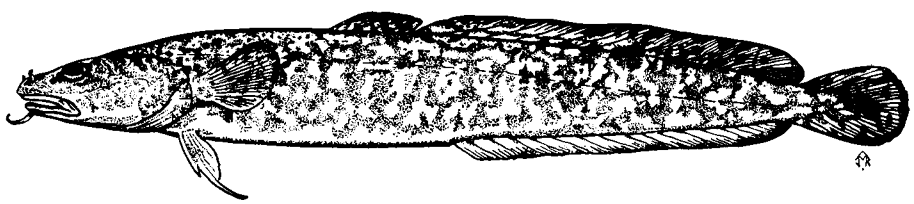
AQUATIC HABITAT AND FISHERIES STUDIES UPPER FISH CREEK, 1992-1994

By

Alvin G. Ott, Phyllis Weber Scannell, and Alan H. Townsend

Technical Report No. 95-4



The Alaska Department of Fish and Game
Habitat and Restoration Division

January 1995

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We thank Mr. Hemming and Mr. Winters (ADF&G, Habitat and Restoration Division), Ms. McNay, and Mr. Evenson and Mr. Clark (ADF&G, Sport Fish Division) for assisting with field work. Constructive review of the report was provided by Mr. Winters, Mr. Andersen and Mr. Fleming (ADF&G, Sport Fish Division), Mr. Jeffress (FGMI), Mr. McGroarty (ADNR), Mr. Scannell (USFWS), Mr. Vohden (ADNR), and Ms. Hanson (NMFS). Final editing was performed by Ms. Warner.

ABSTRACT

Over 4,000 Arctic grayling were estimated in pond habitat in Last Chance Creek in 1993. In 1994, we found large numbers of Arctic grayling and burbot occur in abandoned settling ponds in the Fish Creek valley. Arctic grayling spawned successfully in inlets and outlets of settling ponds, grew rapidly until 180 mm, matured early (2+ and 3+) at a small size (average 180 mm), and moved to cooler stream habitats from ponds when reaching 200 mm.

The Arctic grayling in the Last Chance Creek pond complex and in Fish Creek abandoned settling ponds will colonize the freshwater reservoir when it fills with water. Most of the fish in upper Fish Creek will not be adversely effected by construction of the freshwater dam. We speculate that the 66.8 ha (165 acre) freshwater reservoir will provide habitat suitable for rearing, overwintering, and spawning for both burbot and Arctic grayling. We believe that populations of burbot and Arctic grayling will be established over time in the freshwater reservoir providing, at mine closure, a recreational sport fishery.

INTRODUCTION

Fairbanks Gold Mining, Inc. (FGMI) a wholly owned subsidiary of Amax Gold Inc., is developing a hardrock gold mine located about 25 km northeast of Fairbanks in the headwaters of Fish Creek, a tributary of the Little Chena River (Figure 1). The deposit has proven and probable reserves of 4.1 million ounces of gold with potential for additional reserves. Development of the project will involve an open-pit mine, mill, tailing impoundment, freshwater reservoir, and related facilities (Figure 2). The gold ore is crushed, ground, processed in a slurry, and gold is extracted in tanks containing carbon and dilute cyanide in the mill complex. The thickened tailing slurry will be treated using the patented INCO SO_2/Air process for cyanide detoxification prior to discharge to the tailing pond. Maximum probable weak acid dissolved (WAD) cyanide levels in the tailing pond after mixing should be 1.0 mg/L. Other states (Nevada, California) have established limits of 50 mg/L (WAD cyanide) as being acceptable for closed systems with open water (Eisler 1991).

FGMI began environmental baseline work in 1989 and from the beginning worked cooperatively with state and federal agencies, environmental organizations, the Fairbanks North Star Borough, and the public to identify and address environmental issues. The tailing dam and impoundment were designed with pump-back wells, interceptor wells, and monitoring wells to ensure zero discharge. The dam will be constructed on bedrock with a low permeability. Water flowing through tailing and under the dam will be collected in the pump-back and interceptor wells and recycled to the impoundment. Water quality monitoring in pump-back and interceptor wells will provide data to evaluate concentrations of metals, solids, and cyanide as the tailing impoundment is filled. Monitoring wells

Figure 1. Fort Knox Project Location

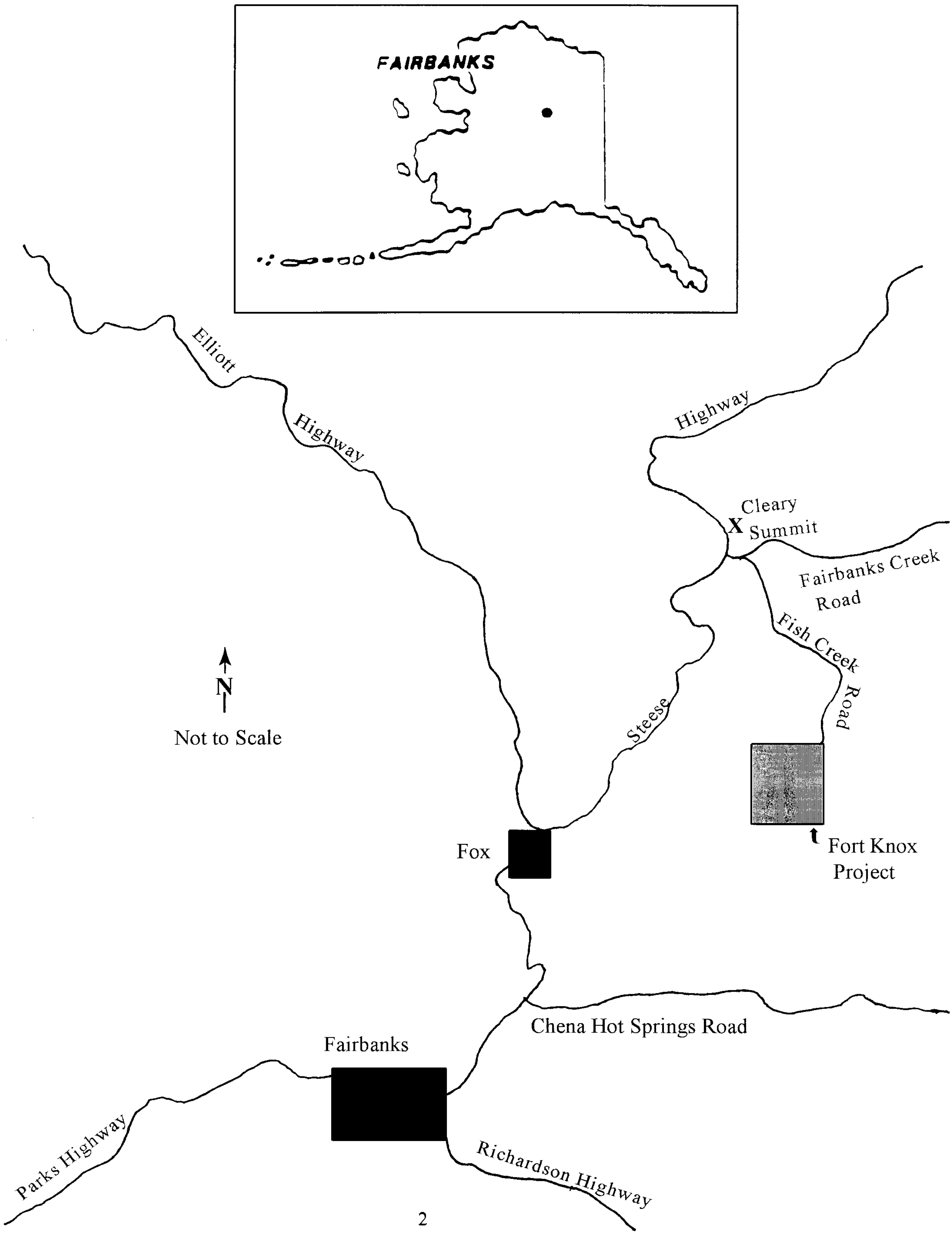
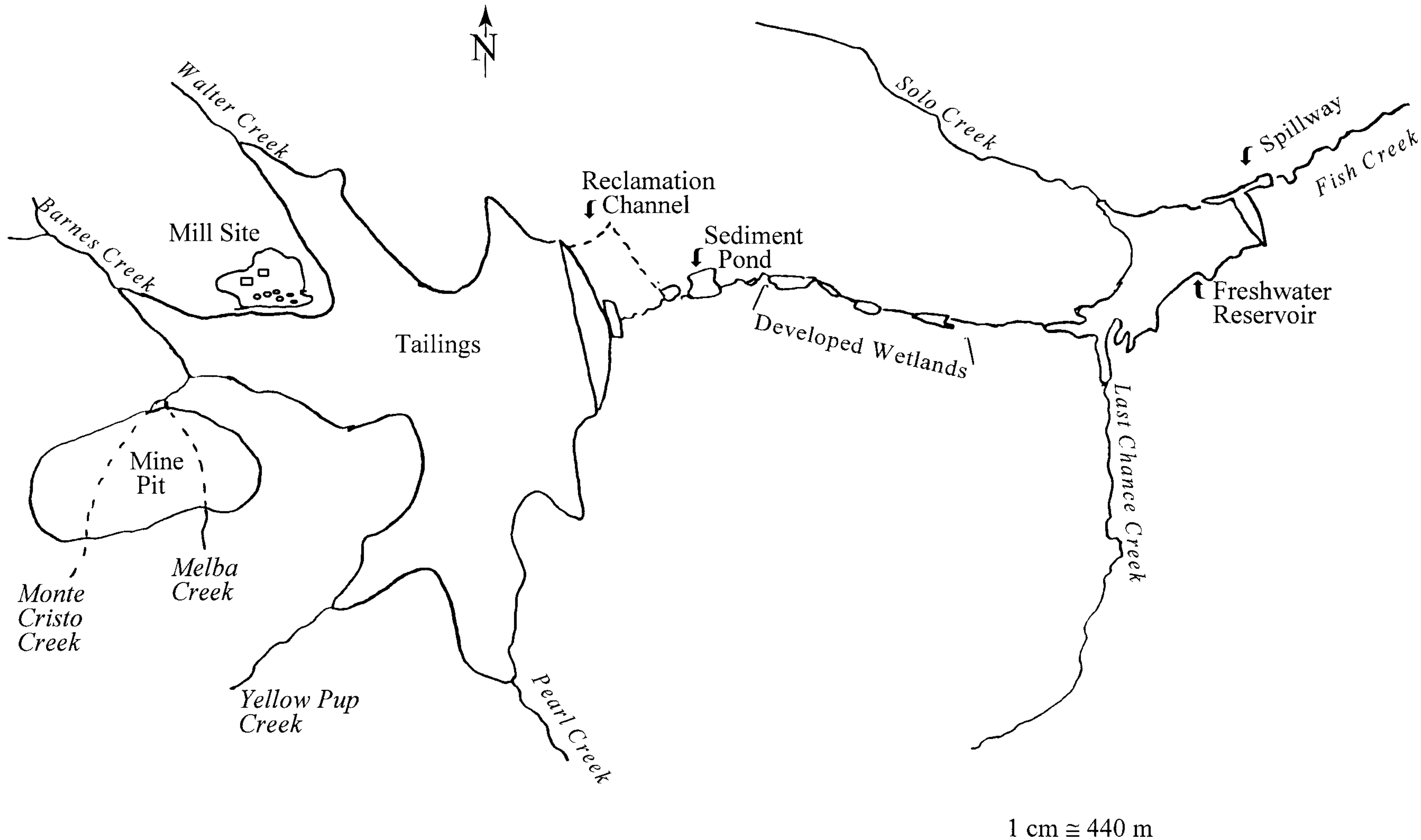


Figure 2. **The open-pit mine, tailing impoundment, freshwater reservoir, and related facilities for the Fort Knox Gold Mine.**



downstream of the interceptor wells will provide assurance that the system is functioning as a zero discharge facility. The Alaska Department of Environmental Conservation (ADEC) issued a solid waste permit to FGMI on February 7, 1994, for disposal of treated tailing. Terms and conditions of the ADEC permit cover water quality monitoring, water quality standards to be met in pump-back water and in the tailing impoundment, water quality standards for site closure, bonding, and post-mining water quality monitoring. A water quality monitoring plan (FGMI 1993) for tailing facilities process fluids, surface and subsurface waters, and characterization of material for acid rock drainage was developed by FGMI and incorporated by reference as part of ADEC's solid waste permit.

