Technical Report No. 11-06

Arctic Grayling and Burbot Studies at the Fort Knox Mine, 2011

by Alvin G. Ott
and William A. Morris

Solo Creek Bay, Overflow on Aufeis, May 2011
Photograph by Alvin G. Ott

November 2011

Alaska Department of Fish and Game
Division of Habitat

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ARCTIC GRAYLING AND BURBOT STUDIES AT THE FORT KNOX MINE, 2011

By

Alvin G. Ott and William A. Morris

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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

Table of Contents

List of Tables

List of Figures

Acknowledgements

We thank Fairbanks Gold Mining Inc. (FGMI) (Lauren Roberts, Delbert Parr, and Dave Stewart) for their continued support of our work to monitor fish and wildlife resources in the Water Supply Reservoir, tributaries, and developed wetlands. Jack Winters and Brad Wendling (Alaska Department of Fish and Game) and Delbert Parr and Dave Stewart (FGMI) provided constructive review of our report.

Executive Summary

Water Quality

●Water quality data were not collected in winter 2010/2011.

Arctic Grayling Stilling Basin

●There was no surface flow to the stilling basin from fall 2009 through late May, 2011 (page 8)

●Predominantly small (< 250 mm) Arctic grayling were captured in the stilling basin in 2011 (n = 81). We hypothesize that larger Arctic grayling (> 250 mm) present in previous sample years either moved downstream into Fish Creek or died (page 8)

●There were no recaptures in 2011 – therefore, an estimate of the Arctic grayling population could not be made (page 9)

Arctic Grayling Water Supply Reservoir

●Arctic grayling spawning began on May 17 in the Pond F outlet channel and active spawning was observed on May 23 and 24. In the channel connecting Ponds D and E spawning was first observed on May 24 at a water temperature of 4°C (page 13)

●Arctic grayling fry were observed in the Pond F outlet and in Pond D – though we do not estimate fry abundance, fry were numerous in Pond D in early August (page 14)

●The spring 2010 population estimate for Arctic grayling ≥ 200 mm long was 4,346 fish (95% CI 3,870 to 4,822) (page 15)

●Strong recruitment of small Arctic grayling was observed in spring 2011 – we marked 198 new fish between 200 and 230 mm long (page 16)

●Average annual growth of Arctic grayling in the WSR continued to be strong, but were less in 2010 than in 2009 (page 18)

●Data on population size and average growth of fish ≤ 250 and > 250 mm indicates an inverse relationship between population size and average growth (pages 18 and 19)

Burbot Water Supply Reservoir

●We caught 117 burbot in the WSR that ranged from 117 to 472 mm long – 6 were larger than 400 mm (page 20)

Introduction

Fairbanks Gold Mining Incorporated (FGMI) began construction of the Fort Knox hard-rock gold mine in March 1995. The mine is located in the headwaters of the Fish Creek drainage about 25 km northeast of Fairbanks, Alaska (Figure 1). The project includes an open-pit mine, mill, tailing impoundment, water supply reservoir (WSR), and related facilities. Construction of the WSR dam and spillway was completed in July 1996. In 2007, state and federal permits were issued for the construction, operation, and closure of a valley fill heap leach facility located in Walter Creek upstream of the tailing pond. Work continued throughout 2011 on the Walter Creek valley fill heap leach facility.

Figure 1. Aerial photograph provided by FGMI – water supply reservoir in lower part of photo and the tailing dam and impoundment in the upper Fish Creek valley.

A chronology of events for 2011, with emphasis on biological factors, is presented in Appendix 1. The chronology for previous years (1992 to 2010) can be found in Technical Report 10-5 titled "Arctic grayling and burbot studies at the Fort Knox Mine, 2010" (Ott and Morris, 2010).

Rehabilitation, to the extent practicable, has been concurrent with mining activities and natural revegetation of some disturbed habitats has been rapid. Wetland construction between the tailing dam and WSR began in summer 1998. A channel connecting wetlands along the south side of the Fish Creek valley was built in spring 1999. In-channel excavation, drainage rock placement, and channel reconstruction work to mitigate aufeis in Last Chance Creek was conducted in fall 2001 and again in fall 2008. Repair work on dikes separating Ponds D and E and the channel connecting the ponds was completed in summer 2002. Buell and Moody (2005) provided recommendations for additional work to enhance fish and wildlife habitats between the tailing dam and WSR. Some of their key recommendations are summarized below:

- Remove the culvert connecting the head of Pond C to the channel presently conveying high runoff (during breakup) on the north side of the road in the bottom of the Fish Creek valley to allow high runoff flows to remain in the north side drainage;
- Continue implementing wetland rehabilitation and restoration work in the Fish Creek valley between the tailing dam and WSR and continue to systematically document usage by wildlife and waterfowl until closure;
- Explore development of a "pilot" passive treatment constructed wetland for the purpose of removing arsenic, antimony, and any other "problem" elements from tailing seepage water that might reduce or eliminate long-term pump-back requirements;
- Start planning and designing future Fish Creek alignment from the tailing embankment to the small drainage on the north side of the Fish Creek valley bottom; and
- Develop a detailed plan and implementation schedule for the conversion of the existing causeway across the WSR into re-vegetated islands to increase habitat diversity and improve water exchange/circulation.

