Station 151 (end of mixing zone in Mainstem Red Dog Creek
- ●Work to expand and relocate the water treatment plant sand filters was initiated
- ●Bons Pond (the site of a fish transplant made in 1994 and 1995), estimated Arctic grayling population for summer 2003 was 6,773 - for summer 2004 was 5,739 – and for summer 2005 was 5,356

Appendix 1 (continued)

2006

●ADEC amended the site-specific criteria (SSC) for TDS in Mainstem Red Dog Creek, the 500 mg/L limit during Arctic grayling spawning was removed and replaced with a 1,500 mg/L limit on February 15, 2006, and EPA approved the new SSC in April 2006

●North Fork Red Dog Creek, extensive areas of aufeis existed, turbidity and organic debris high due to erosion and thermal degradation, in several reaches flow was not in stream channel due to aufeis

●Arctic grayling spawning/water temperature data collected, early spring warming followed by cold weather, adult Arctic grayling entered North Fork Red Dog Creek in late May and due to cold water temperatures abandoned spawning and outmigrated from the creek in mid-June

●Four Arctic grayling captured in North Fork Red Dog Creek in spring 2006 were fish that had been marked in Bons Pond

●Review of ADEC's draft 401 certification to the renewal of the NPDES was completed and we provided a letter of support (March 10, 2006) to ADEC, including our concurrence with ADEC's decision to not require Whole Effluent Toxicity (WET) limits

●Effects to Ikalukrok Creek from Cub Creek seep continued, but were minor

●Major precipitate observed on streambed in Middle Fork Red Dog Creek below effluent outfall in August, precipitates (orange colored) evident for at least 1 km downstream of effluent outfall and precipitates continued upstream through the clean water bypass to Connie and Rachel creeks

●Fish weir operating as designed

●Work continued on the design for the Red Dog tailing backdam, the dam will be located on the south side of the tailing pond and will be constructed of earth fill with a concrete/soil aggregate/bentonite cutoff wall, the dam will be constructed to a final height of 986 ft., construction anticipated during 2006 and 2007

●In July, windrows of dead capelin were documented at the Port Site, die off after spawning is normal, only a small percentage survive spawning

●Total count of chum salmon in Ikalukrok Creek on August 16 was 4,185, the highest number reported since 1990

●In 2006, slightly elevated Zn concentrations persisted and TCAK initiated a field investigation comprised of sampling along the clean water bypass, although not definitive, results indicated that the Mine Sump might have been the source of increased Zn concentrations, modifications were made in operational procedures to ensure containment of contaminated waters in the Mine Sump

●Bons Pond (the site of a fish transplant made in 1994 and 1995), estimated Arctic grayling population for summer 2006 was 4,249

Appendix 1 (continued)

2007

- ●ADEC issued the Certificate of Reasonable Assurance for NPDES Permit AK-003865-2 on February 12, 2007. EPA issued the proposed NPDES permit for the Red Dog Mine discharge on March 7, 2007. Both actions were appealed and on September 28, 2007, EPA signed the NPDES Permit withdrawal. EPA intends to reissue the NPDES Permit upon completion of the Supplemental EIS for Aqqaluk Extension. In the interim, TCAK will operate under the 1998 NPDES Permit
- ●OHMP completed Technical Report No. 07-04 which summarized aquatic biomonitoring in Bons and Buddy creeks from 2004 to 2006. OHMP recommended that aquatic biomonitoring at four sites in Bons and Buddy Creeks and field work to estimate the Arctic grayling population in Bons Pond continue
- ●On May 17, 2007, ADNR issued the Certificate of Approval to Construct a Dam Red Dog Back Dam (AK00303)
- ●On May 24, we notified EPA that open flow existed in North Fork and Mainstem Red Dog creeks. TCAK received written permission from EPA to begin discharge from Outfall 001 and discharge was initiated on May 25
- ●Two fyke nets were fished in North Fork Red Dog Creek in spring 2007 to determine when Arctic grayling spawning was finished. Based on net catches, observed spawning activity in Mainstem Red Dog Creek, outmigration of mature fish from Mainstem Red Dog Creek as observed on June 3, and the lack of any spawning activity in Mainstem Red Dog Creek on June 3, OHMP determined that spawning was completed on June 2
- ●On June 6, EPA notified TCAK that the TDS load in Mainstem Red Dog Creek could be increased to 1,500 mg/L due to the fact that Arctic grayling spawning was complete
- ●Seven Arctic grayling captured in North Fork Red Dog Creek in spring 2007 were fish that had been marked in Bons Pond. Recruitment of Arctic grayling to North Fork Red Dog Creek from the Bons Pond population is occurring
- ●Fish weir, on Middle Fork Red Dog Creek, is operating as designed
- ●Arctic grayling spawning success, as determined by presence of fry, was very good in 2007 due to early spawning, low water following spawning for most of the summer, and warm water temperatures. Numerous fry were seen in North Fork Red Dog, Mainstem Red Dog, Ikalukrok, and Bons creeks. Arctic grayling fry in mid-August average 64 mm long (n = 26, 58 to 71 mm, SD = 3.1)
- ●Middle Fork Red Dog Creek contained an orange, tan colored precipitate that extended both above and below the waste water discharge point and was visible downstream to the fish weir

Appendix 1 (continued)

2007

●Our two estimates for adult chum salmon in Ikalukrok Creek (downstream of Station 160) were 1,408 and 1,998 along with about 100 adult Dolly Varden and 8 Chinook salmon
●Work on a Supplemental EIS for the Aqqaluk Extension project began with a draft scoping document in August, public meetings in early October, and draft alternatives scoping in December
●TCAK continued to make improvements to the mine's clean water bypass system. In October, galvanized culvert was installed replacing sections of HDPE lined ditch in Middle Fork Red Dog Creek upstream of Shelly Creek and continued upstream to the Rachel Creek confluence. In addition, the section of HDPE lined ditch in Connie Creek was converted to culvert as well

2008

●Work on the SEIS for the Aqqaluk Extension continued during 2008. Input via the State's LMPT coordinator was made periodically with emphasis on the alternatives being considered, the aquatic biology background section, and the monitoring plan for both the Red Dog and Bons/Buddy Creek drainages
●On May 5, 2008, we distributed copies of our technical report titled "Aquatic biomonitoring at Red Dog Mine, 2007 National Pollution Discharge Elimination System Permit No. AK-003865-2" covering work done in summer 2007
●On May 13, 2008, we notified ADEC that based on information provided by TCAK that open water flow existed in North Fork Red Dog, Mainstem Red Dog, and Ikalukrok creeks and that wastewater discharge could commence under the conditions of state and federal permits
●On May 28, 2008, TCAK reported to EPA that TDS on May 16 exceeded the permit limits in effect at the time of the discharge
●In spring 2008, Kivalina residents and NANA collected a number of adult Dolly Varden in the Wulik River and planned to have the fish analyzed for metals by Columbia Analytical Lab. Input regarding sampling protocol for adult Dolly Varden was provided to TCAK and NANA on June 6
●June 24, 2008, we reported to TCAK the successful completion of spring work on Arctic grayling in North Fork Red Dog and Mainstem Red Dog creeks and Bons Creek/Bons Pond. In spring 2008, we had at least three age classes of immature fish present in our North Fork Red Dog Creek sample and 18% of these recaptures were fish originally marked in Bons Pond. Our estimated population of Arctic grayling in Bons Pond for summer 2007 was 4,363 fish ≥ 200 mm

Appendix 1 (continued)

2008

●On July 9, 2008, we participated in a teleconference with TCAK and Tetra Tech (contractor for the Aqqaluk SEIS) to discuss the potential impacts to Mainstem Red Dog Creek if the wastewater discharge was moved to the ocean. A short narrative describing possible changes to Mainstem Red Dog Creek was prepared and distributed
●On July 16, 2008, ADF&G sent a letter to TCAK that summarized results of our early July field work when we sampled periphyton, aquatic invertebrates, and fish at the NPDES and ADEC sample sites
●In early August, 2008, ADF&G Commissioner Denby Lloyd spent several days at Red Dog that included a briefing, tour of mine facilities, and an overflight of the project area including Ikalukrok Creek, Wulik River, Port Site, and the haul road from the port to the mine
●On August 13, 2008, ADF&G sent to TCAK a summary of fish work done in early August. Using a helicopter, we estimated 3,820 chum salmon in Ikalukrok Creek on August 6 – one of our highest counts since surveys began in 1990
●On August 21, 2008, ADF&G sent to TCAK a summary of Arctic grayling spawning in Mainstem Red Dog and North Fork Red Dog creeks that covered from 2001 to 2008. The report includes a temperature-based criterion for determining when the majority of Arctic grayling spawning in Mainstem Red Dog Creek is substantially complete
●On September 3, 2008, a settlement was reached between all five plaintiffs residents of Kivalina and TECK on a lawsuit that alleged violations of the mine's NPDES permit. On October 23, 2008, a Consent Decree was entered with the Department of Justice as required under a CWA lawsuit. Principle to the agreement was a commitment (barring certain requirements) by TECK to design, permit and construct a pipeline to carry treated mine effluent to the ocean
●TCAK prepared and submitted on August 26, 2008, a draft Fugitive Dust Risk Management Plan
●On October 3, 2008, ADF&G sent by letter to TCAK results of the fall Dolly Varden overwintering survey in the Wulik River. Overall the count of Dolly Varden was lower than in the recent past; however, it was noted that very few small fish (first year migrants) were present. More chum salmon (16,215) were seen from Sivu to Driver's Camp – more chum salmon than have been seen before
●TCAK prepared and submitted a draft monitoring plan for state agency review in early November 2008. The objective is to develop one comprehensive monitoring plan for all state and federal permits pertaining to the mine site as defined by the ambient air boundary. In November and December, we provided input to the States LMPT on the monitoring plan which when completed will be incorporated by reference into the 401 Certification and the ADEC Waste Management Permit

Appendix 1 (continued)

2008

●Adult Dolly Varden and juvenile Dolly Varden for selected metals analyses were prepared and sent to Columbia Analytical Laboratory in mid-November
●November 24, 2008, the SEIS for Red Dog Aqqaluk Extension was released by EPA for public review
●On December 22, 2008, we received a CD for the Red Dog Mine Closure and Reclamation Plan – the final draft for agency review. The closure and reclamation plan are the result of over six years of work by TCAK in consultation with state and federal agencies and the public

2009

●Continued to review and provide comments on the SEIS for the Red Dog Aqqaluk Extension project with emphasis on the monitoring plan prepared by Teck that covers both the Bons/Buddy Creek and Red Dog Creek drainages
●During 2009, Teck continued construction of the back dam/cutoff wall and the next raise of the main dam
●On February 10, 2009, the National Park Service issued a news release that they had released a report titled "Assessment of Metals Exposure and Sub-Lethal Effects in Voles and Small Birds Captured Near the Delong Mountain Regional Transportation System Road, Cape Krusenstern National Monument, Alaska, 2006"
●On February 12, 2009, we received notification that the legal company name for Red Dog was now changed to Teck Alaska Incorporated and in simple form will be known as Teck
●On May 1, 2009, ADF&G distributed copies of the report titled "Aquatic Biomonitoring at Red Dog Mine, 2008 National Pollution Discharge Elimination System Permit No. AK-003865-2"
●On May 5, 2009, ADF&G by email stated that we have no objection to Teck beginning the discharge of treated water to Middle Fork Red Dog Creek
●On May 6, 2009, ADF&G provided written input to ADEC on Teck's Monitoring Plan
●Several field inspections of the fish weir on Middle Fork Red Dog Creek were made by ADF&G - the weir was operating in compliance with the Fish Habitat Permit
●In early June, ADF&G monitored the Arctic grayling spawning run in Mainstem Red Dog and North Fork Red Dog creeks. Six adult Dolly Varden were collected in the Wulik River near Tutak Creek by Teck
●In early July we successfully completed collection of periphyton, aquatic invertebrates and fish at all NPDES required sample sites as well as 4 sites located in the Bons/Buddy Creek drainages