FGMI also prepared a reclamation plan for all lands disturbed by the project (FGMI 1994a). The reclamation plan calls for segregation and stockpiling of surface organic materials for seed bed preparation, revegetation of rock dumps, and stabilization of abandoned placer mine cuts; the relocation of a recreational trail; and closure of the tailing impoundment to meet state water quality standards. To the extent practical, FGMI included concurrent reclamation into the project design. The reclamation plan was submitted to both the Alaska Department of Natural Resources (ADNR) and the U.S. Army Corps of Engineers (ACOE) to support permit applications. The ADNR issued a millsite permit and upland mining lease in February 1994 and the U.S. Army Corps of Engineers permitted the project with a Section 404 permit on May 5, 1994. The millsite permit, upland mining lease, and Section 404 permit incorporated by reference the FGMI reclamation and water quality monitoring plans.

The FGMI reclamation plan calls for construction of 18.2 ha (45 acres) of developed wetlands between the tailing impoundment and upstream limit of the freshwater reservoir pool in habitat highly disturbed by past placer mine activities. The probability of successful wetland development is high based on natural revegetation in portions of the Fish Creek valley (Figure 3). Wetland creation will provide waterfowl and shorebird habitat, fisheries habitat upon site closure, and will significantly improve water quality entering the freshwater reservoir. These wetlands also may prove valuable as a final passive treatment for waters leaving the tailing impoundment at site closure. Wetlands will be designed with a fish barrier at the downstream limit to prevent entry by fish to the wetlands during the operational phase of the project. ADF&G authorized the design of the fish barrier with the condition that it be removed and fish passage reestablished as part of final reclamation.

The mill is being designed to process between 36,000 and 50,000 tons of ore per day. Operation of the mill at 36,000 tons per day will require 0.57 $m^3 \cdot s^{-1}$ (9,000 gpm) process water; about 0.38 $m^3 \cdot s^{-1}$ (6,000 gpm) will be supplied by recycling from the tailing pond and 0.19 $m^3 \cdot s^{-1}$ (3,000 gpm) will be from runoff, drainage, and water stored in the freshwater reservoir. Significant water (0.14 to 0.17 $m^3 \cdot s^{-1}$) [2200 to 2750 gpm] is tied up interstitially within the tailing.

FGMI conducted detailed hydrological surveys in the upper Fish Creek drainage, monitoring flows in both surface and subsurface waters (FGMI 1994b). These data, combined with results of long-term hydrological studies on Caribou Creek, led to the decision that a freshwater reservoir was needed to ensure adequate water supply for year round operation of the mill, particularly for startup and during periods of below average precipitation. FGMI sited and designed a freshwater dam in Fish Creek immediately below the confluence of Last Chance and Solo creeks. The freshwater reservoir will have a maximum surface area of 66.8 ha (165 acres) and will store 4.92×10^6 m^3 (4,000 acre-feet) of water. FGMI estimates the

Figure 3. Natural revegetation of ice rich material adjacent to a mine cut (upper photo) and an abandoned settling pond (lower photo) in upper Fish Creek.

freshwater reservoir will impound or regulate about 30% of the downstream flow in Fish Creek. After consultation with federal and state agencies, FGMI decided to design and construct the freshwater dam as a permanent structure. An Agreement for Funding and Post-Reclamation Obligations was signed to cover post-mining maintenance of the freshwater dam with a fund established by FGMI. ADF&G strongly supported the decision to design a permanent dam and the Agreement for Funding and Post-Reclamation Obligations. The final design for the freshwater dam was approved by the ADNR (Dam Safety Permit) and ADF&G issued a Fish Habitat Permit for fish blockage by the dam. Based on resource data collected in the Fish Creek valley, ADF&G decided that mitigation developed by FGMI as part of the project design satisfied the requirements of AS 16.05.840.

Our support for the design of a permanent freshwater dam and associated lake was based on fisheries information collected in 1992 and 1993 in upper Fish Creek (Weber Scannell and Ott 1993, Weber Scannell and Ott 1994). FGMI provided a grant to the ADF&G to conduct fish and water quality studies in the Fish Creek drainage. Based on historical work conducted by Tack (1972), Holmes (1985), and Dames and Moore (1991), a study design was developed and implemented beginning in summer 1992. The broad objectives of the study were to define seasonal use patterns of fish in the drainage, to establish baseline data on water quality and fish distribution, to determine background heavy metals concentrations in fish in the drainage, and to identify mitigative opportunities that could be incorporated into the project design.

We discovered in 1993 that existing small ponds (flooded abandoned mine cuts or settling basins) with an estimated surface area of 5.1 ha (12.7 acres) in upper Last Chance Creek, upstream of the proposed freshwater reservoir, supported a population of more than 4,000 Arctic grayling (Weber Scannell and Ott 1994). Most of the Arctic grayling were less than 200 mm long. These unique ponds are fed by groundwater and surface flows from Last Chance Creek and receive organics from eroding cutbanks. The highly productive aquatic habitat is characterized by warm summer water temperatures, abundant plankton, a variety of invertebrates, and high winter dissolved oxygen concentrations. Caddisflies (Tricoptera), mayflies (Ephemoptera), stoneflies (Plecoptera), snails (Gastropoda), midges (Diptera), and water boatman (Hemiptera) are present in the ponds and large hatches of mayflies were observed during summer 1993. Habitats suitable for spawning, rearing, and overwintering for Arctic grayling exist in these unique pond environments.

The Last Chance Creek pond complex is located at the upper end of the projected limit of the freshwater pool and therefore fish from the ponds will have access to the freshwater impoundment. In their reclamation plan, FGMI (1994a) stated: "the primary objectives in reclaiming Fort Knox are the development of wildlife habitat and a publicly useable open water reservoir and the associated fishery in the open pit, developed wetlands and water supply reservoir." A criterion to determine success for a fishery in the water supply reservoir was developed. We set a goal of having a fish density for Arctic grayling greater than 200 mm of 10 to 20 fish per ha of surface area 10 years following completion of the freshwater dam.

Our fish study in the upper Fish Creek drainage continued during winter 1993-1994 and summer 1994. Our 1994 work included gathering additional baseline data on fish and water quality as these factors relate to construction activities and development of the Fort Knox project, and included field surveillance of construction activities at the freshwater and tailing dam sites. We also examined other settling ponds in the Fish Creek floodplain and collected fish and water quality data during late winter 1993-1994. We report a summary of our findings covering 1992 through 1994 in a Results and Discussion section. We describe the integration of field data into the project design, the life history of Arctic grayling in upper Fish Creek, and applicability of our findings to future development projects in the Conclusion section.

METHODS

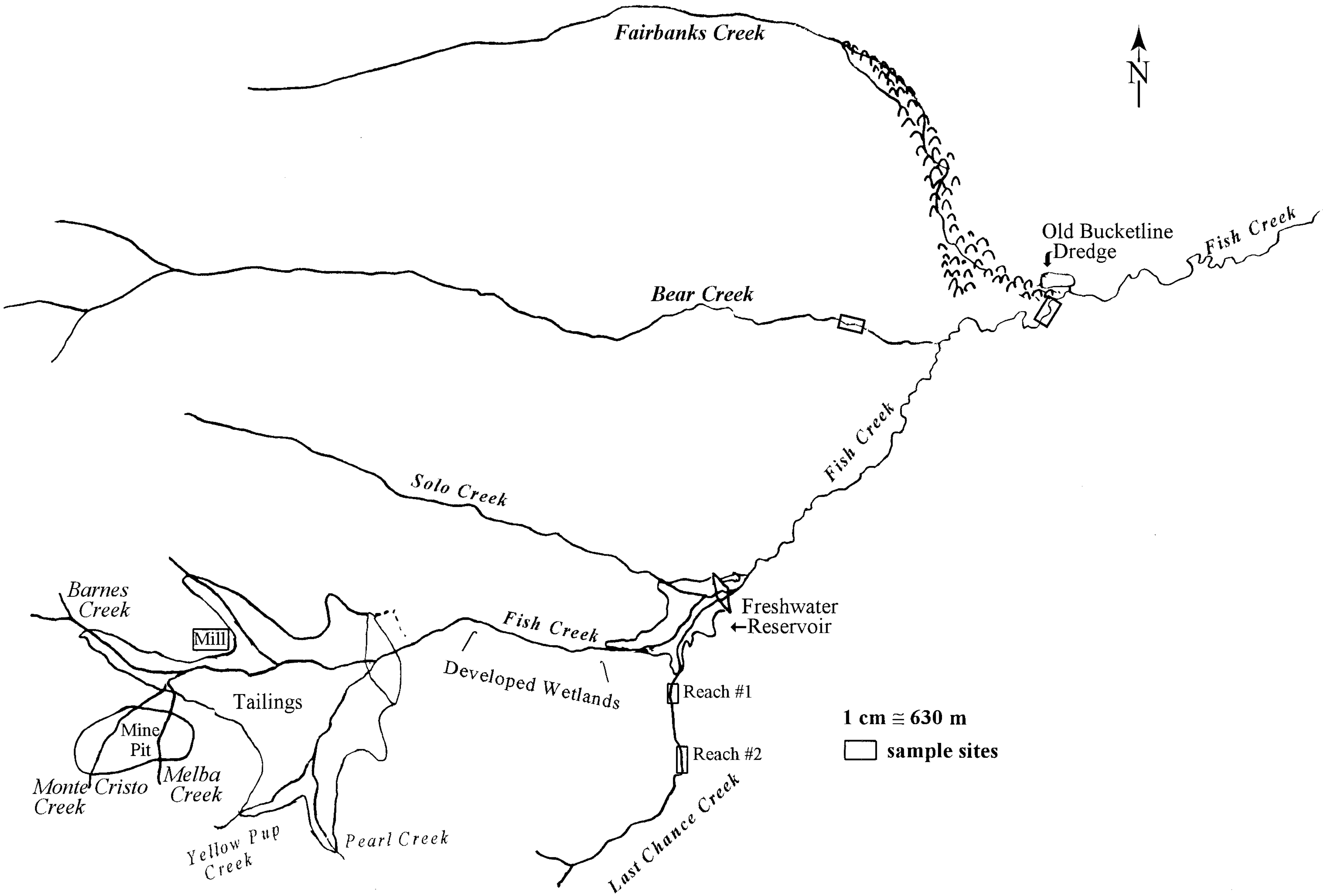
SAMPLING SITES

Baseline sample sites (water quality, fish, benthic invertebrates) were established in 1992 for areas directly impacted by the project. Sample sites were located in stream reaches to be inundated by the freshwater reservoir and in reaches downstream of the freshwater dam where flows would be changed. In 1993, baseline stations were resampled and our work focused on flooded mine cuts and settling basins in Last Chance Creek where large numbers of Arctic grayling were found. Systematic sampling for stream reaches to be flooded by the reservoir was discontinued in 1994, baseline sampling areas were established in Last Chance Creek upstream of the projected limit of the freshwater reservoir, sampling continued in Fish and Bear creeks downstream of the freshwater dam, and fish and water quality sampling were initiated in settling ponds in the Fish Creek floodplain.