Fish research prior to construction of the Fort Knox mine and related facilities began in 1992 and water quality sampling started in summer 1997. Technical Reports (Weber Scannell and Ott 1993, Weber Scannell and Ott 1994, Ott et al. 1995, Ott and Weber Scannell 1996, Ott and Townsend 1997, Ott and Weber Scannell 1998, Ott and Morris 1999, Ott and Morris 2000, Ott and Morris 2001, Ott and Morris 2002a, b, Ott and Morris 2003, Ott and Morris 2005a, b, Ott and Morris 2006, Ott and Morris 2007, Ott and Morris 2009a, b, and Ott and Morris 2010) summarizing each year of work can be found on the Alaska Department of Fish and Game, Division of Habitat's Web Page:

http://www.adfg.alaska.gov/index.cfm?adfg=habitat_publications.main.

Viable populations of Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) exist in the WSR, and both Arctic grayling and burbot inhabit the stilling basin below the WSR. Our report summarizes fish data collected during 2011 and discusses these findings in relation to previous work.

Methods

Water Quality

In recent years, water quality sampling has been conducted once during late winter/early spring. Water quality sampling was not conducted during winter 2010/2011 because spring breakup and the road condition prevented access to the sampling site.

Fish

Fish sampling methods and gear included angling, visual observations, and fyke nets. Multiple fyke net sampling sites in the WSR and developed wetlands, including Last Chance Creek, have been used to capture Arctic grayling (Figure 2). Changes in fyke net locations are made each year to optimize catches and to accommodate fluctuating water levels in the WSR complex. The water surface in the WSR was about 1.5 m lower than the low flow notch in the spillway and water did not flow out of the reservoir in spring 2011.

In spring 2011, only one fyke net was fished in the WSR. The fyke net was set at the mouth of the Pond F outlet Channel #5 (Figure 2). The fyke net was set on May 9 and was checked for fish on May 10, 11, 12, 13, 17, and 24. The net was closed from May 13 to 16 and again from May 17 to 23. All Arctic grayling $\geq$ 200 mm captured were measured to fork length (nearest mm), inspected for tags and condition, and released. Arctic grayling $\geq$ 200 mm were marked with a numbered Floy® T-bar internal anchor tag. Arctic grayling abundance was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951) and variance was estimated (Seber 1982).

