Technical Report No. 12-04

North Slope Flooded Gravel Mine Sites, Case Histories

by Alvin G. Ott
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Parker T. Bradley

Mine Site B, Kuparuk River Unit
Photograph by Carl Hemming

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Alaska Department of Fish and Game
Division of Habitat

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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

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Acknowledgements

We thank the Prudhoe Bay and Kuparuk River oil production units for their financial and logistic support that allowed us to annually conduct field work on rehabilitated and flooded gravel mine sites and associated fluvial habitats. Many people from the oil and gas industry have assisted with this project: Chris Garlasco, Kevin Meyers, Mike Joyce, Martin Bozeman, Larry Krizan, Al Schuyler, Pat Metz, Scott Robertson, Dick Greif, and Caryn Rea (Conoco Phillips Alaska Inc; Phillips Alaska Inc; Arco Alaska Inc.) and Bill Streever, Steve Taylor, Karen Wuestenfeld, and Chris Herlugson (BP Exploration Alaska Inc). Financial support also was provided by the Alaska Coastal Management Program through the Coastal Zone Management Act of 1972.

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And, finally a special note of thanks to Dennis “Moose” Cunningham, who when asked one evening “you don’t have an extra connex hanging around?” proceeded to very quickly set up and make ready a very nice 40-foot connex labeled “Broadfish” to store our gear.

Introduction

In the early 1970s, state agency permitting and oil field monitoring were sparse with respect to development of the Prudhoe Bay oil field. Oil companies and contractors were extracting gravel from the Putuligayuk, Kuparuk, and Sagavanirktok rivers using shallow scraping of floodplain material and deep mining within active portions of the river. Water also was withdrawn from river systems during winter and summer to support development activities.

In the mid-1970s, the Alaska Department of Fish and Game (ADF&G) received several telephone calls regarding withdrawal of water from the Sagavanirktok and Kuparuk rivers during winter. According to information provided, intake hoses were being clogged with fish and overwintering areas were being drained of water. These overwintering areas were isolated pools of water under the ice cover without any recharge due to frozen streambed materials. The ADF&G began conducting field site inspections and fish overwintering studies in March 1976. Ultimately, working with the North Slope Borough (NSB) and the Alaska Department of Natural Resources (ADNR), the state and the NSB developed a policy that prohibited winter water removal from all North Slope streams between the Canning and Colville rivers during winter.

The policy banning water removal during the winter from streams and restricting in-stream mining of gravel essentially required the oil industry and contractors to find new gravel and water resources. This led to the development of large, deep, gravel mine sites sized to accommodate multiple users. During the permit review process for these sites, the ADF&G recommended buffers be maintained between the gravel sites and nearby rivers and streams. The quantity of overburden (organics and silts) that had to be stripped before reaching suitable gravels increased compared to that found in floodplain sites. For example, depth of overburden at sites in the Kuparuk River Unit was sometimes in excess of 16 m. The stripped overburden typically was stockpiled adjacent to the mine site. The end result was development of a number of deep gravel mine sites with large stockpiles of overburden. Some of the gravel mine sites were converted, either naturally or by manmade diversions, to water reservoirs. This process was followed by state and federal agencies and the oil industry for about ten years ending in the mid-1980s.

In 1986, the Habitat and Restoration Division of the ADF&G started collecting fish, water quality, and physical data on flooded gravel mine sites in the Prudhoe Bay and Kuparuk oil fields. The study design and approach were based in large-part on results obtained from a five-year USFWS funded gravel mine site research project (Woodward Clyde Consultants 1980). Results from the USFWS gravel mine site project clearly indicated that, depending upon site-specific factors, rehabilitated mine sites could provide high-quality habitat for fish and wildlife (Woodward Clyde Consultants 1980). Sites studied as part of the USFWS work included North Slope (Sagavanirktok, Kavik, and Shaviovik), western Alaska (Penny and Sinuk), and interior Alaska (Jim, Tanana, and Middle Fork Koyukuk) rivers.

Since 1986, the ADF&G conducted sampling on flooded North Slope gravel mine sites that had been rehabilitated to provide fish habitat. Fyke-nets were used as the primary sampling tool to collect fish. We conducted mark/recapture sampling events in several mine sites to estimate the size of selected fish populations. We made dissolved oxygen and temperature profiles by depth during the open-water season and in late winter. Physical measurements were directed at obtaining depth data to estimate volumes of water. Flooded gravel sites connected with fluvial systems have large volumes of water and maintain high concentrations of dissolved oxygen throughout the year, including during winter under ice cover of up to two meters. Based on results of multiple years of sampling, gravel removal guidelines designed to produce productive habitats for fish and wildlife were developed and have been implemented at new mine sites (McLean 1993).

In the late 1980s, the ADF&G changed its policy with respect to the location and design of material sites based on fish, water quality, and physical data collected by ADF&G and others. Our policy change simply stated that ADF&G would be receptive to reviewing new proposed gravel sites in floodplain habitats based on site-specific data, potential impacts to fish and wildlife resources, and the potential enhancement of habitats for fish and wildlife.

During the last 20 years, the oil and gas industry has prepared rehabilitation plans for all existing gravel mine sites in the North Slope oilfields. To the extent practicable, the criteria established by the ADF&G (McLean 1993) have been used to guide rehabilitation plans for existing sites, their expansion, and for new sites. The rehabilitation of Kuparuk Mine Sites B and D in the Kuparuk River Unit, the Kuparuk Deadarm mine site in the Prudhoe Bay Unit Western Operating Area, Sag Site C and Put 27 in the Prudhoe Bay Unit Eastern Operating Area, the Badami mine site, the Northstar mine site, and the Alaska Department of Transportation and Public Facilities (ADOT&PF) mine site have been completed (Figure 1).

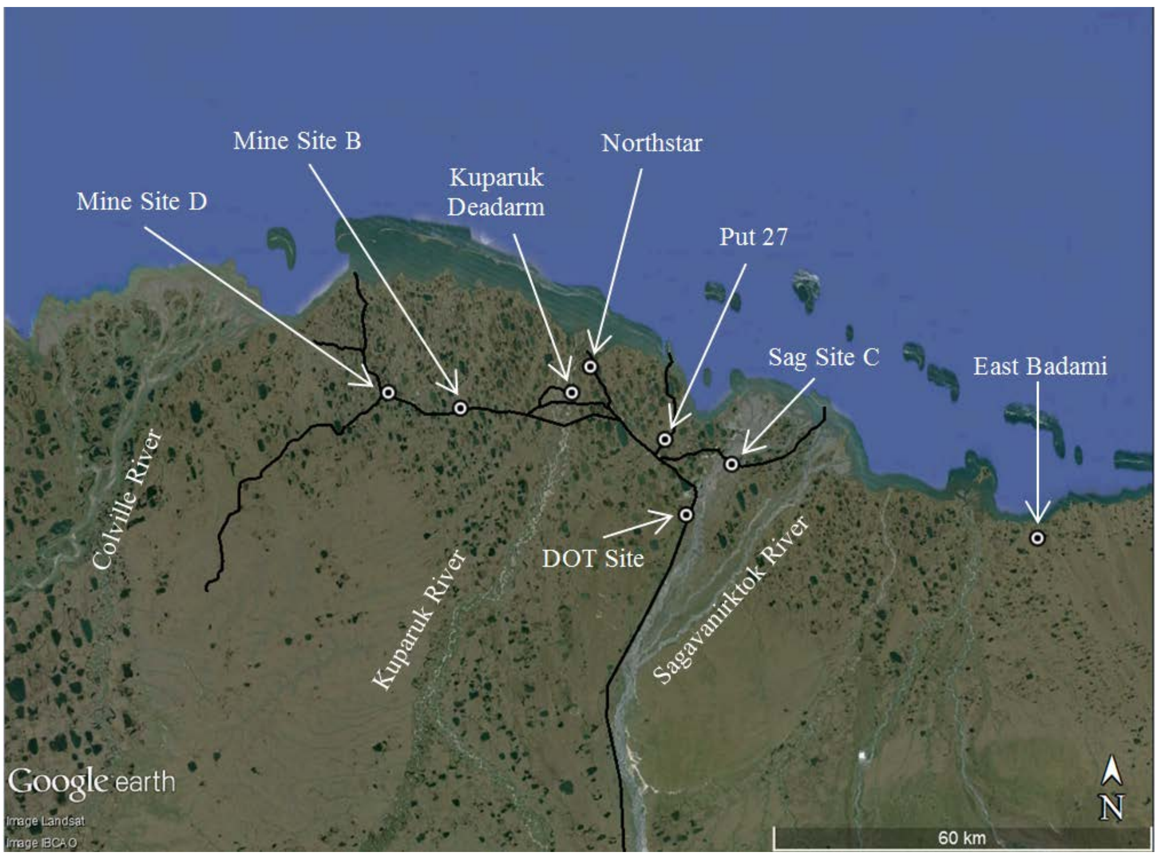

Figure 1. Flooded gravel mine sites across the North Slope oilfields.

Methods

Methods used during our gravel mine site study have changed over time. A summary of methods used to sample water and fish is presented in Table 1 and a more detailed description of methods follows in narrative form.

Table 1. Water and fish sampling methods used from 1987 to 2012 in North Slope flooded mine sites.

Mine Site	Water Quality (1987-1997)	Water Quality (1998-2004)	Fish (1986-1987)	Fish (1988-2012)
Kuparuk Mine Site D	vanDorn water bottle	Hydrolab Minisonde4		fyke nets, angling
Kuparuk Mine Site B	vanDorn water bottle	Hydrolab Minisonde4	gill nets, minnow traps	fyke nets, angling
Kuparuk Deadarm	vanDorn water bottle	Hydrolab Minisonde4	gill nets, minnow traps	fyke nets
Kuparuk Delta		Hydrolab Minisonde4		fyke nets
Put 27	vanDorn water bottle	Hydrolab Minisonde4		gill nets, minnow traps, fyke nets
DOT Deadhorse Site		Hydrolab Minisonde4		fyke nets, angling
Sag Site C	vanDorn water bottle	Hydrolab Minisonde4	gill nets, minnow traps	fyke nets
East Badami Creek		Hydrolab Minisonde4		fyke nets

Fish

Fish sampling was conducted one to four times a year during the study. Sampling almost always occurred during the open-water season, typically in late June, late July, and again in late August/early September. After 1995, most of the fish sampling was conducted late in the summer (late July to late August), when catches were higher and age-0 Arctic grayling (*Thymallus arcticus*), if present, were large enough to catch in the fyke nets.

During years when population estimates were desired, two sampling periods were used, one to mark fish and a second sampling event to determine the number of recaptures marked during the first event. These data were used to estimate the population size of the selected fish species.

During initial surveys in 1986 and 1987 at some of the mine sites (Kuparuk Mine Site B, Kuparuk Deadarm, and Sag Site C), variable mesh experimental gill nets, both floating and sinking, were used to determine if fish were present. The gill nets were 38.1 m long, consisting of five 7.6 m panels having stretched mesh sizes of 1.3, 2.5, 3.8, 5.1, and 6.4 cm (Hemming 1988). Winter sampling, with sinking gill nets, was done under the ice using the "Murphy Stick" method (Bendock 1980).

Additionally, minnow traps baited with salmon eggs also were used from 1987 to 1989 to determine if juvenile salmonids or ninespine stickleback (*Pungitius pungitius*) were present. Since that time, fish sampling has primarily been done with fyke nets. Angling, under certain conditions, has been used in sites with Arctic grayling.

Fish sampling gear consisted predominantly of 3.7 m long fyke nets with two 1.2 m^2 entrance frames, five hoops, a 1.8 m long cod end (fish collection/holding area), and two 1.2 m X 9.1 m wings attached to the sides of the first entrance frame. Smaller nets were used at sites where helicopter access was required (0.9 m^2 entrance frame with 0.9 m X 7.6 m wings). Nets were set from shore with a 30.5 m (large nets) or 15.2 m (small nets) lead net designed to funnel fish into the fyke-net (Figure 2). Nets were set and then checked at about 24-hour intervals. All fish, except ninespine stickleback, captured were identified and measured to fork length (FL) to the nearest mm, and released on site. Ninespine stickleback were counted and released with no length measurement. Catch per unit of effort (CPUE) for fyke nets is expressed as the number of fish caught per net day (24 h).

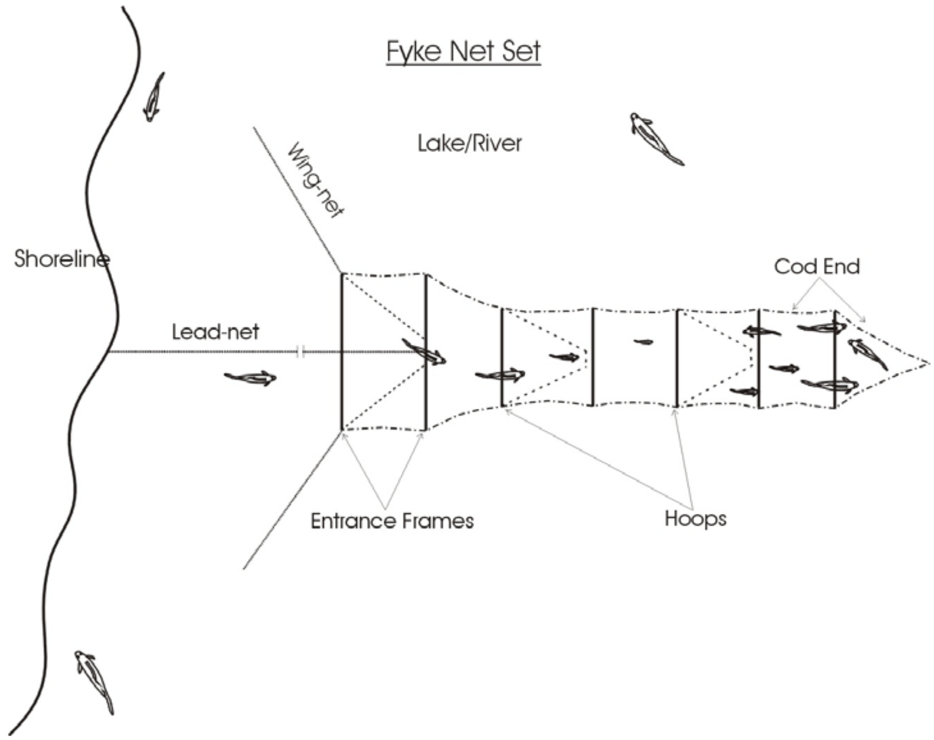

Figure 2. Fyke net set with lead from shoreline into the waterbody.

When large numbers of ninespine stickleback were caught, their numbers were estimated using a strainer that held an average of 135 fish. Occasionally fish were retained for positive laboratory identification, age validation, or for otolith microchemistry analysis.

In Kuparuk Mine Sites B and D in the Kuparuk River Unit, captured Arctic grayling $\geq$ 200 mm were marked with a numbered Floy® T-bar internal anchor tag. The abundance of Arctic grayling at these sites 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

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

Water Quality

Water quality data were collected using several different techniques over the years of this program. Data were collected as a depth profile from the surface to the bottom of each site at 1 m intervals. Depth profiles were conducted opportunistically, typically once during summer and once again in late winter.

Before 1998, water samples at depth were collected using a vanDorn water sampling bottle. Water samples were transferred to glass B.O.D. bottles; samples collected for dissolved oxygen (DO) were fixed on site and analyzed later. Conductivity and total dissolved solids (TDS) were measured during each water sampling event with a Check Mate 90 multi-meter (Corning Inc., Corning, NY) with a conductivity probe attached. Temperature was measured with a digital Fahrenheit thermometer or a mercury-based Celsius thermometer. In some instances, water temperatures were read from the pH meter or Check Mate 90.

DO (mg/L), hardness, and alkalinity from each water sample were measured using a Hach Digital Titrator (Model #16900-01) (HACH Company, Loveland, CO). The procedure for measuring DO was the 300 ml B.O.D. bottle method as outlined in the digital titrator manual. Hardness was determined using the Hach Digital Titrator Method for total hardness in mg/L as $CaCO_3$. Alkalinity, expressed as mg/L of $CaCO_3$, was determined using a colormetric method described in the titrator manual.

Since 1998, water quality data have been collected using a Hydrolab® Minisonde4® water quality probe connected to a Surveyor 4® digital computer display unit. Water temperature (°C), DO, percent DO saturation, conductivity (*u*S/cm), and pH were collected at each site at each depth.

Mine Site D, Kuparuk

Mine Site D is a 15.6 ha, 18 m deep site, located on Charlie Creek (local name), a small beaded tundra stream tributary to the Ugnuravik River (Figure 3). The Ugnuravik River is a beaded tundra stream that drains an 85 km^2 area. Peak spring discharge in the Ugnuravik River is about 28 m^3/s (Drage et al 1983). Ninespine stickleback and fourhorn sculpin (*Myoxocephalus quadricornis*) were found in the Ugnuravik River prior to development of the Kuparuk Oilfield (Woodward-Clyde Consultants 1980).

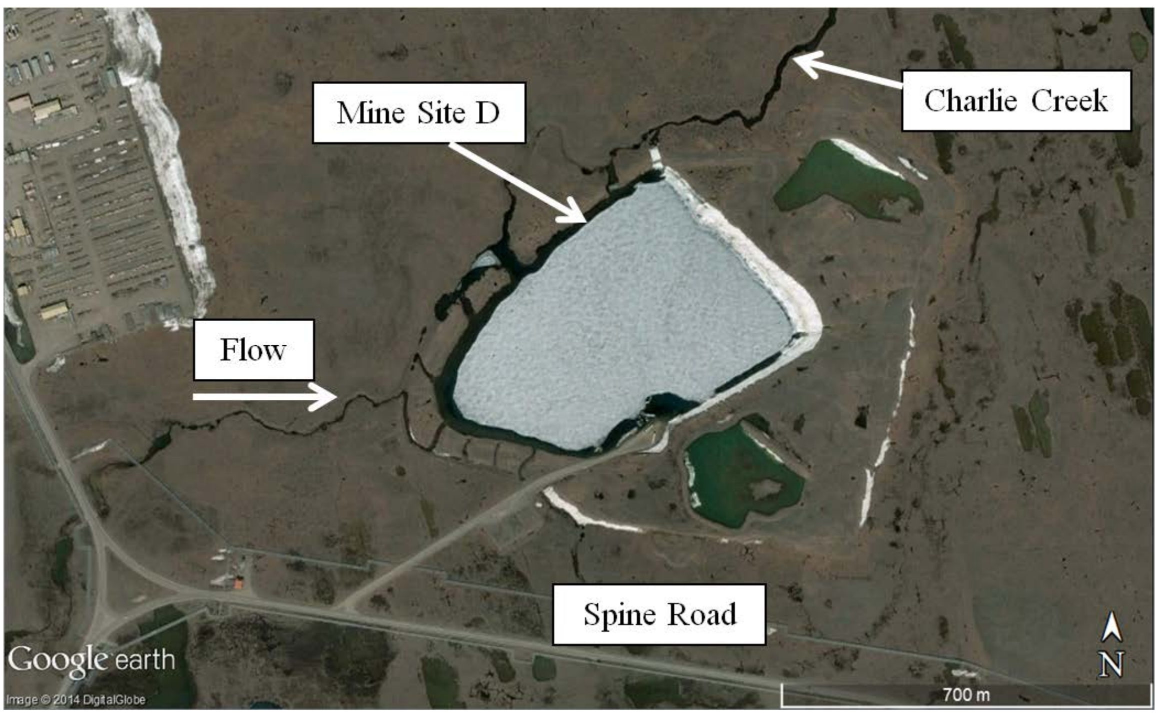

Figure 3. Mine Site D in the Kuparuk River Unit.

Fish Habitat Permit (FGIII-39-84) was issued to ARCO Alaska Inc. to construct a high-flow connection from Charlie Creek to Mine Site D on June 1, 1984. Water from Charlie Creek was to be diverted to flood the abandoned Mine Site D, thereby making it into a water reservoir. The diversion structure was designed to only allow peak breakup flows to enter the mine site and was armored to prevent scour. The diversion structure failed from thermal and hydraulic erosion and the entire flow of Charlie Creek entered Mine Site D.

After numerous meetings and discussions, it was decided to let Charlie Creek fill Mine Site D under the assumption that the thermal and hydraulic erosion would cease once the mine site filled with water. In 1986, Mine Site D filled reestablishing flow in Charlie Creek. Minimal thermal or hydraulic erosion has occurred since the site was flooded. Maximum water depth in Mine Site D is 18.3 m with an average depth of 14.0 m (Hemming 1995). Mine Site D contains about 580 million gallons of fresh water.

Rehabilitation efforts were completed in early May 1990 and included: construction of several inlet and outlet channels between Charlie Creek and Mine Site D, removal of overburden berms from the south and west side of the mine site, improvements to the access road culvert, and excavation of two perched ponds on top of the overburden stockpile located east of the site (Hemming 1995). Material removed from the overburden berms was placed on top of the ice to provide organic and fine grained material to the basin after the ice thawed. The northwest outlet channel lowered the water surface elevation in the mine site, thus drying the other inlet and outlet channels. Three failed attempts were made to fill in and stabilize the northwest outlet channel. Charlie Creek now flows directly into Mine Site D and leaves the mine site via the northwest outlet channel. One small unnamed tributary enters the southwest corner of Mine Site D.

Fish

To the best of our knowledge, Arctic grayling were not present in the Ugnuravik River and its tributaries when, in 1992, 710 Arctic grayling were transplanted from the Kuparuk River and Smith and Pebble creeks to Mine Site D (Hemming 1994) in an attempt to establish a population in the flooded mine site (Figure 4). Most Arctic grayling were less than 75 mm long and 53 were considered to be mature fish (> 300 mm) (Figure 4).

In 1993, we began to sample Mine Site D using fyke nets (Appendix 1). Catch composition over our entire sampling period (1993 to 2013) was dominated by ninespine stickleback (50,488) and Arctic grayling (1,943). Other species captured include broad whitefish (*Coregonus nasus*) and least cisco (*Coregonus sardinella*). While catches of ninespine stickleback were the largest, most of these fish were caught during the first six years of sampling (Figure 5). CPUE of ninespine stickleback dropped substantially after 2001 and remained low through 2013.

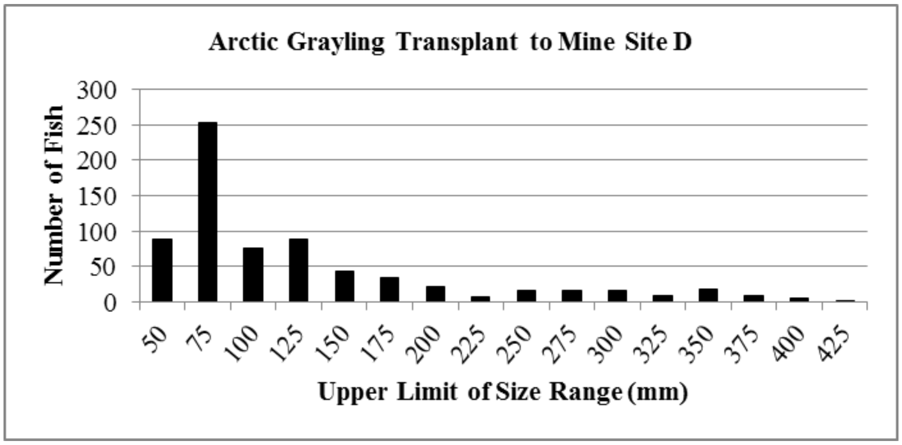

Figure 4. Length frequency distribution of Arctic grayling transplanted from the Kuparuk River drainage, including Smith and Pebble Creeks in 1992.