Fish data from pool/riffle sequences were combined for purposes of analyses due to significant annual changes in stream character within sample reaches. Periodically we also sampled upper Fish Creek, including lower Solo and Last Chance Creeks, to collect tag recovery data. Sample sites in upper Last Chance, lower Fish, and Bear Creeks will be used for post-construction monitoring (Figure 4).

A fish sample reach in Solo Creek upstream of the proposed freshwater reservoir was not established. Solo Creek is incised, contains thermokarst pools greater than 1 m (3 ft) deep, has a substrate of unconsolidated silts and organics, has virtually complete canopy of riparian vegetation, has undercut banks, and contains abundant

Figure 4. Fish sample sites for post-construction monitoring in the Fish Creek drainage.



stream channel debris. Fish collection using seines or an electrofisher was not possible in Solo Creek.

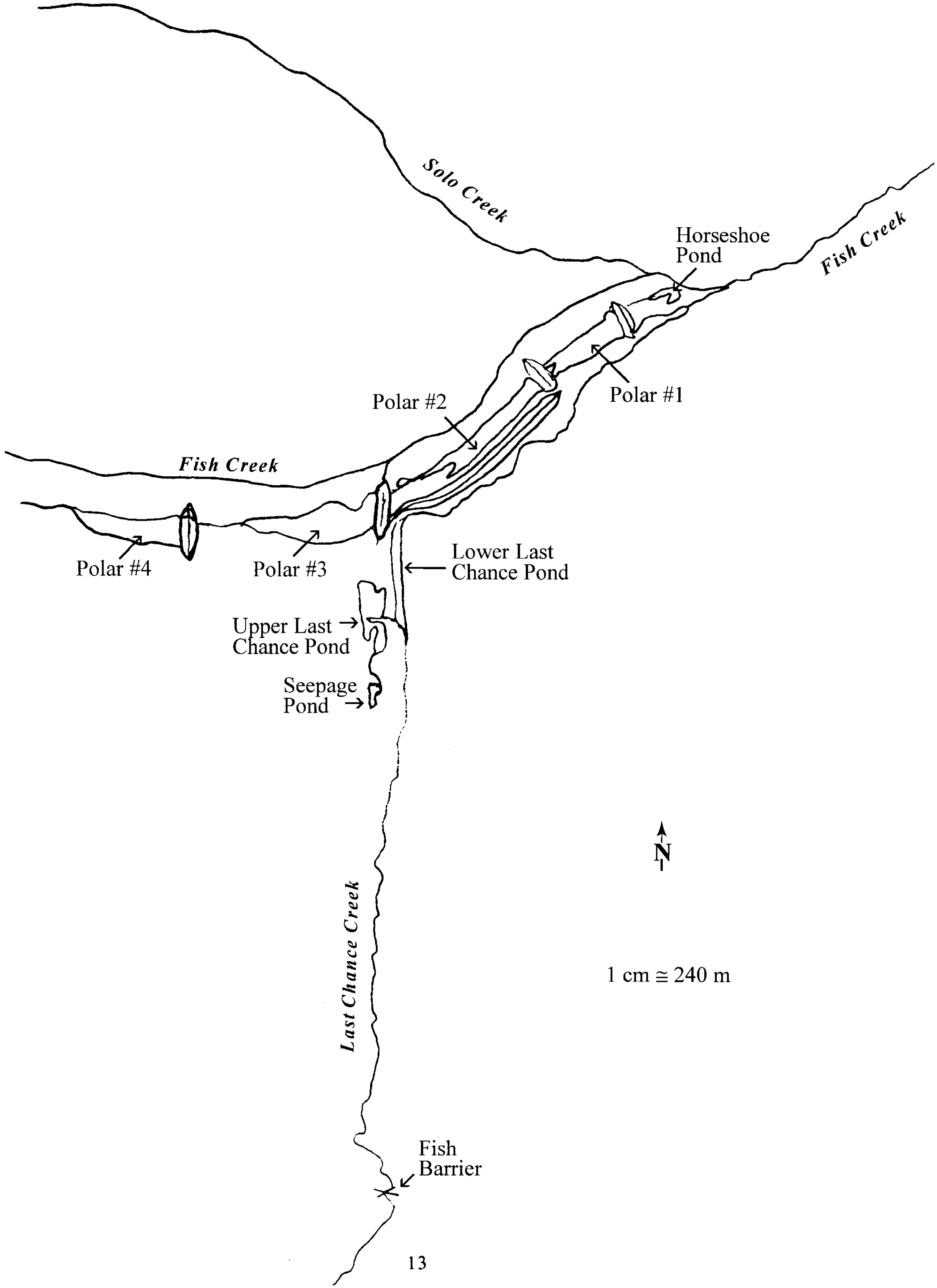
WATER QUALITY

Temperature was measured with a hand-held thermometer or a digital electronic thermometer. Settleable solids were measured with an Imhoff Cone, according to standard methods (APHA 1985). We collected water samples in clean 1000 ml plastic containers and kept refrigerated samples until analyzed for turbidity and total suspended solids. The ADNR, Division of Water, Water Quality Laboratory conducted all water quality analyses. U.S. Environmental Protection Agency (USEPA) method 180.1 was used for turbidity and USEPA method 160.2 was used for total suspended solids (Kopp and McKee 1983).

Temperature, flow, turbidity, and total suspended solids were measured in Fish Creek immediately upstream of Fairbanks Creek. Water level was measured with a pressure transducer and automated recorder, calibrated with stream flow measurements taken throughout the year. Water was sampled for turbidity and total suspended solids four times daily with an automated water sampler. Daily water samples were composited into one sample to give an average amount for the day.

Water samples were collected from ponds located in the floodplain of both Fish and Last Chance creeks with a VanDorn water sample bottle (Figure 5). In November 1993 and March 1994, we collected water samples with a peristaltic pump. Dissolved oxygen was measured using the azide modification of the Winkler titration (APHA 1985) and a Yellow Springs Instrument Co. dissolved oxygen meter.

Figure 5. Pond complexes in Upper Last Chance Creek and Fish Creek.



In July we collected water samples from both Last Chance ponds and Polar #1 pond, the inlet to the upper Last Chance pond, Fish Creek downstream of Polar ponds, and Horseshoe pond. Samples were analyzed for predominate cations (method AES 0029) and anions (EPA method 300.0): Ca, Mg, Na, K, Cl, NO_3^-, $PO_4^{\equiv}$, and $SO_4^{=}$ (Kopp and McKee 1983).

FISH

We collected fish using several techniques and methods including electrofisher, fyke-net, minnow traps, angling, and small mesh dip net. Most fish were collected with an electrofisher. Generally, we captured, identified, measured (fork length), and released fish. We also made visual observations in clear water streams and ponds.

We collected fish with a Smith-Root model 15-A backpack electrofisher using a single pass upstream beginning at the downstream end of the sample reach. Some Arctic grayling and burbot were retained for age and sex determination and stomach content analyses. Arctic grayling were marked with an adipose fin clip and those greater than 149 mm fork length were marked with numbered Fine Fabric Floy-tags.

The fyke-net was 3.7 m (12 ft) long with two 0.9 m (3 ft) square entrance frames, five hoops, a 1.8 m (6 ft) cod end, and 0.9 m (3 ft) by 7.6 m (25 ft) net wings attached to the entrance frame. The center lead was 30.4 m (100 ft). The net was set with the center lead perpendicular to the pond bank.

We used minnow traps baited with salmon roe placed in perforated plastic containers to collect fish from ponds. Traps were fished from 24 to 72 hours and rebaited if reset. A 0.3 m (1 ft) square frame dip net with fine mesh was used in shallow water to collect young-of-the-year Arctic grayling.

RESULTS AND DISCUSSION

UPPER LAST CHANCE CREEK

Last Chance Creek upstream from the pond complex was sampled during summer 1994 to establish baseline data on fish use prior to construction of the freshwater reservoir. Sample reaches were located upstream from the projected limits of the freshwater reservoir. Upper Last Chance Creek sample reaches (#1 and #2) were approximately 140 and 150 m long (Figure 4).

Upper Last Chance Creek flows in a single channel with minor braiding through an area that was mined extensively 10 and 30 years ago (Figure 6). Active mining, with the exception of one operation near the headwaters in 1994, has not occurred for about 10 years. A fish barrier exists in Last Chance Creek about 1.2 km above the pond complex. The barrier consists of a 1.0 m waterfall formed by an overburden and gravel dike constructed to pond water for past placer mine activities. Sparse riparian habitat exists along stretches of the creek below the fish barrier. Riffle areas with gravel and cobble are common, pools are infrequent and possess a sand-silt substrate, and the gradient is moderate. Rainstorm events result in rapid runoff within the disturbed area, bedload (sand and silt) movement occurs, and water temperatures appear to fluctuate rapidly in response to air temperature.

Water in Last Chance Creek was clear with a trace of settleable solids in 1994. Water temperature peaked in early August at 11.5°C but generally was less than 9.0°C during June and July. On May 2, Last Chance Creek was 80% ice free and one Arctic grayling was observed during a visual survey. Arctic grayling were present when electrofishing began on May 10 and by May 18 ripe females and males were common. Eighty-seven percent of fifty-five Arctic grayling ranging

Figure 6. Pool/riffle habitat in upper Last Chance Creek in reach #1.

from 139 to 240 mm [average length ($\bar{x}$) = 181.8 mm and standard deviation of the mean (SD) = 20.6 mm] collected in reach #2 were mature (sex products expelled) on May 18 (Table 1). On May 26, only a few ripe males remained. Spawning probably peaked around May 18 at a water temperature of 4.6°C. Young-of-the-year Arctic grayling were not captured in Last Chance Creek until September 5. Eleven were collected in reach #1 but none in reach #2. The average size of young-of-the-year Arctic grayling was 74.0 mm (SD = 6.1). We believe the fry moved upstream into reach #1 from the lower Last Chance pond. Because fry were not observed in Last Chance Creek during either electrofishing or visual surveys until September and then only in the lower sample reach we believe that virtually all natural production of Arctic grayling in the creek was lost during the high-water event in mid-June.

The number of Arctic grayling using upper Last Chance Creek in reach #2 increased between May 10 and 18 when spawning peaked (Table 2). By July 7, Arctic grayling in both reaches had decreased. By August 4, the number of fish using the creek had increased to levels comparable with those seen during peak spawning. Decreased abundance in July probably was due to displacement of fish downstream during the mid-June high water event. Arctic grayling smaller than 130 mm were not found in the creek until August and September. Five fish ranging in size from 95 to 116 mm ($\bar{x}$ = 106.6 mm, SD = 8.0) were collected in August and six between 108 and 127 mm ($\bar{x}$ = 119.5 mm, SD = 7.5) were collected in September. We also found juvenile burbot in upper Last Chance Creek in August and September. Five burbot were taken in August and four in September. All burbot were found in reach #1; one fish was 170 mm long, and the remaining eight were between 130 and 145 mm. We speculate that the smaller Arctic grayling and

Table 1. Length, sex, and maturity of Arctic grayling captured on May 18, 1994, in upper Last Chance Creek.