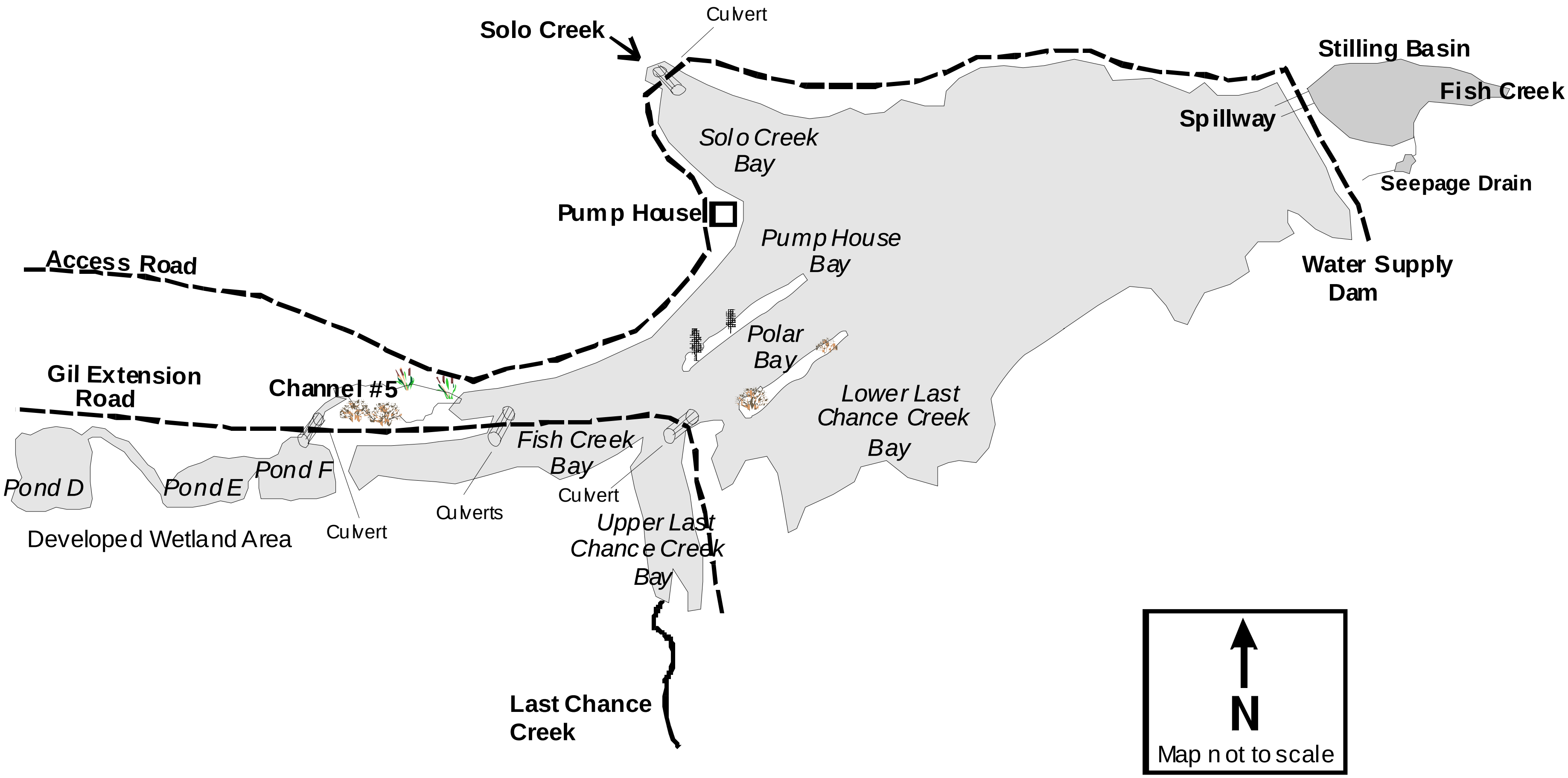

Figure 2. Sample areas in the Fort Knox WSR, stilling basin, and developed wetlands.

Results and Discussion

Water Supply Reservoir, Water Quality

Ponding of water for the WSR began in November 1995. Water surface elevation varied in 1996 and 1997 due to water use and winter seepage below the freshwater dam. The WSR reached the projected maximum water surface elevation of 1,021 feet on September 29, 1998, after a major rainfall event. When full, the WSR contains about 3,363 acre-feet (1.1 billion gallons) of water.

Water levels have remained fairly constant since 1998, except in the winter of 2000/2001 and again in the winters of 2007/2008 and 2009/2010. In 2009/2010, 1,167 acre-feet of water (380 million gallons) was pumped from the WSR (Table 1). Flow over the spillway ceased sometime in the fall of 2009 and flow did not reach the low flow channel in the spillway again until June of 2011.

Table 1. Winter water use from the WSR, 1997 to 2009.

Year	Acre-Feet of Water Removed
1997/1998	660
1998/1999	605
1999/2000	577
2000/2001	1,464
2001/2002	320
2002/2003	337
2003/2004	279
2004/2005	716
2005/2006	659
2006/2007	299
2007/2008	1,176
2008/2009	817
2009/2010	1,167
2010/2011	187

Seepage flow through the WSR was monitored continuously by FGMI and has remained relatively constant over the last 13 years (Table 2).

Table 2. Seepage flow rates below the WSR dam.

Year	Rate of Flow (cfs)	Geometric Mean (cfs)
1999	1.16 to 1.82	1.47
2000	1.03 to 1.86	1.38
2001	1.03 to 1.78	1.31
2002	1.13 to 1.78	1.41
2003	1.13 to 1.78	1.36
2004	1.00 to 1.69	1.28
2005	0.97 to 2.35	1.49
2006	1.30 to 2.35	1.44
2007	1.13 to 1.78	1.32
2008	n/a	n/a
2009	1.06 to 3.55	1.53
2010	1.06 to 1.78	1.38
2011[1]	1.25	1.25

[1]Average flow rates

Aufeis in the developed wetland complex was minimal in the lower portion in spring 2011. Moderate aufeis was observed in the developed wetland complex upstream of Pond D and in Last Chance Creek. Extensive aufeis present in Solo Creek did not melt until June 2011.

Stilling Basin, Arctic Grayling

The stilling basin, located immediately downstream of the WSR spillway, is fed by groundwater, seepage flow, and surface flow (Figure 3). The narrow notch in the spillway was designed to accommodate surface water discharge from the WSR during winter without forming aufeis. Aufeis in the spillway has not been observed since the dam was first overtopped in September, 1998.

Figure 3. Spillway, looking downstream, at Fort Knox freshwater dam in October 2010 (left) and August 2011 (right).

Arctic Grayling Catches and Metrics

We sampled Arctic grayling in the stilling basin in summer 2011 using angling as the capture method. There was no flow in the low flow channel in the spillway from fall 2009 through the summer of 2010 and the winter of 2010/2011. On May 27, 2011, water began to flow over the spillway and into the stilling basin. Surface flow was absent for about 21 months. We sampled 3 times in late July and early August 2011, catching 81 Arctic grayling. There were no recaptures in the sample either from previous years or from fish marked during spring 2011 in the WSR above the dam. Length frequency distribution of fish caught in late July is presented in Figure 4. Data from 2009 and 2010 also are included. Most of the larger Arctic grayling caught in 2009 and 2010 were not present and most likely moved downstream in Fish Creek or died.

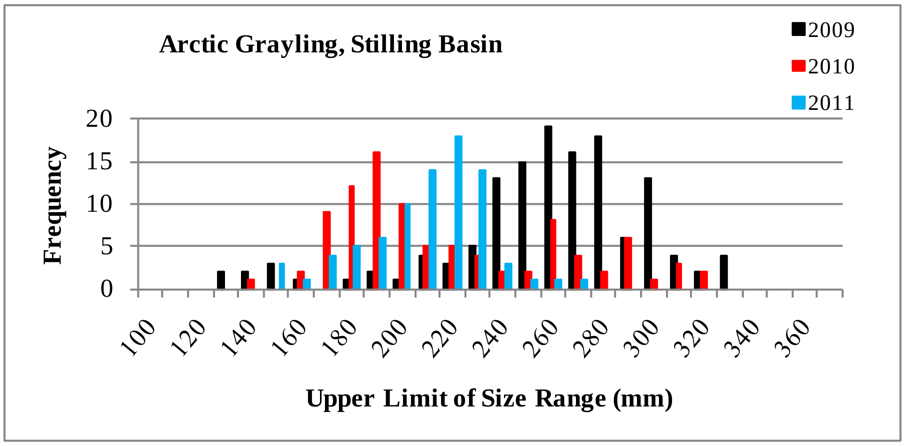

Figure 4. Length frequency distribution of Arctic grayling in the stilling basin (2009 to 2011).