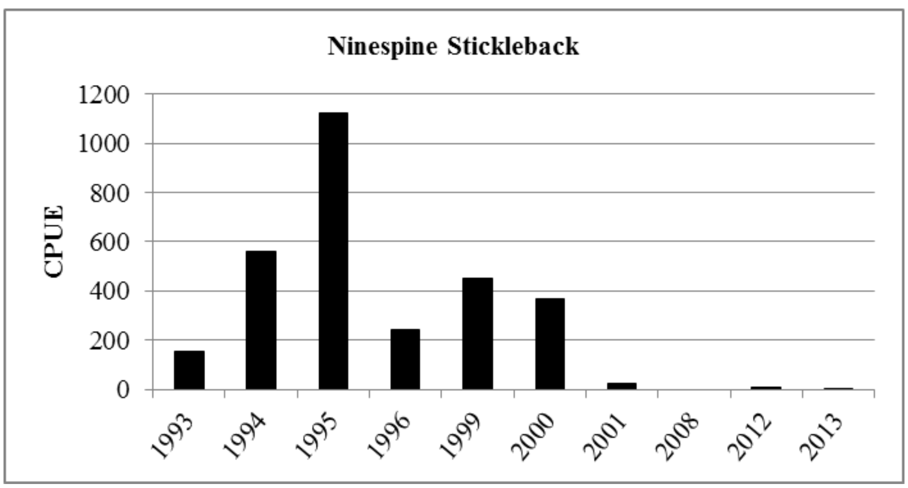

Figure 5. Catch per unit of effort of ninespine stickleback in Mine Site D.

Arctic grayling were introduced to Mine Site D once in 1992. The CPUE (all size classes) of Arctic grayling, with the exception of 2008, has been similar in all sampling years and has ranged from 3.8 to 20.5 fish/day (Figure 6). The CPUE for Arctic grayling fry captured in Mine Site D has ranged from 0.0 to 158.5 fish/day (Figure 7) and only one year exhibited large numbers of fry (2008).

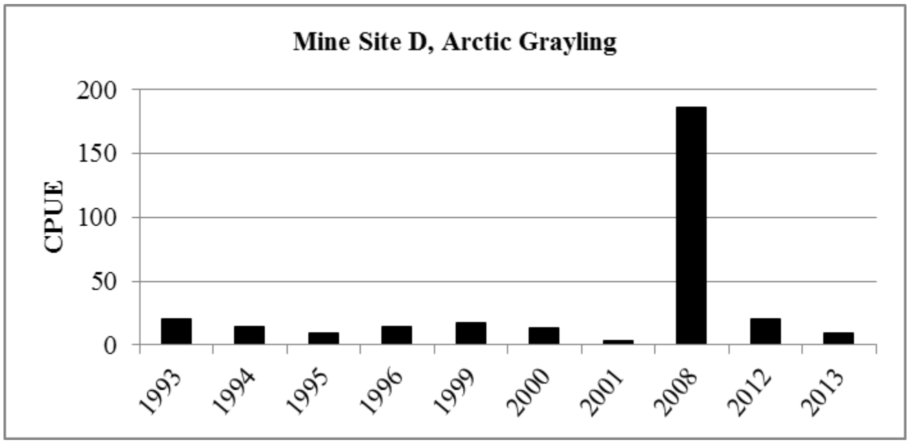

Figure 6. Catch per unit of effort for Arctic grayling (all size classes) in Mine Site D.

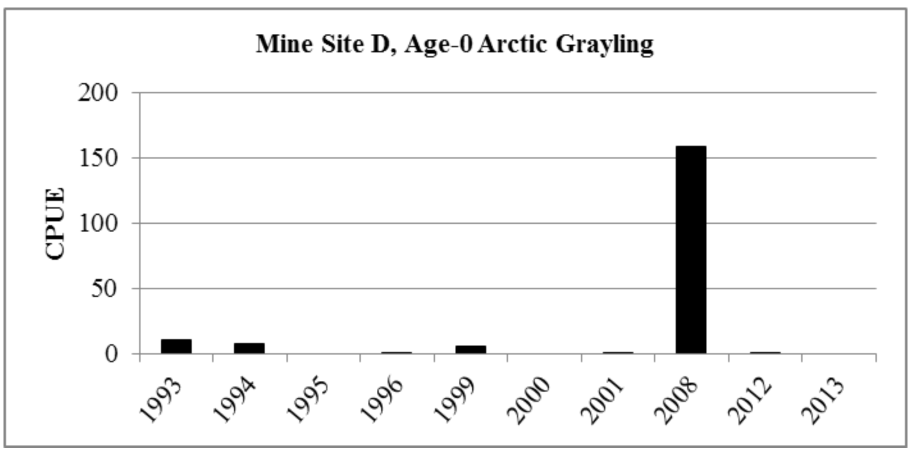

Figure 7. Catch per unit of effort for Arctic grayling fry (<70 mm) in Mine Site D.

Arctic grayling fry were not present in the catches from 1995-1998. Beginning in 1999, all age-0 and adult Arctic grayling and ninespine stickleback captured in fyke nets had at least one leech attached to them and many fish were infested with numerous leeches. Age-0 Arctic grayling often had leeches protruding from beneath their opercular covers; leeches were attached directly to gill filaments. This type and frequency of parasitism probably is lethal to age-0 Arctic grayling. However, in the fall 2008 and mid-summer 2012 and 2013, no leeches were seen on any of the captured fish.

Arctic grayling population estimates for fish ≥ 200 mm were made periodically between 1993 and 1999. The number of fish in the population appeared to decrease from 1995 to 1999 (Figure 8). This decrease may be directly related to the high rate of parasitism by leeches.

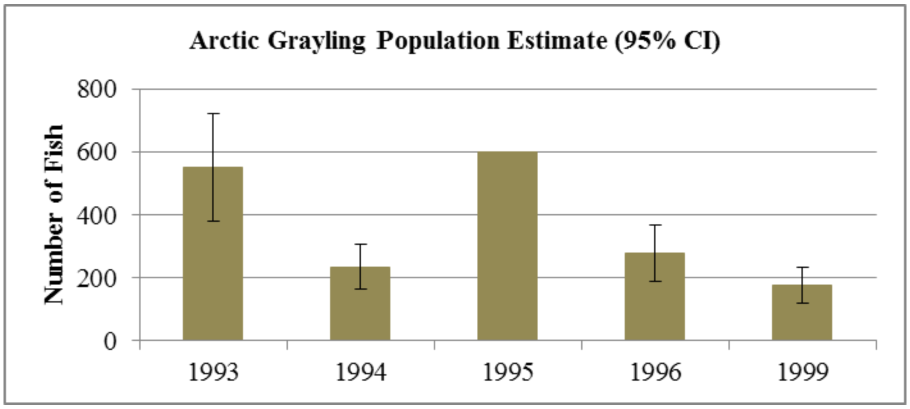

Figure 8. Arctic grayling population estimates in Mine Site D (note, there is no confidence interval for the 1995 estimate).

Only a few broad whitefish have been captured in Mine Site D with the CPUE by year varying from 0.0 to 0.4 fish/net day. Least cisco catches also were low until 2012 when the CPUE jumped to 59.6 (Figure 9).

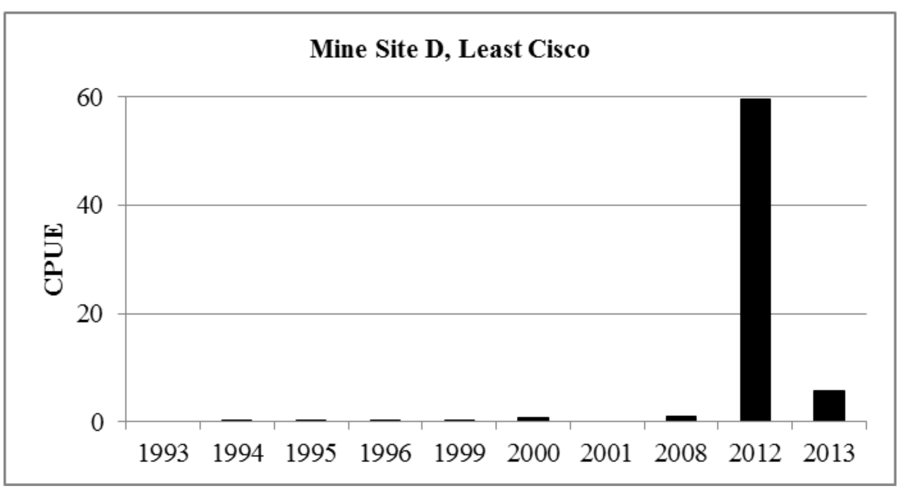

Figure 9. Catch per unit of effort for least cisco in Mine Site D.

Water Quality

Water quality data collected in Mine Site D are presented in Appendix 2. The most recent water quality profiles (DO, temperature, pH, and conductivity) were conducted in April and August of 2001 (Figures 10 and 11). During both seasons, the entire body of water was uniform from top to bottom and DO concentrations were near saturation. Late winter DO concentrations were slightly higher than those in August; however, as DO is relative to water temperature, the summer concentrations were actually higher in saturation. DO saturation ranged from 97.0% to 94.2% during summer and from 87.9% to 84.0% during winter. There was no depletion of oxygen with depth.

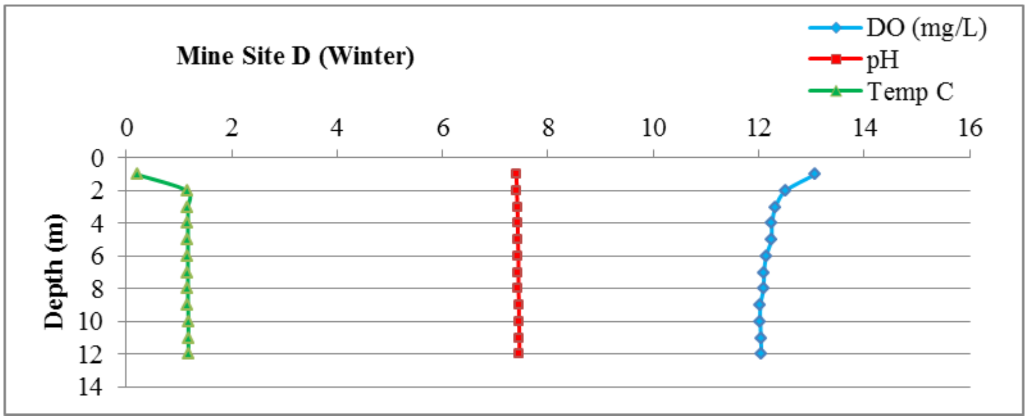

Figure 10. DO, pH, and temperature by depth in Mine Site D in late April 2001.

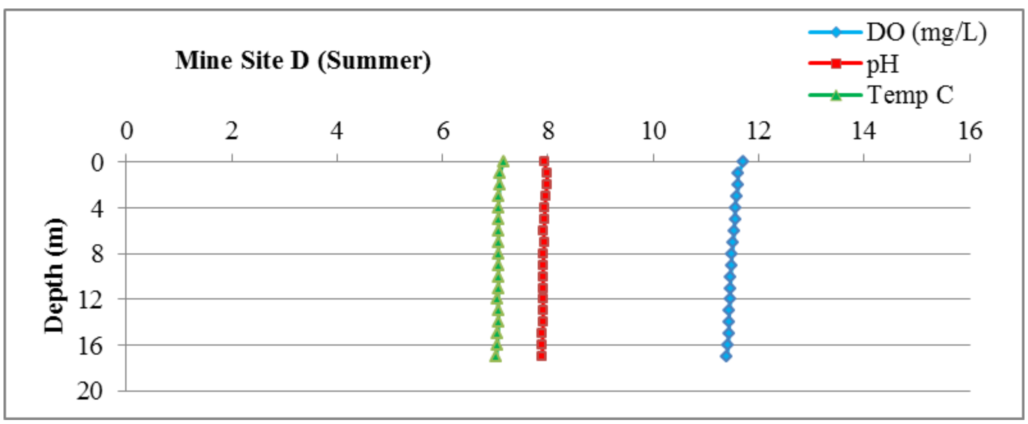

Figure 11. DO, pH, and temperature by depth in Mine Site D in August 2001.

Specific conductance from 1986 to 2001 is presented in Figure 12. Initially, specific conductance was high, but over time has decreased. Mine Site D took nearly two years to fill and during the filling process there was a substantial amount of suspended sediments carried into the waterbody from thawing and eroding ice lens.

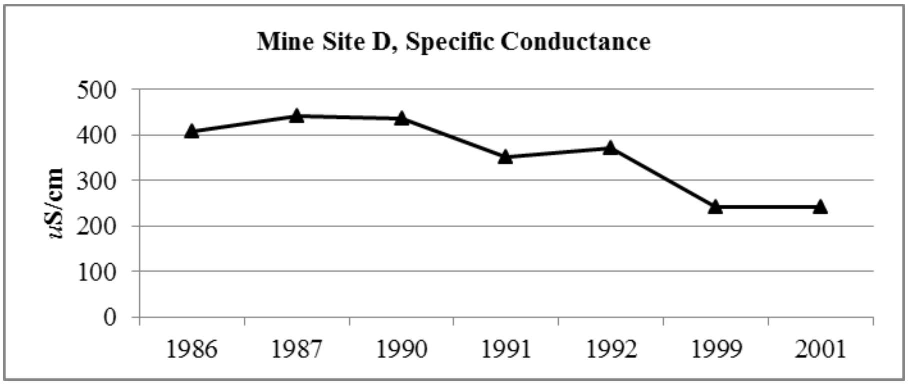

Figure 12. Average specific conductance throughout the water column, Mine Site D.

Mine Site B, Kuparuk

East Creek is a 26 km, beaded, tundra stream that drains a 132 km^2 area (Hemming 1994). East Creek enters Simpson Lagoon between the Colville and Kuparuk rivers. Peak discharge in East Creek often exceeds 28 m^3/s, but by late summer channel sections between pools may become intermittent. Mine Site B is located next to East Creek 16 km upstream from Simpson Lagoon (Figure 13). Fish use of East Creek prior to development of Mine Site B and subsequent flooding likely was limited to the ice-free season because there was no known deep water overwintering habitat in the creek.

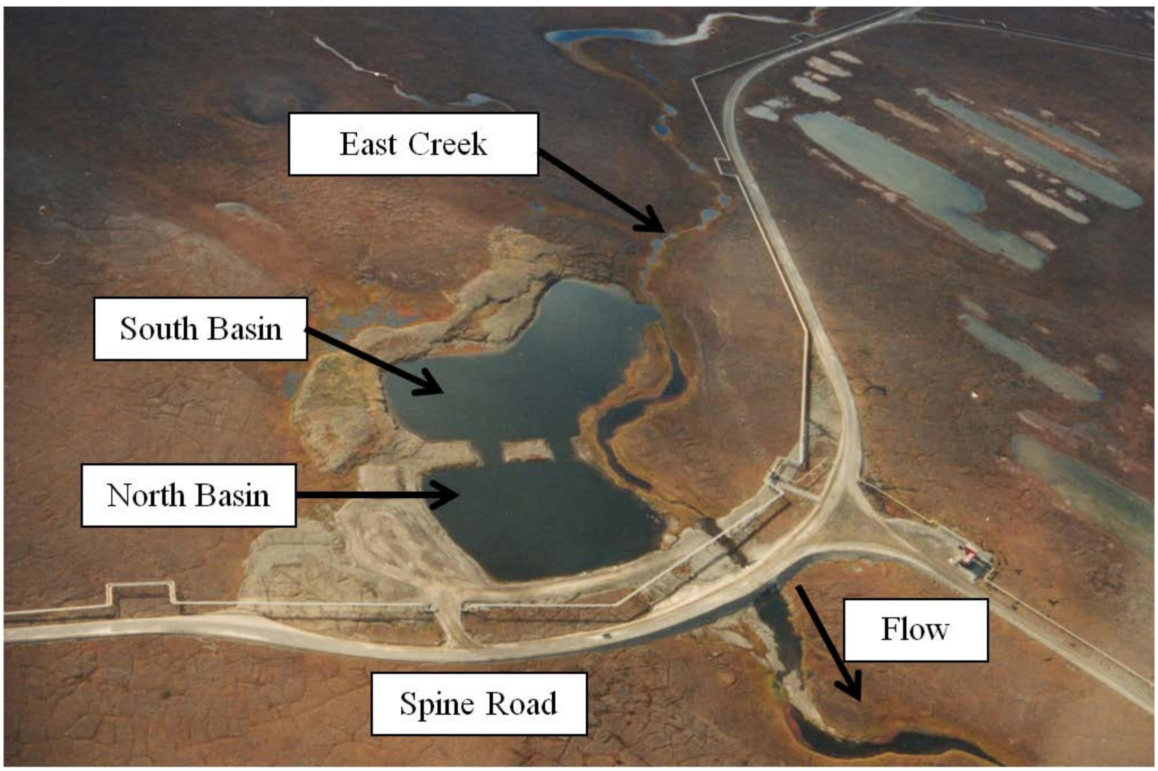

Figure 13. Mine Site B in the Kuparuk River Unit.

Gravel removed from this site was used for the construction of the Spine Road and access road to the Milne Point Unit. The site was flooded in 1978 when water from East Creek filled the excavated basins. Fish moving from other drainages probably were able to enter the flooded pit during high water events. The resultant 3.7 ha pond consists of two basins (1.3 and 2.4 ha). Maximum depth is 11.3 m with a mean depth of 7.1 m (Hemming 1988). In 1989, a channel was dug to directly connect East Creek with the upper end of the South Basin. Two channels were excavated to connect the South and North Basins. These channels provide continuous hydraulic links between East Creek and Mine Site B and a mechanism for fish movement during the ice-free season. Mine Site B holds about 65 million gallons of water and winter water use is quickly replaced each spring during breakup.

Fish

In 1986 and 1987 fish were sampled in Mine Site B with experimental mesh gill nets and minnow traps (Appendix 3). Only broad whitefish and ninespine stickleback were captured. In conjunction with ARCO Alaska, Inc. and British Petroleum Exploration, Alaska, we started a stocking program to introduce Arctic grayling to Mine Site B. Our working hypothesis was that Arctic grayling would use Kuparuk Mine Site B for overwintering and East Creek for spawning. Arctic grayling were not captured or observed in East Creek prior to the transplant.

In 1989, 1992, and 1993, we transplanted 734 Arctic grayling ranging in size from 40 to 403 mm from the Sagavanirktok and Kuparuk rivers to Mine Site B (Winters 1990; Hemming 1995) (Figure 14). Arctic grayling (n = 212) were moved from the upper Sagavanirktok River in 1989. In 1992, 280 Arctic grayling captured in the Kuparuk River were transported to Mine Site B.

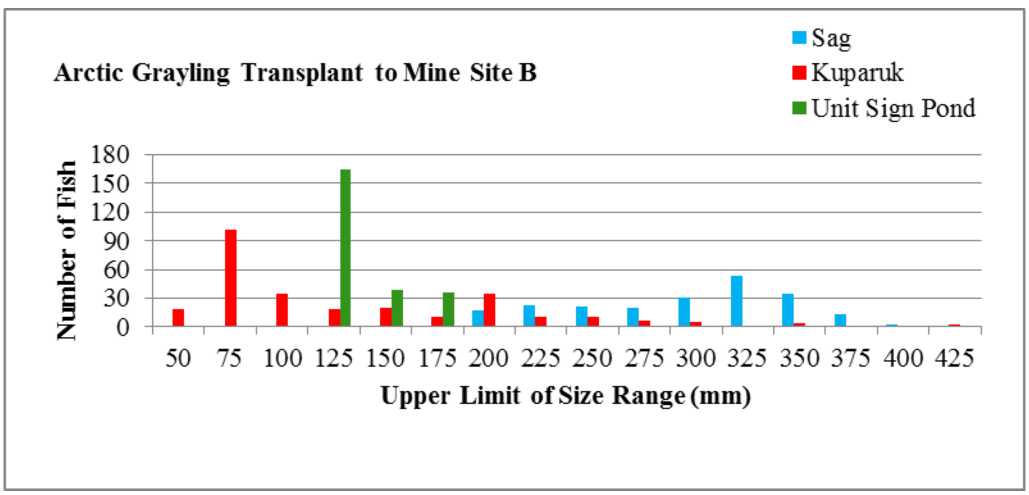

Figure 14. Length frequency distribution of Arctic grayling transplanted from the Sagavanirktok River (1989), Kuparuk River (1992), and Unit Sign Pond (1993).

In June 1993, age-0 and age-1 Arctic grayling were caught in the Kuparuk River and Smith Creek and moved to a small-isolated tundra pond to rear during the summer (Hemming 1995). In early September 1993, 242 age-0 and age-1 Arctic grayling were recaptured in the tundra pond and transplanted to Mine Site B. The average growth increment for the tundra pond fish was 61 mm or 0.87 mm/day (Hemming 1995). Survival rate, from introduction until capture, in Unit Sign Pond was 94.5%.

Catch composition over our entire sampling period (1987 to 2004) was dominated by ninespine stickleback (293,861) and Arctic grayling (4,194). Other species captured include broad whitefish, least cisco, Dolly Varden (*Salvelinus malma*), round whitefish (*Prosopium cylindraceum*), humpback whitefish (*Coregonus pidschian*), and one adult chum salmon (*Oncorhynchus keta*). While catches of ninespine stickleback were the largest, most of these fish were caught during the first three years of sampling (Figure 15). The CPUE of ninespine stickleback dropped substantially after 1991 and remained low through 2004.

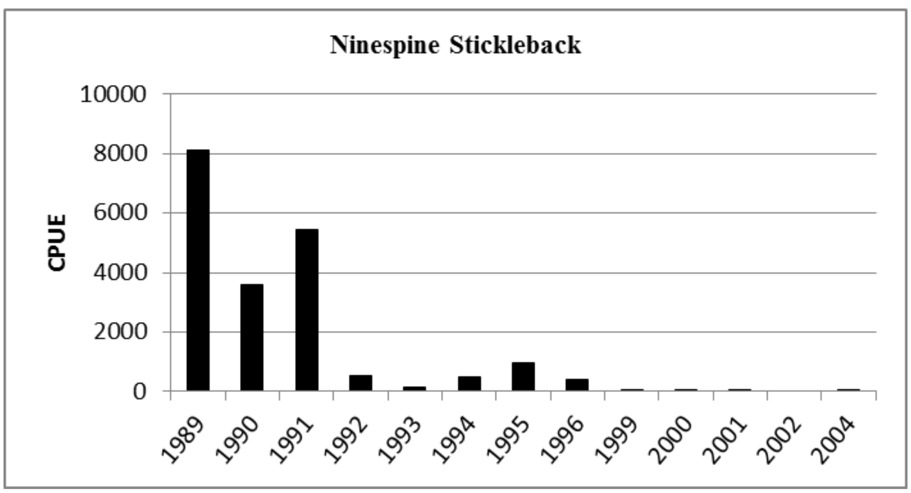

Figure 15. Catch per unit of effort of ninespine stickleback in Mine Site B and East Creek.

Arctic grayling were first introduced to the flooded mine site in 1989. The CPUE (all size classes) of Arctic grayling was relatively low the first two years and then began to increase in 1992 (Figure 16). The huge increase in 1993 was due to the catch of 1,327 age-0 Arctic grayling (Figures 16 and 17). Strong recruitment of age-0 Arctic grayling was only seen in one sampling year. In most years, there did not appear to any substantial number of age-0 fish.