Fork Length (mm)	Sex	Mature
139		no
148	male	yes
160		no
160	male	yes
160	male	yes
163		no
163		no
164	male	yes
166		no
168	male	yes
169	male	yes
169	male	yes
170	male	yes
170	male	yes
170	male	yes
170	male	yes
170	male	yes
171		no
172	male	yes
172	male	yes
174	male	yes
174	male	yes
175	male	yes
175	male	yes
176	male	yes
176	male	yes
176	male	yes
176	male	yes
179	male	yes
180	male	yes
180	male	yes
180	male	yes
181		no
181	male	yes
182	male	yes
182	male	yes
183	male	yes
183	male	yes
184	male	yes
185	male	yes

Table 1. (Continued)

Fork Length (mm)	Sex	Mature
188	male	yes
189	male	yes
190	male	yes
192	male	yes
193	male	yes
194	male	yes
199	female	yes
204	female	yes
208	female	yes
214	male	yes
218	male	yes
225	male	yes
234	male	yes
237	male	yes
240	male	yes

Table 2. Number of fish caught, excluding young-of-the-year Arctic grayling, in Last Chance Creek upstream of the projected freshwater pool using an electroshocker (1994).

Date	Sample Site (Reach)	AG	BB	Total Fish
5/10/94	#1	118	0	118
7/7/94		68	0	68
8/4/94		130	5	135
9/5/94		114	4	118
5/10/94	#2	26	0	26
5/18/94[1]		55	0	55
5/26/94[1]		32	0	32
7/7/94		41	0	41
8/4/94		67	0	67
9/5/94		65	0	65

AG = Arctic grayling and BB = burbot

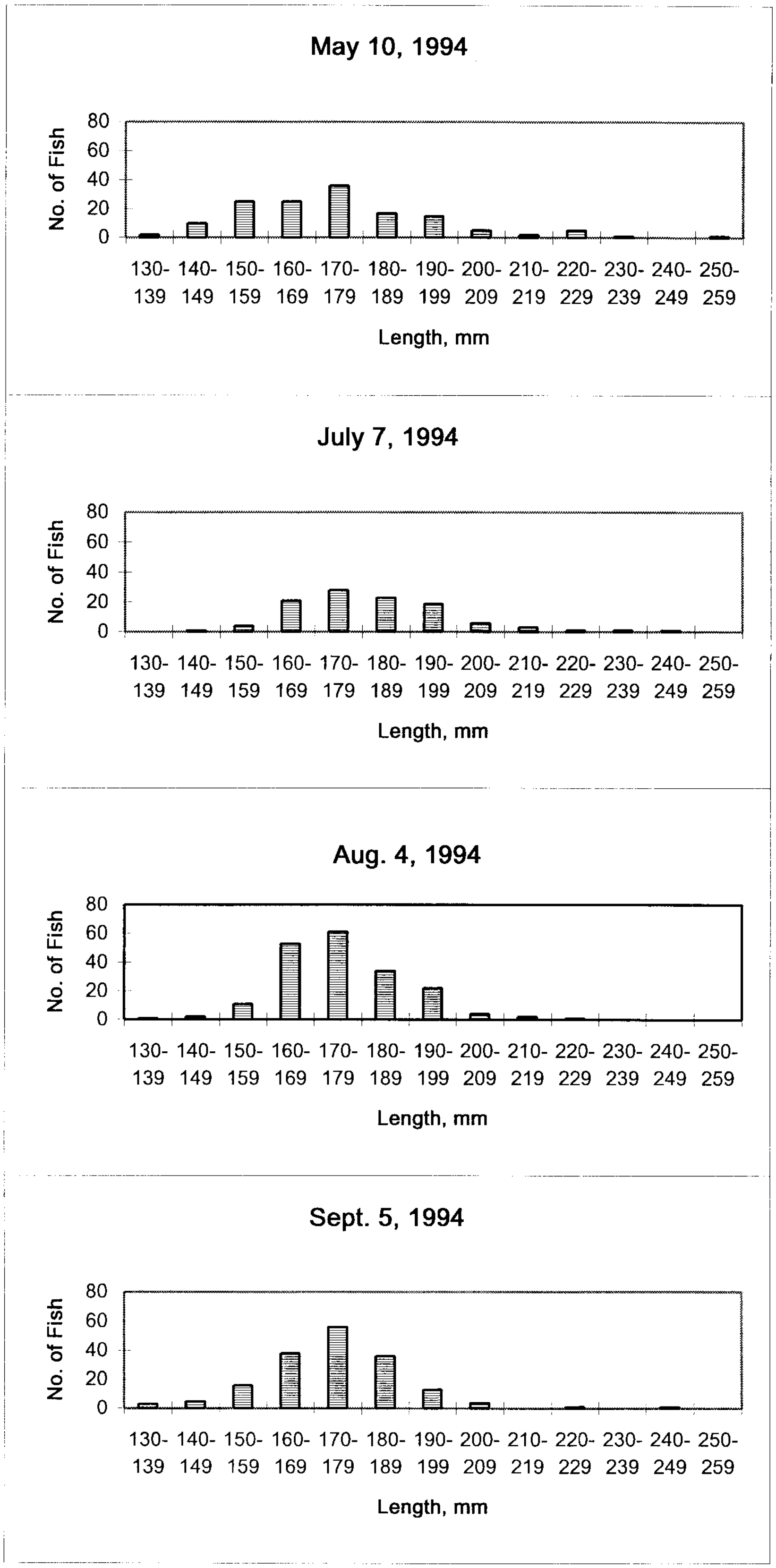
[1]We sampled reach #2 on May 10, 18, and 26 for the purpose of documenting spawning time. Reach #1 was not sampled on May 18 and 26 to minimize disturbance to spawning fish.

burbot moved into the creek from the lower pond and that the Arctic grayling are probably age 1+.

A length frequency distribution for Arctic grayling is presented in Figure 7. Most of the Arctic grayling ranged from 150 to 199 mm. Approximately 50 percent of the fish greater than 200 mm left the creek during late summer. The percentage of fish from 150 to 199 mm was 95 and 92 on August 4 and September 5. On September 29, visual surveys of the creek revealed an absence of fish in reach #2 with some Arctic grayling still present in reach #1. Anchor ice had formed in the creek and frazil ice was present in the water column. We assumed that most of the Arctic grayling had outmigrated downstream to the lower Last Chance Creek pond for overwintering.

Arctic grayling using upper Last Chance Creek during the ice-free season included fish previously tagged in the upper and lower Last Chance Creek pond complex, upper Fish Creek, Solo Creek, and lower Last Chance Creek. Six Arctic grayling tagged in upper Fish Creek on May 11 were recaptured in upper Last Chance Creek on May 18. Five fish marked on April 20, 1994 (prebreakup), in the upper Last Chance Creek pond complex were caught in upper Last Chance Creek in early May. Recapture data clearly indicate a directed movement of Arctic grayling into upper Last Chance Creek in early May for spawning. We also documented the movement of five Arctic grayling from upper Last Chance Creek to upper Fish Creek during summer 1994. Some of the Arctic grayling that spawned in upper Last Chance Creek remained in the creek to rear. Seven of 55 fish tagged on May 18, the peak of spawning, in reach #2 were recaptured in August or September.

Figure 7. Length frequency distribution of Arctic grayling collected in upper Last Chance Creek during summer 1994.



LAST CHANCE CREEK POND COMPLEX

The Last Chance Creek pond complex contains several ponds (mine cuts used as settling ponds) fed by groundwater and Last Chance Creek (Figure 5). The seepage pond has a surface area of about 0.04 ha (0.1 acres), the upper pond is 2.4 ha (6.0 acres) with 0.1 ha (0.2 acres) of littoral habitat, and the lower pond covers about 1.4 ha (3.2 acres) with limited shallow water where the creek enters the pond (Figure 8).

In 1993, we estimated 2,013 (95% confidence interval = 1513 - 2739 fish) Arctic grayling were in the lower pond and 2,289 (95% confidence interval = 1800 - 2817 fish) in the upper pond (Weber Scannell and Ott 1994). A mine cut containing both deep (> 2 m) and shallow water habitat referred to as the seepage pond is located upstream of the upper Last Chance pond. Fed by groundwater, a small surface flow exits the seepage pond and flows through an old settling pond which has been completely colonized with sedges and willows. The small stream leaving the seepage pond is less than 0.5 m wide with water less than 0.2 m deep. Flow in the channel remains constant throughout summer. In 1993, fish were not observed in the seepage pond or outlet channel.

In November 1993, 11 Arctic grayling from the upper pond and 10 from the lower pond were removed by angling and their stomach contents analyzed. Fish were actively feeding and some were sexually mature (Weber Scannell and Ott 1994). Mayflies (Ephemoptera) were found in fish from the upper pond but not the lower pond and caddisflies (Tricoptera) and stoneflies (Plecoptera) were only present in fish taken from the lower pond. Midges (Diptera: Chironomidae) and water boatman (Hemiptera: Corixidae) were found in Arctic grayling from both ponds. Snails (Gastropoda) were present in stomachs from upper pond fish only.

Figure 8. Habitat characteristics of upper (top photo) and lower (bottom photo) Last Chance Creek ponds.

Twenty-four Arctic grayling were collected from the ponds (12 from the upper and 12 from the lower) on March 31, 1994 (Table 3). Seventy-five percent from the upper pond were sexually mature and ranged from 155 to 194 mm ($\bar{x}$ = 173.8, SD = 9.4). In the lower pond, 67% were mature and ranged from 156 to 218 mm ($\bar{x}$ = 184.9, SD = 18.9).

On May 2, 1994, the upper pond was still nearly 100% ice covered. The seepage channel into the upper pond was flowing and three Arctic grayling were observed. These fish returned to the upper pond, disappearing under the ice. Water temperature in the seepage channel was 10.1°C on May 10 but no fish were seen. On May 20 we observed numerous Arctic grayling in the seepage pond and we collected, marked, and released 33 fish. Many of the Arctic grayling were ripe and appeared to be spawning in the shallow-water portion of the seepage pond where the water temperature was 10.2°C. Although active spawning was not observed in the upper pond we assume some occurred since young-the-year were seen on July 7 in both the upper Last Chance pond and seepage pond. Two of the Arctic grayling present in the seepage pond had been tagged on April 20, 1994, through the ice in the upper Last Chance Creek pond. The number of adult Arctic grayling in the seepage pond decreased during the summer but young-of-the-year fish and some adults were still present on August 11.

Arctic grayling tagged in summer 1993 in upper and lower Last Chance Creek ponds were recaptured just prior to breakup 1994 and during the ice-free season in the upper and lower Last Chance ponds and in upper Last Chance Creek. Eighteen tagged Arctic grayling ranging from 152 to 225 mm grew from 0 to 45 mm annually with an average growth of 17.8 mm (SD = 12.3) (Table 4). When larger fish (greater than 198 mm) are excluded from the sample, the annual rate of growth averages 22.4 mm (SD = 12.3).