During our angling sampling, catch per unit of effort (CPUE) varied from 4.2 to 14.7 fish per hr in 2011 (Table 3). In 2010, the CPUE ranged from 3 to 15.3 fish per hr.

Table 3. Catch of Arctic grayling in the stilling basin in 2010 and 2011.

Date	Fishing Effort (hr)	Arctic Grayling	Catch/Hr
5/3/2010	4	30	7.5
5/5/2010	3	15	5
5/7/2010	1	3	3
6/25/2010	3	46	15.3
7/26/2011	6	36	6
7/29/2011	6	25	4.2
8/2/2011	1.5	22	14.7

The estimated population of Arctic grayling in the stilling basin between the years 2007 to 2009 ranged from a low of 815 in 2008 to a high of 1,199 in 2009 (Figure 5, Appendix 2). No population or growth estimates for 2010 can be made as we had no recaptures in 2011.

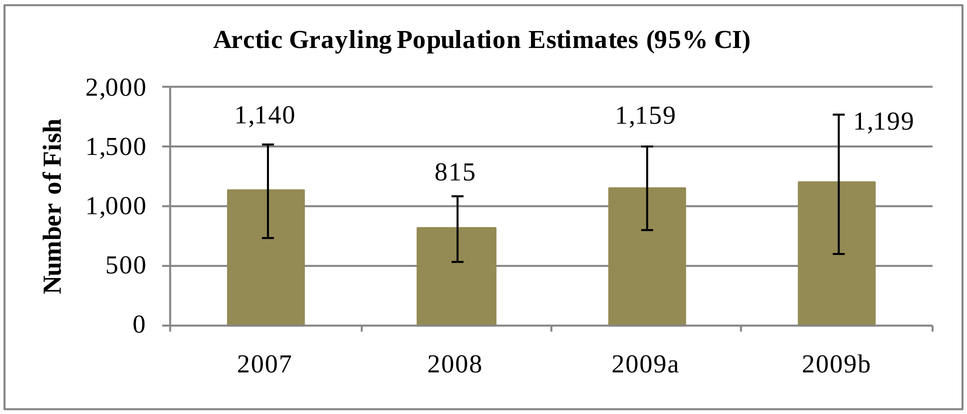

Figure 5. Estimates of the Arctic grayling population in the stilling basin (2009a is an in-season estimate – 2009b uses the recapture event in spring 2010).

We handled 1,190 Arctic grayling (recaptures or new marks) in spring 2011 in the WSR. Water began flowing over the spillway on May 27, 2011. However, in July and August 2011, there were no recaptures of fish marked in spring 2011 (May 10 to 24) in the WSR in the stilling basin sample. In previous years of sampling, we have caught Arctic grayling in the stilling basin in the spring and summer that were seen that same spring in the WSR and in those years water was flowing through the spillway. These data suggest that migration from the WSR to the stilling basin occurs primarily during the spawning period when fish are actively seeking warm water spawning habitats.

Water Supply Reservoir, Arctic Grayling

Arctic grayling were found throughout the Fish Creek drainage prior to construction of the WSR. Fish were concentrated in flooded mine cuts in Last Chance Creek. The population appeared stunted: fish larger than 220 mm were rare; annual growth was 9 mm; and size at maturity was small (148 mm for males, 165 mm for females). Successful spawning was limited to inlets and outlets of the flooded mine cuts and upper Last Chance Creek. Flooding of the WSR inundated the inlets and outlets of mine cuts, thus eliminating this spawning habitat. Since flooding of the WSR, aufeis in Last Chance Creek has been substantial (Figure 6). We have only observed successful spawning by Arctic grayling in Last Chance Creek in 2004 and 2005.

Figure 6. Photograph of 2 m thick aufeis field in Last Chance Creek, 2006.

Very few fry were captured or observed from 1996 through 1998 in the WSR and Last Chance Creek (less than 10 were observed). In spring 1999, FGMI constructed an outlet channel (Channel #5) to connect the developed wetland complex with the WSR (Figure 2). Channel #5 was constructed to bypass a perched pipe and provided fish access to potential spawning and rearing habitat in the wetland complex. Arctic grayling have successfully spawned in the wetland complex every year since 1999 and have used most of the wetland complex in the majority of years. However, substantial aufeis and resultant cold water temperatures in the wetland complex, in addition to newly created beaver dams, limited availability of, and access to, spawning habitats in 2002, 2006, and 2007.