Appendix 1 (continued)

2009

- ●Due to extremely low flows, Teck ceased the discharge at Outfall 001 from July 22 around 0600 hr to August 2 around 1400 hr. In our sample reach at Station 151 in Mainstem Red Dog Creek, we observed hundreds of Arctic grayling fry and caught 7 juvenile Dolly Varden in minnow traps. At Station 10 in Mainstem Red Dog Creek we observed several Arctic grayling fry and two adults and caught 6 juvenile Dolly Varden and 5 slimy sculpin. The Arctic grayling fry observed were actively feeding and showed no sign of stress. These results were obtained from July 29 to 31, 2009, and represent conditions in the creek without water from the wastewater discharge
- ●On August 19, 2009, we reported to Teck the successful completion of spring work on Arctic grayling in North Fork Red Dog and Mainstem Red Dog creeks and Bons Creek/Bons Pond. In spring 2009, we again saw strong recruitment of Arctic grayling to North Fork Red Dog Creek and 13% of these recaptures were fish originally marked in Bons Pond. Our estimated population of Arctic grayling in Bons Pond for summer 2008 was 2,216 ≥200 mm – a fairly substantial decrease from the summer 2007 estimate of 4,363
- ●Provided to Teck via email on September 3 the protocols that should be used to handle a fish for pathological work
- ●On September 25, 2009, Mr. Fred DeCicco (Fisheries Services and Supplies) and Mr. Brendon Scanlon (ADF&G) conducted aerial surveys for Dolly Varden in the Wulik River and chum salmon in Ikalukrok Creek
- ●On November 24, 2009, ADF&G transmitted to Teck by letter a summary of Arctic grayling spawning in Mainstem Red Dog and North Fork Red Dog creeks (2001 through 2009)
- ●On December 2, 2009, ADNR issued the Reclamation Plan Approval for the Red Dog Mine and ADEC issued Waste Management Permit No. 0132-BA002 for the Red Dog Mine. Both actions are subject to appeal by third parties
- ●On December 15, 2009, the ADEC issued the Certificate of Reasonable Assurance for the NPDES Permit AK-003865-2 to regulate the discharge of treated wastewater and stormwater from Red Dog Mine

2010

- ●On January 8, 2010, the EPA issued NPDES Permit No. AK-003865-2. The permit shall become effective on March 1, 2010
- ●On January 14, 2010, two nonprofit law firms, representing local tribes and environmental groups, filed an appeal of the state's 401 certification, asserting that certain provisions do not comply with the Clean Water Act

Appendix 1 (continued)

2010

●On February 15, 2010, the same two nonprofit law firms filed a petition for review of the EPA permit with the Environmental Appeals Board. In a letter dated February 26, 2010, EPA stayed several contested conditions of NPDES Permit No. AK-003865-2
●On March 11, 2010, the US Department of the Army issued permit POA-1984-12-M45 to Teck which would authorize development of the Aqqaluk Pit at the Red Dog Mine
●On March 17, 2010, EPA Region 10 withdrew conditions from the 2010 NPDES Permit No. AK-003865-2, including: Part IA.1, Table 1 effluent limits for lead (monthly average limit), selenium (daily maximum limit), zinc, and weak acid dissociable (WAD) cyanide, and; Part IA.7.a – effluent limitations for Total Dissolved Solids (TDS). Those permit conditions not withdrawn, which include the entire permit except the conditions identified above, became fully effective and enforceable on March 31, 2010. As a result of this withdrawal, the following conditions in the 1998 NPDES Permit No. AK003865-2 remain in effect until further agency action: Part IA.1 – effluent limitations for lead (monthly average limit), selenium (daily maximum limit), zinc, TDS, and total cyanide
●On May 20, 2010, Teck announced plans to proceed with development of Aqqaluk
●In early June, ADF&G monitored the Arctic grayling spring spawning migration in the Red Dog Creek drainage and in Bons Pond – strong recruitment of immature Arctic grayling was seen in North Fork Red Dog Creek
●On June 14, 2010, ADNR responded to a Legislative Research Services request for information on what happened at Red Dog during the past – ADF&G provided input on the request including a copy of Appendix 1 (chronology of events)
●In early July, we collected periphyton and aquatic invertebrate samples at all sites, except Bons Creek where there was no surface flow present
●On July 12, 2010, ADF&G sent a letter to Teck that included a document titled "Comparison of adult Dolly Varden (*Salvelinus malma*) tissue metals concentrations from fish caught in 2008 in the Wulik River Kivalina, Alaska." The document compares metals concentrations between fish collected by Kivalina and those collected by ADF&G
●We estimated the Arctic grayling population (fish $\geq$200 mm) in North Fork Red Dog Creek in spring 2009 at 1,368 fish (SD = 418) based on the 2010 recapture event
●We estimated the Arctic grayling population (fish $\geq$200 mm) in Bons Pond in spring 2009 at 2,180 (SD = 539) based on the 2010 recapture event
●On September 24, 2010, Mr. Fred DeCicco (Fisheries Services and Supplies) and Mr. Brendon Scanlon (ADF&G) conducted aerial surveys for Dolly Varden in the Wulik River and chum salmon in Ikalukrok Creek – they also estimated 548 adult Dolly Varden in Ikalukrok Creek

Appendix 1 (continued)

2010

●An Arctic grayling tagged in North Fork Red Dog Creek was recaptured by an sport fisherman in the Wulik River due west of the mine and near the Lik Deposit on August 15, 2010

●Seasonal discharge from Outfall 001 was initiated on May 6 and terminated on September 22, 2010

2011

●Technical Report No. 11-01 titled "Aquatic biomonitoring at Red Dog Mine, 2010 National Pollution Discharge Elimination System Permit (NPDES) No. AK-003865-2" was submitted to EPA and ADEC on February 2, 2011

●In mid-February, Teck approved funding to support a radio telemetry project on Arctic grayling in North Fork Red Dog Creek

●On March 11, 2011, ADNR approved modifications (fertilizer rates and composition, use of wild native seeds) to the Reclamation Plan

●On March 30, 2011, ADNR approved modifications to the waste rock segregation criteria as submitted by Teck

●Reports were received from hunters in April of a foul odor up the Wulik River and Teck responded by sending out an inspection crew – they went to Jakes seep along Ikalukrok Creek – the seep was active with a fair amount of gas being released and the odor was very noticeable downwind

●On May 8, 2011, Teck notified EPA (by letter) of plans to utilize Waste Treatment Plant (WTP1) in parallel with WTP2 in order to facilitate more efficient treatment of tailings impoundment (reclaim) water

●On May 15, 2011, Teck notified EPA (by letter) that the discharge through Outfall 001 was initiated at about 0830 – seasonal discharge was terminated on September 24, 2011

●On June 6, 2011, Teck sent a letter to ADF&G summarizing work conducted to clear bridges and culverts of snow and ice along the Port Road prior

●On June 13, 2011, Teck notified EPA by letter of an exceedance in TDS collected at Outfall 001 on May 17 – Teck also indicated that they continue to be in compliance with TDS at Station 151

●In early June, ADF&G monitored the Arctic grayling spring spawning migration in the Red Dog Creek drainage and in Bons Pond – strong recruitment of immature Arctic grayling was seen in North Fork Red Dog Creek

●On June 2, 7 adult Dolly Varden were captured and retained for metals analyses of selected tissues

●15 mature Arctic grayling were surgically implanted with radio transmitters between June 5 and 11 – all fish were caught and tagged in North Fork Red Dog Creek

Appendix 1 (continued)

2011

●Arctic grayling with radio transmitters were radio-located in July, September, October and November – initially they distributed throughout the Ikalukrok Creek drainage but by fall most were in lower Ikalukrok Creek in a reach used by chum salmon for spawning – on the last survey in early November most of the fish were in the Wulik River between the mouth of Ikalukrok Creek to a location several km downstream of the mouth of Tutak Creek

●In mid-July, periphyton and aquatic invertebrate samples were collected at all the NPDES and ADEC sites

●In late August, 2011, juvenile Dolly Varden sampling was conducted and 42 fish were retained for whole body metals analyses

●On September 27, 7 adult Dolly Varden were captured and retained for metals analyses of selected tissues and an aerial survey of chum salmon spawners in Ikalukrok Creek was conducted on September 25 – 1,507 chum salmon (live and dead) were counted

●Two aerial surveys of Dolly Varden in the Wulik River were flown (September 26 and October 6). The first survey found 16,916 Dolly Varden, but on October 6 DeCicco estimated 64,499 Dolly Varden – a substantial increase from the earlier survey

●seasonal discharge from Outfall 001 was terminated on September 24, 2011

●on November 5, an aerial tracking survey to relocate 14 radio tagged Arctic grayling was conducted finding 9 in the Wulik River, 2 in lower Ikalukrok Creek, 2 in North Fork Red Dog Creek, and 1 in Grayling Junior Creek – the fish in North Fork Red Dog and Grayling Junior creeks had not moved and are presumed to be dead

2012

●Technical Report No. 12-02 titled "Aquatic biomonitoring at Red Dog Mine, 2010 National Pollution Discharge Elimination System Permit (NPDES) No. AK-003865-2" was submitted to EPA and ADEC on March 1, 2012

●Discharge through Outfall 01 to Red Dog Creek began on May 8 and was postponed on June 8 with treated discharge water then routed to either the main pit or back to the tailings impoundment for the remainder of the 2012. Discharge to Red Dog Creek was postponed to facilitate repairs to the water treatment plant and was not resumed due to elevated Se concentrations

●In early June, ADF&G monitored the Arctic grayling spring spawning migration in the Red Dog Creek drainage and in Bons Pond – strong recruitment of immature Arctic grayling was seen in North Fork Red Dog Creek in 2012 (recruitment has been strong the last 6 years)

Appendix 1 (concluded)

2012

●In early June, radio tagged Arctic grayling were radio-located. Analysis of relocation sites for each fish indicated a 64% mortality rate from 2011 to spring 2012

●On June 3 and 4, adult Dolly Varden were captured and retained for metals analyses of selected tissues – these fish were caught by angling in the Wulik River near Station 2

●In early June, Arctic grayling were captured in Bons Creek and Bons Pond. Growth rates for summer 2011 increased compared with previous years and fish appeared to be more robust and in better condition

●In June, Teck made required notifications to EPA and the State that TDS at Outfall 001 exceeded the end-of-pipe limitation, but TDS did not exceed the applicable state water quality standard at Station 151 in Mainstem Red Dog Creek

●In June, Teck made required notifications to EPA and the State that Se analytical results for Outfall 001 potentially exceeded the limitation set in the 1998 NPDES permit. Currently, Teck is not discharging to Red Dog Creek.