Table 3. Length, sex, and maturity of Arctic grayling captured on March 31, 1994, in the upper and lower Last Chance Creek ponds.

Pond	Fork Length (mm)	Sex	Mature
Upper	155	male	no
	165	female	yes
	169	male	no
	170	female	yes
	171	male	yes
	174	female	yes
	175	female	yes
	176	female	yes
	178	male	yes
	178	male	yes
	181	male	no
	194	male	yes
Lower	156	female	yes
	161	male	no
	168	female	no
	172	male	yes
	173	male	yes
	183	male	yes
	195	male	no
	196	female	no
	197	male	yes
	198	male	yes
	202	male	yes
	218	female	yes

Table 4. Growth of Arctic grayling collected in Last Chance Creek including the upper pond complex (1992 - 1994).

Length at Marking (mm)	Time at Large (Days)	Growth (mm)	Growth /Year (mm)
152	457	34	27
154	351	18	19
154	362	26	26
158	357	16	16
160	321	21	24
160	362	20	20
162	347	33	35
163	405	50	45
164	426	15	13
165	321	25	28
167	347	10	11
168	351	14	15
169	357	9	9
179	321	22	25
198	341	0	0
207	389	9	8
225	383	0	0
225	434	0	0

On September 29, 1994, Arctic grayling were observed milling at the outlet of the upper Last Chance pond. The outlet was blocked with leaves and after removing the leaves we counted 64 fish in 30 minutes moving from the upper to the lower Last Chance pond. The upper and lower Last Chance ponds were completely ice-covered by early November but open surface flow still existed between the two ponds. Movement of Arctic grayling from the upper to the lower Last Chance pond has been documented both visually and through recapture of individually tagged fish. However, movement of fish from the lower to upper pond has not been confirmed.

Water Quality for Last Chance Creek Ponds

During winter both ponds have temperatures near zero and, except near the bottom, dissolved oxygen concentrations average 50% saturation (Table 5). In summer water temperatures are slightly higher in the upper pond than the lower pond; dissolved oxygen concentrations are near saturation in the upper pond (Table 6). In July the upper pond had formed a thermocline with water temperatures about 4 C colder at 4 m depth than at the surface or at 2 m.

Alkalinity ($CaCO_3$) and hardness measured during summer are higher than in downstream Fish Creek or Last Chance Creek (Tables 5 and 6), probably due to the higher input of groundwater in the ponds. The pH was circumneutral in both ponds and ranged from 6.7 to 7.0.

Concentrations of Ca, Mg, and NO_3·N (Table 7) are lower than in the downstream waters of the Chena and Little Chena Rivers (Oswood et al. 1992). Concentrations of pond Na, K, and SO_4 are similar to the Chena and Little Chena Rivers, and concentrations of pond Cl are higher although considerably lower than average

Table 5. Temperature and dissolved oxygen at depth in the Last Chance Creek ponds, March 1994.

	Depth m	Temp. C	D.O. mg/L	% Saturation
Upper Pond				
	0	ice		
	0.9	ice		
	1.2	0.5	8.7	60.4
	1.8	0.5	8.1	56.2
	2.4	1.0	7.1	50
	3.0	1.5	5.5	36.3
	3.7	2.4	4.4	32.2
Lower Pond				
	0	ice		
	0.9	ice		
	1.0	ice		
	1.2	0.6	8.9	62
	1.8	0.6	8.0	55.7
	2.4	0.6	3.9	27.2
	3.0	1.1	1.8	12.7

Table 6. Water quality characteristics of Last Chance Creek ponds during July, 1993.

	Depth m	Temp. C	D.O. mg/L	Alkalinity mg/L	Hardness mg/L	pH
Upper Pond						
	0	19.1	11	60	71	6.7
	2.0	20.7	11.1	59.5	75	
	4.0	16.8	10.1	56.7	69	
Lower Pond	0	14.9	8.8	44.6	59	7.0

Table 7. Concentrations of major cations and anions in Last Chance Creek ponds, 1994. Data from ADNR, Division of Water.

	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	NO_3·N mg/L	PO_4 mg/L	SO_4 mg/L
Upper LC Cr Pond	19.5	6.08	0.76	0.22	0.33	<0.02	<0.05	18
Inlet to Upper LC Cr Pond	20.1	6.01	1.86	0.88	0.41	0.11	<0.05	16.4
Lower LC Cr Pond	13.7	4.09	3.91	0.69	0.24	0.06	<0.05	14.2

concentrations for freshwater in the United States (0.3 mg/L in the ponds compared to 8.3 mg/L average for the United States (Wetzel 1983).

Nostoc, a cyanobacteria capable of fixing atmospheric nitrogen, is abundant in both ponds during summer. The abundance of *Nostoc* suggests that nitrogen fixation is a major source of nitrogen in both ponds. The inlet seep to the upper pond contains higher concentrations of $NO_3 \cdot N$ than the ponds. This may be due to the higher densities of *Nostoc* in the inlet water. Low concentrations of $NO_3 \cdot N$ and PO_4 are probably due to high uptake rates in the ponds and are not necessarily indicative of low N and P concentrations or of low productivity.

FISH CREEK POND COMPLEX

We initiated water quality and fish sampling in several old mine cuts converted to settling ponds in the Fish Creek floodplain (Figure 5). The ponds, separated by gravel dikes, have been actively used as settling ponds for the past ten years (Figure 9). Ponds were not actively used during summer 1994 for placer mining water treatment.

The pond complex is fed by both surface and subsurface flows passing between ponds via intragravel flow, culverts, and overflow channels. Gravel berms at the two downstream ponds failed in summer 1992 and created an outlet channel with surface flow. The lowest pond (Polar #1) has both an outlet with surface flow and a seep fed by intragravel water. The seep enters another pond referred to as Horseshoe pond before water merges with Fish Creek. Limited fish sampling was conducted in the two lower ponds (Polar #1 and #2), Horseshoe pond, the channel connecting Polar #1 and #2, and the outlet channel and seepage channel from Polar #1 in summer 1994. Water quality samples were collected from Polar #1 pond.

Figure 9. The upper end (top photo) and shoreline (bottom photo) of Polar #1 pond in the Fish Creek drainage.

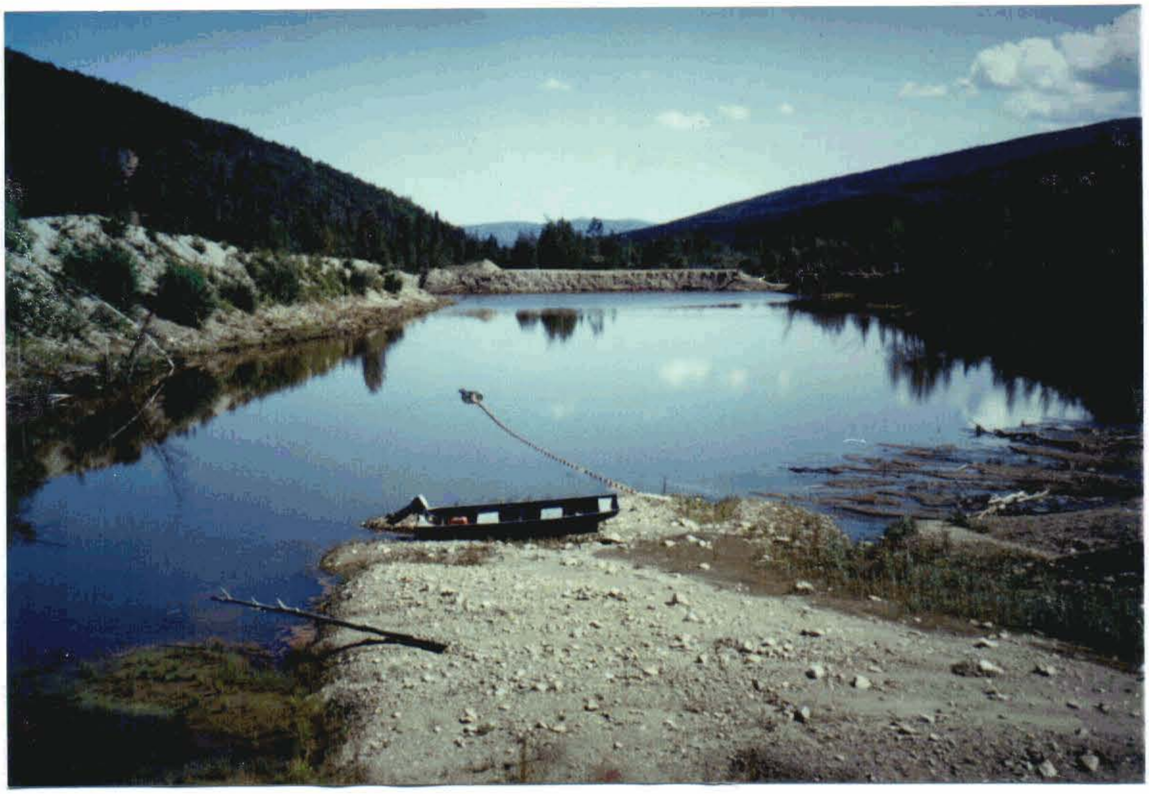
We checked water depths in Polar #1 by running a transect north to south and east to west. Water depths in Polar #1 were uniform, grading from less than 0.2 m at the upstream end to a maximum depth of 1.2 m. Most of the pond contained waters 1.0 m deep. Water temperature in the pond complex in early May was substantially higher than in Last Chance Creek. On May 11, water temperature in the outlet from Polar #1 was 10.3°C. Nineteen Arctic grayling were collected in the outlet, and all except an 83 mm fish, were ripe males. Four Arctic grayling (three ripe males, one unknown) were captured in the seepage channel from Polar #1 where the water temperature was 7.3°C. Water in Last Chance Creek on May 11 was 0.9°C and was still influenced by melting aufeis. We observed several Arctic grayling spawning where the overflow channel exits Polar #1. The overflow channel from Polar #1 was sampled again on May 18 and only one Arctic grayling was collected. We believe most of the spawning in the Polar #1 outlet and seepage channel occurred prior to May 11 (Figure 10). Sampling for young-of-the-year Arctic grayling in the Polar #1 overflow was conducted on June 16 and August 18, 1994. On June 16, we collected 18 young-of-the-year fish ranging from 28 to 40 mm ($\bar{x}$ = 31.8, SD = 3.1) and on August 18 we captured 14 fish ranging from 52 to 91 mm ($\bar{x}$ = 71.2, SD = 12.3). Numerous young-of-the-year Arctic grayling were observed actively feeding at the surface of both Polar #1 and #2 ponds and Horseshoe pond during July and August 1994.

In August 1993, we collected 18 burbot in the seepage channel entering and leaving Horseshoe pond. These burbot ranged from 80 to 110 mm (Weber Scannell and Ott 1994). Previous electrofishing work in Fish, Solo, and Last Chance creeks immediately downstream and upstream of the overflow and seepage channel produced very few burbot. Number of burbot collected in these sample reaches in 1992, 1993, and 1994 was 1, 7, and 9.

Figure 10. Arctic grayling spawned in the seepage water from Polar #1 (top photo) and numerous young-of-the-year fry reared in Horseshoe pond (bottom photo) during summer 1994.