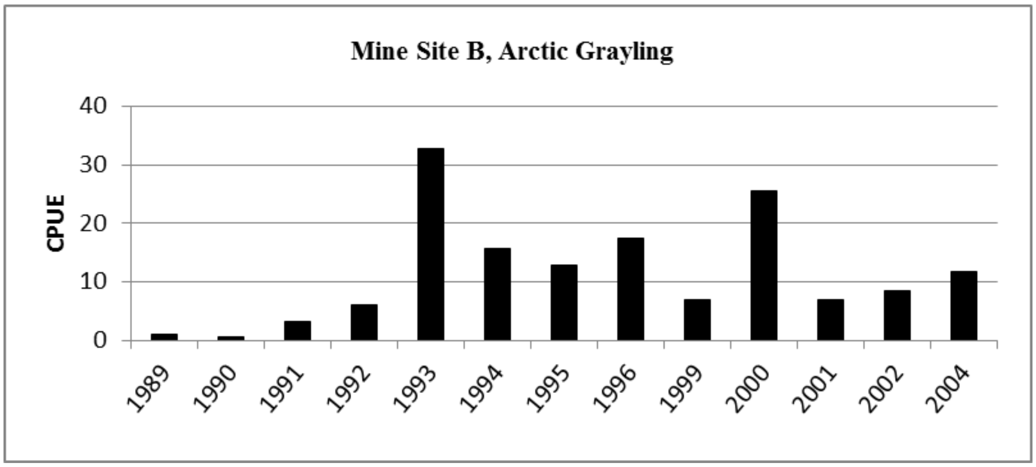

Figure 16. Catch per unit of effort for Arctic grayling (all sizes) in Mine Site B and East Creek.

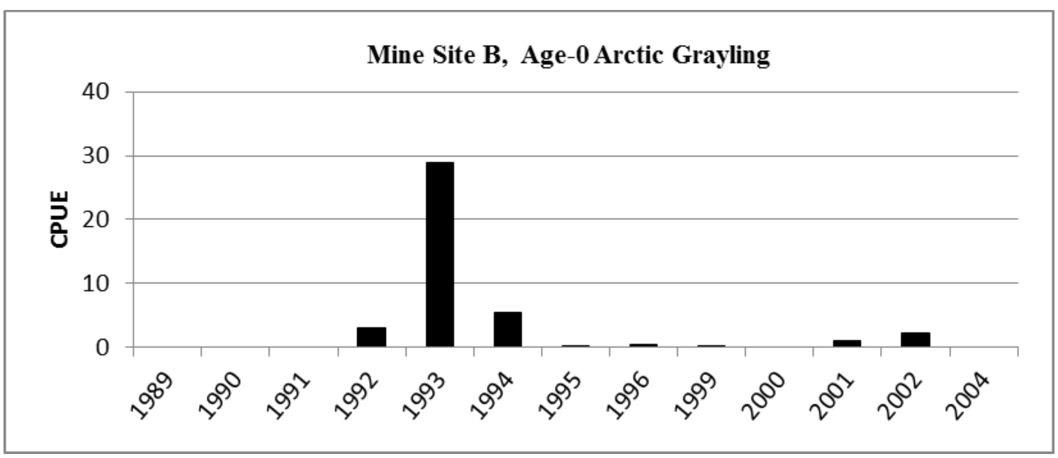

Figure 17. Catch per unit of effort for Arctic grayling fry (<70 mm) in Mine Site B and East Creek.

Arctic grayling population estimates for fish ≥200 mm fork length were made periodically. The Arctic grayling population took some time to establish following the transplant of fish to Mine Site B. The population steadily increased since 1996 and was estimated to be 1,250 fish in 2004 (Figure 18).

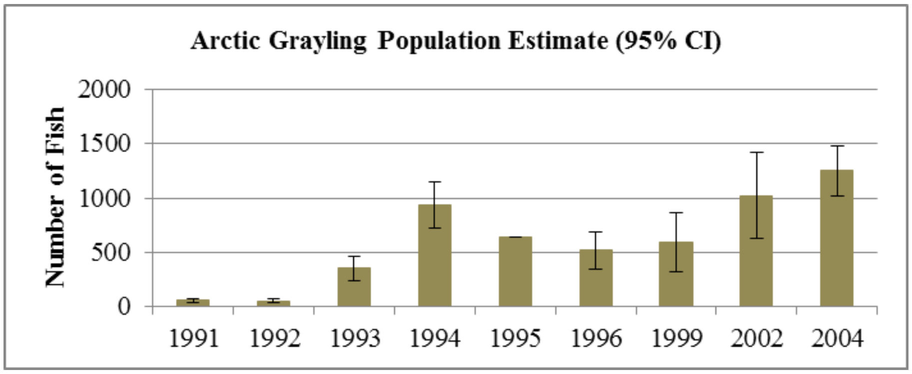

Figure 18. Arctic grayling population estimates in Mine Site B and East Creek

The CPUE for whitefish (broad, round, and humpback) and least cisco was higher from 1989 to 1991, then decreased to very low catches from 1992 to 1996, and increased from 1999 to 2004 (Figure 19). Least cisco, broad whitefish, and round whitefish were caught beginning in 1990, but humpback whitefish were not present until 2002. Age-0 broad whitefish and least cisco have been caught in Mine Site B, but to date, age-0 round and humpback whitefish have not been captured.

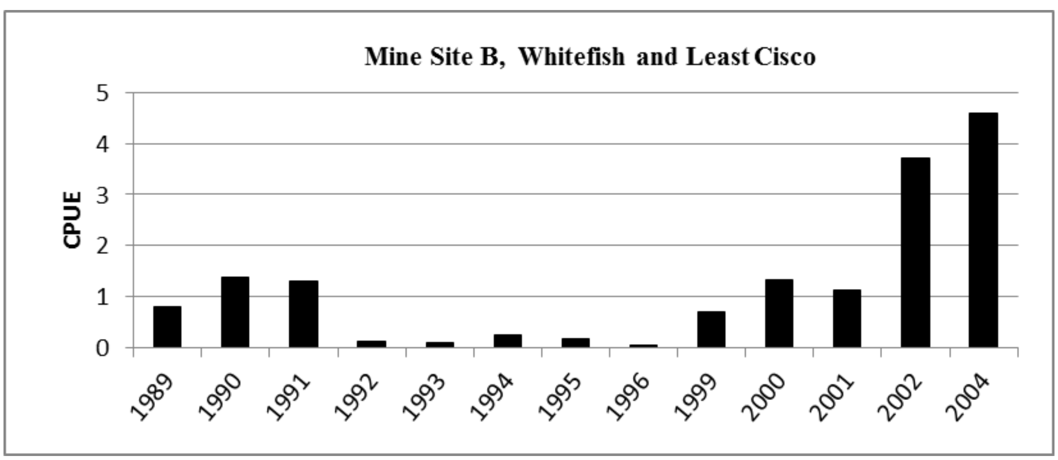

Figure 19. Catch per unit of effort for whitefish and least cisco in Mine Site B and East Creek.

Radio-telemetry work was conducted with broad whitefish in Lake Judith and Sagavanirktok River (located in the Prudhoe Bay oilfield complex) in the late 1990's (Morris 2000). Based on this work, a radio-telemetry project on broad whitefish in Mine Site B was initiated in August 2004 (Morris and Winters 2004). Ten adult broad whitefish were implanted with radio-transmitters during summer 2004 (average length 516 mm, 486 to 540 mm). Seven of the fish radio-tagged were judged to be 2003 non-spawners and likely to spawn in fall 2004, as determined by relatively good body condition (Figure 20). Three broad whitefish tagged were judged to be post-spawning fish and as such would not be expected to spawn in fall 2004. Radio-tracking flights revealed that in winter 2004/2005, 60% of the fish left East Creek and 40% stayed in Mine Site B to overwinter. One of the broad whitefish that left East Creek was relocated in the Colville River at Ocean Point. That fish later returned to Mine Site B the following summer.

Figure 20. Full-bodied robust fish (left) are typical of fish that did not spawn in the previous fall/winter and are likely to spawn in the coming fall/winter. Skinny, less robust-bodied fish (right) are indicative of fish that did spawn the previous fall/winter and are unlikely to spawning in the coming fall/winter. Photographs from Teshekpuk Lake Study.

Water Quality

Water quality data were collected in 1990, 1992, and 2001 (Appendix 4). Types of data collected were not consistent among years, but generally included DO, temperature, pH, and conductivity measured at one-meter intervals to create depth profiles for seasonal and annual comparisons. Both basins of Mine Site B were sampled in April 2001 and again in August 2001. Results from the winter sampling event show more than adequate DO concentrations in both lobes to support overwintering fish (Figure 21). Dissolved oxygen was depressed with depth in the north lobe of Mine Site B.

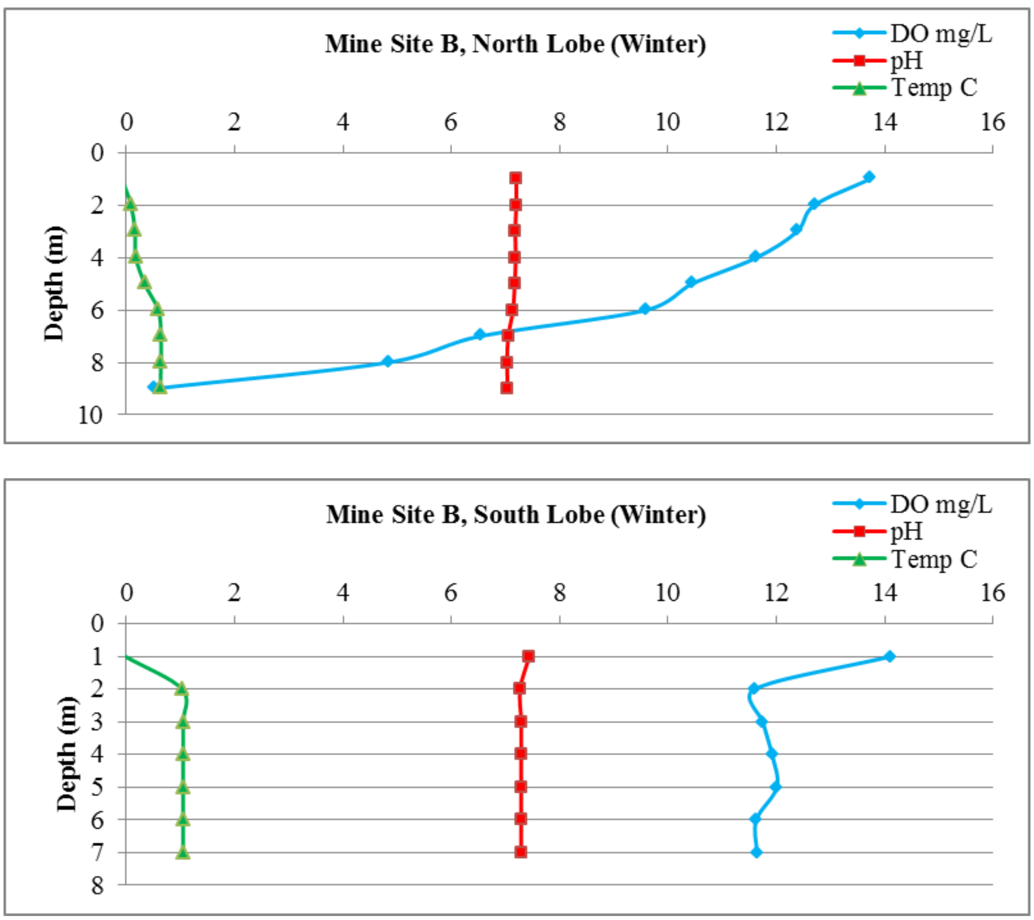

Figure 21. DO, pH, and temperature by depth in Mine Site B in April 2001.

On August 21, 2001, during the open water season, water was completely mixed from top to bottom with little variation in the parameters measured (Figure 22). The profiles indicate that the basins are similar with respect to pH and DO; however, water temperature is consistently around 0.7°C warmer in the north basin than in the south basin.

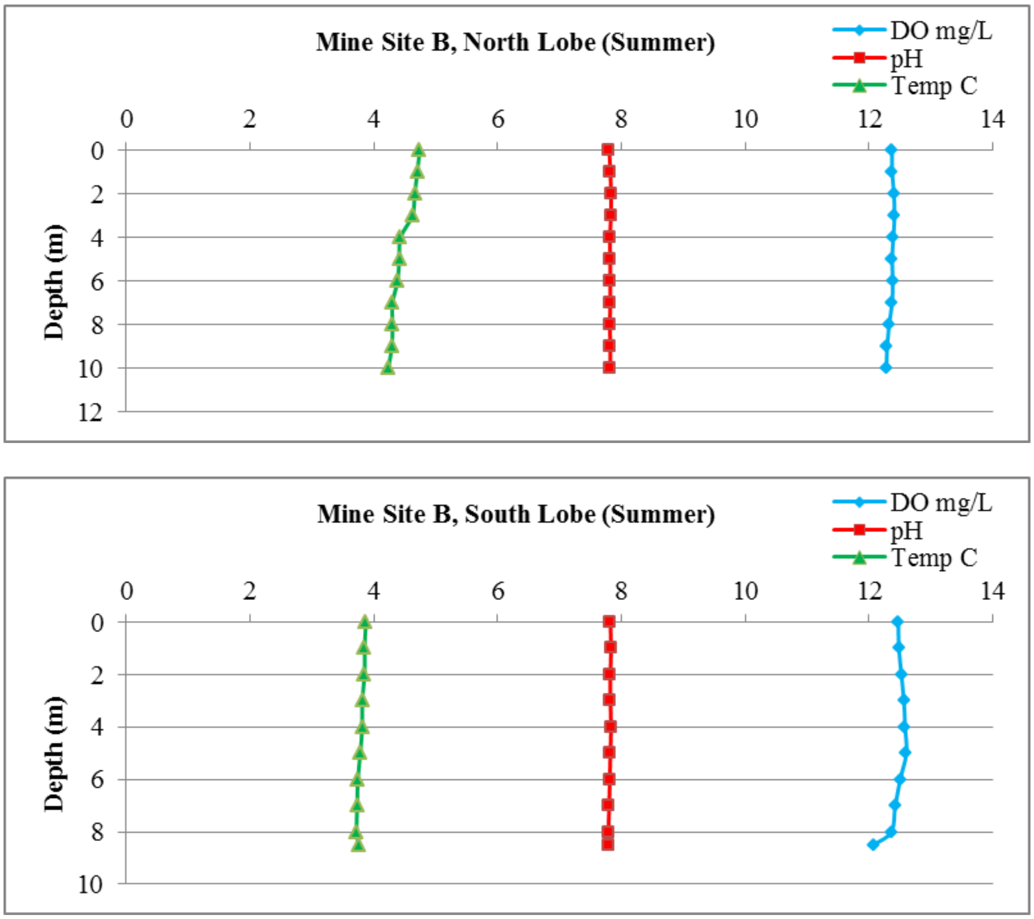

Figure 22. DO, pH, and temperature by depth in Mine Site B on August 21, 2001.

Kuparuk River Mine Site, Deadarm

In 1987, we began a sampling program in the Kuparuk Deadarm located in the floodplain of the Kuparuk River (Hemming 1988). The Kuparuk Deadarm was a side channel of the Kuparuk River that was isolated from the river with a gravel road to the M Pad drill site. The site consisted of six connected flooded gravel mine sites covering 58.3 ha (Figure 23). The lower sites were flooded by water backing up into the high-water channel from the East Channel of the Kuparuk River in 1986. A control structure (pipe with a valve) was located in the road separating the site from the river. Each spring during breakup this control structure can be opened to fill the mine site with water. BP Exploration excavated an expansion to Kuparuk Deadarm Reservoir #5 in the winter of 1988/1989 to provide gravel for a new drill site pad and access road. Spring high water flooded the excavation creating a 6.2 ha bay estimated to be less than 2.5 m deep (Hemming 1990). A large overburden dike was breached to connect the new site with the older portion of Kuparuk Deadarm #5 in 1991. The flooded Kuparuk River Deadarm gravel sites are interconnected and contain at least an estimated 1.1 billion gallons of water.

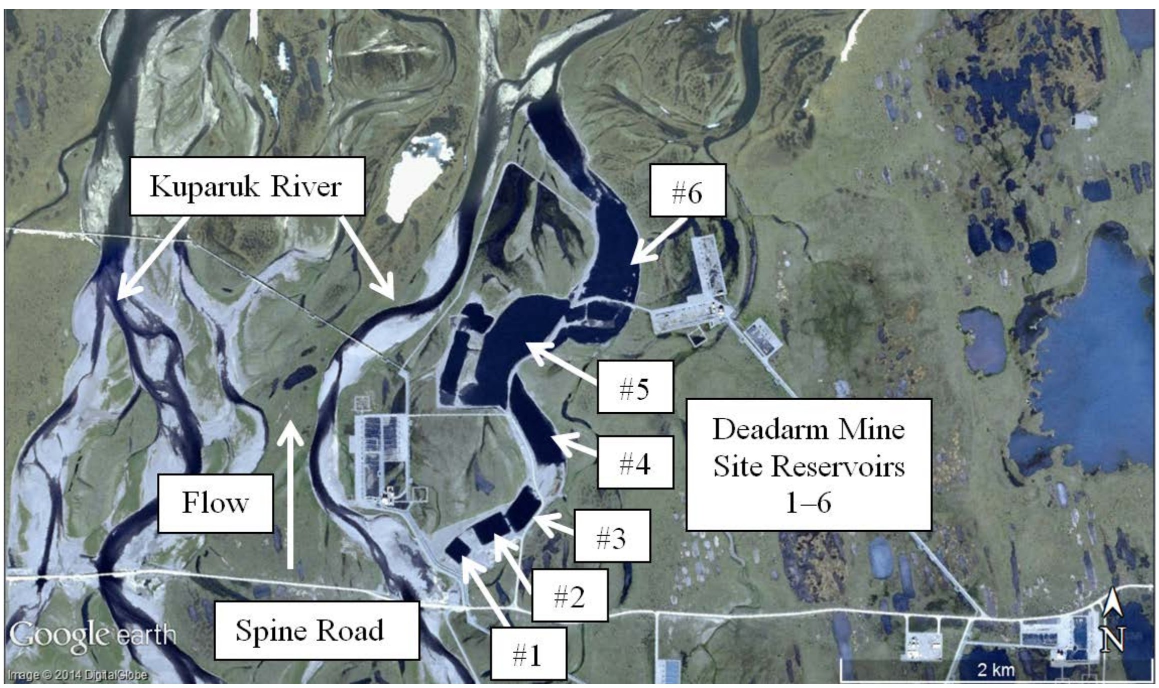

Figure 23. Kuparuk River Deadarm Mine Site

The Kuparuk River drains a 9,200 km^2 tundra watershed. Multiple channels are separated by islands that are relatively stable and frozen. Perched wetlands exist on some of these island features. The Kuparuk River was classified as a split channel river system. It has been estimated that 78% of the annual discharge occurs in June (Drage et al. 1983). Some stream reaches of the Kuparuk River maintain water beneath the ice throughout the winter months. The deep water zones occur at the confluence of subchannels and in reaches where flow impinges on a resistant bank. These deep waters provide overwintering habitat for fish (Bendock 1977). The Kuparuk River is known to support several freshwater species, including Arctic grayling, slimy sculpin, ninespine stickleback, and burbot (*Lota lota*). Anadromous broad whitefish, Arctic cisco (*Coregonus autumnalis*), least cisco, and pink salmon (*Oncorhynchus gorbuscha*) are present.

Fish

In 1987, we sampled flooded gravel sites in the Kuparuk River Deadarm. Gill nets captured Arctic grayling and Arctic cisco in winter under ice. Fyke net sampling during the open water seasons of 1989 and 1995 captured Arctic grayling, broad whitefish, least cisco, burbot, slimy sculpin, and ninespine stickleback (Appendix 5). The most common species present in the flooded mine site was Arctic grayling. Most of the Arctic grayling captured were juvenile fish less than 150 mm (Figure 24).

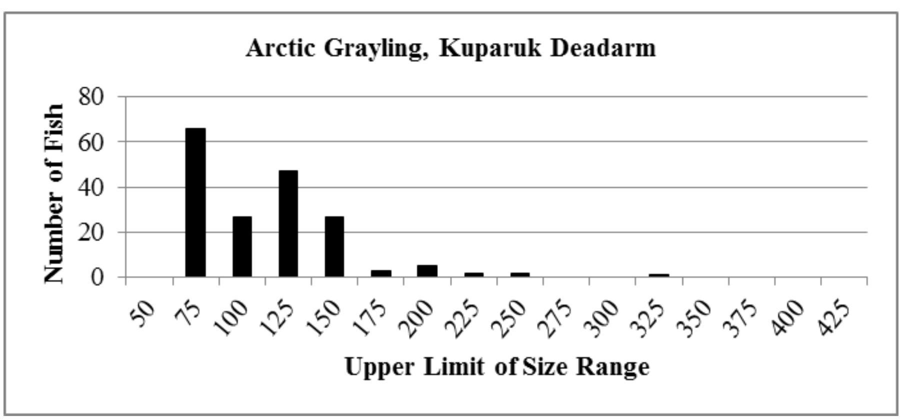

Figure 24. Length frequency distribution of Arctic grayling in the Kuparuk Deadarm.

Fyke nets fished in the Kuparuk River in 1992 and 1993 at sites near the Kuparuk Deadarm captured Arctic grayling, broad whitefish, slimy sculpin, burbot, and ninespine stickleback. As in the Kuparuk Deadarm, the most common species caught was Arctic grayling. Most of the Arctic grayling captured were juvenile fish less than 150 mm (Figure 25). Juvenile Arctic grayling were present in both the river and Kuparuk Deadarm, although more large adult Arctic grayling were captured in the Kuparuk River. The CPUE in the flooded Kuparuk Deadarm Reservoir #5 for Arctic grayling was 19.5 whereas it was 10.7 in the Kuparuk River.

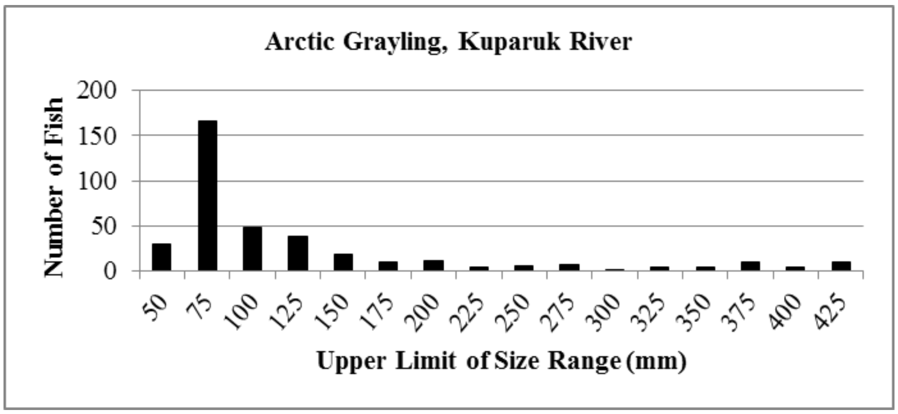

Figure 25. Length frequency distribution of Arctic grayling in the Kuparuk River.

Water Quality

Water quality in the Kuparuk Deadarm #5 Site and the Kuparuk River is best summarized by the April 2001 profile (Figures 26 and 27) (Appendix 6). Late April represents the worst-case scenario fish would encounter in terms of water quality throughout the year. The profile of the Kuparuk Deadarm #5 demonstrates a well-mixed, highly oxygenated body of water (nearly 90% saturated from top to bottom) in this deepest aliquot of the Deadarm. Conditions provide good overwintering habitat for fish. In the Kuparuk River, the pH was nearly identical, the temperature lower, and the DO concentrations were about half of those found in the Kuparuk Deadarm #5 Site.