●In early July, periphyton and aquatic invertebrate samples were collected in accordance with permit requirements

●In August, Teck made required notifications to EPA and the State that the diversion structure along the western perimeter of the Aqqaluk Pit had over-topped as a result of a major precipitation event (over three inches of precipitation during a 24-hr period). A temporary repair of the diversion structure was made immediately

●Our mid-August field trip (August 11 to 19) to Red Dog to sample juvenile Dolly Varden was made, but due to extremely high rainfall actual sampling could not be done

●Three aerial surveys of Dolly Varden in the Wulik River were flown (September 27 and 29 and October 10). The second survey (best conditions) found 21,084 Dolly Varden in the Wulik River

Appendix 2. Periphyton Standing Crop

2012 Chloro Results - Red Dog		IDL = 0.10 mg/m^2	Linear Check Maximum = 73.2mg/m^2								
		EDL = 0.10 mg/m^2						**Phaeo Corrected**			
Daily Vial #	Site/Volume (liters)	Station /Site	Date Collected	Date Analyzed	Vial Chl a	**Chl a mg/m2**	**Below Instrument Detection Limit (0.16 mg/m^2) OR Above Linear Check (73.2 mg/m^2)**	**Chl a mg/m2**	**664/665 Ratio**	Chl b mg/m2	Chl c mg/m2
1	Blank			01/08/13	0.00	0.00	**Below Detection Limit**	**0.00**	0.00	0.00	0.00
2	Buddy us Road	221	July 2012	01/08/13	0.62	2.50		**2.24**	1.62	0.12	0.19
3	Buddy us Road	221	July 2012	01/08/13	1.03	4.12		**3.63**	1.59	1.01	0.00
4	Buddy us Road	221	July 2012	01/08/13	0.35	1.41		**1.39**	1.72	0.11	0.00
5	Buddy us Road	221	July 2012	01/08/13	0.22	0.86		**0.85**	1.73	0.05	0.08
6	Buddy us Road	221	July 2012	01/08/13	0.56	2.26		**2.14**	1.67	0.33	0.00
7	Buddy us Road	221	July 2012	01/08/13	0.32	1.27		**1.17**	1.65	0.10	0.03
8	Buddy us Road	221	July 2012	01/08/13	0.73	2.91		**2.67**	1.64	0.15	0.24
9	Buddy us Road	221	July 2012	01/08/13	0.44	1.77		**1.71**	1.70	0.09	0.06
10	Buddy us Road	221	July 2012	01/08/13	1.19	4.76		**4.49**	1.65	1.55	0.05
11	Buddy us Road	221	July 2012	01/08/13	0.40	1.59		**1.50**	1.67	0.09	0.12
12	North Fork Red Dog	12	July 2012	01/08/13	1.76	7.02		**6.30**	1.61	1.21	0.50
13	North Fork Red Dog	12	July 2012	01/08/13	0.69	2.76		**2.35**	1.56	0.23	0.16
14	North Fork Red Dog	12	July 2012	01/08/13	1.22	4.89		**4.49**	1.63	1.09	0.19
15	North Fork Red Dog	12	July 2012	01/08/13	1.05	4.20		**3.52**	1.55	0.55	0.24
16	North Fork Red Dog	12	July 2012	01/08/13	0.42	1.68		**0.80**	1.68	0.06	0.01
17	North Fork Red Dog	12	July 2012	01/08/13	1.29	5.14		**4.59**	1.61	0.71	0.44
18	North Fork Red Dog	12	July 2012	01/08/13	1.16	4.66		**2.14**	1.63	0.48	0.31
19	North Fork Red Dog	12	July 2012	01/08/13	0.59	2.34		**2.14**	1.63	0.35	0.15
20	North Fork Red Dog	12	July 2012	01/08/13	0.70	2.81		**2.46**	1.59	0.28	0.22
21	North Fork Red Dog	12	July 2012	01/08/13	0.52	2.08		**1.71**	1.53	0.25	0.09
22	Ik us Red Dog	9	July 2012	01/08/13	0.41	1.63		**1.50**	1.64	0.15	0.08
23	Ik us Red Dog	9	July 2012	01/08/13	0.34	1.36		**1.28**	1.67	0.13	0.08
24	Ik us Red Dog	9	July 2012	01/08/13	0.29	1.14		**1.07**	1.67	0.00	0.01
25	Ik us Red Dog	9	July 2012	01/08/13	0.40	1.59		**1.39**	1.59	0.09	0.12
26	Ik us Red Dog	9	July 2012	01/08/13	0.42	1.69		**1.71**	1.76	0.00	0.14
27	Ik us Red Dog	9	July 2012	01/08/13	0.21	0.82		**0.75**	1.64	0.00	0.12
28	Ik us Red Dog	9	July 2012	01/08/13	0.28	1.13		**1.07**	1.67	0.08	0.08
29	Ik us Red Dog	9	July 2012	01/08/13	0.25	1.00		**0.96**	1.69	0.00	0.06
30	Ik us Red Dog	9	July 2012	01/08/13	0.74	2.94		**2.67**	1.63	0.30	0.17
31	Ik us Red Dog	9	July 2012	01/08/13	0.64	2.55		**2.24**	1.60	0.10	0.19
32	Blank			01/08/13	0.00	0.00	**Below Detection Limit**	**0.00**	#DIV/0!	0.08	0.00
2 Double	Buddy us Road DBL	221	July 2012	01/08/13	0.63	2.54		**2.46**	1.70	0.17	0.26
1	Blank			01/09/13	0.00	0.00	**Below Detection Limit**	**0.11**	0.00	0.00	0.00
2	Buddy blw falls		July 2012	01/09/13	1.74	6.94		**5.77**	1.53	1.67	0.26
3	Buddy blw falls		July 2012	01/09/13	1.64	6.57		**6.19**	1.67	0.58	0.42
4	Buddy blw falls		July 2012	01/09/13	1.76	7.04		**6.62**	1.67	0.35	0.45
5	Buddy blw falls		July 2012	01/09/13	2.95	11.79		**10.47**	1.60	1.53	**0.46**
6	Buddy blw falls		July 2012	01/09/13	3.52	14.07		**12.60**	1.61	0.87	**0.83**
7	Buddy blw falls		July 2012	01/09/13	4.56	18.24		**17.52**	1.69	1.78	1.51
8	Buddy blw falls		July 2012	01/09/13	3.36	13.46		**12.39**	1.64	1.19	0.63
9	Buddy blw falls		July 2012	01/09/13	5.38	21.52		**17.30**	1.52	2.62	0.34
10	Buddy blw falls		July 2012	01/09/13	4.19	16.76		**14.63**	1.59	1.60	0.36
11	Buddy blw falls		July 2012	01/09/13	5.60	22.41		**20.93**	1.66	0.22	2.01
12	Ik ds Dudd	160	July 2012	01/09/13	1.84	7.36		**5.66**	1.48	1.00	0.29
13	Ik ds Dudd	160	July 2012	01/09/13	0.80	3.18		**2.88**	1.63	0.11	0.17
14	Ik ds Dudd	160	July 2012	01/09/13	1.37	5.50		**4.91**	1.61	0.90	0.00
15	Ik ds Dudd	160	July 2012	01/09/13	0.96	3.82		**3.42**	1.62	0.12	0.15
16	Ik ds Dudd	160	July 2012	01/09/13	0.73	2.92		**2.78**	1.68	0.01	0.10
17	Ik ds Dudd	160	July 2012	01/09/13	1.09	4.35		**3.95**	1.63	0.34	0.08
18	Ik ds Dudd	160	July 2012	01/09/13	2.79	11.15		**10.47**	1.66	1.54	0.28
19	Ik ds Dudd	160	July 2012	01/09/13	1.15	4.61		**4.27**	1.65	0.53	0.12
20	Ik ds Dudd	160	July 2012	01/09/13	0.78	3.14		**2.99**	1.68	0.14	0.08
21	Ik ds Dudd	160	July 2012	01/09/13	1.05	4.22		**3.84**	1.63	0.32	0.13

Appendix 2 (concluded)

22	Bons Cr us Bons Pond		July 2012	01/09/13	0.56	2.22		**2.03**	1.63	0.19	0.07
23	Bons Cr us Bons Pond		July 2012	01/09/13	0.19	0.77		**0.75**	1.70	0.02	0.03
24	Bons Cr us Bons Pond		July 2012	01/09/13	0.10	0.41		**0.32**	1.50	0.04	0.04
25	Bons Cr us Bons Pond		July 2012	01/09/13	0.15	0.59		**0.53**	1.63	0.02	0.09
26	Bons Cr us Bons Pond		July 2012	01/09/13	0.24	0.95		**0.96**	1.75	0.09	0.04
27	Bons Cr us Bons Pond		July 2012	01/09/13	0.39	1.54		**1.39**	1.62	0.12	0.03
28	Bons Cr us Bons Pond		July 2012	01/09/13	0.51	2.04		**1.92**	1.67	0.19	0.13
29	Bons Cr us Bons Pond		July 2012	01/09/13	0.33	1.32		**1.28**	1.71	0.06	0.12
30	Bons Cr us Bons Pond		July 2012	01/09/13	0.29	1.14		**1.07**	1.67	0.00	0.11
31	Bons Cr us Bons Pond		July 2012	01/09/13	0.52	2.10		**1.92**	1.64	0.01	0.08
32	Blank			01/09/13	0.00	0.00	**Below Detection Limit**	**0.00**	0.00	0.00	0.00
27 Double	Bons Cr us Bons Pond DBL		July 2012	01/09/13	0.41	1.62		**1.60**	1.71	0.23	0.15
11 Double	Buddy blw falls DBL		July 2012	01/09/13	5.47	21.86		**20.83**	1.68	0.24	2.08
1	Blank			01/10/13	0.01	0.04	**Below Detection Limit**	**0.11**	#DIV/0!	0.05	0.06
2	Mainstem Red Dog	10	July 2012	01/10/13	2.45	9.79		**8.44**	1.57	1.93	0.47
3	Mainstem Red Dog	10	July 2012	01/10/13	3.99	15.97		**13.99**	1.58	3.42	1.32
4	Mainstem Red Dog	10	July 2012	01/10/13	2.57	10.28		**8.76**	-0.06	2.06	0.64
5	Mainstem Red Dog	10	July 2012	01/10/13	2.12	8.50		**7.48**	1.59	1.59	0.64
6	Mainstem Red Dog	10	July 2012	01/10/13	3.32	13.27		**11.85**	1.60	2.98	0.65
7	Mainstem Red Dog	10	July 2012	01/10/13	2.66	10.63		**8.97**	1.55	2.24	1.12
8	Mainstem Red Dog	10	July 2012	01/10/13	1.10	4.41		**3.74**	1.55	1.33	0.82
9	Mainstem Red Dog	10	July 2012	01/10/13	1.96	7.85		**6.30**	1.51	1.11	0.75
10	Mainstem Red Dog	10	July 2012	01/10/13	0.99	3.96		**3.31**	1.54	0.75	0.24
11	Mainstem Red Dog	10	July 2012	01/10/13	2.30	9.22		**8.81**	1.58	1.75	0.35
12	Mid Fork Red Dog	26	July 2012	01/10/13	1.02	4.06		**3.74**	1.64	0.55	0.19
13	Mid Fork Red Dog	26	July 2012	01/10/13	0.27	1.08		**0.96**	1.60	0.18	0.06
14	Mid Fork Red Dog	26	July 2012	01/10/13	0.33	1.31		**1.28**	1.71	0.15	0.09
15	Mid Fork Red Dog	26	July 2012	01/10/13	0.18	0.73		**0.75**	1.78	0.04	0.04
16	Mid Fork Red Dog	26	July 2012	01/10/13	0.18	0.72		**0.75**	1.78	0.13	0.00
17	Mid Fork Red Dog	26	July 2012	01/10/13	0.50	1.99		**1.82**	1.63	0.21	0.13
18	Mid Fork Red Dog	26	July 2012	01/10/13	0.25	0.99		**0.85**	1.57	0.14	0.10
19	Mid Fork Red Dog	26	July 2012	01/10/13	0.42	1.67		**1.60**	1.68	0.22	0.04
20	Mid Fork Red Dog	26	July 2012	01/10/13	1.25	5.00		**4.81**	1.68	0.81	0.07
21	Mid Fork Red Dog	26	July 2012	01/10/13	0.42	1.67		**1.60**	1.68	0.20	0.14
22	Blank			01/10/13	0.00	0.00	**Below Detection Limit**	**0.00**	#DIV/0!	0.00	0.00
4 Double			July 2012	01/10/13	2.58	10.32		**8.76**	1.55	2.19	0.77