Minnow traps baited with salmon roe were fished in Horseshoe and Polar #1 and #2 ponds. Burbot were collected in Polar #1 and Horseshoe pond on July 8, 1994. Three minnow traps fished for 24 hours in Horseshoe pond caught 21 burbot (x = 7 fish/trap). Four traps placed in Polar #1 captured 27 burbot in 24 hours. On August 18, we fished two minnow traps in Polar #2 catching eight burbot in a 24-hour set. We also placed seven buckets in Polar #1; five set along the shoreline and two in the middle of the pond. Thirteen burbot were collected from the five shoreline traps and 11 were caught in two traps fished in the middle of the pond. Three traps placed in Horseshoe pond for 24 hours on August 18 captured 10 burbot.

A fyke-net in Polar #1 was fished for 28 hours and caught 69 Arctic grayling and 46 burbot (Figure 11). Length frequency distribution for the burbot and Arctic grayling is presented in Figure 12. Only one of the 69 Arctic grayling had been marked during previous sampling work. Based on a low recapture rate (which generally runs greater than 10%) and the fact that few, if any, juvenile burbot are captured in sample areas (e.g., Solo, upper Fish, and lower Last Chance creeks) located immediately downstream of Polar #1, we believe that these fish probably use Polar #1 for spawning, rearing, and overwintering. Seventy-two percent of the Arctic grayling were 130 to 170 mm long (Figure 12). Burbot appeared to fall into two size groups; from 130 to 150 mm and a second size peak from 180 and 190 mm. We reset the fyke-net and allowed it to fish for 72 hours. Water temperatures warmed in Polar #1 to 23.3°C on July 11 when the fyke-net was checked. Because of the warm water we decided not to measure and mark fish to reduce mortalities from handling. We caught and released 109 Arctic grayling and 99 burbot. Numerous young-of-the year Arctic grayling were present in the pond but were not caught by the fyke-net.



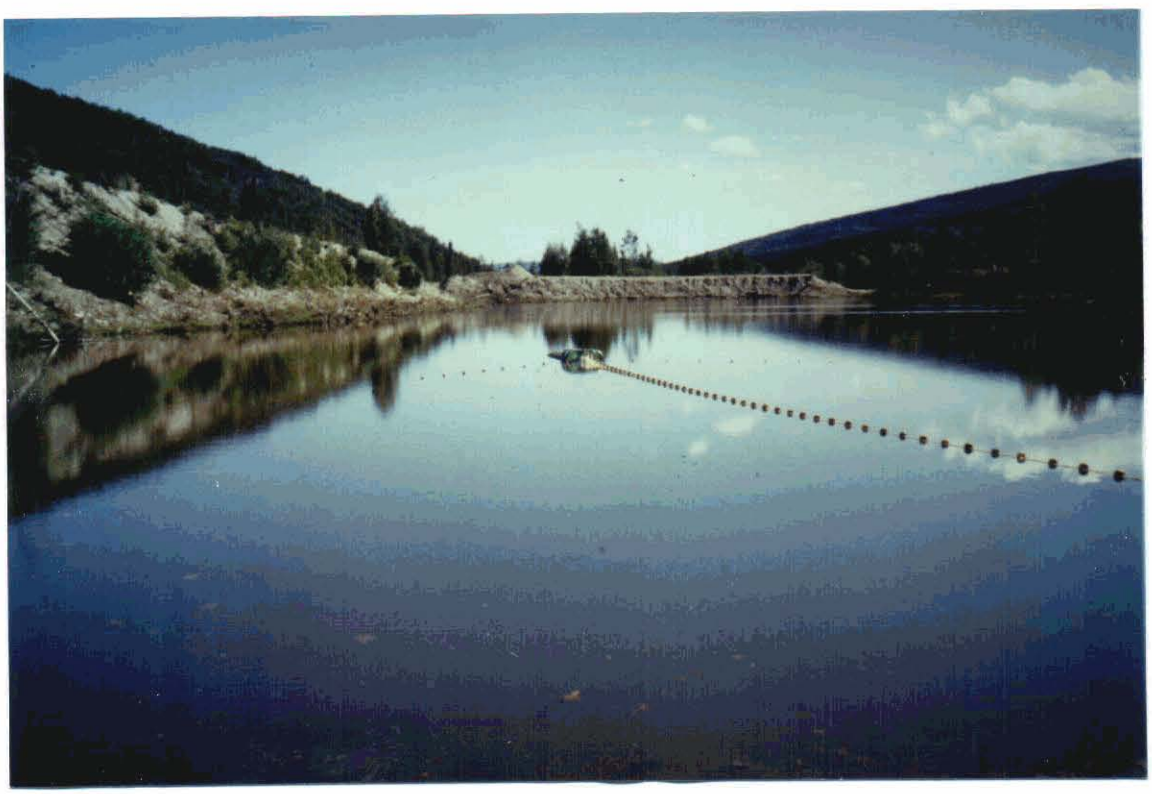
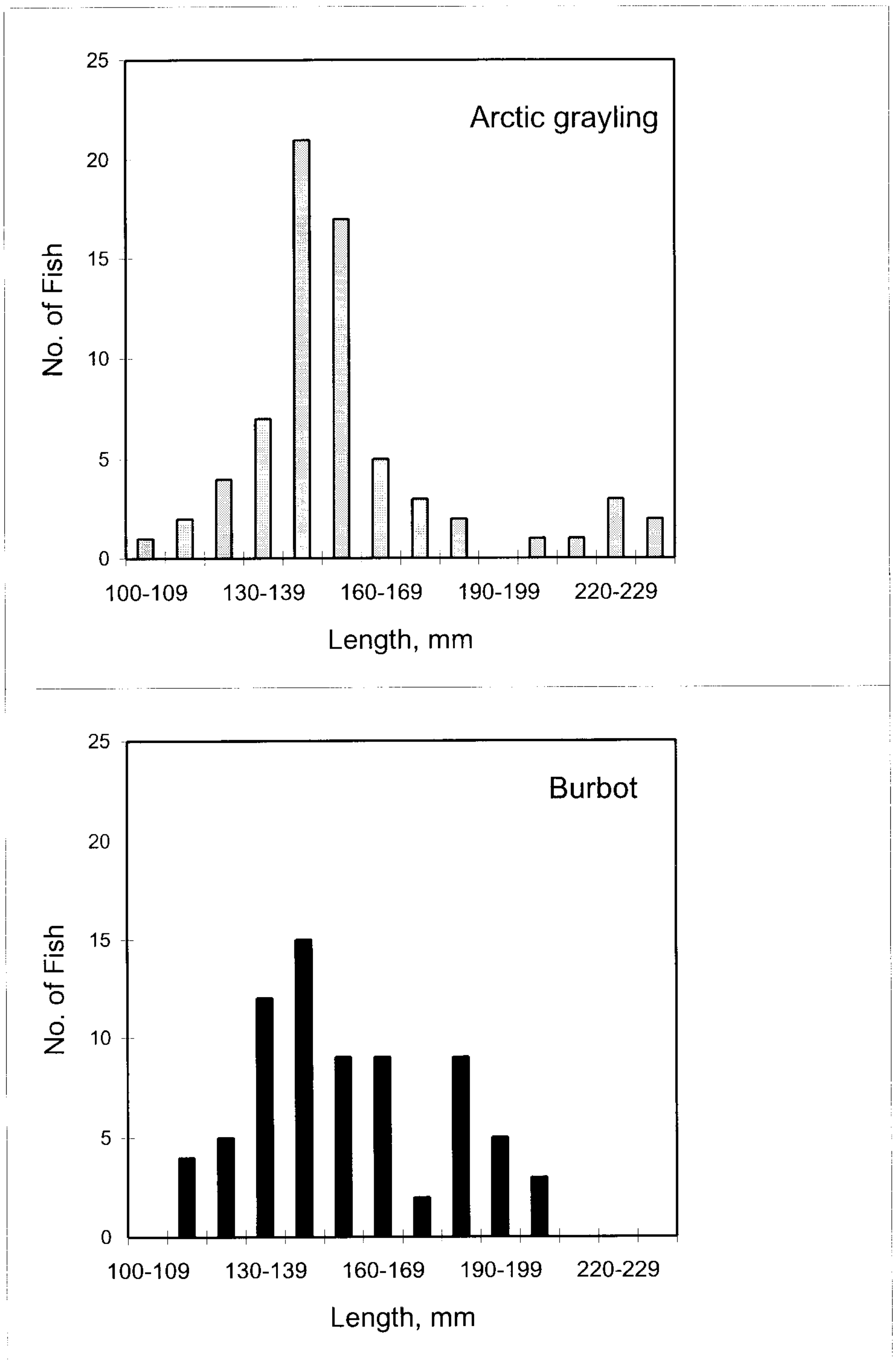


Figure 11. A fyke-net fishing in Polar #1 pond.

Figure 12. Length frequency distribution for Arctic grayling and burbot collected in a fyke-net fished in Polar #1 pond.



Water Quality for Polar and Horseshoe Ponds

Water temperatures in the Polar #1 rose quickly during July from 15.8 C on July 8 to 19 C on July 11 and remained high in August (20.5 C). Water temperatures in August approached sub-lethal levels of 20 to 24 C for Arctic grayling (Weber 1991). Although no mortalities were observed in the pond, Arctic grayling mortalities did occur in the fyke-net.

Water in the Polar pond and the Horseshoe pond contained higher concentrations of Ca, Mg, K, Cl, NO_3·N, and SO_4 than Fish Creek below the two ponds (Table 8). Higher concentrations of cations are probably due to mineral sources. The Polar pond served as a settling pond for a placer mining operation and the Horseshoe pond contains abundant suspended sediments.

UPPER FISH CREEK

Upper Fish Creek, Solo Creek, and Last Chance Creek (lower portion below pond complex) were sampled in 1994. Pool-riffle sequences established in these creeks in 1992 and 1993 were not fished due to flooding caused by multiple beaver dams. Fish passage in Solo Creek was blocked by a beaver dam located within 30 m of its confluence with Fish Creek and fish passage was partially blocked in Fish Creek by a beaver dam. Although multiple beaver dams were present in Last Chance Creek, fish were able to move both upstream and downstream as individually tagged fish were recaptured above and below the dams.

Arctic grayling tagged in 1992, 1993, and 1994 were recaptured in 1993 and 1994 in Upper Fish Creek. Twenty-one Arctic grayling ranging from 151 to 285 mm when tagged had highly variable annual growth rates ranging from 0 to 32 mm (Table 9). Four individual fish marked at 200 to 202 mm had annual growth rates

Table 8. Concentrations of major cations and anions in Fish Creek and adjacent ponds, 1994. Data from ADNR, Division of Water.

	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	NO_3-N mg/L	PO_4 mg/L	SO_4 mg/L
Fish Creek	11.1	3.02	3.08	0.88	0.21	0.09	<0.05	10.6
Polar Pond	26.2	6.57	4.05	1.86	0.29	0.17	<0.05	14.4
Horseshoe Pond	26.2	6.56	1.80	1.86	0.34	0.14	<0.05	14.5

Table 9. Growth of Arctic grayling collected in Upper Fish, lower Last Chance, and Solo creeks (1992 - 1994).

Length at Marking (mm)	Time at Large (Days)	Growth (mm)	Growth /Year (mm)
151	359	24	24
154	357	16	16
157	301	19	23
163	349	31	32
175	308	7	8
177	740	23	11
184	277	4	5
191	374	17	17
194	291	6	8
200	384	14	13
200	400	20	18
202	276	2	3
202	301	0	0
207	283	9	12
218	374	8	8
223	283	0	0
227	301	3	4
235	283	4	5
256	276	2	3
260	328	3	3
285	283	5	6

of 0, 3, 13, and 18 mm. The highest growth recorded was for fish between 151 and 163 mm.