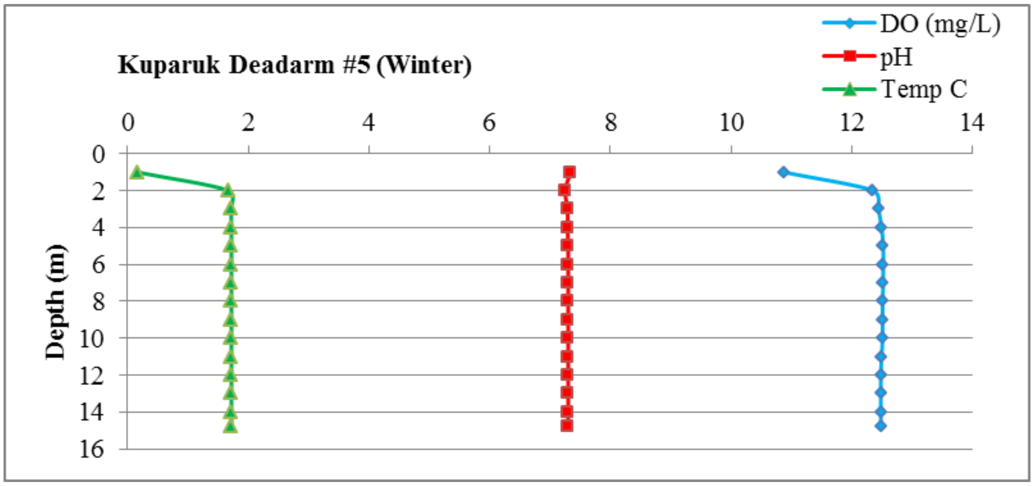

Figure 26. DO, pH, and temperature by depth in Kuparuk Deadarm #5 in April 2001.

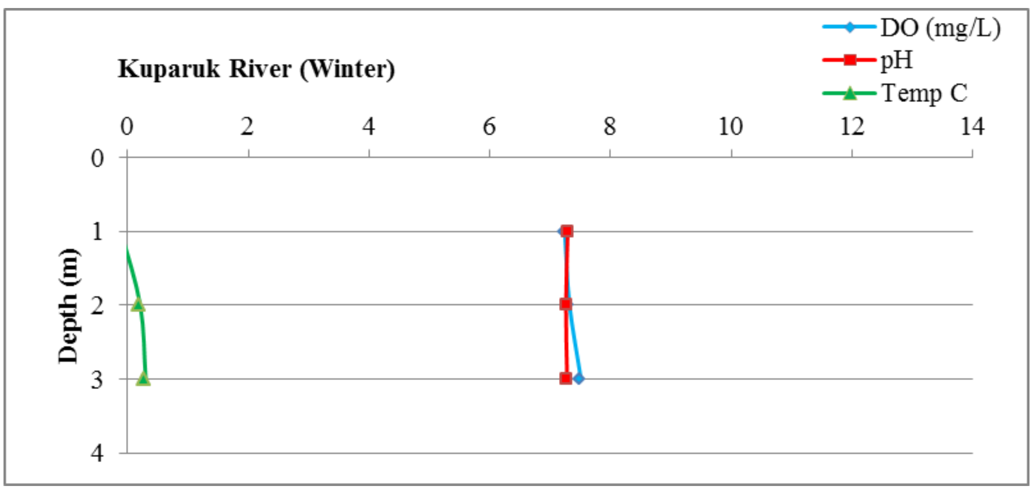

Figure 27. DO, pH, and temperature by depth in the Kuparuk River in April 2001.

Northstar Mine Site

Gravel requirements for the construction of the Northstar Island were estimated to be between 400,000 and 1.2 million cy. The large range of material needs was based on the potential inability to reuse material from Seal Island, a nearby abandoned drilling island. Although the plan for island construction was to reuse as much material from the old island as possible, the material source permitted was for the entire amount potentially required (1.2 million cy). Material was mined during winter 1999/2000 and the site was prepared for final rehabilitation by spring breakup 2000. The actual volume of gravel removed from the site was about 600,000 cy, which created a maximum depth of about 6.1 to 6.7 m. The Northstar Mine Site is located within the lower Kuparuk River Delta about 2.4 km upstream from Gwydyr Bay (Figure 28). Proximity to the Beaufort Sea made it likely the site would experience periods of high salinity.

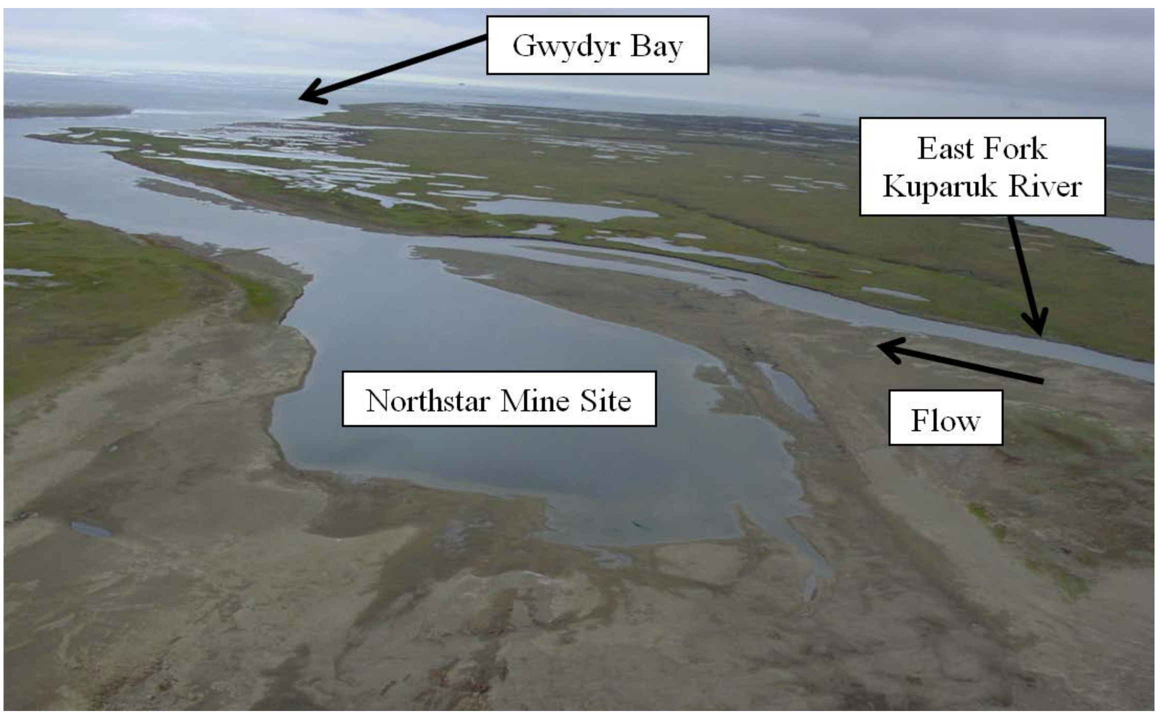

Figure 28. Northstar Mine Site.

The mine site configuration was inspected in May 2000 to ensure the site conformed to the approved rehabilitation plan. The site had been rehabilitated in accordance with the approved plan and was constructed to provide shallow littoral habitat along the east and southeast margins. The shallow area farthest to the north was designed for a final submerged depth of 1.2 m at the bank, deepening to 1.8 m before dropping off into the deep portion of the site. A shallow area in the middle of the east bank of the mine site was filled to an expected depth of 0.3 to 0.6 m using 8,000 cy of material from the abandoned Kuparuk State No. 1 Airstrip. The final portion of the east bank littoral zone was configured to be between 1.2 and 1.8 m deep and wrap around part of the south bank. Two piles of material were placed in the site, one in the southeast deep portion of the site, and one in the south end of the site to provide habitat diversity. Material comprising these mounds was less-thaw stable than the material used in the littoral areas and the final configuration of these features was believed likely to change with settling over time. Similar material was left along the western edge of the site about 6.1 m offshore to form a reef.

Break-up in spring 2000 was more extreme than usual, causing the Northstar Mine Site to flood from the upstream (southern) end. Several defined channels, largely dry at the time of the inspection, extended from the Kuparuk River to the southern end of the site. This event appeared to alter the final configuration of the site. The shallow area along the southeast end of the site was larger than planned, a result of the Kuparuk River moving material from the south bank into the mine site. It is unknown if the two mounds placed in the site were still present or if they had been eroded and distributed throughout the mine site floor.

Similarly, the fate of the reef type structure left on the western edge of the site was unknown. The constructed shallow areas along the east margin of the site were largely intact. The differing depths expected between the northeast, east, and southeast benches were present. The actual depths differed from expected, but the site was configured with adequate littoral habitat, especially with the added shallow habitat along the southern margin. Some portions of the east central margin were above water (as the plan indicated may occur), but most of the area was below water and shallow. The entire shallow area along the eastern margin was moated, with increased depth directly offshore rapidly progressing to shallower depths further from the bank. The area consisted of a fine organic substrate ranging from 0.15 to over 0.3 m deep.

Fish

Fyke nets fished in the Northstar Mine Site in August 2000 and August 2002 captured Arctic grayling, broad whitefish, least cisco, round whitefish, slimy sculpin, fourhorn sculpin, and ninespine stickleback (Appendix 7). Least cisco dominated the catch in 2000, but Arctic grayling were most abundant in 2002. Numerous, dime-sized, jellyfish were caught in August 2000. Two adult least cisco were caught in August 2000 (Figure 29). The majority of the least cisco and Arctic grayling captured were juveniles (Figures 30 and 31).

Figure 29. Least cisco captured at the Northstar Mine Site in August 2000.

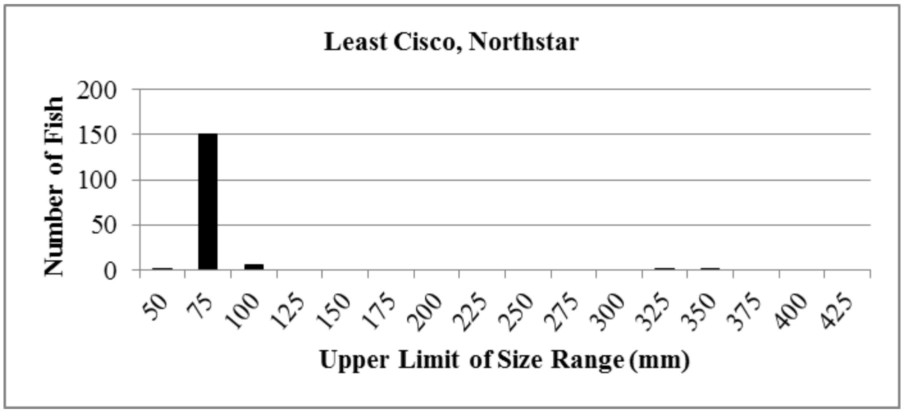

Figure 30. Length frequency distribution of least cisco in August 2000.

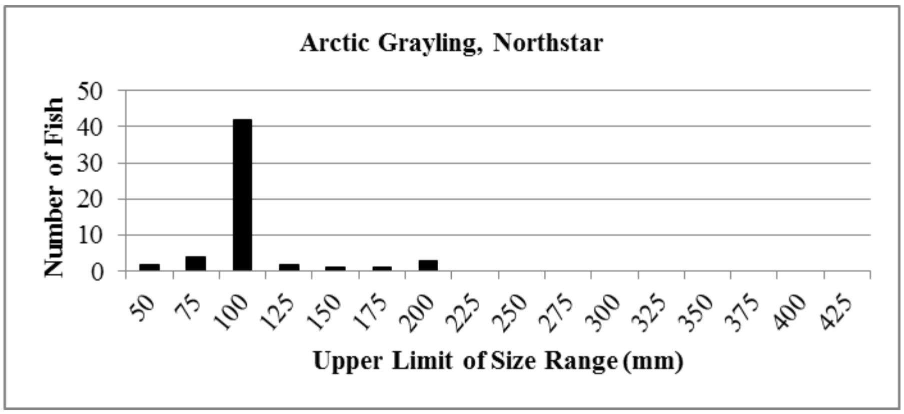

Figure 31. Length frequency distribution of Arctic grayling in August 2002.

Water Quality

Water quality was characterized with a single measurement at the southern-most end of the site near Net Site #2 in May 2000. Water temperature was 10.1 C°, DO was 89.4% saturated with an absolute reading of 9.43 mg/L, and pH was basic at 7.91. Conductivity was determined to be 21,307 μS/cm; this value was well above the calibration standards used to calibrate the instrument but still offers a fair representation of the salinity conditions. This conductivity is nearly as high as would be expected in the nearshore area, indicating the site had been inundated by saline water.

Winter water quality data were collected when the site was ice covered in April 2001 (Appendix 8). DO concentrations were uniform from just below the ice surface to the bottom, with a slight increase on the bottom (Figure 32). Measurement of pH indicated slightly acidic conditions from top to bottom. The slight increase in DO at the bottom of the site is an artifact of the extremely low temperature and high salinity measured in the water column. Specific conductance was about 0.06 S/cm which roughly equals 40 ppt salinity, or hyper saline water (Figure 32). The hyper saline conditions allowed the water body to super cool to around –2.3 C°. Attempts to clear the saline slush from the hole in the ice were unsuccessful. The water quality probe felt as if it were in slush throughout the entire water column with the exception of the deepest 0.5 m or less of water. The majority of the water body was ice covered with a thick layer of slush extending nearly to the bottom.

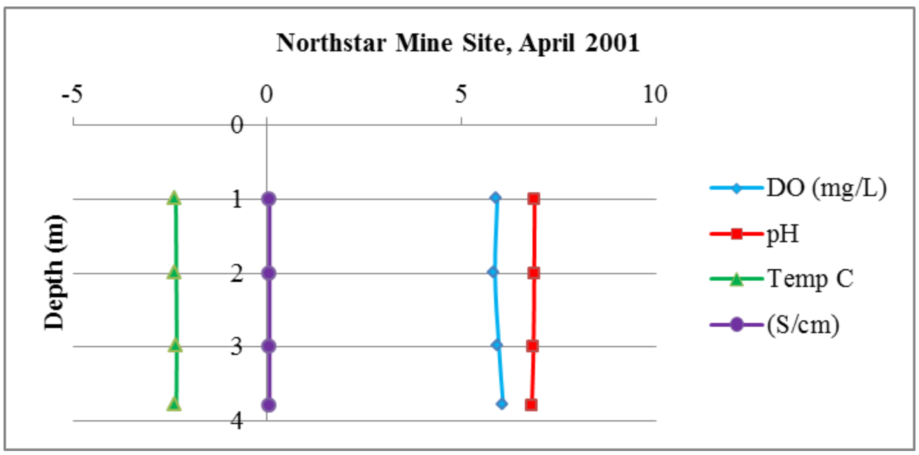

Figure 32. DO, pH, temperature, and salinity by depth in the Northstar Mine Site located in the Kuparuk River in April 2001.

Put 27 Mine Site

The Putuligayuk River Excavation is a 9.5 ha pool resulting from gravel extraction operations during the early development of the Prudhoe Bay oilfield (Hemming 1990). This site was located in the Putuligayuk River and has a maximum depth of 4.3 m and a mean depth of 3.8 m (Hemming 1990). The site is located about 6.4 km upstream of Prudhoe Bay (Figure 33).

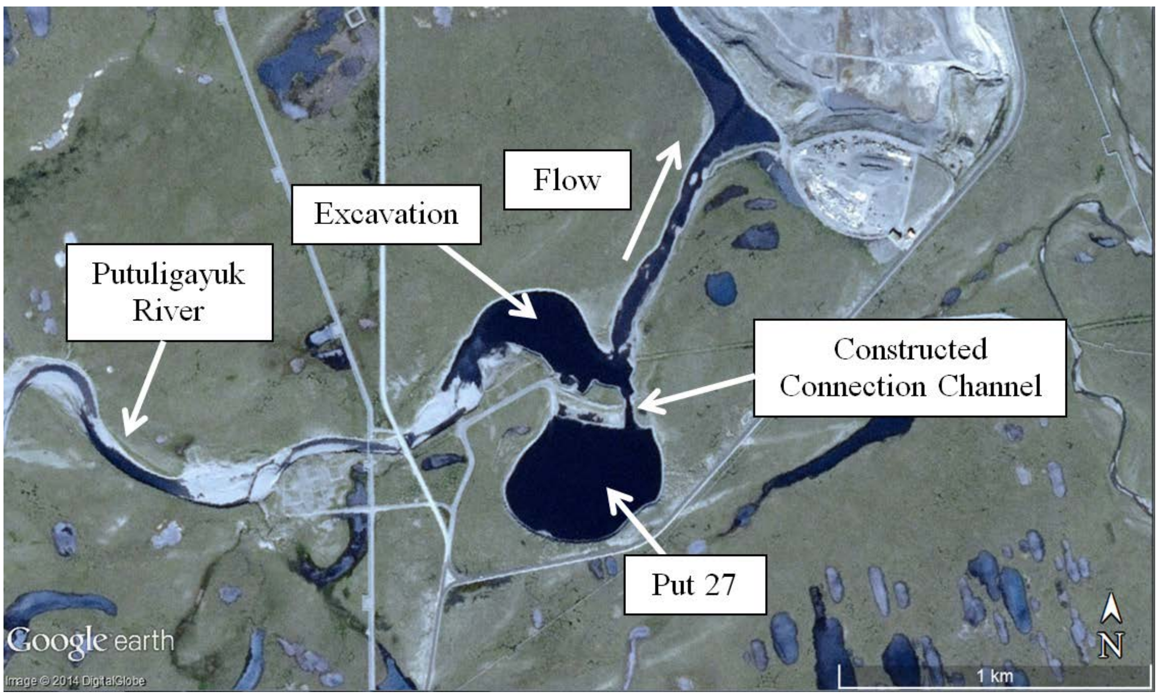

Figure 33. Putuligayuk (Put) River Mine Site

Put 27 was created in 1973 by mining within a large oxbow of the Putuligayuk River. A buffer (115 m wide) with a gravel flood control berm separated the Putuligayuk River from Put 27. Put 27 is located immediately south of the gravel extraction area in the main channel of the Putuligayuk River. In March 1989, we recommended construction of a channel connecting the river and Put 27 to provide a permanent connection to allow fish access to rearing and overwintering habitat.

BPXA developed a rehabilitation plan for Put 27 that included a connection with the Putuligayuk River. The connection was completed in April 1990 and Put 27 filled with water during the 1990 spring breakup, creating a large, deep lake feature. The flooded Put 27 Mine Site is about 14.2 ha and about 20 m deep.

Fish data for the Putuligayuk River prior to our sampling, which began in 1989, was limited. Ninespine stickleback was the only fish species known to use the Putuligayuk River, but it was hypothesized that other fish species were present.

Fish

We sampled the Putuligayuk River in the "Excavation", the flooded Put 27 Mine Site, and the Putuligayuk River upstream of the spine road (Figure 33). We sampled from 1989 to 1998 and captured 13 fish species (Appendix 9). Most fyke net sampling occurred in the Putuligayuk River "Excavation" and the Put 27 Mine Site. Ninespine stickleback, broad whitefish, and fourhorn sculpin were the most abundant fish species caught.

Marine species captured included Arctic flounder (*Liopsetta glacialis*), starry flounder (*Platichthys stellatus*), and Arctic cod (*Boreogadis saida*). Small numbers of Arctic grayling, Arctic cisco, least cisco, round whitefish, rainbow smelt (*Osmerus mordax*), threespine stickleback (*Gasterosteus aculeatus*), and Dolly Varden were present (Appendix 9).

Water levels at sampling sites in the "Excavation" and Put 27 Mine Site could fluctuate substantially during sampling events from winds moving saline water into and up the Putuligayuk River. These changes in water levels and salinity probably had direct effects on fish catches.

All Dolly Varden captured in the Putuligayuk River sampling area were first year, sea-run fish. The 21 Dolly Varden averaged 187 mm (140 to 241 mm, SD = 24). They were silvery and most likely from the Sagavanirktok River system.

For one sampling event in late August 1993, we used gill nets to capture fish in the "Excavation". Eight broad whitefish (429 to 485 mm), seven least cisco (297 to 358 mm), and one Dolly Varden (140 mm) were captured.

Ninespine stickleback catches were highly variable. At the Put 27 Ramp location, the CPUE of ninespine stickleback was highest in 1995, and relatively low in 1993 and 1994 (Figure 34).

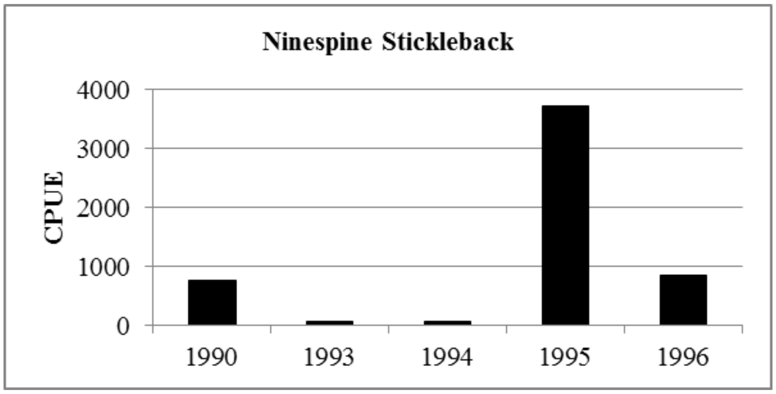

Figure 34. Catch per unit of effort of ninespine stickleback in the Put 27 Mine Site at the ramp.

Most broad whitefish captured in fyke nets were juvenile fish, probably age-0 and 1 (Figure 35). Most of the larger broad whitefish were those captured when gill nets were used.

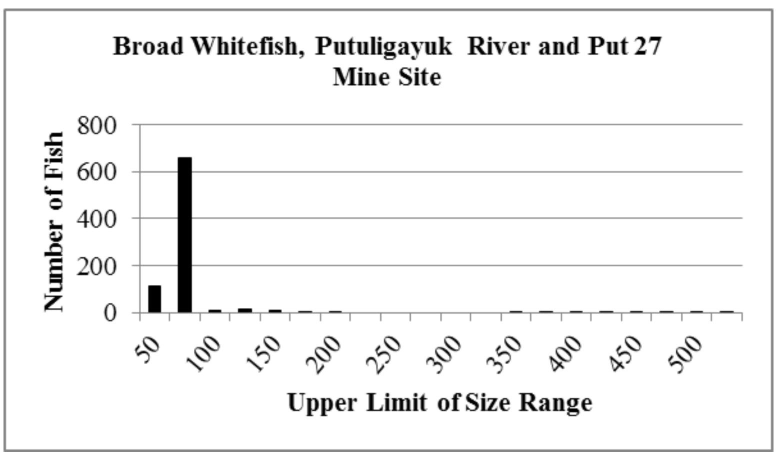

Figure 35. Length frequency distribution of broad whitefish in the Putuligayuk River and Put 27 Mine Site.

The catch of juvenile broad whitefish (age-0 and 1) in the Put 27 Mine Site increased over time (Figure 36). The highest CPUE occurred in 1996 when 29 broad whitefish per net day were caught.

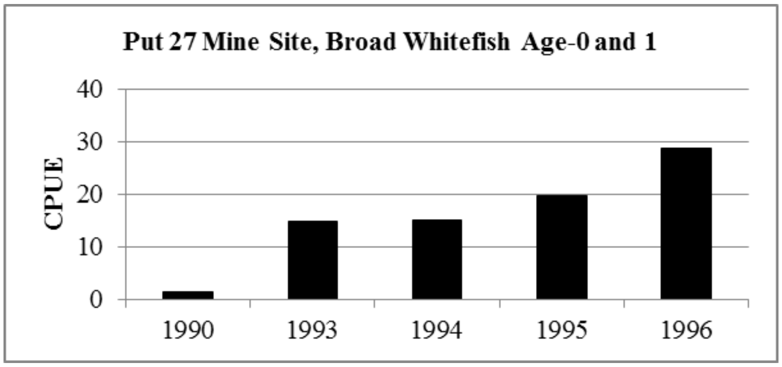

Figure 36. Catch per unit of effort of broad whitefish in the Put 27 Mine Site at the ramp.