Arctic Grayling Spawning (Timing, Temperature, and Fry Presence)

In spring 2011, we fished a fyke net in the WSR at the mouth of the outlet channel from Pond F. The fyke net was set on May 9 and was pulled on May 24. Water levels rose steadily in the WSR during sampling (Figure 7). Aufeis was minimal, compared with previous years, in Last Chance Creek and in the developed wetland complex. Beavers had not reconstructed the dams in the wetland complex and fish had access to the creek and Ponds D, E, and F in spring 2011. The fyke net was closed May 13 through 16 and May 18 through 23 to allow fish to move into the wetland complex. This also served to distribute our sample throughout the majority of the spawning period.

Figure 7. Photographs of fyke net in the WSR on May 10 (left) and May 17 (right). Water levels rose about .7 m between May 10 and 17, 2011.

Observations of Arctic grayling spawning activity, ice conditions, and distribution of fish in the developed wetland complex are presented in Table 4. We first captured Arctic grayling on May 10 in the WSR at the mouth of Channel #5. Catches increased daily and peaked on May 17 (Figure 8). On May 24, our catch was 48 Arctic grayling, and included 20 males, 19 ripe females, and 1 not ripe female – 8 fish were known within-season recaptures and were released. Generally, toward the end of the spring sampling events, we start catching fish between 100 and 200 mm long; however, we only caught 3 fish less than 200 mm (187, 189, and 198) in spring 2011.

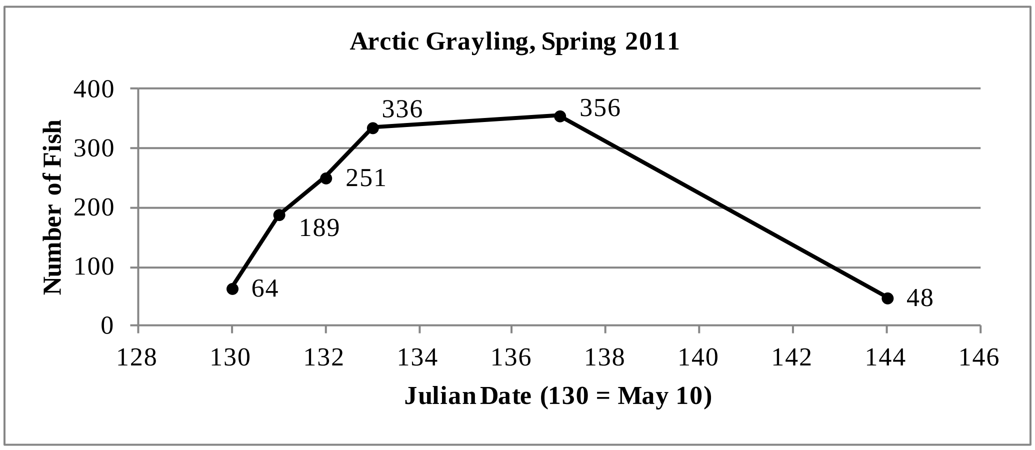

Figure 8. Catch per unit of effort (grayling/day/fyke net) for Arctic grayling in spring 2010 in the wetland complex.

We first observed males defending territories on May 16 in the Pond F outlet channel. Active spawning began on May 17 (peak water temperature = 5.1°C) and peaked on May 23 and 24 (peak water temperature = 13.6 and 13.3°C). There was a rapid rise in the daily peak water temperature between May 20 (5.2°C) and May 21 (7.3°C) (Figure 9). Mature ripe fish continued to enter the wetland complex and spawning likely continued beyond our sample period.

Table 4. Spawning activity, ice conditions, and distribution of Arctic grayling in spring 2011.

Date	Pond F Outlet Channel	Ponds E and F	Pond D Outlet Channel	Pond D	Channel C
5/9/2011	fyke net set in WSR where Pond F channel enters Pond F outlet in WSR	100% ice covered, outlet of Pond F open	continuous flow, some ice on banks but channel is open	100% ice cover	aufeis in lower portion of channel, upper portion open channel flow
5/10/2011	caught 64 Arctic grayling, mostly ripe males, no spawning activity	no change, no spawning activity	no change, no spawning activity	no change, no spawning activity	no change, no spawning activity
5/11-13/2011	caught 776 Arctic grayling, mostly males, no spawning activity	slight changes, a little more open water, no spawning activity	slight changes, a little more open water, no spawning activity	slight changes, a little more open water, no spawning activity	slight changes, a little more open water, no spawning activity
5/16/2011	reset fyke net, net was closed on 5/13/2011	Pond F outlet area open, 4°C water in outlet, males defending territories	water temperature 2°C, no fish observed	slight change, no spawning activity	slight changes
5/17/2011	checked fyke net, net was closed	active spawning observed	no fish observed	slight change, no fish observed	slight changes
5/23/2011	reset fyke net, opened up the wings	lots of spawning activity, 9°C water	no fish observed	still had pan ice floating, 4°C water	most of the channel is free of ice
5/24/2011	checked and pulled the fyke net	lots of spawning activity, 11°C water	grayling observed spawning in D channel, 4°C water	ice free	checked upper end for fish, no fish observed, walked down channel, flows go subsurface under the vegetation and ice, ice under the vegetative mat