Appendix 3. Aquatic Invertebrate Drift Samples

Middle Fork Red Dog Creek, Station 20, Drift Samples Invertebrates														
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total aquatic taxa	15	15	19	15	28	23	20	16	26	25	15	15	25	16
												\		
Tot. Ephemeroptera	9	0	17	4	6	44	41	7	23	29	16	1	30	2
Tot. Plecoptera	3	5	43	20	34	38	28	9	11	13	4	0	20	5
Tot. Trichoptera	0	0	0	0	0	0	1	0	1	1	1	0	1	0
Total Aq. Diptera	104	40	153	121	449	28	92	6	80	72	45	103	197	18
Misc.Aq.sp	9	17	73	17	55	46	177	5	82	52	38	10	181	3
% Ephemeroptera	8%	0%	6%	2%	1%	28%	12%	26%	12%	17%	15%	1%	7%	7%
% Plecoptera	3%	7%	15%	13%	7%	24%	8%	35%	6%	8%	4%	0%	5%	17%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	1%
% Aq. Diptera	83%	64%	53%	75%	83%	18%	27%	22%	41%	43%	43%	90%	46%	64%
% other	7%	28%	26%	10%	10%	29%	52%	18%	42%	31%	37%	9%	42%	11%
% EPT	10%	8%	21%	15%	7%	52%	21%	60%	18%	25%	20%	1%	12%	25%
% Chironomidae	80%	36%	51%	73%	73%	16%	24%	15%	35%	39%	38%	86%	44%	51%
% Dominant Aquatic Taxon	46%	36%	31%	43%	48%	30%	42%	37%	22%	22%	37%	75%	28%	38%
Volume of water (m3)	378	551	933	310	702	880	302	296	384	249	285	78	733	72
average water/net	76	110	187	62	140	176	60	59	77	50	57	16	147	14
StDev of water volume	24	26	89	14	38	91	26	9	52	8	11	9	28	3
Estimated total inverts/m3 water	2.92	0.6	1.7	6.2	6.6	1.1	19.4	0.6	7.4	16.2	23.2	10.1	4.7	3.1
Estimated aquatic inverts/m3 water	1.7	0.6	1.5	2.6	3.9	0.9	5.6	0.4	2.6	3.4	1.8	7.3	2.9	2.0
average inv/m3	3.2	0.6	1.8	6.1	6.4	1.2	19.5	0.6	10.5	16.3	24.1	11.7	4.7	3.3
average aq. Invertebrates/m3 water	1.8	0.57	1.64	2.59	3.74	0.95	5.33	0.45	3.53	3.39	1.8	8.2	3	2.1
Stdev of aq. Inv. Den.	1.3	0.21	0.38	0.58	1.07	0.27	0.97	0.21	1.86	0.7	0.25	3.2	0.4	1.7
Total aquatic invertebrates	627	309	1431	810	2719	783	1694	133	980	835	523	573	2145	144
Total. terrestrial invertebrates	477	10	185	1115	1889	170	4158	59	1875	3210	6096	218	1290	82
Total invertebrates	1104	319	1616	1925	4608	953	5852	192	2855	4045	6619	791	3435	226
% Sample aquatic	57%	97%	89%	42%	59%	82%	29%	69%	34%	21%	8%	72%	62%	64%
% Sample terrestrial	43%	3%	11%	58%	41%	18%	71%	31%	66%	79%	92%	28%	38%	36%
Average # aquatic inverts / net	125	62	286	162	544	157	339	27	196	167	105	115	429	29
stdev aq inv/net	59	20	111	56	242	69	178	11	20	35	30	51	86	22
Average # terr. inverts / net	95	2	37	223	378	34	832	12	375	642	1219	44	258	16
Average # inverts / net	221	64	323	385	922	191	1170	38	571	809	1324	158	687	45
stdev inv/net	68	21	127	156	376	85	532	13	55	191	259	74	206	49
Total Larval Arctic Grayling/site	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