Water quality was sampled periodically in Fish, Last Chance, and Solo creeks from 1992 through 1994. In 1992, settleable solids in Fish Creek, immediately below the confluence of Solo and Fish creeks, was 4.5 ml/L on June 17 (Weber Scannell and Ott 1993). Solids decreased to trace amounts later in summer 1992 and remained at trace levels until August when solids were measured at 7.5 ml/L (Weber Scannell and Ott 1994). Placer mine activities in upper Fish Creek terminated in fall 1993 and there was no active mining in 1994. A melting ice lens in upper Fish Creek fed by rainfall and snowmelt was still contributing sediments to Fish Creek in 1994. After completion of a stream diversion in mid-May, separating clear water from waters draining from the ice lens, settleable solids decreased considerably in Fish Creek (Table 10). Water containing settleable and suspended solids was directed into a large settling basin but overflow from the basin reentered Fish Creek. Heavy rain in mid-June eroded the diversion berm between the clean water bypass and water from the melting ice lens and settleable solids increased in Fish Creek. The diversion was rebuilt but overflow from the settling pond which was then full of sediments began to muddy Fish Creek. In mid-July the entire flow from the melting ice lens was ditched into the settling basin complex paralleling Fish Creek. Water containing high levels of settleable solids had to travel through five settling ponds with a significant portion of the water moving via intragravel flow through berms separating the ponds. Waters entered Polar #2 Pond only slightly turbid with no settleable solids. Settleable solids in Fish Creek decreased in early August to zero and the creek remained clear for the remainder of the summer (Table 10).

Table 10. Settleable solids in Fish Creek near Solo and Last Chance creeks, Last Chance Creek, and Solo Creek in summer 1994.

	Date Sampled	Settleable Solids (ml/L)	Temperature (°C)
Fish Creek	May 10	3.5	6.8
	May 11	2.5	
	May 18	0.2	
	May 20	0.2	
	May 26	0.1	5.1
	June 1	trace	
	July 8	1.5	10.0
	August 2	ND	12.6
	August 18	ND	
Last Chance Creek	May 10	trace	0.9
	May 17	trace	
	July 8		4.6
Solo Creek	May 11		2.9
	July 8	trace	6.3

BEAR CREEK

Bear Creek enters Fish Creek about 4 km below the proposed freshwater dam. Bear Creek is incised, mostly shaded, and flows from north-facing slopes. Melting ice lenses occur along the banks. The temperature is as much as 4°C colder than Fish Creek. Water temperatures in Bear Creek reached 7.9°C and 7°C in July 1992 and 1993 (Weber Scannell and Ott 1993, Weber Scannell and Ott 1994). During 1994, the highest water temperature recorded was 10.9°C.

The water is generally clear and stained; the highest turbidity was measured in June following breakup when it was 5.7 NTU and settleable solids were trace. By July no settleable solids were detected.

Bear Creek has low alkalinity (18 mg/L as $CaCO_3$) and low hardness (29.5 mg/L) after breakup when snowmelt flowed into the creek. By July alkalinity increased to 57.5 mg/L ($CaCO_3$) and hardness to 79 mg/L.

Six pool-riffle sample areas were established in Bear Creek in 1992 and then increased to 11 pool-riffle combinations in 1993 and 1994. Young-of-the-year Arctic grayling were not found in Bear Creek in 1992 and only four were captured and released in August 1993 and 1994. Generally, fish catch increased between May and the end of summer sampling (Table 11). The number of Arctic grayling and round whitefish in the expanded sample reach was greater in 1994 than in 1993 and burbot were captured for the first time in 1994 (Table 11).

Arctic grayling tagged in 1992, 1993, and 1994 were recaptured in 1993 and 1994 in Bear Creek. In 1993, we captured a juvenile Arctic grayling in Bear Creek that was released in the Chena River. Two fish collected in Bear Creek during 1994 were originally marked in upper Fish Creek near Last Chance and Solo creeks and

Table 11. Number of fish caught, excluding young-of-the-year Arctic grayling, in Bear Creek using an electroshocker (1992 to 1994).

Date Sampled	AG	SS	RWF	BB	LNS	Total Fish
6/18/92	3	0	0	0	0	3
7/21/92	26	0	6	0	0	32
8/25/92	36	4	24	0	0	64
5/19/93	3	0	2	0	0	5
7/12/93	17	3	0	0	0	20
8/11/93	20	2	1	0	0	23
5/16/94	11	0	0	0	0	11
7/6/94	22	5	1	0	0	28
8/2/94	30	3	24	4	0	61
9/6/94	36	2	11	2	0	51

AG = Arctic grayling, SS = slimy sculpin, RWF = round whitefish, BB = burbot, and LNS = longnose sucker one Bear Creek Arctic grayling moved to upper Fish Creek. Eight Arctic grayling ranging in size from 170 to 280 mm grew from 3 to 12 mm annually with an average growth of 7.6 mm (SD = 3.2) (Table 12).

FISH CREEK AT FAIRBANKS CREEK

The Fish Creek sample reach near Fairbanks Creek contains five pool-riffle sequences and the reach has been sampled each year since 1992. Arctic grayling, slimy sculpin, round whitefish, burbot, and longnose sucker use Fish Creek (Weber Scannell and Ott 1993). Young-of-the-year Arctic grayling were not present in 1992 and 1994 but several were collected in 1993 (Weber Scannell and Ott 1994). Except for July and August 1993, Arctic grayling and round whitefish dominated the catch (Table 13).

In 1992 and 1993, water in Fish Creek was highly turbid. Turbidity was lower in 1994 and clear water conditions were documented in August 1994. Water temperatures reached 11°C and 12°C in July of 1992 and 1993. In 1994, the highest temperature recorded was 11.8°C in early August.

Arctic grayling tagged in 1992, 1993, and 1994 in Fish Creek near Fairbanks Creek were recaptured in 1993 and 1994; however, all but one fish were recaptured in the same area. One Arctic grayling tagged in Fish Creek was recaptured in the Chena River. Seven Arctic grayling ranging from 154 to 225 mm grew from 5 to 14 mm annually with an average growth of 9.6 mm (SD = 3.5) (Table 14).

Table 12. Growth of Arctic grayling collected in Bear Creek (1992 - 1994).

Length at Marking (mm)	Time at Large (Days)	Growth (mm)	Growth /Year (mm)
170	356	8	8
200	356	10	10
204	390	9	8
225	419	14	12
227	389	3	3
227	385	10	9
242	356	3	3
280	356	8	8

Table 13. Number of fish caught, excluding young-of-the-year Arctic grayling, in Lower Fish Creek using an electroshocker (1992 to 1994).

Date Sampled	AG	SS	RWF	BB	LNS	Total Fish
7/22/92	9	1	7	1	4	22
8/26/92	14	4	4	2	0	24
5/18/93	9	1	0	0	0	10
6/17/93	22	3	9	0	0	34
7/13/93	40	37	26	2	0	105
8/10/93	14	29	10	2	0	55
5/17/94	26	4	2	1	0	33
7/5/94	20	3	18	2	0	43
8/3/94	5	1	8	1	0	15
9/6/94	20	3	29	0	0	52

AG = Arctic grayling, SS = slimy sculpin, RWF = round whitefish, BB = burbot, and LNS = longnose sucker

Table 14. Growth of Arctic grayling collected in Fish Creek near Fairbanks Creek (1992 - 1994).

Length at Marking (mm)	Time at Large (Days)	Growth (mm)	Growth /Year (mm)
154	722	16	9
163	347	11	12
177	739	13	6
183	295	7	9
184	277	4	5
200	383	14	13
225	330	13	14

SUMMARY

Results of our three years of field work investigating fisheries resources in upper Fish Creek and working with FGMI in the design of the Fort Knox hardrock gold mine are summarized. First, we discuss the integration of fisheries data with the design of the Fort Knox project. Second, we summarize what we believe to be the life history of Arctic grayling in the upper Fish Creek drainage. Finally, we discuss how our results might be used in the review and permitting of future development projects.

INTEGRATION OF FIELD DATA WITH PROJECT DESIGN

When we started our review of the proposed Fort Knox hardrock gold mine it was our perception that few, if any, fish would be impacted by the project. Site inspection trips made to upper Fish Creek placer mine operations between the late 1970s and early 1990s indicated a highly disturbed system with degraded water quality (e.g., high suspended sediment concentrations) throughout the ice-free season. As mining proceeded up the valley, streams were realigned and mine cuts were converted to settling basins. Nonpoint source pollution from hydraulic stripping of overburden and natural erosion were common. Extensive zones of ice-rich organic soils eroded into creeks and settling basins as they melted during the summer months.

In 1992, our first year of fish sampling in the Fish Creek valley, we learned that Arctic grayling were relatively common in all sample areas including lower and upper Fish Creek, lower Solo Creek, Bear Creek, and lower Last Chance Creek. Based on preliminary data, FGMI worked with state and federal agencies as project designs and concepts were developed. The need to construct a freshwater reservoir to ensure adequate water for the mine startup and operation was identified by FGMI and the possibility of developing a fishery in the freshwater reservoir became a topic for discussion. Negotiations continued and an agreement was reached between FGMI and state and federal agencies to construct a permanent freshwater dam and to plan for development of a recreational fishery as a post-mining land use.

In 1993, we continued the fish monitoring study and began sampling in abandoned flooded settling ponds located in and adjacent to Last Chance Creek. Over 4,000 Arctic grayling were estimated in the Last Chance Creek pond complex. Sampling continued in the Last Chance Creek pond complex during the winter of 1993-1994 and data were obtained that indicated winter water quality conditions were highly favorable to support fish. Fish were collected through the ice in early fall and in late winter prior to breakup. The Last Chance Creek pond complex was located at the upper end of the projected limit of the freshwater reservoir and therefore would not be affected by construction activities until the dam was complete and the reservoir filled. Our 1993 and early 1994 findings provided support for the concept of developing a fishery in the freshwater reservoir since the Last Chance Creek fish would be available to colonize the freshwater reservoir through natural dispersal. Based on these findings, we made the decision to permit the freshwater dam without requiring a fish ladder or compensation for the fish block.

FGMI continued to financially support our study in 1994 and we proceeded to gather additional data on sample sites downstream of the freshwater dam and in settling basins in the Fish Creek valley. Although data are limited, we found that the Fish Creek ponds referred to as Polar #1 and #2 also supported large numbers of fish. We also discovered that in addition to Arctic grayling, burbot were common in Polar #1, Polar #2, and Horseshoe pond. These ponds will be inundated by the freshwater reservoir, allowing fish direct access to the impoundment.

In October 1994, FGMI's contractor installed a diversion ditch to bypass surface waters around the tailing and freshwater dam sites in preparation for dam construction planned to start in March 1995. Plans and specifications for the diversion at the freshwater dam were developed by FGMI and construction activities were monitored by ADF&G. The freshwater diversion channel was completed on October 19. The diversion channel intercepts waters from Last Chance, Fish, and Solo creeks and routes the water to the north side of the valley, through a constructed settling basin, and an outflow channel connected to Fish Creek. Construction was completed in a timely manner and with minimal impact to water quality. Overflow and ice damming occurred in the lower portion of the diversion channel but by mid-November flows had cut a channel through the slush ice and the stream had iced over with fresh snow cover (Figure 13). Flow through the freshwater diversion channel was stable. The diversion channel for the tailing dam also was completed and flows appeared stable by mid-November 1994. Clearing of the freshwater dam site and areas to be flooded by the impoundment were initiated. It is anticipated that clearing for dam construction will be complete by January 1995.