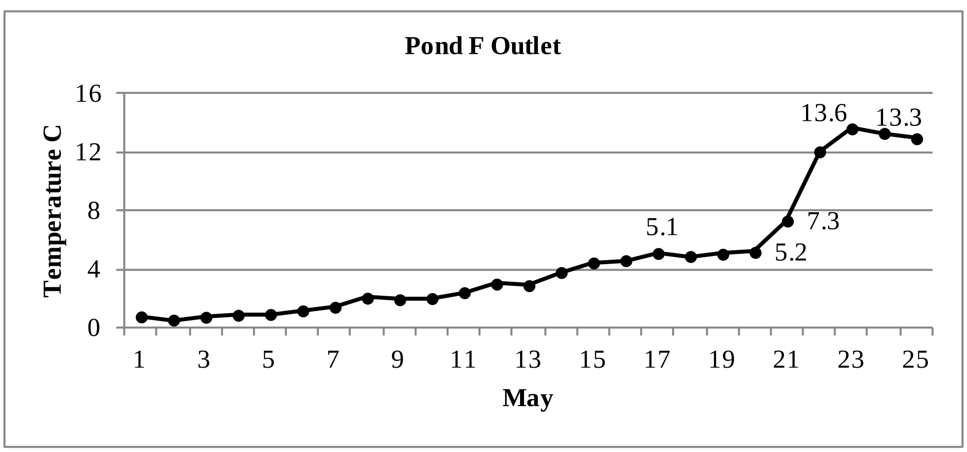

Figure 9. Peak daily water temperatures in Pond F outlet channel, May 2011.

Spawning was not observed in the channel connecting Pond D and E until May 24. Similar to previous years, colder water temperatures in the Pond D outlet due to aufeis delayed spawning use in this portion of the wetland complex. On May 24, the peak water temperature in the Pond F outlet was 13.3°C whereas it was 4°C in the Pond D outlet channel. About 10 Arctic grayling fry were observed in Pond F on July 25 – their size was estimated at > 50 mm. Fry also were observed surface feeding in Pond D on August 2.

Two spent females were caught on May 17 and 1 spent female on May 24 (Figure 10). Ripe females were present in catches throughout our sampling effort. The percent of females judged to be ripe increased from 32% on May 17 to 90% on May 24. Based on previous years of sampling, spent females stay in the wetland complex ponds for several weeks before moving back to the WSR. Because our sampling effort is designed to capture fish moving into the spawning area, it is not unexpected that our post spawning catch rate of spent females is low.

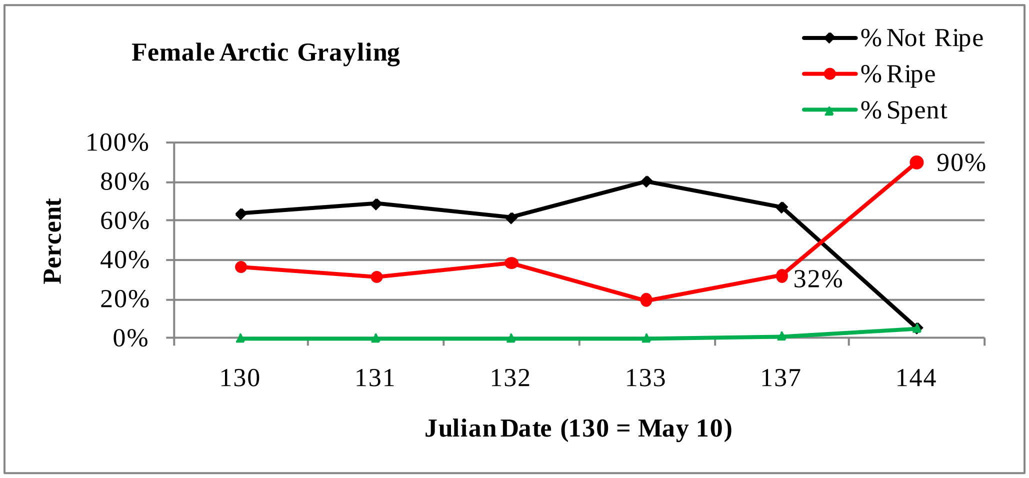

Figure 10. The percent not ripe, ripe, and spent female Arctic grayling captured in a fyke net fished in the WSR, 2011.

Arctic Grayling Catches and Metrics

The abundance of Arctic grayling was estimated in the WSR using spring 2010 as the mark event and spring 2011 as the recapture event. In spring 2010, there were 858 marks when newly tagged and recaptured fish were combined. In spring 2011, 996 Arctic grayling ≥ 230 mm were captured, and of those, 196 were recaptures. For the 2010 estimated Arctic grayling population, length frequency distributions were compared for fish marked in spring 2010 with those recaptured in spring 2011 to eliminate those fish handled in 2011 that would have been too small (< 200 mm) to mark in spring 2010. We reduced the total number of marked fish (1,194) handled in spring 2011 by 198 fish that were < 230 mm long, yielding a total of 996 fish handled in 2011 for use in estimating the 2010 population.

The spring 2010 population estimate for Arctic grayling ≥ 200 mm long was 4,346 fish (95% CI 3,870 to 4,823) (Figure 11 and Appendix 3). As predicted based on the spring catch in 2010 (Ott and Morris 2010), the Arctic grayling population has increased.