A radio-telemetry project was conducted in the Prudhoe Bay Oil Field complex from 1997 to 1999. Broad whitefish were caught in Lake Judith and surgically implanted with radio-tags. Some of the radio-tagged broad whitefish moved from Lake Judith to the Putuligayuk River and Put 27 during late summer/early fall (Morris 2000) (Figure 37).

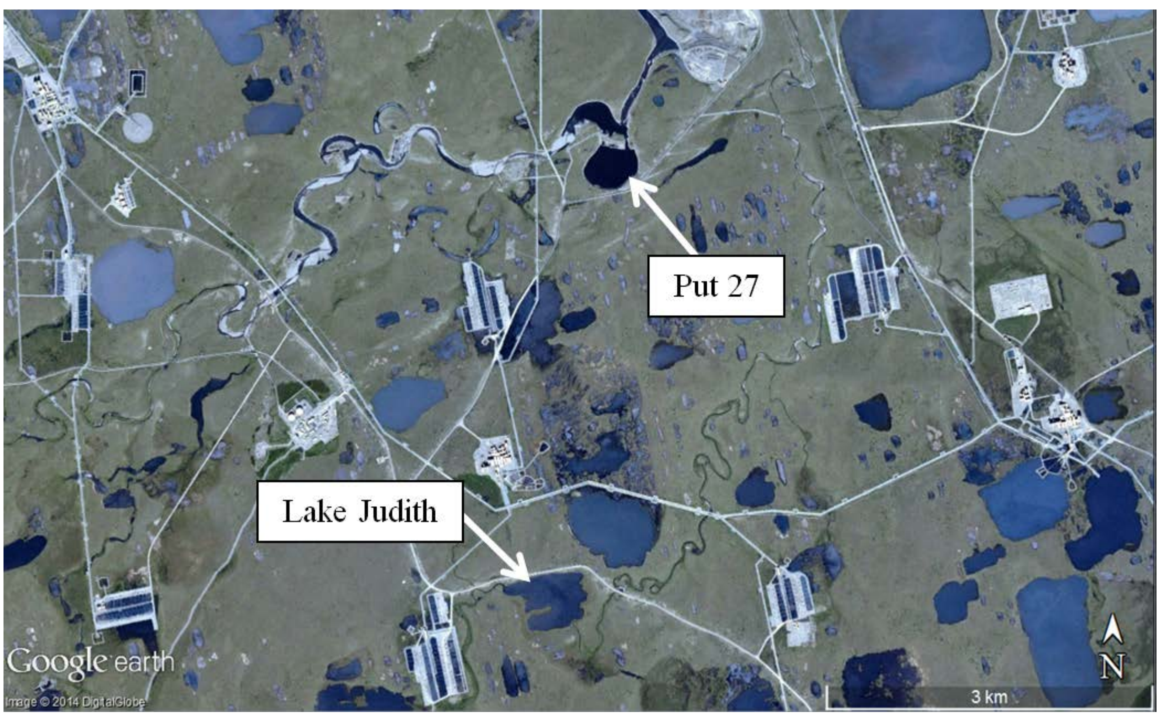

Figure 37. Lake Judith, located in the Little Putuligayuk River and the Put 27 Mine Site.

The mouths of the Little Putuligayuk and Putuligayuk Rivers are located in Prudhoe Bay. Some of the broad whitefish wintered successfully in Put 27 and the "Excavation" portion of the river (Morris 2000) (Figure 33). Broad whitefish seemed to spend prolonged periods of time at the upstream end of the "Excavation" portion of the river, adjacent to Put 27, at a shallow riffle during the September spawning season (Morris 2000).

Water Quality

Depth profile data including temperature, DO, pH, specific conductance and salinity were collected during the first year after the mine site flooded and periodically through 2001 (Appendix 10). Changes in water composition have occurred, primarily increased salinity with depth. The upper 2 to 5 m of water column was brackish, but salinities were below 2 ppt in summer and 8 ppt in winter (Figures 38 and 39).

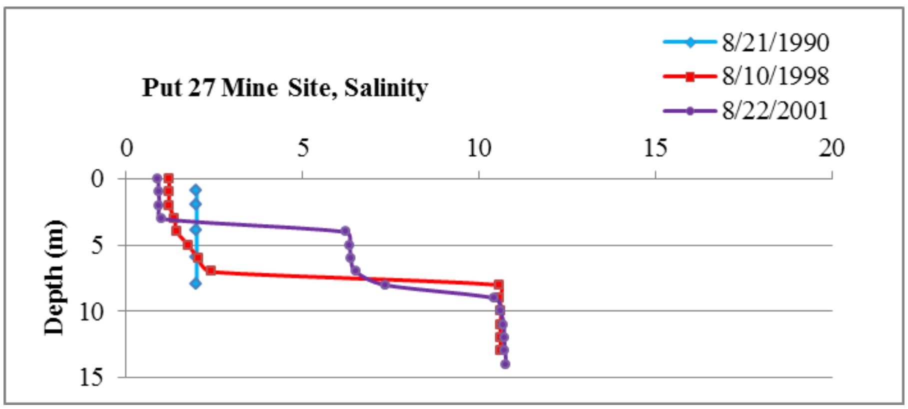

Figure 38. Salinity (ppt) in Put 27 Mine Site during open water (1990 to 2001).

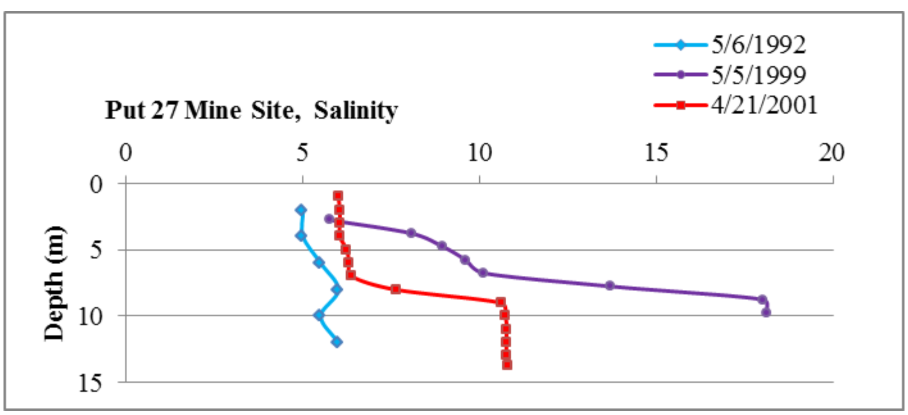

Figure 39. Salinity (ppt) in Put 27 Mine Site during winter (1992 to 2001).

When first sampled after flooding in summer 1990, the water body was filled with low salinity, highly oxygenated water. Water sampling conducted in winter 1992 indicated that while the water was still highly oxygenated from top to bottom, salinity increased with depth. Dissolved oxygen concentrations decreased substantially with depth during both the open water season and winter (Figures 40 and 41). The upper portion of the water column remains highly oxygenated.

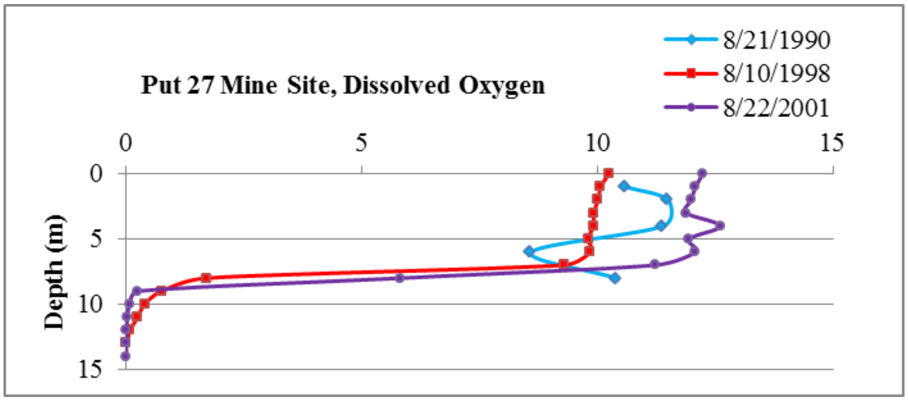

Figure 40. Dissolved oxygen in Put 27 Mine Site during open water (1990 to 2001).

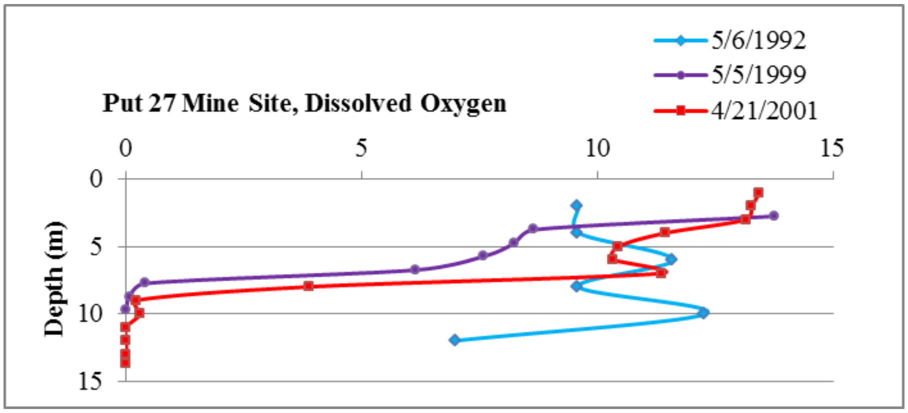

Figure 41. Dissolved oxygen in Put 27 Mine Site during winter (1992 to 2001).

While the deeper water in Put 27 does not provide suitable habitat for freshwater fish species or fish in general, there exists a layer of water several meters thick that is highly oxygenated and brackish. This habitat is used by brackish water tolerant and marine fish species during the open water season and during the winter.

Alaska Department of Transportation and Public Facilities Mine Site

In 1997, a gravel mine site operated by the Alaska Department of Transportation and Public Facilities (DOT) was flooded as part of the site rehabilitation plan. Additional rehabilitation work to overburden piles around the site margins was conducted during winter 1999/2000. The DOT Mine Site (MS 102) was connected to a tundra stream draining a large wetland complex to the west of the site (Figure 42).

Figure 42. DOT Mine Site in a Sagavanirktok River tributary.

The stream runs east from the mine site to the Sagavanirktok River about 0.75 km downstream. The mine site was designed to create fish overwintering habitat, and to provide a shallow bench around the margins of the pit for aquatic vegetation to take root and provide habitat for fish and aquatic invertebrates. A second aliquot separate from the DOT Mine site was mined in the early 2000s to provide gravel for airport improvements. A channel connecting the second aliquot with the initial site has been authorized, but not yet constructed.

The DOT Mine Site proximity to the Sagavanirktok River and the outlet channel connection with the river made it likely that fish species present in the river would use the flooded area and wetland complex.

Fish

Fish sampling with fyke nets conducted annually from 1998 to 2001 captured Arctic grayling, broad whitefish, least cisco, round whitefish, Dolly Varden, slimy sculpin, and ninespine stickleback (Appendix 11). Catch composition was dominated by ninespine stickleback and Arctic grayling. Some Dolly Varden had parr marks indicating that they had not made their first seaward migration. The CPUE of ninespine stickleback was variable from 1998 to 2001, but reached its lowest rate in 2001 (Figure 43).

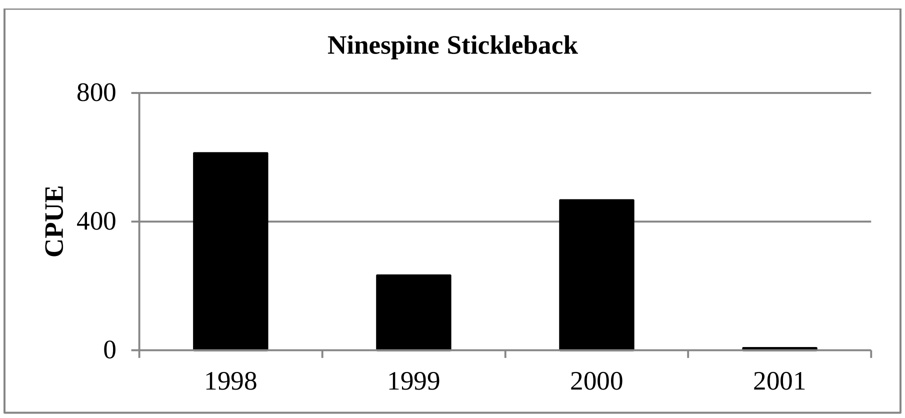

Figure 43. Catch per unit of effort of ninespine stickleback in the DOT Mine Site.

Arctic grayling were caught each year, but only in 1998 were fry present in the August sampling period. The CPUE of Arctic grayling age-1 or older varied from a low of 2.8 in 1999 to a high of 9.7 in 2000 (Figure 44). The Arctic grayling caught were representative of most size classes present in the Sagavanirktok River drainage (Figure 45).

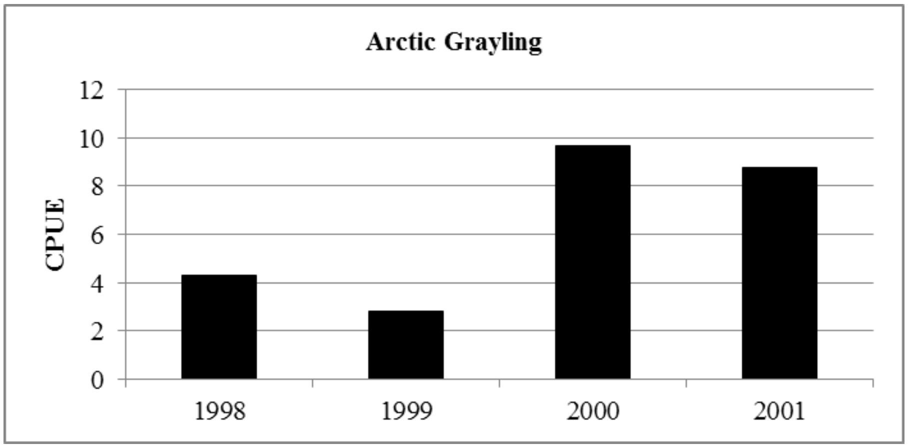

Figure 44. Catch per unit of effort of Arctic grayling in the DOT Mine Site.

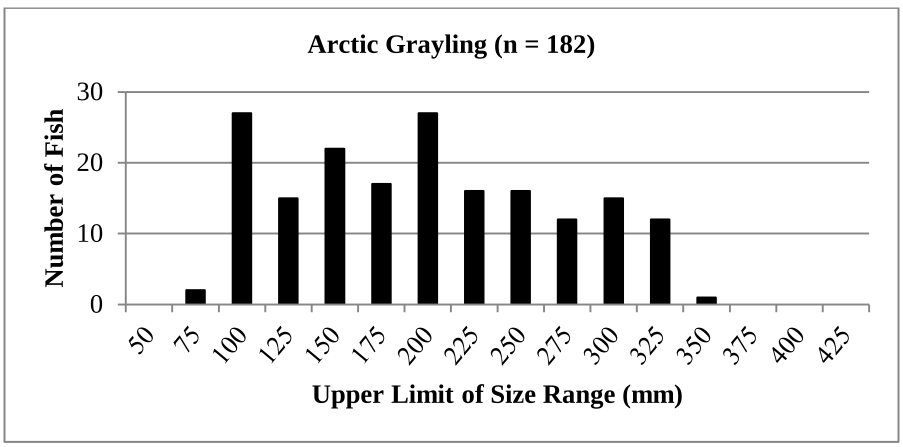

Figure 45. Length frequency distribution of Arctic grayling in the DOT Mine Site.

Water Quality

Water quality data were collected in winter and late summer 2001 (Appendix 12). Late winter DO concentration was 4.18 mg/L at the bottom and ranged from 12.02 to 13.36 mg/L from the top of the water column to a depth of 14 m (Figure 46). Dissolved oxygen concentrations during August 2001 were between 11 and 12 mg/L at all depths (Figure 47). Adequate DO exists to support fish throughout the year in the DOT Mine Site.

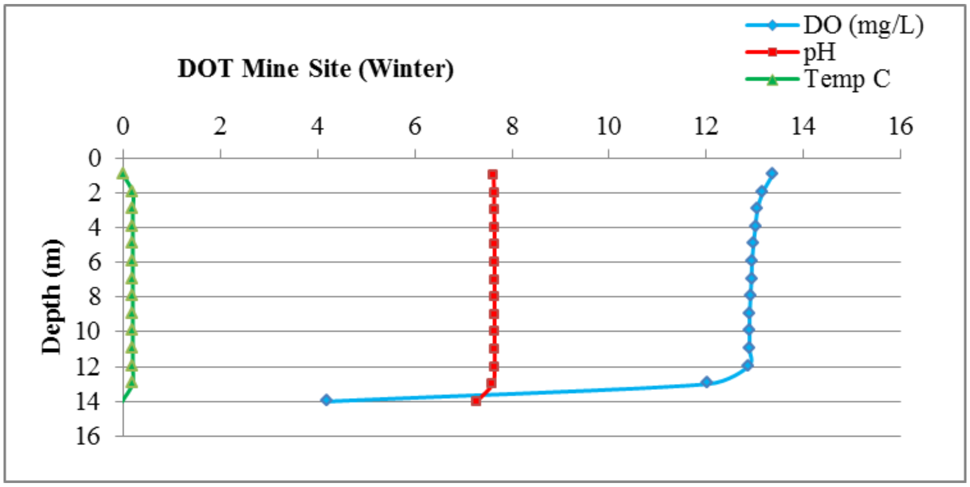

Figure 46. DO, pH, and temperature by depth in the DOT Mine Site in April 2001.

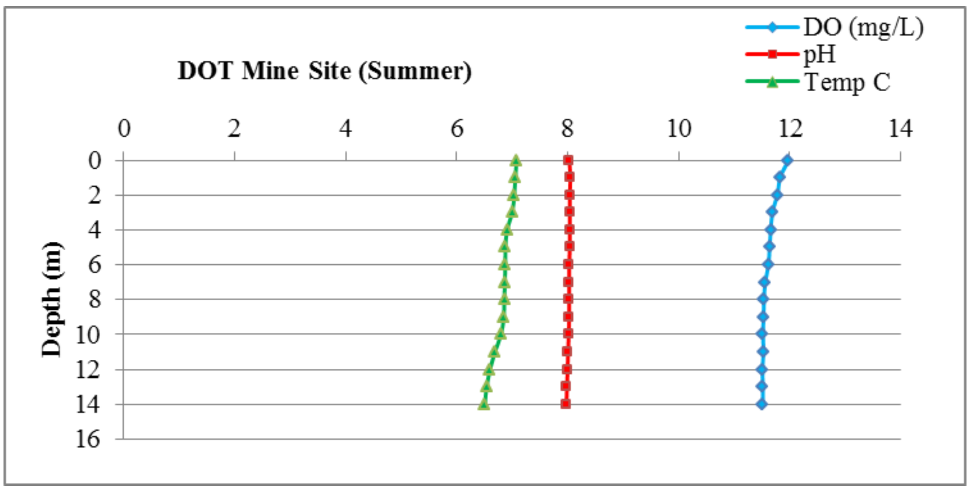

Figure 47. DO, pH, and temperature by depth in the DOT Mine Site in August 2001.

Sagavanirktok River Mine Site C

The Sagavanirktok River Mine Site C (Sag Site C) is a 15.5 ha site located in the floodplain of the West Channel of the Sagavanirktok River (Figure 48). Sag Site C is bounded on the south by a gravel causeway/road (Spine Road) that crosses the river (west to east). The mine site was flooded in early June 1986 when a perimeter berm on the west side was breached allowing breakup flows to enter the site (Hemming 1988). Sag Site C filled in a 72-hr period with about 700 million gallons of water.

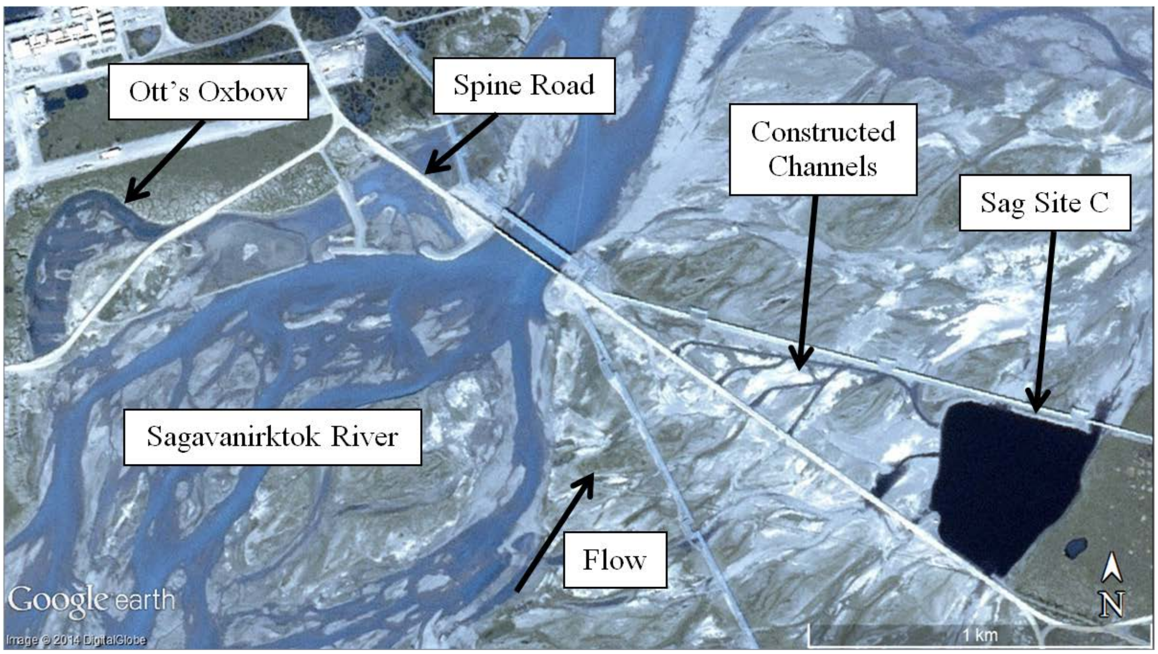

Figure 48. Sag Site C in the floodplain of the Sagavanirktok River.

During spring breakup in 1987, an outlet channel formed in the northeast corner of Sag Site C and continuous surface flow connecting the mine site with the river existed throughout the summer. The Sagavanirktok River system supports one of the most diverse fish communities in the various streams, rivers, and lakes in the North Slope oilfield complex.

In fall 1987, a habitat enhancement project for Sag Site C was designed, permitted, and completed by ARCO Alaska, Inc. The project involved removing part of a 183 m long gravel perimeter berm on the west side of Sag Site C and excavating a 2.0 ha shallow-water zone to a depth of 1.2 m (Hemming 1989).

In early June 1989, spring flood waters in the Sagavanirktok River caused a failure in the Spine Road, depositing outwash gravels in the floodplain and on the ice in Sag Site C. As the ice melted, gravel was deposited into the shallow water zone, reducing littoral habitat to 0.3 ha (Hemming 1990). The outlet channel expanded, debris was carried into the site, and tundra subsidence began along the east side of Sag Site C.