North Fork Red Dog Creek, Station 12, Drift Samples Invertebrates														
Date:	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total aquatic taxa	13	13	18	16	26	20	21	15	21	23	19	17	19	22
Tot. Ephemeroptera	67	14	20	170	194	38	198	882	163	57	66	26	79	33
Tot. Plecoptera	23	94	117	40	64	5	5	19	11	77	18	4	22	26
Tot. Trichoptera	4	6	6	0	4	0	0	0	1	4	1	3	11	1
Total Aq. Diptera	700	314	1134	116	716	27	333	755	641	1574	2113	1092	3245	203
Misc.Aq.sp	30	69	226	43	188	17	39	32	135	320	251	140	536	221
% Ephemeroptera	8%	3%	1%	46%	16%	44%	34%	52%	17%	3%	3%	2%	2%	7%
% Plecoptera	3%	19%	8%	11%	6%	5%	1%	1%	1%	4%	1%	0%	1%	5%
% Trichoptera	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	85%	63%	75%	31%	62%	31%	58%	45%	67%	77%	86%	86%	83%	42%
% other	4%	14%	15%	12%	16%	19%	7%	2%	14%	16%	10%	11%	14%	46%
% EPT	11%	23%	9%	57%	23%	50%	35%	53%	18%	7%	3%	3%	3%	12%
% Chironomidae	54%	36%	57%	22%	27%	25%	36%	14%	61%	32%	55%	33%	23%	17%
% Dominant Aquatic Taxon	45%	32%	43%	46%	35%	48%	34%	44%	36%	45%	43%	54%	61%	25%
Volume of water (m3)	559	221	747	226	672	672	380	368	297	329	681	187	1015	287
average water/net	112	44	149	45	134	134	76	74	59	66	136	37	203	57
StDev of water volume	80	12	54	23	37	64	54	10	24	20	45	22	49	22
Estimated total inverts/m3 water	9.2	11.8	10.2	13.5	9.3	0.9	12.4	23.6	18.3	33.2	28	37.4	20.2	9.8
Estimated aquatic inverts/m3 water	7.4	11.2	10	8.1	8.7	0.6	7.6	23	16	30.9	18	33.8	19.2	8.4
average inv/m3	14.2	11.5	10.2	15	10	0.8	16.3	23.5	19.9	33.5	28.1	35.3	21.2	10.1
average aq. Invertebrates/m3 water	11.4	10.9	10	9.1	9.4	0.6	11.8	22.8	17.5	31.1	18.4	31.3	20.1	8.6
Stdev of aq. Inv. Den.	8.3	5.7	1.5	5.3	5.2	0.2	9.4	3.9	6.6	7.8	2.83	11.6	7.9	0.7
Total aquatic invertebrates	4120	2486	7509	1839	5827	435	2875	8442	4750	10159	12242	6324	19465	2417
Total. terrestrial invertebrates	1044	129	117	1211	426	159	1833	248	670	745	6843	677	1070	395
Total invertebrates	5164	2615	7626	3050	6254	594	4708	8691	5420	10904	19085	7000	20535	2812
% Sample aquatic	80%	95%	98%	60%	93%	73%	61%	97%	88%	93%	64%	90%	95%	86%
% Sample terrestrial	20%	5%	2%	40%	7%	27%	39%	3%	12%	7%	36%	10%	5%	14%
Average # aquatic inverts / net	824	497	1502	368	1165	87	575	1688	950	2032	2448	1265	3893	483
stdev aq inv/net	138	352	545	161	409	60	278	448	265	802	764	977	1286	174
Average # terr. inverts / net	209	26	23	242	85	32	367	50	134	149	1369	135	214	79
Average # inverts / net	1033	523	1525	610	1251	119	942	1738	1084	2181	3817	1400	4107	562
stdev inv/net	274	339	560	188	434	97	587	447	308	848	1480	1048	1378	188
Total Larval Arctic Grayling/site	1	3	1	0	0	0	0	0	9	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Mainstem Red Dog Creek, Station 10, Drift Samples Invertebrates														
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total aquatic taxa	11	7	19	12	21	17	15	20	22	24	17	15	24	15
Tot. Ephemeroptera	2	0	6	14	313	24	54	77	56	25	10	1	16	3
Tot. Plecoptera	35	16	34	30	292	16	36	45	144	50	15	6	27	36
Tot. Trichoptera	0	1	3	0	1	0	7	0	1	3	1	0	4	0
Total Aq. Diptera	182	20	676	129	438	37	396	87	558	1301	347	57	708	102
Misc.Aq.sp	3	2	82	8	58	9	82	73	141	106	49	10	271	68
% Ephemeroptera	1%	1%	1%	8%	28%	28%	9%	27%	6%	2%	2%	2%	2%	1%
% Plecoptera	16%	41%	4%	17%	27%	18%	6%	16%	16%	3%	4%	8%	3%	17%
% Trichoptera	0%	3%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	82%	52%	84%	71%	40%	43%	69%	31%	62%	88%	82%	76%	69%	49%
% other	1%	4%	10%	4%	5%	11%	14%	26%	16%	7%	12%	14%	26%	32%
% EPT	17%	44%	5%	25%	55%	47%	17%	43%	22%	5%	6%	10%	5%	19%
% Chironomidae	69%	25%	79%	62%	24%	39%	36%	22%	60%	55%	60%	68%	51%	22%
% Dominant Aquatic Taxon	61%	42%	64%	52%	29%	30%	33%	23%	42%	52%	43%	55%	38%	30%
Volume of water (m3)	869	356	1323	255	688	1239	665	417	422	384	378	139	966	311
average water/net	174	71	265	51	138	248	133	83	84	77	76	28	193	62
StDev of water volume	122	27	56	15	39	54	65	13	20	10	24	16	17	20
Estimated total inverts/m3 water	1.4	0.6	3.1	3.8	8.2	0.5	7.5	4.8	13.5	22.6	9.2	4.1	6.7	4.4
Estimated aquatic inverts/m3 water	1.3	0.5	3	3.6	8	0.3	4.3	3.4	10.7	19.4	5.6	2.7	5.3	3.4
average inv/m3	1.9	0.7	3.2	4.2	8.6	0.5	8.2	5	14	22.8	8.8	3.2	6.6	4.5
average aq. inverts/m3 water	1.8	0.6	3.1	4	8.4	0.4	4.6	3.5	11.1	19.5	5.3	2.1	5.3	3.5
Stdev of aq. Inv. Den.	1.3	0.3	0.8	2.1	1.9	0	1.6	1.4	2.3	3.6	1.4	1.4	1.3	0.5
Total aquatic invertebrates	1111	192	4003	910	5503	427	2875	1410	4497	7427	2109	370	5125	1048
Total. terrestrial invertebrates	136	21	121	49	121	173	2119	609	1218	1252	1351	205	1311	311
Total invertebrates	1247	213	4123	959	5624	600	4993	2018	5715	8679	3461	575	6437	1359
% Sample aquatic	89%	90%	97%	95%	98%	71%	58%	70%	79%	86%	61%	64%	80%	77%
% Sample terrestrial	11%	10%	3%	5%	2%	29%	42%	30%	21%	14%	39%	36%	20%	23%
Average # aquatic inverts / net	222	38	801	182	1101	85	575	282	899	1485	422	74	1025	210
stdev aq inv/net	126	25	182	47	152	16	311	66	83	227	242	76	315	52
Average # terr. inverts / net	27	4	24	10	24	35	424	122	244	250	270	41	262	62
Average # inverts / net	249	43	825	192	1125	120	999	404	1143	1736	692	115	1287	272
stdev inv/net	153	27	171	51	152	25	529	69	111	218	358	116	355	63
Total Larval Arctic Grayling/site	5	5	0	2	1	0	0	0	0	45	2	0	1	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Ikalukrok Creek, Station 9, Drift Samples Invertebrates														
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total aquatic taxa	8	9	15	13	21	16	13	18	20	20	24	14	19	22
Tot. Ephemeroptera	11	63	267	213	138	208	571	67	225	122	151	4	129	109
Tot. Plecoptera	17	13	159	24	54	30	189	57	98	64	21	4	62	28
Tot. Trichoptera	0	0	0	0	0	0	1	0	1	0	0	0	3	0
Total Aq. Diptera	10	58	1252	285	485	196	185	56	217	193	370	167	1625	416
Misc.Aq.sp	9	8	56	5	23	23	23	25	24	162	125	10	113	26
% Ephemeroptera	24%	44%	15%	40%	19%	45%	59%	33%	40%	23%	23%	2%	7%	19%
% Plecoptera	36%	9%	9%	5%	8%	7%	19%	28%	17%	12%	3%	2%	3%	5%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	22%	41%	72%	54%	70%	43%	19%	27%	39%	36%	56%	90%	84%	72%
% other	19%	6%	3%	1%	3%	5%	2%	12%	4%	30%	19%	5%	6%	4%
% EPT	60%	54%	25%	45%	27%	52%	79%	60%	57%	34%	26%	4%	10%	24%
% Chironomidae	21%	39%	69%	52%	65%	25%	15%	18%	35%	28%	31%	49%	76%	46%
% Dominant Aquatic Taxon	32%	45%	65%	44%	57%	36%	37%	24%	35%	20%	24%	44%	63%	29%
Volume of water (m3)	260	478	833	575	450	2772	555	352	382	390	601	265	792	540
average water/net	52	96	167	115	90	554	111	70	76	78	120	53	158	108
StDev of water volume	25	16	106	29	23	161	12	16	23	22	46	19	28	41
Estimated total inverts/m3 water	1.5	1.6	10.7	4.9	8.7	1.4	11.4	3.8	9	11.3	8.4	3.8	13.9	9.7
Estimated aquatic inverts/m3 water	0.9	1.5	10.4	4.6	7.8	0.8	8.7	2.9	7.4	6.9	5.5	3.5	12.2	5.4
average inv/m3	1.6	1.6	12	5	8.9	1.4	11.4	3.9	9.5	13.7	8.4	4	14.3	11.7
average aq inverts/m3 water	1	1.5	11.7	4.7	7.9	0.9	8.7	3	7.9	8.3	5.5	3.7	12.6	6.4
Stdev of aq. inv. Den.	0.6	0.3	4.6	0.8	1	0.1	1.7	1.2	2.5	6.2	1.3	0.8	4	4.06
Total aquatic invertebrates	232	714	8668	2635	3497	2288	4848	1028	2822	2707	3330	926	9662	2890
Total. terrestrial invertebrates	159	66	220	168	403	1507	1482	325	606	1704	1741	92	1377	2375
Total invertebrates	391	780	8888	2803	3900	3795	6330	1353	3427	4410	5071	1018	11039	5264
% Sample aquatic	59%	92%	98%	94%	90%	60%	77%	76%	82%	61%	66%	91%	88%	55%
% Sample terrestrial	41%	8%	2%	6%	10%	40%	23%	24%	18%	39%	34%	9%	12%	45%
Average # aquatic inverts / net	46	143	1734	527	699	458	970	206	564	541	666	185	1932	578
stdev aq inv/net	26	46	822	102	115	90	255	81	120	266	347	63	516	278
Average # terr. inverts / net	32	13	44	34	81	301	296	65	121	341	348	18	275	475
Average # inverts / net	78	156	1778	561	780	759	1266	271	685	882	1014	204	2208	1053
stdev inv/net	51	50	849	99	110	158	296	94	173	424	491	65	581	585
Total Larval Arctic Grayling/site	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Ikalukrok Creek below Dudd Creek Station 7, and Station 160 starting in 2010 under new permit														
Year Sampled	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total aquatic taxa	10	12	18	9	18	24	18	22	18	24	19	14	19	24
Tot. Ephemeroptera	1	4	138	12	59	23	152	114	126	17	33	4	38	31
Tot. Plecoptera	9	102	43	12	37	8	4	29	21	21	8	2	6	2
Tot. Trichoptera	0	1	1	0	1	2	0	2	1	1	0	0	0	1
Total Aq. Diptera	38	319	262	111	1054	95	529	323	1356	1335	1558	371	867	181
Misc.Aq.sp	3	105	22	2	36	44	8	83	187	119	28	92	61	64
% Ephemeroptera	1%	1%	30%	8%	5%	13%	22%	21%	7%	1%	2%	1%	4%	11%
% Plecoptera	17%	19%	9%	8%	3%	4%	1%	5%	1%	1%	1%	0%	1%	1%
% Trichoptera	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	75%	60%	56%	81%	89%	55%	76%	59%	80%	89%	96%	79%	89%	65%
% other	7%	20%	5%	1%	3%	26%	1%	15%	11%	8%	2%	20%	6%	23%
% EPT	18%	20%	39%	17%	8%	19%	22%	26%	9%	3%	3%	1%	5%	12%
% Chironomidae	66%	39%	51%	36%	22%	43%	59%	43%	68%	18%	14%	29%	55%	35%
% Dominant Aquatic Taxon	63%	39%	46%	46%	67%	31%	38%	27%	58%	71%	82%	50%	36%	32%
Volume of water (m3)	190	513	617	359	866	1182	303	617	502	491	659	1236	801	550
average water/net	38	103	123	72	173	236	61	123	100	98	132	247	160	110
StDev of water volume	23	54	40	23	19	114	14	35	33	56	46	101	29	21
Estimated total inverts/m3 water	1.8	5.7	3.9	2.2	7.2	1	15.3	5.2	23.1	17.7	13.6	2.4	6.4	3.0
Estimated aquatic inverts/m3 water	1.3	5.2	3.8	1.9	6.9	0.7	11.4	4.5	16.9	15.2	12.3	1.9	6.1	2.5
average inv/m3	2.5	6	4.1	2.3	7.3	1	15.4	5.6	26.1	17.9	14.1	2.3	6.4	3.1
average aq inverts/m3 water	1.7	5.4	4	2	7	0.8	11.4	4.9	18.8	15.6	13	1.8	6	2.7
StDev of aq. Inv. Density	1	1.3	1	0.8	1.5	0.1	3.4	2	7.6	1.8	2.7	0.6	2.9	1.0
Total aquatic invertebrates	253	2657	2335	684	5940	857	3465	2759	8455	7466	8136	2347	4860	1397
Total. terrestrial invertebrates	90	291	54	114	291	279	1181	428	3112	1224	791	574	252	249
Total invertebrates	343	2948	2389	798	6232	1136	4646	3187	11567	8689	8927	2920	5112	1646
% Sample aquatic	74%	90%	98%	86%	95%	75%	75%	87%	73%	86%	91%	80%	95%	85%
% Sample terrestrial	26%	10%	2%	14%	5%	25%	25%	13%	27%	14%	9%	20%	5%	15%
Average # aquatic inverts / net	51	531	467	137	1188	171	693	552	1691	1493	1627	469	972	279
stdev aq inv/net	27	309	64	56	167	63	292	111	209	842	421	308	502	53
Average # terr. inverts / net	18	58	11	23	58	56	236	86	622	245	158	115	50	50
Average # inverts / net	69	590	478	160	1246	227	929	637	2313	1738	1785	584	1022	329
stdev inv/net	29	328	66	53	167	84	352	130	276	1012	487	386	533	64
Total Larval Arctic Grayling/site	0	2	0	14	1	0	0	0	0	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	1	0	0	1	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	7	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Bons Creek below Blast Road, upstream of Bons Pond									
Year Sampled	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total aquatic taxa	17	23	16	14	19	14	11	20	15
Tot. Ephemeroptera	3	15	7	6	6	9	3	67	13
Tot. Plecoptera	1	1	1	1	3	1	0	1	0
Tot. Trichoptera	0	0	0	0	0	0	0	0	0
Total Aq. Diptera	39	82	23	367	347	251	46	507	37
Misc.Aq.sp	7	66	10	56	114	17	8	86	20
% Ephemeroptera	6%	9%	17%	1%	1%	6%	5%	10%	18%
% Plecoptera	2%	1%	2%	0%	1%	3%	0%	0%	1%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	77%	50%	56%	86%	74%	0%	81%	77%	53%
% other	14%	40%	25%	13%	24%	90%	14%	13%	29%
% EPT	8%	10%	19%	2%	2%	4%	5%	10%	18%
% Chironomidae	68%	27%	43%	72%	20%	81%	75%	70%	46%
% Dominant Aquatic Taxon	60%	38%	38%	50%	53%	76%	61%	48%	46%
Volume of water (m3)	349	104	68	86	79	87	16	176	53
average water/net	70	21	14	17	16	17	3	35	11
StDev of water volume	10	11	3	3	8	12	1	7	5
Estimated total inverts/m3 water	1.3	23	4.6	31.5	55.4	25.7	21.8	21.3	9.5
Estimated aquatic inverts/m3 water	0.7	7.9	3.1	24.8	29.9	16.1	17.9	18.8	6.7
average inv/m3	1.3	23	4.6	31.5	57.6	31.8	20.2	21.5	12.5
average aq inverts/m3 water	0.7	9.6	3.2	25	30.4	19	16.1	19.1	8.37
StDev of aq. Inv. Density	0.5	4.9	1.3	8.4	4.6	8.5	9.5	3.9	5.07
Total aquatic invertebrates	251	823	208	2147	2354	1392	283	3302	353
Total. terrestrial invertebrates	209	1564	105	574	2012	834	63	450	147
Total invertebrates	460	2387	313	2721	4365	2226	346	3752	500
% Sample aquatic	55%	34%	66%	79%	54%	63%	82%	88%	71%
% Sample terrestrial	45%	66%	34%	21%	46%	37%	18%	12%	29%
Average # aquatic inverts / net	50	165	42	429	471	278	57	660	71
stdev aq inv/net	40	58	14	154	218	135	43	141	25
Average # terr. inverts / net	42	313	21	115	402	167	13	90	29
Average # inverts / net	92	477	63	544	873	445	69	750	100
stdev inv/net	79	336	17	207	428	169	48	187	43
Total Larval Arctic Grayling/site	0	10	0	78	0	0	0	3	14
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Bons Creek (Station 220), just upstream of confluence with Buddy Creek												
Year Sampled	2004	2005	2006a	2006b	2007a	2007b	2008a	2008b	2009	2010c	2011	2012
Total aquatic taxa	20	18	17	19	16	17	19	20	19		27	
Tot. Ephemeroptera	7	51	17	17	95	95	63	63	130		12	
Tot. Plecoptera	3	5	8	8	8	8	29	29	7		14	
Tot. Trichoptera	1	1	0	0	4	4	4	4	0		2	
Total Aq. Diptera	48	63	122	122	1391	1391	2112	2112	1044		260	
Misc.Aq.sp	3	8	241	5255	34	1590	134	1322	95		191	
% Ephemeroptera	11%	40%	4%	0%	6%	3%	3%	2%	10%		2%	
% Plecoptera	5%	4%	2%	0%	1%	0%	1%	1%	1%		3%	
% Trichoptera	2%	1%	0%	0%	0%	0%	0%	0%	0%		0%	
% Aq. Diptera	77%	50%	31%	2%	91%	45%	90%	60%	82%		54%	
% other	5%	40%	62%	97%	2%	51%	6%	37%	7%		40%	
% EPT	18%	44%	7%	0%	7%	3%	4%	3%	11%		6%	
% Chironomidae	46%	43%	30%	2%	35%	17%	72%	48%	50%		25%	
% Dominant Aquatic Taxon	45%	43%	53%	89%	56%	50%	67%	48%	45%		29%	
Volume of water (m^3)	698	76	612	612	150	150	317	317	216		409	
average water/net	140	15	122	122	30	30	63	63	43		82	
StDev of water volume	59	7	44	44	21	21	20	20	12		47	
Estimated total inverts/m^3 water	0.8	11.2	5.0	46.0	63.7	115.6	41.7	60.5	36.2		6.3	
Estimated aquatic inverts/m^3 water	0.4	8.4	3.2	44.2	51.1	103.0	37.0	55.8	29.6		5.9	
average inv/m^3	0.9	11.2	5.0	46.0	130.0	222.4	42.3	61.4	35.2		7.6	
average aq inverts/m^3 water	0.4	8.1	3.3	46.4	107.4	199.8	37.8	56.8	28.6		7	
StDev of aq. Inv. Density	0.2	2.2	0.8	21.5	136.8	232.8	11.0	11.0	12.4		3	
Total aquatic invertebrates	312	636	1943	27013	7654	15436	11706	17648	6375		2393	
Total. terrestrial invertebrates	273	217	1143	1143	1892	1892	1494	1494	1427		198	
Total invertebrates	585	853	3086	28156	9546	17328	13200	19142	7802		2591	
% Sample aquatic	53%	75%	63%	96%	80%	89%	89%	92%	82%		92%	
% Sample terrestrial	47%	25%	37%	4%	20%	11%	11%	8%	18%		8%	
Average # aquatic inverts / net	62	127	389	5403	1531	3087	2341	3530	1275		479	
stdev aq inv/net	56	66	108	2101	854	2008	766	993	833		188	
Average # terr. inverts / net	55	43	229	229	378	378	299	299	285		40	
Average # inverts / net	117	171	617	5631	1909	3466	2640	3828	1560		518	
stdev inv/net	59	88	239	2183	1108	2288	872	1098	992		197	
Total Larval Arctic Grayling/site	0	0	0	0	1	1	0	0	0		0	
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0		0	
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0		0	
2006a is without Daphniids and 2006b is with Daphniids												
2007a is without Ostracods and 2007b is with Ostracods												
2008a is without Ostracods and 2008b is with Ostracods												
2010c and 2012 site not sampled, no flowing water												