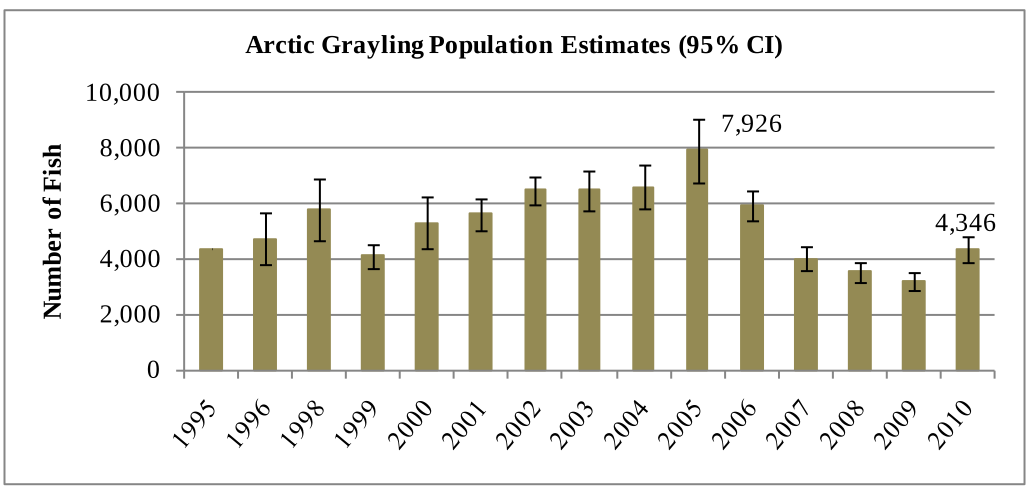

Figure 11. Estimates of the Arctic grayling population in the WSR.

The gradual decrease in the total population of fish ≥ 200 mm from 2005 to 2009 is attributed to a lack of recruitment because of reduced availability and quality of spawning habitat in the developed wetland complex. However, spawning in 2008 extended throughout the wetland complex and from 2009 through 2011 spawning was observed from Pond D downstream. Increased spawning success from 2008 to 2011 suggests access to spawning habitat was improved by the removal of beaver dams in spring 2008. Use of the upper portion of the wetland complex (upstream of Pond D) has not occurred from 2008 to 2011. From 2008 to 2010 extensive aufeis was present and likely limited upstream movement. Substantial aufeis also was present in spring 2011 and flow had been forced into the ground below the ice in Channel C.

Substantial recruitment of fish ≥ 200 mm was observed in spring 2010 and again in spring 2011 (Figure 12). We captured 198 fish between 200 and 230 mm long that we marked in spring 2011. Recruitment observed during the spring of 2011 is likely from fry produced in 2008, the first year of beaver management. Continued recruitment is anticipated along with increases in the Arctic grayling population.

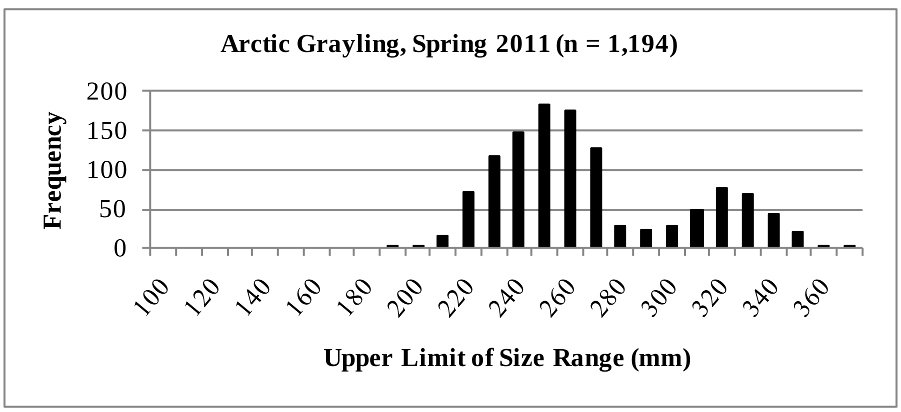

Figure 12. Length frequency of Arctic grayling in the WSR and developed wetlands in spring 2011.

Most of the fish caught in spring 2011 were mature (693 males, 475 females) with only 25 fish judged as immature (Figure 13). The percent males, females, and immature in the catch was 58, 40, and 2. Mature females as small as 187 mm were measured, while the smallest ripe male was 200 mm long.

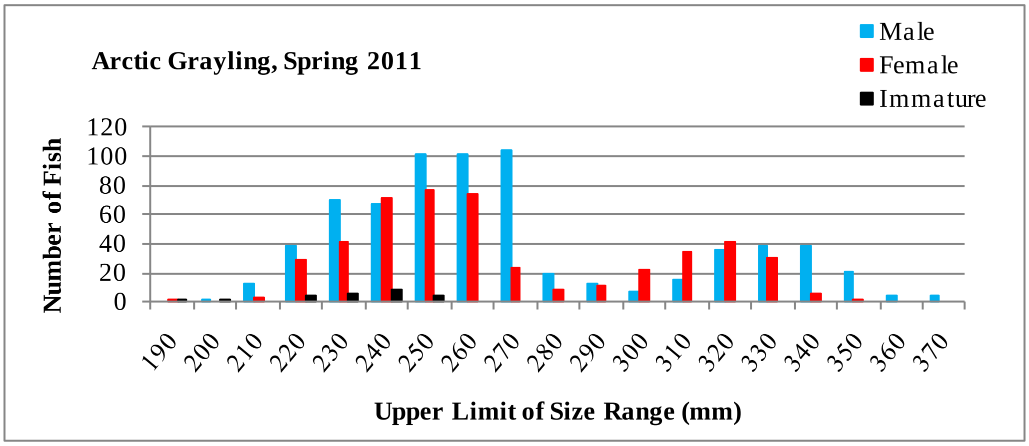

Figure 13. Mature versus immature Arctic grayling in spring 2011.