Based on the large number of Arctic grayling in upper Fish Creek upstream of the freshwater dam, the availability of spawning habitat in the upper Last Chance Creek pond complex, and anticipated suitable overwintering water quality in the freshwater reservoir, it appears highly likely that a fishery can be established in the freshwater impoundment by natural colonization.

Figure 13. The freshwater diversion channel ice damming and overflow (top photo) and after flows had cut a new channel covered with fresh ice and snow (bottom photo).

LIFE HISTORY OF ARCTIC GRAYLING IN UPPER FISH CREEK

Arctic grayling spawned in inlets and outlets of settling ponds, in settling ponds, and in Last Chance and Bear creeks. Spawning occurred at least ten days earlier in 1994 in waters influenced by ponds than in Last Chance Creek due to elevated water temperatures in the ponds. Survival of eggs in Last Chance Creek in 1994 probably was nonexistent and based on the low numbers of young-of-the-year in Bear Creek in 1992, 1993, and 1994, spawning success is low in Bear Creek. It appears that most of the young-of-the-year Arctic grayling entering the population in upper Fish Creek originate from waters associated with settling ponds. Habitats where spawning was successful had the following characteristics: (1) elevated water temperatures in early May (i.e., 10°C); (2) fed by groundwater or surface flow from or into an abandoned settling pond; (3) flow regulated by natural or artificial structures and not subject to high water events; (4) abundant zooplankton; and (5) substrate consisting of tailing, silt, and emergent vegetation. In these habitats, eggs and fry are not lost or displaced by high-water events because flows are controlled and moderated by artificial (seepage flow through gravel dikes) and natural conditions (groundwater). Furthermore, young-of-the-year fry grew rapidly because of warm water temperatures and an abundant supply of zooplankton. Arctic grayling fry in the outlet of Polar #1 pond averaged 31.8 mm on June 16 and 71.2 mm on August 18 with four to six weeks of time remaining for growth prior to freezeup.

Most of the Arctic grayling captured in the upper Last Chance pond in June 1993 were between 140 and 160 mm. A sample of fish from Polar #1 pond in July 1994 showed the same pattern; most fish were between 140 and 160 mm. We believe, based on the length frequency distribution, that fish which dominate the catch in the ponds are age 2+. Actual growth data have been collected for fish greater than

150 mm. In the upper and lower Last Chance Creek ponds, the average annual rate of growth was 22.4 mm for fish between 152 and 179 mm at the time of marking. Sexual maturity occurs at a small size (Figure 14). The average size of spawners in 1994 from the upper and lower Last Chance Creek pond and in upper Last Chance Creek was 173.8, 184.8, and 181.8 mm. Growth rates, although highly variable, generally slow dramatically for Arctic grayling after they reach 180 mm.

Some of the Arctic grayling that spawn, rear, and overwinter in the upper Last Chance Creek pond, including the seepage pond, leave the pond environment to overwinter in the lower pond and to spawn in upper Last Chance Creek. In 1993 we collected and measured 295 Arctic grayling from the upper pond and only one was over 200 mm. Movement out of the upper Last Chance Creek pond is documented based on tag recovery data and our visual observations in the fall of 1994 when fish were observed actively moving to the lower pond. Fish greater than 200 mm fork length also are not common in either the lower Last Chance Pond or in Polar #1 pond. We believe that as Arctic grayling reach a larger size (e.g., 180 to 200 mm) they migrate to stream habitats. Catches of fish in Solo, lower Fish near Fairbanks Creek, and Bear creeks generally contain a high percentage of fish greater than 200 mm. We speculate that the movement occurs in response to the following factors: (1) food items in pond habitat, mainly zooplankton, are not preferred by the larger fish; (2) warm water temperatures (15 to 24°C) are not preferred for rearing by larger Arctic grayling.

Burbot which where thought to be present in low numbers in upper Fish Creek are believed to be abundant in the Polar #1, Polar #2, and Horseshoe ponds. Although we did not make a population estimate, we did collect 46 juvenile burbot in a 24-hour fyke net set in Polar #1 and we averaged nearly seven burbot per minnow trap in early July in both Horseshoe and Polar #1 ponds. Catch rates for juvenile

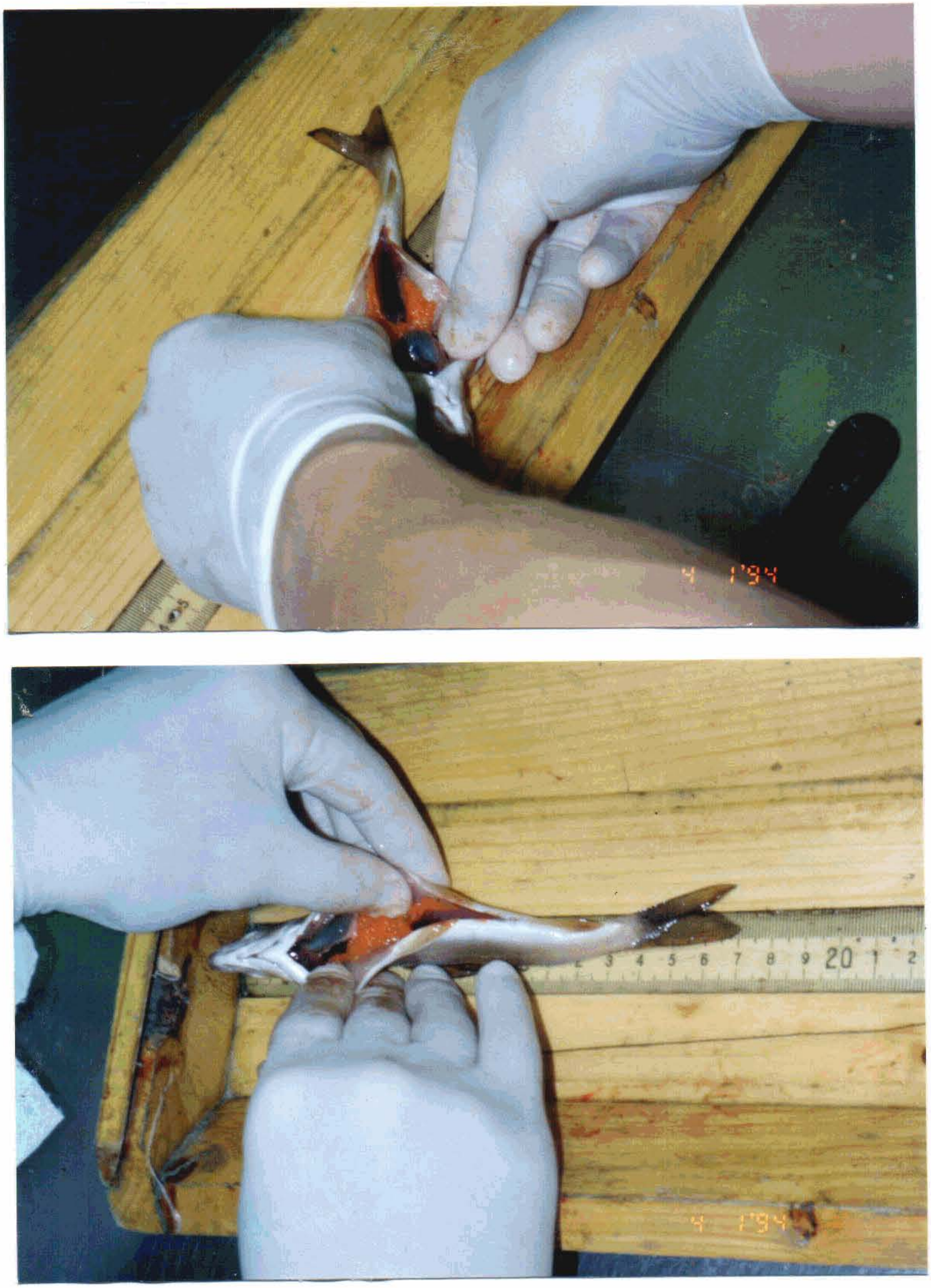


Figure 14. A 165 mm long mature Arctic grayling from Upper Last Chance pond.

burbot exceed any that we have encountered in sampling streams in interior Alaska. Although larger adult burbot have not been found, we believe, based on length frequency distribution, that these burbot must be spawned in the pond environments. As with the Arctic grayling, juvenile burbot are probably feeding on the abundant zooplankton, benthic invertebrates, and young-of-the-year Arctic grayling.

In conclusion, we believe that there exists populations of Arctic grayling and burbot in upper Fish Creek that spawn in waters influenced by abandoned settling ponds. The Arctic grayling exhibit rapid growth for the first two years, mature at age 2+ at a small size (average of 180 mm), and migrate from the pond habitats to cooler streams once they reach a larger size (> 180 mm).

FUTURE DEVELOPMENT PROJECTS

Many development projects require aquatic habitat modification. Over the past years we have worked actively with a number of companies and state and federal agencies to develop effective mitigation for projects involving aquatic habitat modifications. Our work with FGMI on the Fort Knox project is an example of how environmental field data can be used in making project design decisions. We believe the key factor is a commitment on the part of the resource agencies and the project sponsor to gather environmental field data and to use these data in making project decisions. In the Fort Knox case, FGMI made the commitment early in the process and continues to work effectively with state and federal agencies.

A number of studies also have been conducted on the effects of placer mining in aquatic habitats. Generally, results of these studies indicate negative impacts of mining to water quality, benthic invertebrates, fish, and riparian habitat (Van

Nieuwenhuyse 1983, Simmons 1984, Weber and Post 1985, Wagener and LaPerriere 1985, Weber 1986). Our three year fishery study in the upper Fish Creek drainage also provided data on reduced benthic invertebrates in areas containing elevated suspended solids, lower fish use in Fish Creek with high sediment loads, and loss of riparian habitat. However, in comparison to work conducted in the Birch Creek drainage (Weber and Post 1985, Weber 1986), impacts to fish were substantially different. Rather than a total absence of fish, even in clearwater tributaries as was found in upper Birch Creek (Weber and Post 1985), we did find fish in all waters sampled, including those containing elevated concentrations of suspended sediments. We believe the differential impacts are explainable, in part, by the following site-specific conditions that we found in the upper Fish Creek valley: (1) organic input to the system is extensive, resulting in nutrient input to waters and a seed source for natural revegetation; (2) presence of relatively stable mine cuts and settling ponds interconnected with adjacent creeks and fed by groundwater; (3) flooded pond complexes accessible to fish and containing suitable habitat for spawning, rearing, and overwintering; (4) a winter water supply linked to presence of groundwater and recharge waters emanating from old dredge and placer mine tailing that provide overwintering fish habitat; and (5) lower elevation of Fish Creek with an associated higher ambient summer temperature.

In summary, if site-specific fisheries data had not been collected for the Fort Knox project during the permit review and project design phase and if we had relied on past studies of placer mining impacts and our perception of resource values in upper Fish Creek, we would collectively have not arrived at a decision to construct a permanent freshwater dam and the possibility of developing a significant recreational fishery in upper Fish Creek may have been lost.

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