Appendix 3 (continued)

Buddy Creek (Station 221), upstream of haul road									
Year Sampled	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total aquatic taxa	20	20	19	23	22	17	17	23	21
Tot. Ephemeroptera	2042	232	515	385	110	18	25	409	1878
Tot. Plecoptera	20	18	28	130	86	30	3	48	8
Tot. Trichoptera	0	1	0	1	0	1	2	1	0
Total Aq. Diptera	195	423	476	965	1632	489	654	715	334
Misc.Aq.sp	25	47	84	98	204	73	69	147	36
% Ephemeroptera	89%	32%	47%	24%	5%	3%	3%	31%	83%
% Plecoptera	1%	3%	3%	8%	4%	5%	0%	4%	0%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	9%	59%	43%	61%	80%	80%	87%	54%	15%
% other	1%	32%	8%	6%	10%	12%	9%	11%	2%
% EPT	90%	35%	49%	33%	10%	8%	4%	35%	84%
% Chironomidae	5%	38%	25%	43%	39%	39%	81%	36%	5%
% Dominant Aquatic Taxon	89%	28%	44%	24%	41%	41%	62%	32%	83%
Volume of water (m3)	771	235	600	242	489	318	183	437	71
average water/net	154	47	120	48	98	64	37	87	14
StDev of water volume	146	18	65	30	18	34	16	46	3
Estimated total inverts/m3 water	16.2	22	11.5	39.7	24.6	19	31	15.7	160.6
Estimated aquatic inverts/m3 water	14.8	15.3	9.2	32.7	20.8	9.6	20.6	15.1	159.3
average inv/m3	20.1	22	11.5	47	25	22.3	35.4	19.2	165.8
average aq inverts/m3 water	18.1	17.2	9.3	38.9	21	11.1	25.1	18.4	164.5
StDev of aq. Inv. Density	10.1	7.5	2.1	16.1	4.2	4.7	16.8	10.3	84.4
Total aquatic invertebrates	11414	3607	5515	7892	10161	3050	3767	6593	11276
Total. terrestrial invertebrates	1074	1572	1404	1698	1900	2971	1897	289	90
Total invertebrates	12488	5179	6918	9590	12061	6021	5664	6882	11366
% Sample aquatic	91%	70%	80%	82%	84%	51%	67%	96%	99%
% Sample terrestrial	9%	30%	20%	18%	16%	49%	33%	4%	1%
Average # aquatic inverts / net	2283	721	1103	1578	2032	610	753	1319	2255
stdev aq inv/net	1459	176	575	555	391	144	410	642	1016
Average # terr. inverts / net	215	314	281	340	380	594	379	58	18
Average # inverts / net	2498	1036	1384	1918	2412	1204	1133	1376	2273
stdev inv/net	1540	323	752	683	394	380	852	670	1014
Total Larval Arctic Grayling/site	0	0	0	1	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0

Appendix 3 (concluded)

Buddy Creek (below falls), downstream of the canyon and haul road											
Year Sampled	2004	2005	2006a	2006b	2007	2008	2009	2010	2011a	2011b	2012
Total aquatic taxa	18	19	16	18	25	20	13	14	28	29	19
Tot. Ephemeroptera	578	328	253	253	1316	124	776	6	139	139	112
Tot. Plecoptera	9	12	32	32	92	21	18	0	30	30	4
Tot. Trichoptera	1	2	0	0	7	2	0	0	3	3	0
Total Aq. Diptera	363	855	199	199	2284	2011	4424	1478	1525	1525	187
Misc.Aq.sp	71	19	125	2461	444	206	153	56	230	1773	37
% Ephemeroptera	57%	27%	42%	9%	32%	5%	14%	0%	7%	4%	33%
% Plecoptera	1%	1%	5%	1%	2%	1%	0%	0%	2%	1%	1%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	35%	70%	33%	7%	55%	85%	82%	96%	79%	44%	55%
% other	7%	2%	21%	84%	11%	9%	3%	4%	12%	51%	11%
% EPT	58%	28%	47%	10%	34%	6%	15%	0%	9%	5%	34%
% Chironomidae	11%	64%	22%	4%	40%	67%	69%	65%	57%	32%	38%
% Dominant Aquatic Taxon	56%	43%	33%	69%	30%	46%	50%	50%	44%	44%	31%
Volume of water (m3)	1326	271	612	612	593	633	347	128	741	741	120
average water/net	265	54	122	122	119	127	69	26	148	148	24
StDev of water volume	160	12	29	29	63	57	19	15	23	23	6
Estimated total inverts/m3 water	4.5	35.9	7.3	26.4	42.4	20.8	81.5	87.5	15.8	26.2	14.4
Estimated aquatic inverts/m3 water	3.9	22.5	5	24.1	34.9	18.7	77.4	60.3	13	23.4	14.1
average inv/m3	4.4	35.9	7.3	26.4	47.5	26.4	83.4	73.3	15.9	26.4	14.5
average aq inverts/m3 water	3.9	22.6	5	24.8	39.4	23.6	79	52.5	13	25.5	14.2
StDev of aq. Inv. Density	2.2	3.3	1.6	9.7	16	15.3	11.9	20.6	3.3	4.9	3.1
Total aquatic invertebrates	5109	6085	3041	14723	20713	11820	26860	7706	9639	17358	1698
Total. terrestrial invertebrates	876	3645	1400	1400	4439	1320	1431	3479	2091	2091	35
Total invertebrates	5985	9730	4441	16123	25152	13140	28291	11185	11730	19448	1733
% Sample aquatic	85%	63%	68%	91%	82%	90%	95%	69%	82%	89%	98%
% Sample terrestrial	15%	37%	32%	9%	18%	10%	5%	31%	18%	11%	2%
Average # aquatic inverts / net	1022	1217	608	2945	4143	2364	5372	1541	1928	3472	340
stdev aq inv/net	744	279	222	1201	1812	352	1247	1322	567	787	105
Average # terr. inverts / net	175	729	280	280	888	264	286	696	418	418	7
Average # inverts / net	1197	1946	888	3225	5030	2628	5658	2237	2346	3890	347
stdev inv/net	893	494	322	1224	2337	432	1244	2327	761	922	108
Total Larval Arctic Grayling/site	0	0	0	0	1	0	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	1	0	0	0	0	0	0	0	0	0
2006a is without Daphniids and 2006b is with Daphniids											
2011a is without Ostracods and 2011b is with Ostracods											

Appendix 4. Juvenile Dolly Varden Whole Body Metal Concentrations, 2012

Dolly Varden juveniles were not collected at Red Dog in 2012 due to high water during the month of August.