The ADF&G investigated seven scour pools associated with culvert batteries located along the Spine Road and made recommendations for restoration work (Ott 1993). Short-term rehabilitation options focused on highwater channels located along the Spine Road where surface flows became isolated from overwintering habitat during low flow conditions. In 1996, the U.S. Army Corps of Engineers (ACOE) issued a permit to ARCO Alaska Inc. for dredging of material upstream of seven culvert batteries (#1 through #7) in the Spine Road (Figure 49). As a condition of the ACOE permit, scour pools along the Spine Road (#1 through #6) were to be monitored through site photographs, description, and collection of fish (Ott and Morris 1999).

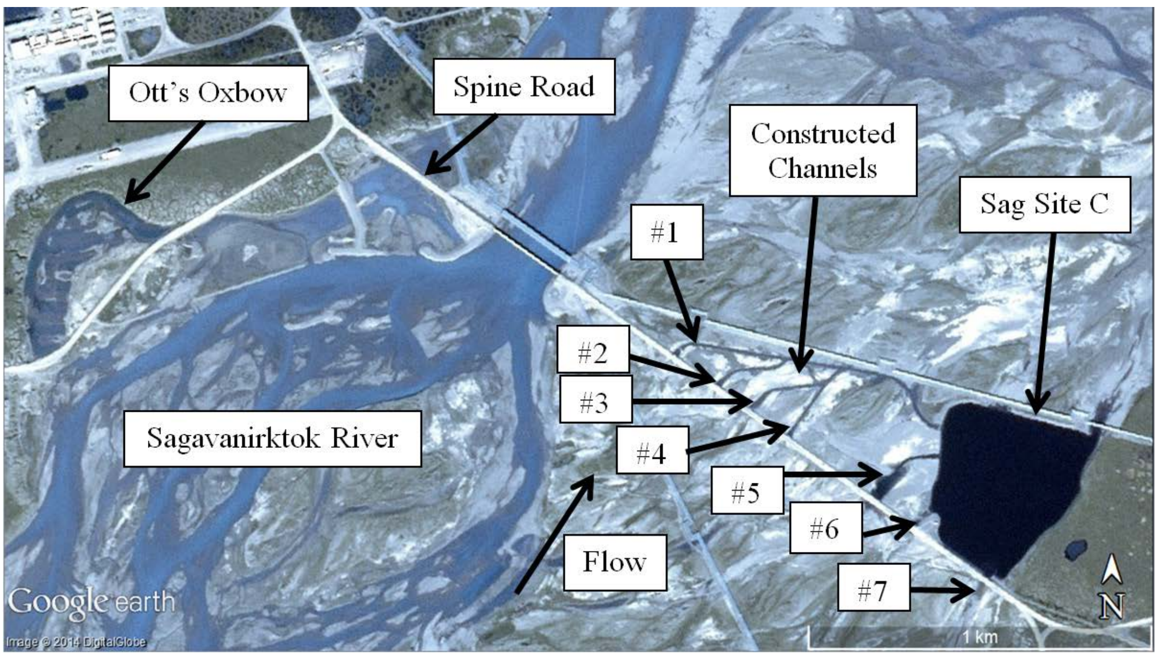

Figure 49. Culvert batteries (#1 through #7) in the Spine Road crossing of the West Channel Sagavanirktok River.

Ott and Morris (1999) recommended connecting the first six scour pools with Sag Site C thus providing fish access to overwintering habitat. The channel connections between the scour pools and the primary channel leading to Sag Site C were completed in summer 2002 (Figure 49), with some minor additional work done late in the fall. Some minor in-water work was conducted after 2002 and the channels are still operating as designed.

Fish

Sag Site C was sampled for fish from 1986 to 1990, and again in 1993. Most sampling was done with fyke nets; however, gill nets were used in 1986 and 1987 (Appendix 13). The Sag River scour pools were sampled annually from 1996 to 1999 with fyke nets. Seine hauls were made in 1996 in scour pools #4, #5, and #6, because the water was too deep to set a fyke net (Appendix 13).

Arctic grayling, broad whitefish, least cisco, round whitefish, Dolly Varden, slimy sculpin, burbot, and ninespine stickleback were captured in Sag Site C. The most common fish species present in Sag Site C were Arctic grayling and ninespine stickleback. Although ninespine stickleback were numerous in Sag Site C, virtually all these fish were caught in 1989 at the outlet in one fyke net.

In the isolated scour pools, now connected to Sag Site C, we caught Arctic grayling, broad whitefish, round whitefish, Dolly Varden, slimy sculpin, burbot, and ninespine stickleback. All fish caught were transferred to either Sag Site C or the Sagavanirktok River. Arctic grayling, broad whitefish, and round whitefish were the most common species collected in the scour pools. In both Sag Site C and in the scour pools, most of the Arctic grayling, broad whitefish, and round whitefish were predominantly age-0 and 1 juvenile fish.

The length frequency distribution for Arctic grayling caught in fyke nets in 1989, 1990, and 1993 in Sag Site C is presented in Figure 50 and for the scour pools in the floodplain of the Sagavanirktok River in Figure 51. Use of both the flooded Sag Site C gravel site and the scour pools is predominantly by age-0 and 1 Arctic grayling. This pattern of use is the same for juvenile broad whitefish and round whitefish (Figures 52 and 53). Sag

Site C and the now connected scour pools provide aquatic habitat used predominantly by juvenile fish.

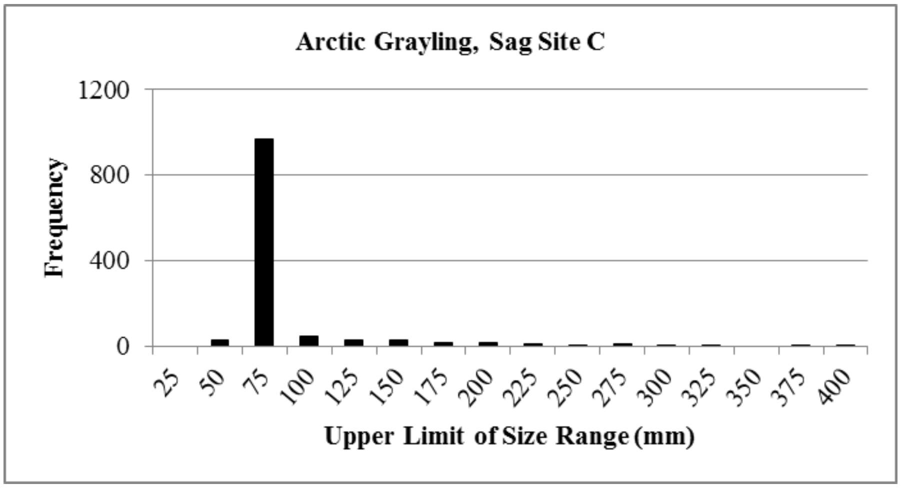

Figure 50. Length frequency distribution of Arctic grayling in Sag Site C.

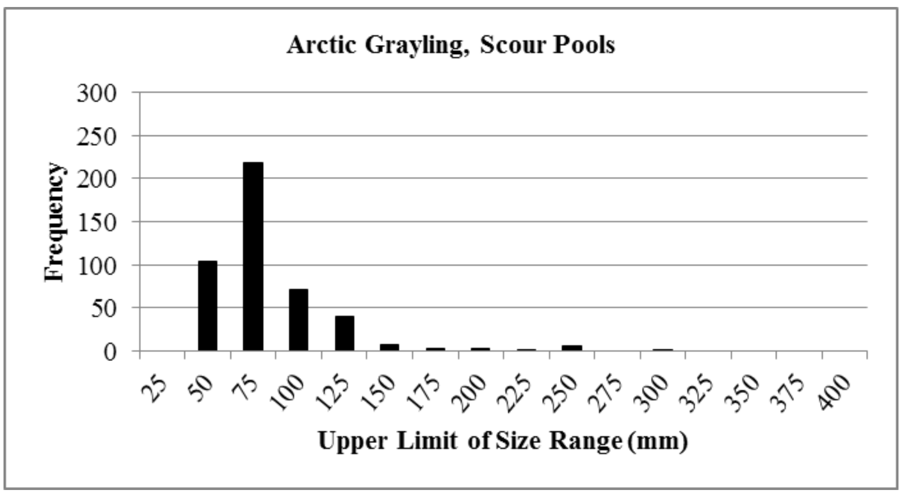

Figure 51. Length frequency distribution of Arctic grayling in Sagavanirktok River scour pools.

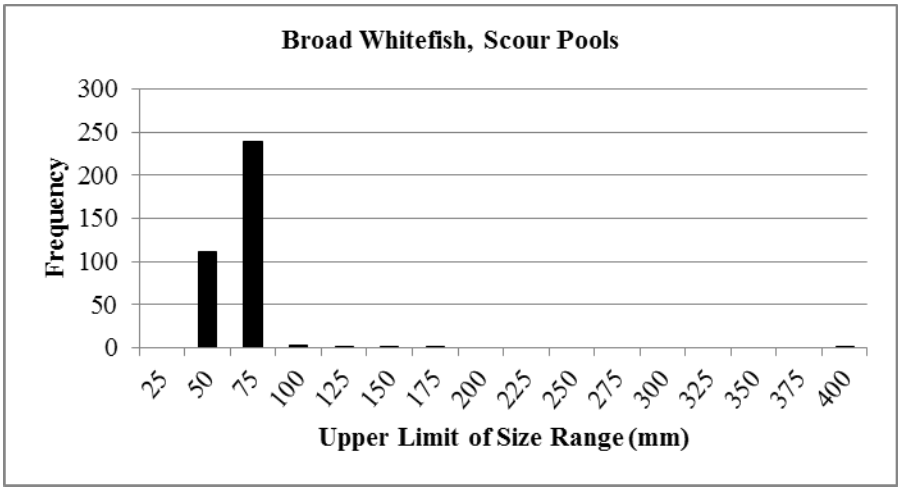

Figure 52. Length frequency distribution of broad whitefish in Sagavanirktok River scour pools.

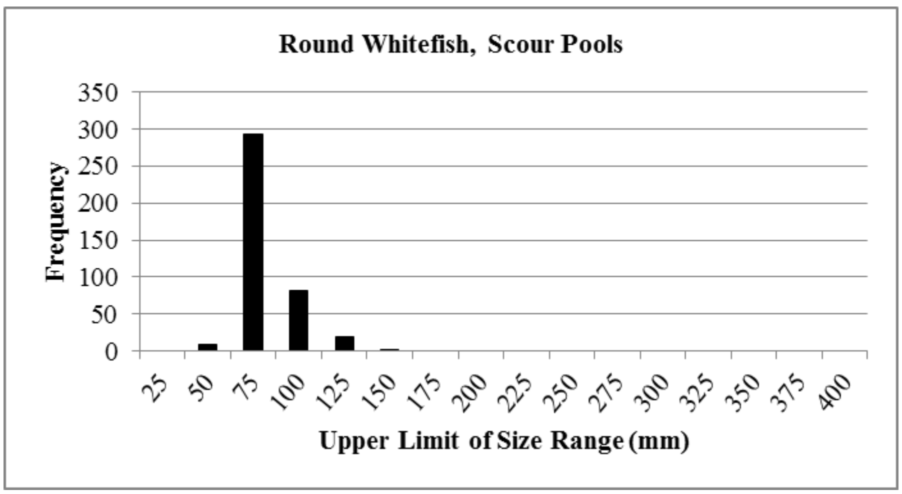

Figure 53. Length frequency distribution of round whitefish in Sagavanirktok River scour pools.

Age-0 Arctic grayling were caught in both the Sagavanirktok River scour pools and in Sag Site C. In 1989, the CPUE for Arctic grayling fry was 109.4, but in all the remaining years, the catch was low (0.0 to 18.3 fish/day/fyke net) (Figure 54).

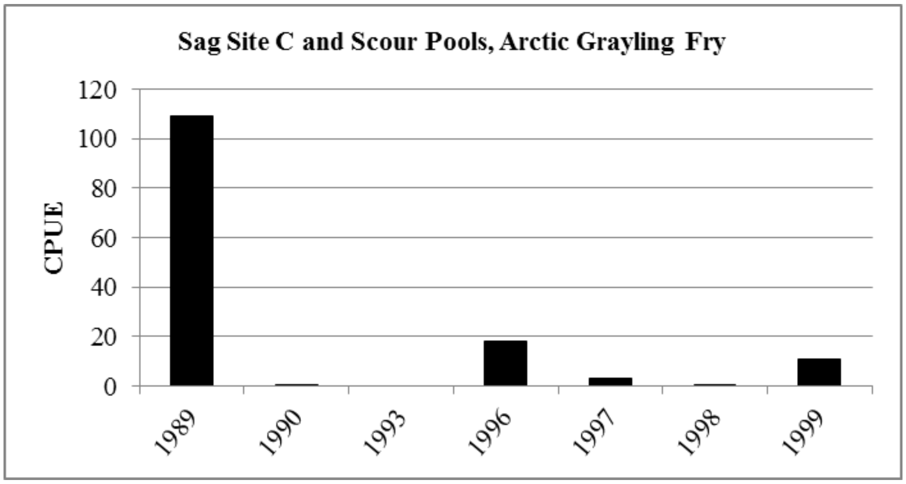

Figure 54. Catch per unit of effort for Arctic grayling fry (<70 mm) in Sag Site C (1989, 1990, and 1993) and Sagavanirktok River scour pools (1996 to 1999).

Water Quality

Summer (open water) water quality data were collected on July 13, 1988 (Figure 55). Dissolved oxygen concentrations were high (12.9 to 14.4 mg/L) and water temperatures varied from 3.1 to 3.4°C (Appendix 14).

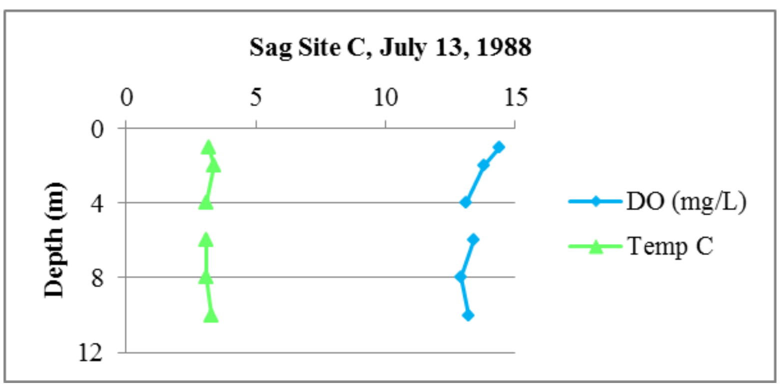

Figure 55. DO and temperature by depth in Sag Site C in mid-summer 1988.

Water quality data were collected during late winter 1987 and 2001. Data indicated that Sag Site C was filled with highly oxygenated, (10.5 mg/L DO just below the ice to 11.2 mg/L DO at 18 m), cold (about 1°C from top to bottom) fresh water (conductivity around 100 *u* S/cm from top to bottom) (Hemming 1988) (Figure 56). Measurements of pH also were similar from top to bottom at 7.7 units. Water quality data collected in April 2001 was identical in pattern in that the body of water was isothermal and fully mixed; however, water temperature was somewhat higher (Figure 57). The specific conductance was around 230 uS/cm in April 2001.

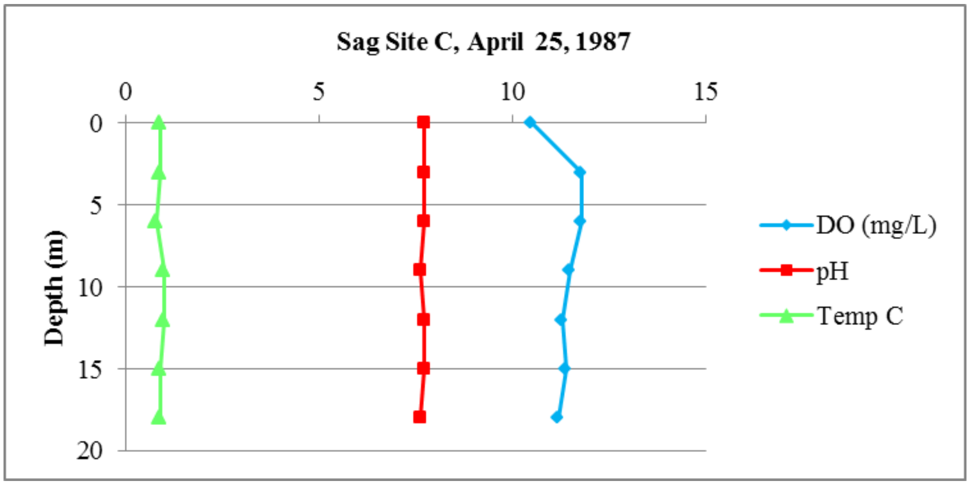

Figure 56. DO, pH, and temperature by depth in Sag Site C in late winter 1987.

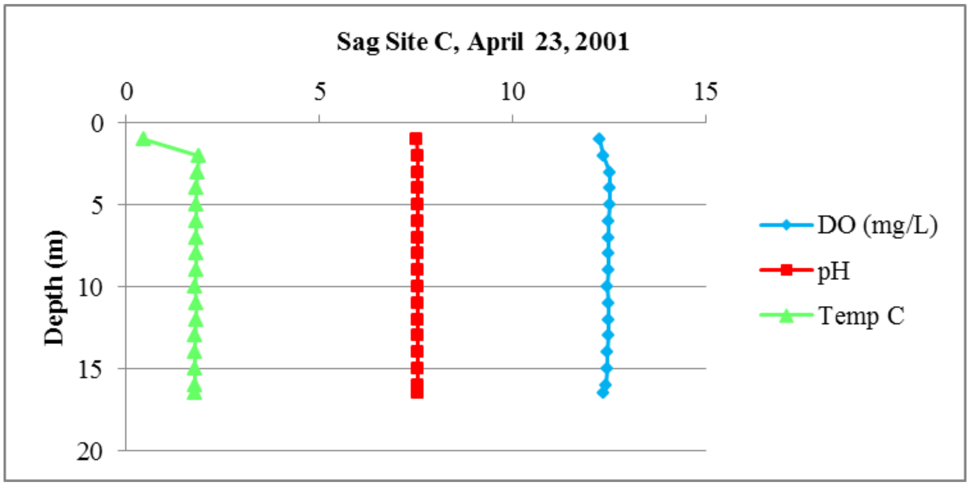

Figure 57. DO, pH, and temperature by depth in Sag Site C in late winter 2001.

East Badami Creek Mine Site

The Badami Mine Site was established to provide gravel for road and pad construction, including a stockpile of material for maintenance, and for a water source to support operations of the Badami oilfield (Figure 58). Gravel removal was completed in 1996 and the mine site rehabilitated. A channel connecting the mine site with East Badami Creek was constructed on the east corner of the mine site. The site was designed to provide a source of overwintering habitat for fish and a shallow bench (0.5 to 1.0 m) for vegetation to root and foster fish and waterfowl food organism production. The site was designed to be 10 m deep to provide adequate under-ice water for fish overwintering and for industrial water use.

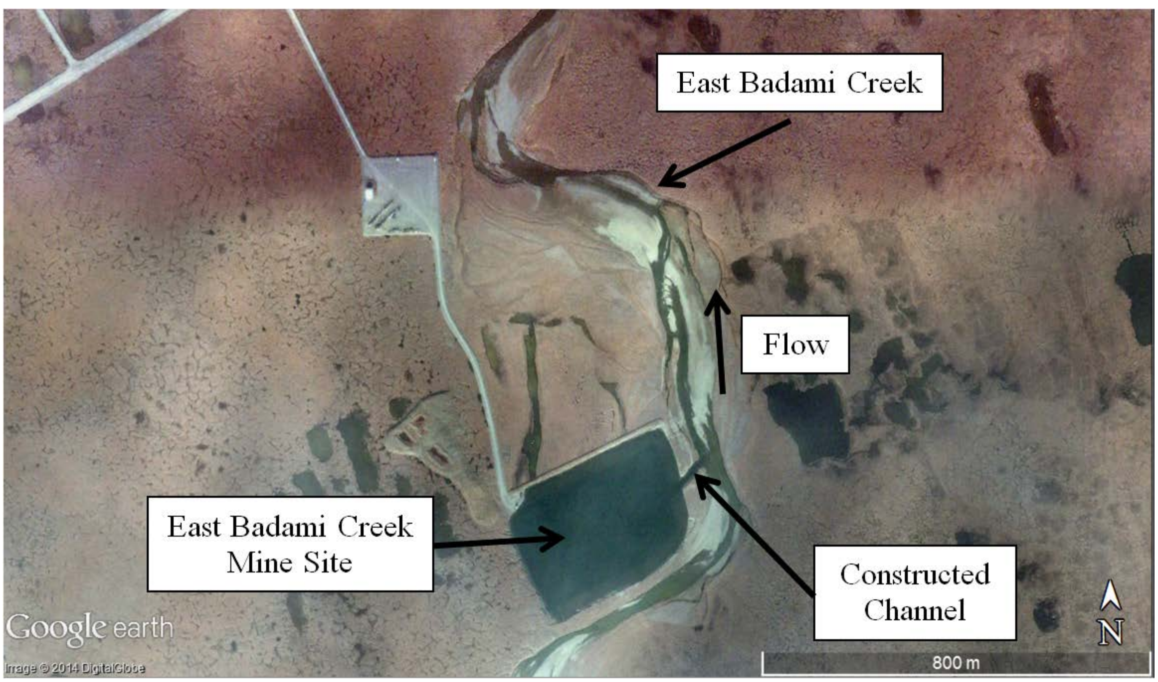

Figure 58. East Badami Mine Site.

Fish

Fish sampling with fyke nets was conducted in East Badami Creek in 1994 and 1995 prior to mine site permitting and development. These sampling events documented low numbers of Arctic grayling (3), Dolly Varden (3), slimy sculpin (1), and four horned sculpin (10) and high numbers (13,908) of ninespine stickleback (Hemming and Ott 1994, Hemming 1996, Hemming and Morris 1997, and Hemming and Morris 1998) (Appendix 15).

After the site was flooded, fyke nets fished each year from 1997 to 2000 caught two least cisco, eight Dolly Varden, one slimy sculpin, and 1,054 ninespine stickleback (Appendix 15). Catch per unit of effort for ninespine stickleback (fish/net day) in the Badami Mine Site decreased from baseline data (pre-mining) collected in the creek in 1994 and 1995 (Figure 59). The highest catch pre-mining was 727 fish/day whereas the highest catch post-mining was 238 fish/net day in 1997.

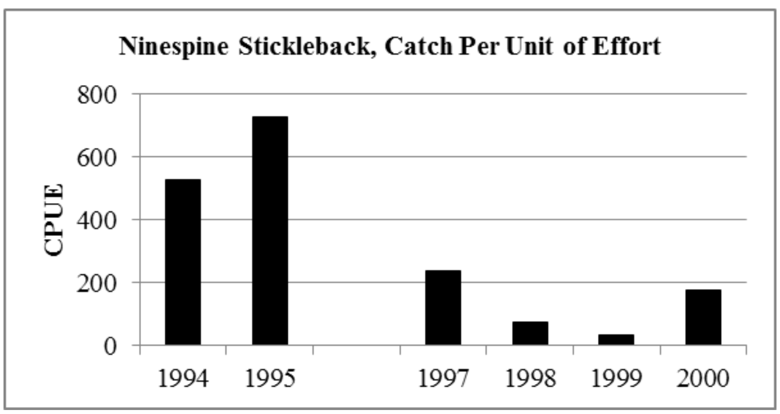

Figure 59. Catch per unit of effort of ninespine stickleback in East Badami Creek (1994 and 1995) and the Badami Mine Site (1997 to 2000).