Appendix 5. Dolly Varden Metals Data, Wulik River 2012

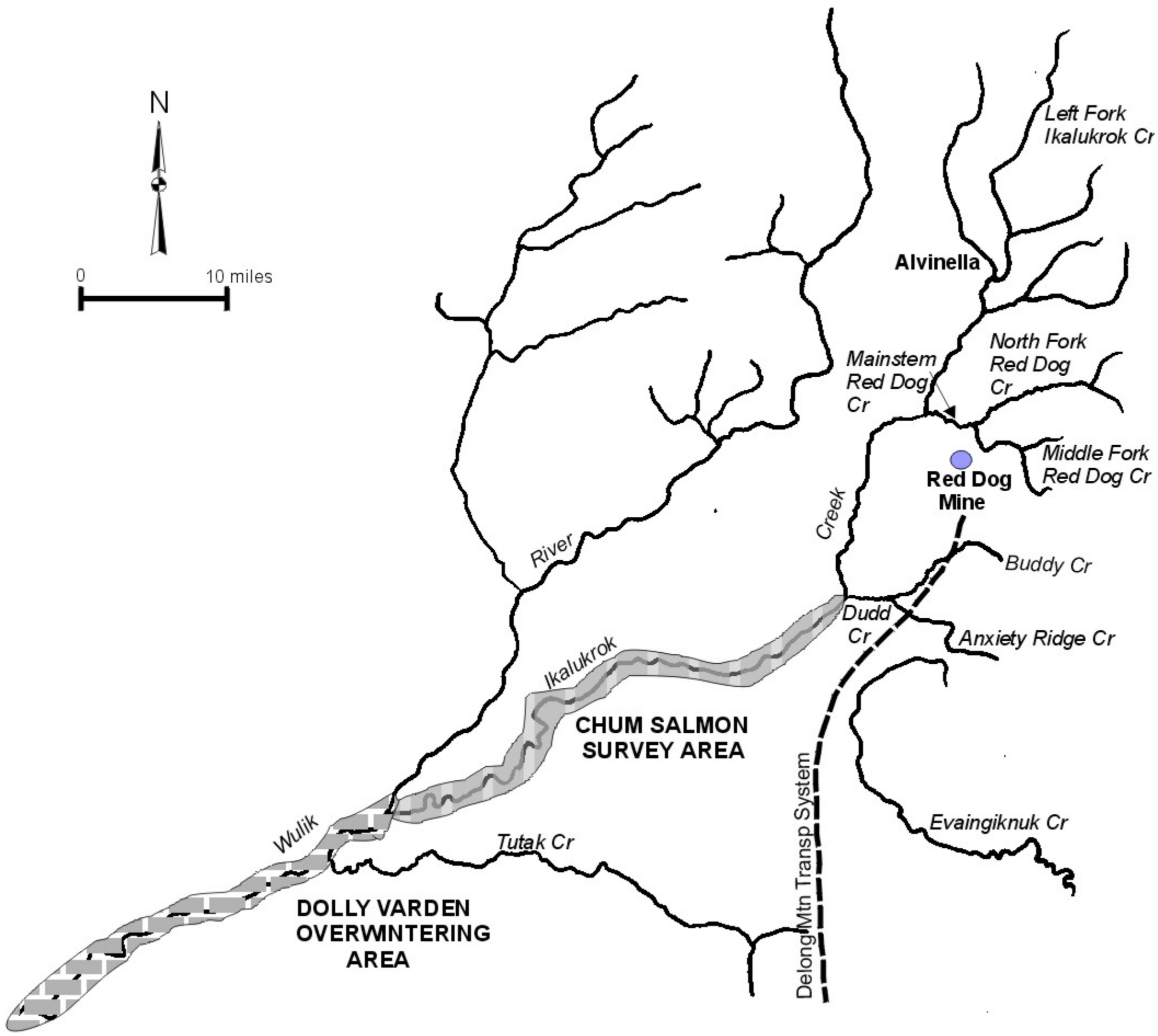
Tissue	Sample Identification	Sex	Weight (g)	Length (mm)	Age Fresh	Age Salt	Total Age	Cd (mg/Kg)	Cu (mg/Kg)	Pb (mg/Kg)	Se (mg/Kg)	Zn (mg/Kg)	Hg (mg/Kg)	% Solids
Kidney	060412WUDVA1	F	2122	585				2.00	4.1	0.03	10.0	85.0	0.08	22.0
Kidney	060412WUDVA2	M	3429	675	3	5	8	2.64	2.6	<0.02	7.0	77.7	0.06	25.2
Kidney	060412WUDVA3	M	2077	585			5	1.49	3.5	<0.02	7.5	91.0	0.06	22.9
Kidney	060412WUDVA4	F	2246	588	4	3	7	2.13	3.2	<0.02	8.5	75.1	0.05	22.5
Kidney	060412WUDVA5	M	2687	638	3	5	8	3.44	3.4	<0.02	8.2	102	0.06	22.7
Kidney	060412WUDVA6	M	2506	643	3	5	8	2.56	4.2	<0.02	7.7	97.9	0.11	20.9
Kidney	060412WUDVA7		duplicate of Fish #2					5.61	2.8	<0.02	8.3	84.1	0.03	23.9
Kidney	092812WUDVA1	F	1976	558			8	2.99	6.7	<0.02	10.2	112	0.1	21.9
Kidney	092812WUDVA2	F	2612	602	3	3	6	2.80	4.5	<0.02	12.9	87.3	0.13	23.6
Kidney	092812WUDVA3	F	4517	707	3	6	9	0.44	2.7	<0.02	13.9	91.7	0.12	23.6
Kidney	092812WUDVA4	F	2852	623	3	4	7	2.56	4.2	<0.02	11.5	109	0.13	22.4
Kidney	092812WUDVA5	F	2112	593	3	5	8	1.52	4.3	<0.02	8.6	126	0.09	22.4
Kidney	092812WUDVA6	F	1721	518			6	2.03	4.6	<0.02	11.3	105	0.09	22.4
Kidney	092812WUDVA7	F	duplicate of Fish #3					1.60	4.1	<0.02	17.2	97.9	0.15	22.9
Liver	060412WUDVA1	F	2122	585				0.92	30.7	0.02	3.3	105	<0.02	28.8
Liver	060412WUDVA2	M	3429	675	3	5	8	0.91	49.9	<0.02	2.8	83.0	0.03	35.0
Liver	060412WUDVA3	M	2077	585			5	0.29	60.5	<0.02	2.8	79.3	<0.02	38.7
Liver	060412WUDVA4	F	2246	588	4	3	7	0.88	29.3	<0.02	2.6	91.2	<0.02	35.7
Liver	060412WUDVA5	M	2687	638	3	5	8	0.50	40.9	<0.02	1.7	56.8	<0.02	42.8
Liver	060412WUDVA6	M	2506	643	3	5	8	0.85	86.5	<0.02	2.8	83.2	0.02	32.9
Liver	060412WUDVA7		duplicate of Fish #2					0.98	47.2	<0.02	2.3	86.6	0.03	38.1
Liver	092812WUDVA1	F	1976	558			8	0.37	54.5	<0.02	3.3	71.8	<0.04	45.5
Liver	092812WUDVA2	F	2612	602	3	3	6	0.77	32.3	<0.02	3.6	74.0	<0.04	45.9
Liver	092812WUDVA3	F	4517	707	3	6	9	0.28	25.3	<0.02	4.8	53.9	<0.04	46.8
Liver	092812WUDVA4	F	2852	623	3	4	7	0.48	30.6	<0.02	2.5	51.8	<0.04	50.0
Liver	092812WUDVA5	F	2112	593	3	5	8	0.49	54.9	<0.02	3.6	96.0	<0.04	37.4
Liver	092812WUDVA6	F	1721	518			6	0.32	29.5	<0.02	3.2	57.6	<0.04	47.6
Liver	092812WUDVA7	F	duplicate of Fish #3					0.33	30.5	<0.02	4.1	69.2	<0.04	45.5
Muscle	060412WUDVA1	F	2122	585				<0.02	3.8	<0.02	1.0	15.3	<0.02	26.1
Muscle	060412WUDVA2	M	3429	675	3	5	8	<0.02	1.1	<0.02	1.1	15.2	<0.02	24.9
Muscle	060412WUDVA3	M	2077	585			5	<0.02	1.0	<0.02	1.1	11.2	<0.02	29.8
Muscle	060412WUDVA4	F	2246	588	4	3	7	<0.02	1.1	<0.02	1.1	12.7	0.02	29.6
Muscle	060412WUDVA5	M	2687	638	3	5	8	<0.02	1.1	<0.02	<1.0	12.9	<0.02	30.4
Muscle	060412WUDVA6	M	2506	643	3	5	8	<0.02	1.4	<0.02	1.1	14.5	0.02	27.4
Muscle	060412WUDVA7		duplicate of Fish #2					<0.02	1.9	<0.02	<1.0	17.2	0.03	27.5
Muscle	092812WUDVA1	F	1976	558			8	<0.02	1.5	<0.02	1.0	15.4	<0.04	35.3
Muscle	092812WUDVA2	F	2612	602	3	3	6	<0.02	1.9	<0.02	1.4	13.9	<0.04	29.6
Muscle	092812WUDVA3	F	4517	707	3	6	9	<0.02	8.6	<0.02	1.5	15.9	<0.04	28.7
Muscle	092812WUDVA4	F	2852	623	3	4	7	<0.02	0.9	<0.02	1.0	11.5	<0.04	30.2
Muscle	092812WUDVA5	F	2112	593	3	5	8	<0.02	1.4	<0.02	1.2	14.6	<0.04	28.4
Muscle	092812WUDVA6	F	1721	518			6	<0.02	1.0	<0.02	1.3	14.4	<0.04	27.1
Muscle	092812WUDVA7	F	duplicate of Fish #3					<0.02	1.8	<0.02	1.5	12.0	<0.04	32.8
Reproductive	060412WUDVA1	F	2122	585				0.02	25.0	<0.02	7.9	397	<0.02	26.4
Reproductive	060412WUDVA2	M	3429	675				0.06	2.4	<0.02	2.8	143	<0.02	19.0
Reproductive	060412WUDVA3	M	2077	585				<0.02	3.6	<0.02	3.0	173	<0.02	18.1
Reproductive	060412WUDVA4	F	2246	588				<0.02	15.8	<0.02	4.9	630	<0.02	28.2
Reproductive	060412WUDVA5	M	2687	638				0.04	2.3	<0.02	3.3	149	<0.02	19.4
Reproductive	060412WUDVA7		duplicate of Fish #2					0.13	6.8	<0.02	2.6	143	<0.03	18.9
Reproductive	092812WUDVA1	F	1976	558				0.06	44.4	0.12	10.1	633	<0.04	24.1
Reproductive	092812WUDVA2	F	2612	602				0.10	40.7	<0.02	8.6	540	<0.04	22.9
Reproductive	092812WUDVA3	F	4517	707				0.06	31.7	<0.02	18.4	1160	<0.04	21.1
Reproductive	092812WUDVA4	F	2852	623				0.06	31.4	<0.02	11.0	665	<0.04	22.4
Reproductive	092812WUDVA5	F	2112	593				0.04	28.9	<0.02	7.7	937	<0.04	27.2
Reproductive	092812WUDVA6	F	1721	518				0.05	31.3	<0.02	10.9	440	<0.04	23.9
Reproductive	092812WUDVA7	F	duplicate of Fish #3					0.05	32.2	<0.02	18.0	1280	<0.04	22.7

Appendix 6. Dolly Varden Aerial Surveys

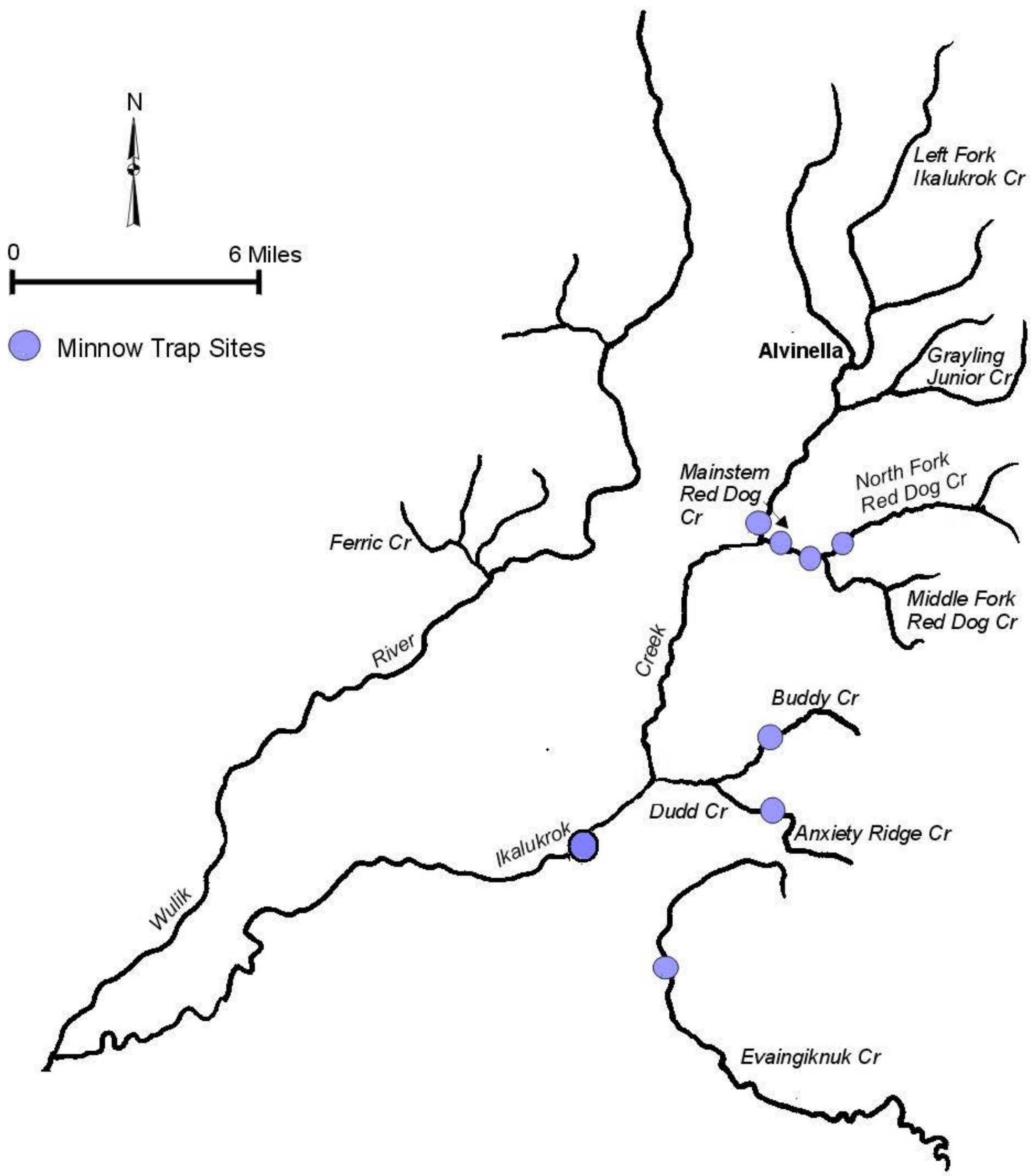
Estimated number of overwintering Dolly Varden in the Wulik River before freezeup. Surveys conducted by ADF&G (DeCicco 1989, 1991-1999, 2001-2002, and 2004-2012).

Year	Wulik River upstream of Ikalukrok Creek	Wulik River downstream of Ikalukrok Creek	Total Fish	Percent of Fish downstream of Ikalukrok Creek
Before Mining				
1979	3,305	51,725	55,030	94
1980	12,486	101,067	113,553	89
1981	4,125	97,136	101,261	96
1982	2,300	63,197	65,497	97
1984	370	30,483	30,853	99
1987	893	60,397	61,290	99
1988	1,500	78,644	80,144	98
During Mining				
1989	2,110	54,274	56,384	96
1991	7,930	119,055	126,985	94
1992	750	134,385	135,135	99
1993	7,650	136,488	144,138	95
1994	415	66,337	66,752	99
1995	240	128,465	128,705	99
1996	1,010	59,995	61,005	98
1997	2,295	93,117	95,412	98
1998	6,350	97,693	104,043	94
1999	2,750	67,954	70,704	96
2001	2,020	90,594	92,614	98
2002	1,675	42,582	44,257	96
2004	16,486	84,320	100,806	84
2005	10,645	110,203	120,848	91
2006	4,758	103,594	108,352	96
2007	5,503	93,808	99,311	94
2008	271	71,222	71,493	99
2009	122	60,876	60,998	99
2010	70	36,248	36,318	99
2011 (September)	500	15,591	16,091	97
2011 (October)	637	62,612	63,249	99
2012	0	21,084	21,084	100
The population estimate (mark/recapture) for winter 1988/1989 for fish >400 mm				
was 76,892 (DeCicco 1990b)				
The population estimate (mark/recapture) for winter 1994/1995 for fish >400 mm				
was 361,599 (DeCicco 1996c)				
Fall 2000 aerial survey was not made due to weather.				
Fall 2003 aerial survey was not made due to weather.				