Water Quality

Water quality data were collected in every open water season from 1998 to 2000 and once during winter in April 2001 (Appendix 16). DO concentrations during the open water season were similar in all years. In August 2000, DO concentrations were > 11 mg/L with a slight decrease with depth (Figure 60). Winter DO concentrations also were high (> 9.96 mg/L) and more than adequate to support overwintering fish (Figure 61). A decrease in DO during winter occurred near the bottom. Winter temperature ranged from minus 0.02 to minus 0.12°C.

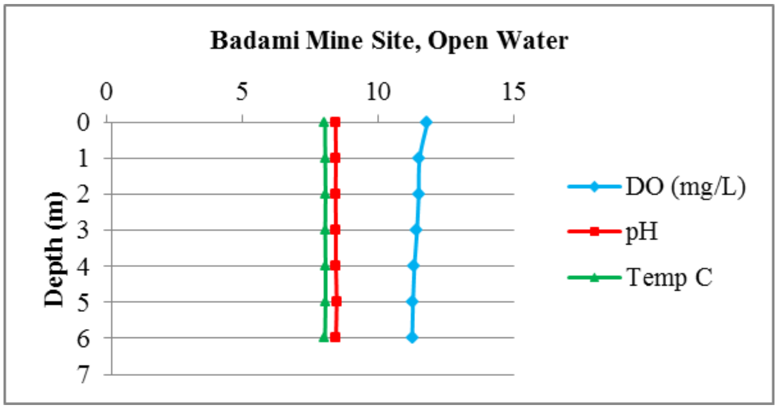

Figure 60. DO, pH, and temperature by depth in Badami Mine Site in August 2000.

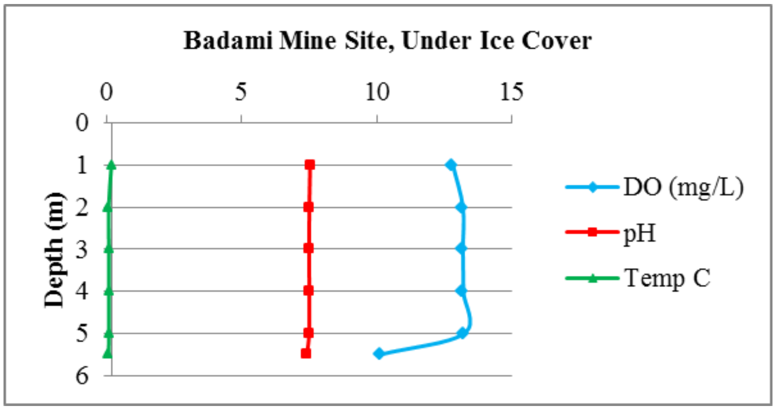

Figure 61. DO, pH, and temperature by depth in Badami Mine Site in April 2001.

Discussion

Water quality and fish information collected at flooded gravel mine sites on the North Slope since 1987 demonstrate that gravel mining can occur within and near rivers and provide high quality fish habitat, especially overwintering habitat (Table 2). The large volume of water available in these sites meets the needs of the oil and gas industry and the Alaska Department of Transportation and Public Facilities. Fish Habitat Permits are issued for water use from the flooded gravel mine sites that leave adequate water for the proper protection of anadromous fish and their habitat.

Table 2. Estimated water volumes in flooded North Slope gravel sites.

Flooded Gravel Mine Site	Millions of Gallons of Water	Quality
Kuparuk Mine Site D	580	fresh
Kuparuk Mine Site B	65	fresh
Kuparuk Deadarm #1, #2, and #3	unknown	fresh
Kuparuk Deadarm #4	190	fresh
Kuparuk Deadarm #5	825	fresh
Kuparuk Deadarm #6	100	fresh
Put 27	690	saline
DOT Mine Site	unknown	fresh
Sag Site C	700	fresh
Badami Mine Site	unknown	fresh

Most fish species using North Slope waterbodies have been documented in flooded gravel mine sites. The quality of the fish habitat and its use by fish is specific to each site and is determined largely by site location, site configuration (accessible shallow water littoral and deep water overwintering), salt water intrusions, stability of the channel connection under various flow conditions, and proximity to streams supporting abundant freshwater fish populations (Table 3). The two sites with high salinity water are the Northstar Mine Site in the Kuparuk River delta and the Put 27 Mine Site located in and adjacent to the lower Putuligayuk River.

Table 3. Habitat quality in flooded North Slope gravel mine sites.

High Quality Fish Habitat Characteristics	Kuparuk Mine Site D	Kuparuk Mine Site B	Kuparuk Deadarm	Kuparuk Delta	Put 27	DOT Mine Site	Sag Site C	East Badami Mine Site
Large Volume (65 to 825 million gallons) of High Dissolved Oxygen (near saturation) Water for Fish Overwintering	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Littoral (Shallow) Aquatic Habitat or Adjacent Wetlands	Yes	Yes	No	No	No	Yes	No	Yes
Channel Connections Stable and Contiguous Providing Free Fish Passage During Ice Free Season	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Irregular Shoreline and Islands	No	Yes	No	No	No	No	No	No
Summary of Arctic Grayling Success	self sustaining population present	self sustaining population present	rearing and winter habitat	not present	not presen t	self sustaining population present	rearing and winter habitat	not present

Flooded mine sites vary from small (Kuparuk Mine Site B at 3.7 ha with an average depth of 7.1 m) to large (Sag Site C at 15.5 ha with an average depth of 20 m) and most have large quantities of high quality water for overwintering fish. The more productive sites have shallow littoral habitat where fish rear during summer and then have direct access to the deep water in the flooded mine site for overwintering. Arctic grayling transplants have been successful at two sites (Kuparuk Mine Sites B and D), where prior to the mine site flooding, this species was not present. Each site is unique with respect to site conformation, depth, aerial extent, water chemistry, and use by fish. Rehabilitation plans can be designed to provide productive habitat for fish for sites in or near stream systems.

Water quality and quantity and fish information from the flooded gravel mine site study were used to refine the ADF&G policy on gravel removal activities on the North Slope. Guidelines for designing and permitting gravel mine sites were developed in 1993 based on these data, along with recommendations from other agencies regarding site design for use by fish, waterfowl, and shorebirds. These guidelines provide direction for companies developing detailed plans for new gravel sites in or near streams.

The oil and gas industry needs gravel and water for oil and gas development. Flooded mine sites can provide for these needs, while providing fish and wildlife habitat upon completion of mining and rehabilitation. When developed in a cellular fashion, portions of large mine sites can be rehabilitated, providing fish and wildlife habitat as well as water for industrial use, while at the same time providing gravel for development within the remainder of the site. Concurrent reclamation also can satisfy the desire of the landowner or state or federal agencies to return the depleted portions of the site to a productive use following mining.

The ADF&G will continue to recommend the ADF&G gravel removal guidelines be used for the development of new mines in both floodplain and upland sites or for expansion of existing sites. The ADF&G intends to collect baseline fish and water quality data when appropriate at proposed mine sites. The ADF&G also intends to collect post-flooding fish and water quality data at new sites to determine the degree and rapidity to which a site becomes productive fish and wildlife habitat. Similarly, additional data will be collected at existing flooded mine sites to add information at individual sites and to record any site changes over time.

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Appendix 1 – Mine Site D, Fish

Mine Site D						
	Fyke Net		Arctic	Broad	Least	Ninespine
	Effort		Grayling	Whitefish	Cisco	Stickleback
Date	(days)	Temp °C	n, mm	n, mm	n, mm	(total number)
6/20 to 25/1993	5	1.7 - 4.4	29, 57-340			50
7/18 to 23, 1993	11	10.2 - 13	63, 66-310	1, 263		527
8/29 to 9/2/1993	10	6.3 - 7.2	441, 49-429			3,466
6/23 to 26/1994	8		35, 63-390			133
8/1 to 4/1994	8		72, 78-297			7,364
8/31 to 9/2/1994	6		206, 47-273	3, 60-442	2, 60-62	4,861
6/20 to 22/1995	6	4.1 - 10.6	69, 54-410	1, 77		2,319
7/17 to 20/1995	8	9 - 14.1	68, 63-334	1, 139	3, 64-174	12,753
8/28 to 31/1995	8	7.0 - 8.0	73, 84-298	1, 84	1, 100	9,581
6/25 to 27/1996	5		73, 99-415			5
7/23 to 25/1996	6		78, 124-435		2, 203-220	600
8/28/1996	2		41, 64-349			2,574
6/23/1999	1		5, 143-349			19
7/28 to 30/1999	5		55, 150-377			76
8/25 to 29/1999	5		126, 54-437	2, 70-72	2, 230-332	4,869
8/14 to 16/2000	3		41, 158-375		2, 245-281	1,098
8/16 to 23/2001	8	5.0 - 7.0	30, 46-374	1, 337		173
8/10 to 11/2008	2	5.6	372, 52-424		2, 142-215	0
7/14 to 16/2012	2.5		51, 64-391	1, 355	149, 60-355	19
7/11 to 12/2013	1.6		15, 165-390		9, 91-355	1

Appendix 2 – Mine Site D, Water Quality

Mine Site D							
				Dissolved	Specific		
	Depth	Temp	Percent	Oxygen	Conductance		
Date	(m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH	cond/100
8/20/1986	0	9.5		14	410	7.8	
	3	9.3		10.8	410	7.8	
	6	9.3		10.9	405	7.8	
	9	9.2		11.6	410	7.7	
	12	9.1		11.6	405	7.8	
	13	9		11	410	7.8	
4/29/1987	0	1.5		13.1	466	7.4	
	3	1		13.3	433	7.2	
	6	0.5		11.8	432	7.3	
	9	0.5		13.2	432	7.3	
	12	0.5		12.8	423	7.3	
	14	0		11.6	460	7.3	
May, 1990	2	1.9		12.8	430	7.7	
	4	1.6		10.6	460	7.2	
	6	1.9		12.6	440	7.63	
	8	1.7		11	420	7.7	
	10	1.8		12.5	430	7.65	
	12	1.7		11.8	430	7.4	
May, 1991	2	0.8		11	450	7.8	4.5
	4	1		13	384	7.6	3.84
	6	1		11	393	7.6	3.93
	8	1		10.5	393	7.7	3.93
	10	0.3		11.3	403	7.7	4.03
	12	1		12.6	393	7.4	3.93
	14	0.8		11.4	393	7.7	3.93
August, 1991	1	7		11.5	308	7.9	
	2			11.8	312	7.9	
	4			11.3	312	7.8	
	6			11.3	307	7.8	
	8	6.8		11.3	304	7.8	
	10			11.5	311	7.7	
	12			11.3	310	7.6	
	14			11.2	313	7.2	
	16	6.5		11.2	313	6.7	
May, 1992	2	0.5		13.7	390	7.8	
	4	0.5		12.7	350	7.7	
	6	0.5		11.7	380	7.7	
	8	0.5			380	7.9	
	10	0.5		13.4	380	7.8	
	12	0.5		12.8	350	7.7	

Appendix 2 - Mine Site D, Water Quality (concluded)

				Dissolved	Specific		
	Depth	Temp	Percent	Oxygen	Conductance		
Date	(m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH	cond/100
7/29/1999	0	7.46	91.7	11.2	242.3	8.1	2.423
	1	7.46	90.5	11.06	242.3	8.16	2.423
	2	7.46	89.9	10.99	242.2	8.21	2.422
	3	7.46	89.6	10.95	242	8.22	2.42
	4	7.46	89.6	10.95	242.4	8.22	2.424
	5	7.46	89.3	10.91	242.6	8.24	2.426
	6	7.46	88.9	10.88	242.4	8.23	2.424
	7	7.45	88.5	10.81	242.2	8.18	2.422
	8	7.45	88.4	10.8	242.1	8.17	2.421
	9	7.44	88	10.75	242.2	8.16	2.422
	10	7.44	87.8	10.73	242.4	8.16	2.424
	11	7.44	87.8	10.73	242.3	8.16	2.423
	11.5	7.43	87.5	10.71	242.9	8.12	2.429
4/23/2001, ice 6 ft, freeboard 7 in	1	0.2	87.9	13.07	265.4	7.4	
	2	1.15	87.2	12.51	262.5	7.41	
	3	1.17	85.8	12.32	262.8	7.42	
	4	1.17	85.5	12.25	262.8	7.43	
	5	1.17	85.1	12.24	262.8	7.43	
	6	1.17	84.8	12.14	262.8	7.44	
	7	1.17	84.3	12.1	262.8	7.44	
	8	1.17	84.3	12.09	263.3	7.44	
	9	1.17	83.8	12.03	263.4	7.45	
	10	1.18	83.8	12.03	263.4	7.45	
	11	1.18	83.9	12.04	263.4	7.46	
	12	1.18	84	12.05	263.1	7.46	
8/21/2001	0	7.16	97	11.71	227.5	7.93	
	1	7.08	96.2	11.61	227.8	7.98	
	2	7.08	96.1	11.61	227.8	7.98	
	3	7.07	95.9	11.58	227.7	7.96	
	4	7.06	95.6	11.55	228	7.94	
	5	7.06	95.6	11.55	228	7.94	
	6	7.06	95.3	11.53	228	7.92	
	7	7.06	95.3	11.52	227.9	7.93	
	8	7.06	95.1	11.49	228.1	7.92	
	9	7.06	95	11.48	228.1	7.91	
	10	7.06	94.9	11.47	228.1	7.91	
	11	7.06	94.9	11.46	228.1	7.91	
	12	7.05	94.8	11.46	227.7	7.91	
	13	7.06	94.7	11.44	228.1	7.91	
	14	7.06	94.7	11.44	227.9	7.91	
	15	7.05	94.6	11.43	228	7.9	
	16	7.04	94.5	11.42	228.1	7.9	
	17	7.02	94.2	11.39	228.3	7.89	

Appendix 3 – Mine Site B, Fish

	Fyke Net		Arctic	Broad	Least	Dolly	Round	Humpback
	Effort		Grayling	Whitefish	Cisco	Varden	Whitefish	Whitefish
Date	(days)	Temp ^oC	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm
8/23 to 24/1989	4		2, 236-324	1, 240	3, 184-209			
10/5/1989	1		3, 324-370					
6/26 to 29/1990	7		15, 250-367	18, 72-332	1, 208		3, 202-203	
8/19 to 24/1990	17		5, 269-355	8, 85-355	7, 112-308			
9/25/1990	3							
6/18 to 23/1991	11		21, 120-385	19, 97-525	10, 194-275	1, 139		
7/15 to 21/1991	8		37, 140-377				1, 265	
8/20 to 21/1991	4		19, 107-390					
6/21 to 26/1992	17		18, 172-385					
7/18 to 24/1992	13		45, 73-387					
9/2 to 3/1992	2		138, 39-388					
6/20 to 25/1993	17		43, 44-417				1, 339	
7/19 to 23/1993	14		71, 87-407					
8/29 to 9/2/1993	15		1395, 39-422	3, 71-74				
6/22 to 26/1994	15		203, 40-410	1, 124				
8/1 to 4/1994	12		200, 36-425	3, 115-530				
8/31 to 9/2/1994	9		166, 40-424	4, 68-200	1, 69			
6/20 to 22/1995	9		113, 48-425	2, 219-485	2, 74-266			
7/17 to 20/1995	12		141, 70-420	1, 94	1, 97			
8/28 to 31/1995	12		171, 43-440					
6/26 to 27/1996	6		93, 60-440	1, 480				
7/23 to 25/1996	9		93, 73-420					
8/28/1996	3		100, 49-405					
6/23 to 28/1999	16		104, 54-437	11, 138-470	1, 240			
8/25 to 29/1999	13		98, 50-404	5, 130-500	1, 200		2, 170-489	
8/14 to 16/2000	6		153, 123-415	3, 226-480	1, 197		4, 175-337	
8/16 to 23/2001	17		119, 43-440	6, 67-404	9, 51-258		4, 200-308	
6/25 to 27/2002	10		114, 44-435	29, 76-548	13, 206-387		3, 200-242	
7/31 to 8/7/2002	40		297, 35-398	122, 82-502	1, 94		6, 225-470	12, 358-415
7/6 to 12/2004	15		175, 85-416	53, 296-540	7, 184-392		6, 183-311	3, 322-385

Appendix 4 – Mine Site B, Water Quality

Mine Site B						
				Dissolved	Specifc	
	Depth	Temp	Percent	Oxygen	Conductance	
Date	(m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH
8/23/1990	1	6.5		11.4	195	8.14
	2	6.5		10.3	210	7.63
	4	6.5		10.9	195	7.87
	6	6.5		11.8	195	7.78
	8	6.5		10.5	195	7.78
5/5/1992	2	0		11.5	280	7.7
	4	0		12	250	7.3
	6	0		10.1	280	7.6
	8	0		1.3	380	7.3
North Lobe, 4/25/2001, ice 5.5 ft, freeboard 4 in	1	-0.08	92.6	13.72	371.9	7.20
	2	0.09	86.3	12.70	368.6	7.20
	3	0.16	84.3	12.38	367.0	7.18
	4	0.18	79.4	11.63	365.9	7.19
	5	0.34	71.6	10.44	363.3	7.17
	6	0.59	66.2	9.60	361.1	7.14
	7	0.64	45.1	6.53	366.3	7.05
	8	0.64	33.3	4.83	384.1	7.03
	9	0.63	3.6	0.52	513.9	7.04
South Lobe, 4/25/2001, ice 5.7 ft, freeboard 4 in	1	-0.02	95.5	14.11	413.4	7.44
	2	1.03	80.9	11.60	397.2	7.27
	3	1.05	82.0	11.75	397.3	7.29
	4	1.05	83.1	11.92	397.1	7.29
	5	1.05	83.8	12.01	397.0	7.29
	6	1.05	81.1	11.63	397.2	7.29
8/21/2001 North Lobe	0	4.74	96.5	12.37	254.2	7.80
	1	4.70	96.3	12.37	254.6	7.82
	2	4.66	96.6	12.40	254.8	7.83
	3	4.62	96.5	12.41	254.7	7.83
	4	4.43	95.9	12.39	257.5	7.81
	5	4.41	95.7	12.37	257.8	7.82
	6	4.38	95.7	12.38	258.3	7.82
	7	4.30	95.6	12.37	259.3	7.82
	8	4.30	94.9	12.32	259.7	7.81
	9	4.29	94.7	12.29	259.8	7.82
	10	4.23	94.6	12.28	261.0	7.82
8/21/2001 South Lobe	0	3.87	95.1	12.47	266.4	7.82
	1	3.85	95.2	12.48	266.0	7.83
	2	3.85	95.4	12.52	266.1	7.82
	3	3.81	95.6	12.56	266.2	7.82
	4	3.81	95.8	12.58	266.2	7.83
	5	3.78	95.9	12.60	266.7	7.82
	6	3.74	94.9	12.50	267.5	7.81
	7	3.73	94.4	12.42	268.3	7.80
	8	3.72	93.9	12.36	268.5	7.79
	8.5	3.75	91.8	12.07	268.9	7.79

Appendix 4 - Mine Site B, Water Quality (concluded)

B Pit North Lobe Water Quality							
April 25, 2001							
Location:	N 70.32153						
	W 149.39662						
Time:	12:00						
Ice Thickness:	5.5'		Freeboard:	4"			
			Dissolved	Specific			
Depth	Temp	Percent	Oxygen	Conductance			
Depth (m)	Temp C	Saturation	DO mg/L	(uS/cm)	pH		cond/100
1	-0.08	92.6	13.72	371.9	7.20		3.719
2	0.09	86.3	12.70	368.6	7.20		3.686
3	0.16	84.3	12.38	367.0	7.18		3.670
4	0.18	79.4	11.63	365.9	7.19		3.659
5	0.34	71.6	10.44	363.3	7.17		3.633
6	0.59	66.2	9.60	361.1	7.14		3.611
7	0.64	45.1	6.53	366.3	7.05		3.663
8	0.64	33.3	4.83	384.1	7.03		3.841
9	0.63	3.6	0.52	513.9	7.04		5.139
B Pit South Lobe Water Quality							
April 25, 2001							
Location:	N 70.32078						
	W 149.39775						
Time:	17:30						
Ice Thickness:	5.7		Freeboard:	4"			
			Dissolved	Specific			
Depth	Temp	Percent	Oxygen	Conductance			
(m)	Temp C	Saturation	DO mg/L	(uS/cm)	pH		cond/100
1	-0.02	95.5	14.11	413.4	7.44		4.134
2	1.03	80.9	11.60	397.2	7.27		3.972
3	1.05	82.0	11.75	397.3	7.29		3.973
4	1.05	83.1	11.92	397.1	7.29		3.971
5	1.05	83.8	12.01	397.0	7.29		3.97
6	1.05	81.1	11.63	397.2	7.29		3.972
7	1.05	81.2	11.64	396.9	7.29		3.969
3" from Bottom							

Appendix 5 – Kuparuk Deadarm and Kuparuk River, Fish

	Fyke Net		Arctic	Broad	Least	Arctic		Slimy	Ninspine
	Effort		Grayling	Whitefish	Cisco	Cisco	Burbot	Sculpin	Stickleback
Date	(days)	Temp ^oC	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm	(total number)
1987, Winter	Gill Net		6, 114-292			8, 368-424			
7/19 to 21/1989	9	10.0 - 14.0	63, 77-308				1, 44	2, 55-87	52
7/18 to 20/1995	3	12.5 - 13.0	117, 60-179		2, 98-104		2, 91-92	1, 43	121
8/30 to 9/1/1995	3	5.0 - 6.0		2, 43-44	5, 56-281		1, 270	3, 41-66	11

Kuparuk River							
	Fyke Net		Arctic	Broad	Slimy		Ninespine
	Effort		Grayling	Whitefish	Sculpin	Burbot	Stickleback
Date	(days)	Temp ^oC	n, mm	n, mm	total #	n, mm	total #
6/21 to 26/1992	11	6.5 - 14.5	88, 49-408	1, 560	9	2, 217-690	7
7/19 to 24/1992	11	13 - 15	104, 70-423		4		3
9/1 to 3/1992	3	6.0 - 8.0	118, 40-110		1	4, 50-650	1
6/21 to 24/1993	10	5.9 - 9.4	65, 48-300		1	9, 59-91	6

Appendix 6 – Kuparuk Deadarm Mine Site and Kuparuk River, Water Quality

Kuparuk Deadarm Mine Site and Kuparuk River							
				Dissolved	Specific		
	Depth	Temp	Percent	Oxygen	Conductance		
Date	(m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH	cond/100
4/25/2001 (Reservoir #5)	1	0.17	73.9	10.88	154.3	7.34	1.543
	2	1.67	87.7	12.35	190.8	7.25	1.908
	3	1.71	88.3	12.44	190.5	7.29	1.905
	4	1.72	88.7	12.49	190.5	7.29	1.905
	5	1.72	88.9	12.52	190.7	7.30	1.907
	6	1.72	88.9	12.52	190.7	7.30	1.907
	7	1.72	88.9	12.52	190.7	7.30	1.907
	8	1.72	88.8	12.51	190.7	7.30	1.907
	9	1.72	88.8	12.51	190.7	7.30	1.907
	10	1.72	88.8	12.51	190.7	7.30	1.907
	11	1.72	88.7	12.49	190.5	7.30	1.905
	12	1.72	88.6	12.48	190.4	7.30	1.904
	13	1.72	88.6	12.48	190.4	7.30	1.904
	14	1.72	88.6	12.48	190.7	7.30	1.907
	14.75	1.72	88.6	12.48	190.7	7.30	1.907
4/25/2001 (Kuparuk River)	1	-0.11	48.8	7.24	409.8	7.29	4.098
	2	0.21	49.9	7.32	409.4	7.26	4.094
	3	0.30	51.3	7.51	409.8	7.28	4.098

Appendix 7 – Northstar Mine Site, Fish

Northstar Mine Site									
	Fyke Net		Arctic	Broad	Least	Round	Slimy	Fourhorn	Ninespine
	Effort		Grayling	Whitefish	Cisco	Whitefish	Sculpin	Sculpin	Stickleback
Date	(days)	Temp ^{o}C	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm	(total number)
8/9/2000	2	10.1	3, 104-157		160, 50-327	1, 182		5, 25-77	30
8/10/2002	4		55, 43-199	7, 98-114	3, 73-176		2, 57-65	15, 42-88	6

Appendix 8 – Northstar Mine Site, Water Quality

Northstar Mine Site								
				Dissolved	Specific			
	Depth	Temp	Percent	Oxygen	Conductance	Salinity		
Date	(m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	(ppt)	pH	cond/100
4/22/2001	1	-2.35	51.2	5.92	60540	40.65	6.88	6.054
	2	-2.34	50.8	5.86	60606	40.71	6.87	6.0606
	3	-2.33	51.6	5.96	60842	40.89	6.85	6.0842
	3.8	-2.34	52.6	6.07	60279	40.35	6.81	6.0279

Appendix 9 – Put 27 Mine Site, Fish

Put 27 Mine Site																
		Fyke Net Effort		Arctic Grayling	Broad Whitefish	Arctic cisco	Least Cisco	Round Whitefish	Dolly Varden	Fourhorn Sculpin	Rainbow Smelt	Arctic Cod	Starry Flounder	Arctic Flounder	Ninespine Stickleback	Threespine Stickleback
Date	Location	(days)	Temp °C	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm	total #	n, mm
7/21/1989	Put River/Put 27	1	11							3, 61-74					14	
8/24/1989	Put River/Put 27	1	12		475					3, 58-98						
6/26 to 28/1990	Put 27 Ramp	3	5 - 6.5	1, 242		1, 125		25, 65-125							4,576	
8/19 to 22/1990	Put 27 Ramp	4	7		11, 59-420	1, 68	1, 186	3, 96-110							716	
9/25/1990	Put 27 Ramp	1	0.7		1, 75	1, 65				1, 75					858	
6/5 to 6/1991	Put River/Put 27	2	0.5 - 0.9												181	
7/18 to 20/1991	Put River/Put 27	3	11.5 - 13				5, 64-83	10, 110-138							1,430	
8/20 to 22/1991	Put River/Put 27	3	6.5 - 7.5		2, 54-114		2, 87-332	1, 127							715	
9/2 to 3/1992	Put River/Put 27	2	5 - 5.5		2, 55-60	1, 90				5, 50-62					28	
7/18 to 22/1993	Put 27 Ramp	5	12 - 13.8		113, 37-73	2, 40-92	1, 81	4, 56-90	2, 155-184	28, 27-145		1, 109		6, 35-60	180	
8/29 to 9/1/1993	Put 27 Ramp	4	5.1 - 7	1, 191	21, 55-77	1, 155	3, 207-326			420, 41-113	1, 66				389	
8/30/1993	Put River/Put 27	gill net			8, 429-485		7, 297-358		1, 140							
8/1 to 4/1994	Put 27 Ramp	4	13.0 - 15		106, 48-128				12, 171-210	11, 43-121			9, 43-62		328	
8/29 to 30/1994	Put 27 Ramp	2	3.5 - 4.5			1, 84			1, 241	18, 47-118				1, 27	117	
7/18 to 21/1995	Put 27 Ramp	4	11.2 - 14.3		8, 98-178	1, 84		1, 135	1, 169	42, 72-203				10, 41-97	22,880	
8/30 to 9/1/1995	Put 27 Ramp	3	5 - 6.5		138, 60-135		3, 135-207			10, 46-149				1, 57	3,146	
6/27 to 28/1996	Put @ B Pad	2	6.0 - 7.0		2, 372-434				1, 167						2	
7/24 to 26/1996	Put @ B Pad	3	15.5 - 17												715	
8/28/1996	Put @ B Pad	1	2.4		1, 77										286	
6/26 to 28/1996	Put 27 Ramp	4	7.0 - 9.0		1, 473				2, 144-166	6, 62-132				8, 47-90	87	
7/24 to 26/1996	Put 27 Ramp	3	13.5 - 14.5		217, 50-500	3, 196-351	7, 154-335		1, 192	4, 80-208				3, 47-90	6,578	
8/28/1996	Put 27 Ramp	1	4.7		17, 64-85			1, 100		1, 47					143	
8/10 to 12/1998	Put River/Put 27	3	11.5 - 12.5		184, 54-501	1, 84	3, 74-85									9, 74-85

Appendix 10 – Put 27 Mine Site, Water Quality

Put 27 Mine Site							
				Dissolved	Specific		
	Depth	Temp	Percent	Oxygen	Conductance		Salinity (ppt)
Date	(m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH	cond/100
8/21/1990	1	7		10.6	760	8.24	2
	2	7		11.5	780	8.33	2
	4	7		11.4	780	8.29	2
	6	7		8.6	780	8.34	2
	8	7		10.4	780	8.31	2
5/6/1992	2	0.5		9.6	9950	7.79	5
(winter)	4	0.5		9.6	9950	7.84	5
	6	0.5		11.6	10200	7.74	5.5
	8	0.5		9.6	10500	7.59	6
	10	0.5		12.3	10200	7.74	5.5
	12	0.5		7	10500	7.64	6
8/10/1998	0	11.98	96.3	10.24	2274	8.46	1.22
	1	11.99	94.8	10.07	2271	8.47	1.22
	2	11.99	94.2	10.01	2275	8.48	1.22
	3	11.88	93.2	9.92	2540	8.48	1.37
	4	11.86	93.2	9.91	2676	8.47	1.44
	5	11.71	92	9.8	3202	8.44	1.77
	6	11.61	92.4	9.85	3750	8.42	2.04
	7	10.69	85.5	9.29	4454	8.28	2.42
	8	1.29	11.7	1.7	17913	7.12	10.57
	9	1.23	5.8	0.76	17964	7.12	10.57
	10	1.2	3.2	0.39	18097	7.13	10.63
	11	1.2	1.8	0.24	17966	7.14	10.6
	12	1.19	0.6	0.08	18005	7.15	10.61
	13	1.18	0	0	18016	7.16	10.61
5/5/1999	2.75	0.59	99.4	13.75	5765	7.75	5.765
(winter)	3.75	2.53	66.9	8.65	8064	7.72	8.064
	4.75	3.64	65.4	8.24	8951	7.76	8.951
	5.75	4.14	61.1	7.57	9603	7.81	9.603
	6.75	3.87	49.3	6.15	10116	7.79	10.116
	7.75	3.48	2.9	0.39	13716	7.17	13.716
	8.75	2.5	0.5	0.06	18028	7.16	18.028
	9.75	2.5	0	0	18108	7.19	18.108

Appendix 10 – Put 27 Mine Site, Water Quality (concluded)

Date	Depth (m)	Temp Temp C	Percent Saturation	Dissolved Oxygen DO (mg/L)	Specific Conductance (uS/cm)	pH	Salinity (ppt) cond/100
4/21/2001	1	-0.24	95.10	13.44	10600	7.39	6.00
winter	2	-0.20	93.90	13.28	10626	7.40	6.04
	3	-0.21	92.90	13.15	10630	7.39	6.04
	4	-0.11	81.50	11.44	10666	7.34	6.04
	5	0.57	75.70	10.45	10964	7.33	6.24
	6	0.68	75.10	10.34	11068	7.30	6.30
	7	0.33	82.00	11.35	11188	7.23	6.38
	8	0.74	28.60	3.89	13271	6.90	7.63
	9	0.63	1.50	0.21	17965	6.84	10.60
	10	0.37	0.37	0.30	18205	6.87	10.73
	11	0.11	0.00	0.00	18264	6.95	10.76
	12	0.07	0.00	0.00	18195	7.98	10.75
	13	-0.05	0.00	0.00	18252	7.04	10.76
	13.75	-0.20	0.00	0.00	18310	7.13	10.80
8/22/2001	0	5.44	97.8	12.24	1720	7.99	0.91
	1	5.44	96.5	12.08	1729	7.99	0.92
	2	5.47	96.0	11.99	1787	8.00	0.95
	3	5.80	95.9	11.88	1906	8.00	1.02
	4	5.78	105.6	12.61	10940	7.49	6.22
	5	2.66	92.2	11.94	11112	7.47	6.33
	6	1.46	90.3	12.08	11191	7.46	6.37
	7	1.03	83.2	11.23	11414	7.44	6.51
	8	0.74	43.0	5.82	12795	7.20	7.35
	9	0.50	1.8	0.25	17656	7.09	10.44
	10	0.30	0.5	0.07	17995	7.17	10.61
	11	0.13	0.1	0.02	18152	7.24	10.70
	12	-0.02	0.0	0	18175	7.34	10.71
	13	-0.16	0.0	0	18198	7.38	10.74
	14	-0.35	0.0	0	18244	7.46	10.77

Appendix 11 – DOT Mine Site, Fish

DOT Mine Site										
		Fyke Net		Arctic	Broad	Least	Round	Dolly	Slimy	Ninespine
		Effort		Grayling	Whitefish	Cisco	Whitefish	Varden	Sculpin	Stickleback
Date	Location	(days)	Temp °C	n, mm	n, mm	n, mm	n, mm	n, mm	n, mm	total #
7/21 to 22/1998	Ramp	2	12.7					6, 140-282		27
7/22/1998	Inlet	1	12.7					1, 110		97
8/25 to 26/1998	South Side	2	10.1	131, 48-240			1, 135	6, 145-284		3,146
8/25 to 26/1998	Inlet	2	10.1	23, 48-236					1, 110	1,144
6/23 to 27/1999	Southwest	5	5.2 - 7.5	8, 62-319		1, 350	1, 109	4, 101-130		123
6/24 to 27/1999	Inlet	4	9.1 - 11	7, 58-67						149
8/26 to 28/1999	Southwest	3	5.2	19, 94-227	1, 207	1, 212				2,788
8/9 to 16/2000	Southwest	6	10.8	58, 90-319	3, 128-390		22, 92-403	1, 110	1, 53	2,797
8/17 to 20/2001	Southwest	4	6.0 - 8.0	18, 80-330	1, 430		1, 85		1, 55	15
8/17 to 20/2001	Ramp	4	6.0 - 8.0	52, 75-325	1, 285		3, 94-348	1, 148		35

Appendix 12 – DOT Mine Site, Water Quality

DOT Mine Site								
					Dissolved	Specific		
		Depth	Temp	Percent	Oxygen	Conductance		Salinity (ppt)
Date	Location	(m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH	cond/100
7/21/1998	Pit Basin	0	12.65	98.0	10.45		8.59	0.14
		1	12.65	94.6	10.05		8.59	0.14
		2	12.65	92.7	9.89		8.60	0.14
		3	12.62	92.3	9.80		8.60	0.14
		4	12.60	91.4	9.72		8.60	0.14
		5	12.60	91.2	9.70		8.59	0.14
		6	12.55	91.1	9.66		8.58	0.14
		7	12.52	90.5	9.64		8.58	0.14
		8	12.08	90.2	9.69		8.55	0.14
		9	9.82	86.9	9.84		8.49	0.14
		9.75	9.65	85.7	9.77		8.50	0.14
8/25/1998	Pit Basin	0	10.16	97.5	10.83		8.71	0.15
		1	10.14	97.1	10.81		8.71	0.15
		2	10.11	96.8	10.76		8.71	0.15
		3	10.09	96.9	10.78		8.71	0.15
		4	9.97	96.7	10.77		8.71	0.15
		5	9.95	96.3	10.74		8.69	0.15
		6	9.93	96.2	10.74		8.69	0.15
		7	9.91	96.0	10.73		8.67	0.15
		7.1	9.91	95.4	10.64		8.71	0.15
6/26/1999	Inlet Channel	0	9.07	95.5	11.7	305.3	8.00	
		1.75	6.34	100.0	11.9	296.3	8.15	
6/26/1999	Pit Basin	0	5.17	95.6	12.28	297.6	8.09	
		1	5.11	95.6	12.28	297.3	8.10	
		2	5.05	95.7	12.33	297.5	8.12	
		3	4.69	96.2	12.5	298.0	8.12	
		4	4.49	96.7	12.65	299.8	8.11	
		5	4.42	97.0	12.7	300.0	8.11	
		6	4.39	96.8	12.68	300.2	8.11	
		7	4.39	96.7	12.67	300.6	8.10	
		7.5	4.37	96.3	12.63	300.0	8.11	

Appendix 12. DOT Mine Site, Water Quality (concluded)

8/10/2000	Pit Basin	0	10.77	92.4	10.34	333.4	8.39	
		1	10.77	91.5	10.25	333.5	8.39	
		2	10.77	90.5	10.13	333.3	8.4	
		3	10.76	90.4	10.13	333.5	8.4	
		4	10.76	90.5	10.14	333.4	8.39	
		5	10.76	90.3	10.11	333.4	8.4	
		6	10.75	90.4	10.12	333.5	8.4	
		7	10.75	90.3	10.12	333.6	8.4	
		8	10.72	90.2	10.1	333.7	8.4	
		9	10.71	89.9	10.09	333.5	8.4	
		10	10.67	89.7	10.07	333.5	8.4	
		11	10.43	88.9	9.99	333.5	8.37	
		12	9.05	81.1	9.47	332.9	8.23	
		13	6.31	68.2	8.45	333.4	7.97	
		13.75	6.02	65.2	8.17	335.2	7.94	
4/22/2001	Pit Basin	1	0.00	91.4	13.36	432.9	7.62	
		2	0.19	90.5	13.16	430.4	7.63	
		3	0.19	89.9	13.05	430.5	7.63	
		4	0.19	89.5	13.01	430.6	7.64	
		5	0.19	89.3	12.97	430.7	7.64	
		6	0.19	89.0	12.94	430.4	7.64	
		7	0.19	88.9	12.93	430.8	7.64	
		8	0.19	88.8	12.91	430.7	7.64	
		9	0.19	88.8	12.89	430.7	7.64	
		10	0.19	88.6	12.89	430.9	7.64	
		11	0.19	88.6	12.89	431.2	7.64	
		12	0.19	88.5	12.86	431.4	7.64	
		13	0.18	82.7	12.02	436.7	7.60	
		14	-0.03	28.5	4.18	481.6	7.27	
8/21/2001	Pit Basin	0	7.08	99.2	11.98	322.0	8.03	
		1	7.06	98.0	11.83	322.0	8.05	
		2	7.04	97.5	11.78	322.0	8.04	
		3	7.00	96.6	11.69	322.0	8.04	
		4	6.91	96.1	11.66	321.6	8.04	
		5	6.88	96.0	11.64	322.0	8.04	
		6	6.88	95.8	11.62	321.8	8.03	
		7	6.87	95.3	11.56	322.2	8.03	
		8	6.86	95.1	11.54	322.5	8.03	
		9	6.85	94.9	11.53	323.2	8.03	
		10	6.80	94.8	11.52	323.5	8.02	
		11	6.69	94.6	11.53	325.2	8.01	
		12	6.60	94.2	11.51	326.0	8.00	
		13	6.54	94.2	11.52	327.7	7.99	
		14	6.51	94.1	11.52	328.2	7.98	

Appendix 13 – Sag Site C and Sag Scour Pools, Fish

Date	Fyke Net Effort (days)	Temp °C	Arctic Grayling n, mm	Broad Whitefish n, mm	Least Cisco n, mm	Round Whitefish n, mm	Dolly Varden n, mm	Slimy Sculpin n, mm	Burbot n, mm	Ninespine Stickleback (total number)
August, 1986	gill/fyke net		19, 214-284				2, 168-490			
July, 1987	gill/fyke net		18, 225-338	1, 445		2, 320-327	1, 470			
7/9 to 16/1988	15	4.6 - 13.2	908	130		474	7		7	
8/4 to 5/1988	7	7.5 - 9.0	85	1		17	3	2		
7/18 to 19/1989	6	10.5 - 13.5	71, 44-317	19, 38-421		227, 34-398	5, 161-203	1, 35	2, 162-165	9
8/24/1989	3	10.0 - 11.0	1031, 40-323	9, 60-87	1, 176	218, 40-405			39, 52-145	2,423
8/24/1990	2	5.5 - 7.0	28, 67-358			1, 290			1, 130	
7/18 to 22/1993	10		29, 116-393	2, 38-41		11, 68-430	8, 53-260	1, 59	1, 85	8

Date	Scour Pool	Fyke Net Effort (days)	Temp °C	Arctic Grayling n, mm	Broad Whitefish n, mm	Round Whitefish n, mm	Dolly Varden n, mm	Slimy Sculpin n, mm	Burbot n, mm	Ninespine Stickleback (total number)
7/23 to 25/1996	#1	2	17.5	51, 54-142		53, 67-118	1, 165	18, 55-108	0	0
7/29/1997	#1	0.9		2, 86-155	5, 44-106	28, 57-89	0	4, 65-86	0	0
8/5/1998	#1	1.1	12.3	7, 75-96	11, 60-66	0	0	1, 74	1, 112	0
8/28 to 29/1999	#1	1.9		8, 46-104	5, 64-66	35, 50-60	0	16, 50-95	0	4
7/23 to 25/1996	#2	2	18	82, 60-184	3, 48-52	18, 45-149	0	6, 73-121	0	0
7/29/1997	#2	1		0	103, 47-98	0	0	5, 41-103	0	4
8/5/1998	#2	1.1	12.1	8, 75-235	39, 62-68	4, 50-104	0	0	0	2
8/28/1999	#2	1		96, 39-128	8, 64-145	134, 50-115	0	3, 26-75	1, 295	0
7/23 to 25/1996	#3	1	15	20, 59-144	65, 47-54	5, 43-70	0	0	0	0
7/29/1997	#3	0.9		0	4, 50-56	0	0	0	0	0
8/5/1998	#3	1.1		8, 82-232	12, 65-73	1, 58	0	0	0	2
6/23/1999	#3	1		0	0	0	0	0	0	0
8/26 to 28/1999	#3	2		30, 42-58	35, 60-75	16, 51-62	0	0	0	2
7/29/1997	#4	0.9		0	2, 48-52	0	0	0	0	0
8/6/1998	#4	0.9		2, 95-105	2, 64	4, 51-98	0	2, 87-110	2, 30	0
6/23/1999	#4	1		0	0	0	0	0	0	2
8/27/1999	#4	1		3, 48-53	1, 59	1, 62	0	0	0	4
7/29/1997	#5	0.9		36, 59-138	4, 43-100	58, 60-122	0	14, 42-103	0	3
8/6 to 7/1998	#5	3		34, 64-245	56, 54-96	44, 54-96	0	2, 38-63	0	10
6/23/1999	#5	1		8, 74-299	1, 158	0	0	8, 39-85	0	10
8/24 to 26/1999	#5	3.5		31, 44-58	0	0	0	48, 41-87	0	44
8/6/1998	#6	1		11, 83-115	0	0	1, 202	4, 78-100	0	4
6/25/1999	#6	1		0	0	1, 117	0	3, 56-87	0	0
8/24 to 26/1999	#6	1.75		3, 43-53	3, 55-57	0	0	11, 36-86	0	250

Appendix 14 – Sag Site C, Water Quality

Sag Site C water quality					
April 25, 1987	under ice				
			Conductivity		
Depth (m)	Temp C	DO (mg/L)	uS/cm	pH	
below ice	0.9	10.5	105	7.7	
3	0.9	11.8	105	7.7	
6	0.8	11.8	105	7.7	
9	1.0	11.5	105	7.6	
12	1.0	11.3	105	7.7	
15	0.9	11.4	105	7.7	
18	0.9	11.2	105	7.6	
April 23, 2001	under ice				
		Percent		Conductivity	
Depth (m)	Temp C	Saturation	DO (mg/L)	uS/cm	pH
1	0.46	83.0	12.26	224.9	7.50
2	1.87	88.5	12.36	230.8	7.56
3	1.86	88.8	12.51	230.6	7.55
4	1.82	88.8	12.52	230.6	7.54
5	1.81	88.8	12.51	230.8	7.56
6	1.80	88.6	12.50	230.5	7.55
7	1.80	88.6	12.49	230.2	7.54
8	1.80	88.5	12.47	230.5	7.54
9	1.80	88.4	12.47	230.3	7.54
10	1.79	88.3	12.46	230.2	7.54
11	1.80	88.4	12.47	230.1	7.54
12	1.80	88.4	12.47	229.7	7.54
13	1.79	88.3	12.47	229.9	7.54
14	1.79	88.3	12.45	230.0	7.55
15	1.79	88.3	12.46	229.9	7.54
16	1.79	88.1	12.43	229.8	7.54
16.5	1.78	87.5	12.34	229.7	7.54

Appendix 14. Sag Site C, Water Quality (concluded)

7/13/1988			
Sag Site C	open water		
Depth (m)	Temp C		DO (mg/L)
1	3.2		14.4
2	3.4		13.8
4	3.1		13.1
5			
6	3.1		13.4
8	3.1		12.9
10	3.3		13.2

Appendix 15 - Badami Creek Mine Site, Fish

Date	Fyke Net Effort (days)	Temp °C	Arctic Grayling n, mm	Least Cisco n, mm	Dolly Varden n, mm	Slimy Sculpin n, mm	Four Horned Sculpin n, mm	Ninespine Stickleback (total number)
7/31-8/2/1994	6		1, 103				2, 68-70	2,431
8/28-31/1994	8		2, 59-74				8, 35-46	4,934
6/20-23/1995	3	5.7						680
7/17-20/1995	3	12			83			4,576
8/28-31/1995	3	3.3			n, 190-196	1, 132		1,287
8/6/1997	2	12.2 - 13.1						475
7/22/1998	2	12.9			3, 180-265			153
7/29/1999	2	6.3 - 6.9						69
8/14/2000	2	7.9		2, 130-143	2, 95-148			357

Appendix 16 - Badami Creek Mine Site, Water Quality

Badami Mine Site					
April 24, 2001					
Location:	N 70.12999				
	W 146.99858				
Time:	10:40				
Ice Thickness:	5'		Freeboard:	4"	
			Dissolved	Specific	
Depth	Temp	Percent	Oxygen	Conductance	
(m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH
1	-0.02	85.4	12.61	292.1	7.33
2	-0.12	87.6	12.98	291.1	7.30
3	-0.11	87.6	12.98	291.1	7.29
4	-0.11	87.8	13.00	291.2	7.30
5	-0.11	88.0	13.03	291.2	7.29
5.5	-0.12	67.3	9.96	292.1	7.21
7/21/1998					
				Specific	
		Percent		Conductance	
Depth (m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH
0	12.96	97.2	10.25		8.62
1	12.94	94.6	9.95		8.65
2	12.95	93.4	9.84		8.66
3	12.94	92.9	9.76		8.67
4	12.93	92.4	9.72		8.67
5	12.94	92.2	9.7		8.67
7/29/1999					
				Specific	
		Percent		Conductance	
Depth (m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH
0	6.96	90.5	11.21	231.5	6.96
1	6.94	90.1	11.17	231.2	6.94
2	6.93	90.2	11.17	232.2	6.93
3	6.93	90.2	11.19	231.5	6.93
4	6.92	90.2	11.18	231.7	6.92
5	6.92	89.3	11.06	232.2	6.92
8/12/2000					
				Specific	
		Percent		Conductance	
Depth (m)	Temp C	Saturation	DO (mg/L)	(uS/cm)	pH
0	7.85	95.7	11.62	164.2	8.24
1	7.86	93.2	11.33	164.6	8.25
2	7.87	93.1	11.30	164.5	8.24
3	7.86	92.5	11.24	164.6	8.25
4	7.87	91.7	11.14	164.5	8.25
5	7.87	91.3	11.09	164.6	8.28
6	7.85	91.0	11.06	164.7	8.25