Appendix 7. Dolly Varden and Chum Salmon Survey Areas



Appendix 8. Juvenile Dolly Varden Sampling Sites



Appendix 9. Juvenile Dolly Varden Catches

Number of Dolly Varden Caught in Late-July/Early August with ten minnow traps per sample site															
Sample Site Description	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Evaingiknuk (Noatak Tributary)	54	27	38	2	7	20	64	71	29	4	67	21	16	48	36
Anxiety Ridge	68	94	271	27	6	33	98	116	121	8	115	75	147	18	43
Buddy	48	154	306	11	34	57	104	59	59	5	183	43	100	115	77
North Fork Red Dog Creek (Sta 12)	0	12	17	1	1	1	0	1	8	0	1	0	3	6	2
Mainstem (below North Fork) (Sta 151)	14	70	86	13	9	12	2	2	6	8	2	13	7	13	7
Mainstem (Station 10)	10	21	66	1	3	12	12	0	10	3	6	5	6	14	8
Ikalukrok Creek (below Dudd)(Sta 7/160)	13	51	55	31	6	17	17	27	36	2	25	7	30	10	32
Ikalukrok Creek (above Mainstem)(Sta 9)	3	44	41	5	2	18	3	12	0	5	7	3	11	37	12
Total Catch Dolly Varden	210	473	880	91	68	170	300	288	269	35	406	167	320	261	217

Appendix 10. Arctic Grayling, Mainstem Red Dog Creek

Observations and catches of Arctic grayling in Mainstem Red Dog Creek below the confluence of North Fork Red Dog and Middle Fork Red Dog creeks since 1994.

7/27/94 – visual, two adults just below North Fork

6/29/95 – angling, one adult just below North Fork
7/17/95 – angling, two adults near rock bluff 0.8 km below North Fork
7/20/95 – visual, one adult near rock bluff 0.8 km below North Fork
8/11/95 – visual, fry (about 30) below North Fork
8/14/95 – angling, 11 adults marked and released, rock bluff 0.8 km below North Fork

6/19/96 – visual, one adult near Station 10
7/15/96 – angling, seven adults marked and released near Station 10
8/11/96 – visual, fry in shallow eddies at mouth of Mainstem
8/12/96 – visual, fry near rock bluff 0.8 km below North Fork

6/25/97 – visual, two adults at rock bluff 0.8 km below North Fork
6/25/97 – drift net, fry caught at Station 10, 13-15 mm long
6/26/97 – angling, 15 adults marked and released near Station 10
6/27/97 – visual, fry numerous at Station 10
8/10/97 – visual, fry in backwaters
9/29/97 – minnow traps, seven fry caught near Station 10

6/10/98 – visual, no fish seen between North Fork mouth and rock bluff 0.8 km downstream
6/28/98 – visual, one adult feeding at rock bluff (0.8 km below North Fork)

5/29/99 – angling, three adults caught just below North Fork mouth
5/30/99 – fyke net, 32 adults caught about 100 m below North Fork mouth
7/8-9/99 – angling, two adults captured, marked, and released near Station 10
7/8-9/99 – visual, 12 adults and some fry near Station 10
7/8-9/99 – visual, two adults at rock bluff (0.8 km below North Fork)
8/9-10/99 – visual, numerous fry in backwaters and along stream margins

Appendix 10 (continued)

6/11-12/00 – fyke net, adults captured, marked, and released 7/28/00 – visual, several fry in backwaters and along stream margins, not numerous
7/5/00 – visual, two adults feeding at rock bluff (0.8 km below North Fork), juvenile observed
7/6/00 – visual, walked most of creek, tagged three adults near Station 10, most pools held one to three adults

6/15-18/01 – visual, walked creek to check for spawners in proposed mixing zone, none observed, one adult seen feeding at rock bluff (about 0.8 km below North Fork)
6/17/01 – angling, 11 adults marked and released near Station 10, all females spent
7/29-31/01 – visual, very few fry seen (about 20 mm), late breakup, cold temperatures resulted in late spawning

5/31/02 – fyke net, seven adults marked and released near Station 10
6/1/02 – fyke net, 31 adults marked and released near Station 10
6/2/02 – fyke net, eight adults marked and released near Station 10
6/3/02 – fyke net, three adults marked and released near Station 10
6/4/02 – fyke net, three adults and three juveniles marked and released near Station 10
6/7/02 – angling, 10 adults and three juveniles marked and released near Station 10, most of the females were spent
7/27/02 – visual, few fry (<10) seen
7/28/02 – visual, adults present near Station 10, three to four per pool

6/11/03 – aerial, 48 adults, two spawning pairs seen
6/12/03 – visual, ten adults, three active spawning pairs observed near Station 10
6/14/03 – angling, eight adults, one spent male near Station 10
7/7/03 – visual, fry in backwaters near Station 10, one group of 30
7/8/03 – visual, ten adults near Station 10
9/7/03 – visual, two adults and five fry near Station 151

5/25/04 – visual, two adult males near Station 10
5/26/04 – fyke net, four adults near Station 10
7/7/04 – visual, fry common near Station 151
7/7/04 – angling, two adults (333, 325 mm) near Station 151
7/8/04 – visual, fry in all backwaters near Station 10
7/8/04 – angling, three adults (373, 297, 356 mm) near Station 10

Appendix 10 (continued)

6/5/05 – aerial, observed 30 adult Arctic grayling, only two sets paired
6/25 and 26/05 – Houghton reported catching about 60 fish in Mainstem between mouth and North Fork Red Dog Creek
7/4/05 – visual, 8 adults and fry (about 70) observed near Station 10
7/28/05 – visual, small numbers of fry in backwaters near Station 10

6/13/06 – visual, five adult Arctic grayling seen in Mainstem near Station 10
6/16/06 – angling, caught 8 Arctic grayling (260 – 355 mm long) in Mainstem just below mouth of North Fork

6/1/07 – visual, several adult male and female Arctic grayling seen near Station 151
6/2/07 – visual, numerous Arctic grayling spawning at 3rd bend downstream of Station 151 in area of cobbles to gravelly sand
6/3/07 – visual, groups of 4 to 5 adults moving downstream in Station 10 area, caught several spent females, fish obviously moving out of Mainstem
7/1/07 – visual, observed large number of fry in side channels and backwaters near Station 10 and three adult Arctic grayling feeding on drift
7/3/07 – visual, observed one adult Arctic grayling at Station 151 and several fry along stream margins
8/9/07 – visual, observed two adult Arctic grayling at Station 151 and saw 35 fry along stream margins, one group of about 25
8/10/07 – visual, observed quite of few Arctic grayling fry in vicinity of Station 10 and caught fry in minnow traps (n = 10, 59 to 68 mm, average 64.1, SD = 2.8)

6/608 – visual, observed one Arctic grayling near Station 151
6/9/08 – visual and angling, walked Station 151 downstream for about 1.6 km and caught one Arctic grayling (363 mm)
6/10/08 – visual and angling, caught 5 Arctic grayling (325 – 425 mm long) just upstream of Station 10, four males and one partially spent female – saw about six fish that we did not catch
7/3/08 – visual, saw one adult Arctic grayling near Station 10
7/4/08 – visual, fry common along stream margins near Station 10, very small (about 15 mm long)
7/4/08 – minnow traps, caught one 67 mm Arctic grayling near Station 151
8/3/08 – minnow traps, caught one 82 mm Arctic grayling near Station 151

Appendix 10 (concluded)

6/13/09 – caught one 408 mm Arctic grayling in Mainstem Red Dog Creek at first rock bluff below North Fork Red Dog Creek
7/2/09 – observed one adult Arctic grayling near Station 151
7/3/09 – observed 8 adult Arctic grayling in pools just upstream of Station 10
7/29/09 – saw large numbers of Arctic grayling fry virtually everywhere in our sample reach in Mainstem Red Dog Creek upstream of Station 151
7/30/09 – observed a few Arctic grayling fry in Mainstem Red Dog Creek near Station 10

7/3/10 – observed fry at Station 10, fry numerous and schools of 5 to 20 seen everywhere we looked
8/15/10 – observed moderate numbers of Arctic grayling fry just upstream of Station 151
8/15/10 – saw two adult Arctic grayling just upstream of Station 10
8/15/10 – observed moderate numbers of Arctic grayling fry upstream and downstream of Station 10

6/7/2011 – one male Arctic grayling (Code #49 – radiotag) radio-located in Mainstem Red Dog Creek along with many other adult Arctic grayling near first bluff below Station 151
6/10/2011 – caught 6 Arctic grayling in Mainstem Red Dog Creek between the mouth of North Fork Red Dog Creek and Station 151
6/11/2011 – two male Arctic grayling (Code 50 and 54 – radiotag) radio-located in Mainstem Red Dog Creek downstream of Station 151
7/17/2011 – aerial survey to relocate radio-tagged Arctic grayling, 13 of 15 fish found – none were in Mainstem Red Dog Creek
8/28/2011 – observed several Arctic grayling fry in Mainstem Red Dog Creek just upstream of Station 151, fry were in backwaters and in a side channel

7/8/2012 – observed Arctic grayling fry near Station 10, broad distribution in vicinity of drift nets, several small schools of 15 to 20 fry

Appendix 11. Arctic Grayling Fry, North Fork Red Dog Creek

Year	Relative Abundance of Fry	Comments
1992	high	100's of fry, late July
1993	low	Few fry in early August, high water
1994	low	High water after spawning probably displaced fry
1995	low	Fry small (<25 mm) in mid-July
1996	high	Schools of 50 to 200 fry common
1997	high	Average size of fry was 10 mm greater than in 1996
1998	low	Cold water, late breakup, high water after spawning
1999	high	Low flows, warm water after spawning, schools of 50 to 100 fry common
2000	low	Cold water, late breakup, spawning 90% done June 13/14, fry small (<25 mm) and rare in mid-July
2001	low	Cold water, late breakup, spawning 90% done June 19, fry small (<25 mm) and rare in mid-July
2002	low	High flows, spawning 90% done June 8, fry small (<35 mm) in early August and rare, more fry seen in Ikalukrok Creek in early July, probably displaced by high water
2003	low	Cold water, late breakup, spawning 90% done June 14, fry small (<25 mm) and rare in early August
2004	low	Early breakup, spawning 90% done by May 31, fry (<30 mm) on July 10
2005	low	Spawning 90% done by June 7, fry present in early July, several groups of 25 to 30 observed to high water
2006	low	Spawning partially abandoned due to cold water temperatures, no fry observed in early August, July surveys not possible due to high water
2007	high	Spawning 90% done by June 3, followed by low water with very little rainfall until mid-August, fry numerous, hundreds seen in shallow water along stream margin, fry averaged 64 mm in early August

Appendix 11 (concluded)

Year	Relative Abundance of Fry	Comments
2008	low	Spawning 90% done by June 9, most fish probably spawned in Mainstem Red Dog Creek, no fry seen along stream margins
2009	low	Most fish probably spawned in Mainstem Red Dog Creek, breakup late, very few fry seen in July or August, fry observed in the reach just upstream of Station 151 indicate some spawning success in North Fork Red Dog Creek
2010	moderate	Breakup early, water flows low, moderate numbers of fry seen in North Fork Red Dog Creek in July, grayling fry caught in minnow buckets on August 16
2011	low	Spawning probably began on June 9, 2011 – no fry were seen in July and in late August a few fry (less than 5) were observed in backwaters
2012	low	observed small numbers (2 to 3) of fry along stream margins in several pools