Average growth of Arctic grayling prior to development of the WSR ranged from 3 to 17 mm per year (Appendix 4). After the WSR was flooded in 1995, annual growth for marked fish increased substantially. Growth rates decreased in 2010 compared with 2009 (Figure 14).

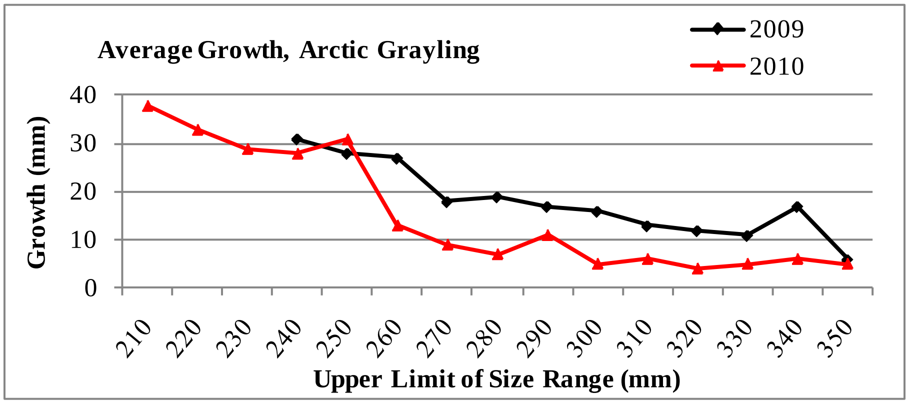

Figure 14. Growth of marked Arctic grayling in the WSR in 2009 and 2010.

We observe an inverse relationship between growth rates and the Arctic grayling population size. Annual growth rates of marked fish peaked in 2001, and then decreased slowly each year through 2004. Growth rates were increasing as the fish population was decreasing in the WSR. Since 2004, growth rates of individual fish have increased, with highest growth seen in summer 2008, as the population continued to decrease. However, growth rates in summer 2009 dropped slightly and probably reflect the large increase in recruitment of new fish to the population. Growth rates in 2010 continued to decrease as the population increased.

Average growth of Arctic grayling for fish ≤ 250 mm and for fish >250 mm for all sample years where population estimates were made is presented in Figure 15. Growth rates for both the smaller (< 250 mm) and larger (≥ 250 mm) cohorts of fish are higher when the population is lower. One possible explanation for the increased growth might be the assumption that with a lower overall population there is an increase in available food for the fish present. These data would indicate that at the higher populations there is not adequate food to maintain the higher growth rates. Further, these data suggest that maintaining the population of fish > 200 mm at around 3,000 to 4,000 individuals might be ideal to produce a stable population with higher average growth rates.

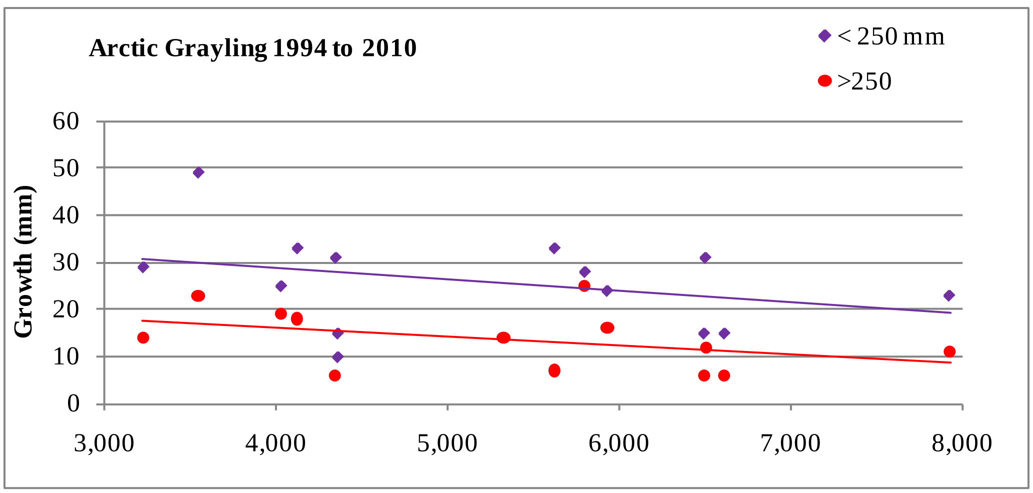

Figure 15. Growth of marked Arctic grayling in the WSR versus the estimated population of fish. Linear trendlines are shown for each group of fish.

Water Supply Reservoir, Burbot

Burbot were captured in spring 2011 in a fyke net fished in the WSR at the mouth of the wetland complex. The fyke net fished for 6 days catching 117 burbot that ranged from 117 to 472 mm long. Small burbot were captured in both 2010 and 2011 indicating mature burbot are still present in the WSR and are spawning successfully (Figure 15). In 2010, the fyke net was fished just above the Gil Causeway, but due to water depths that site was not fishable in spring 2011.

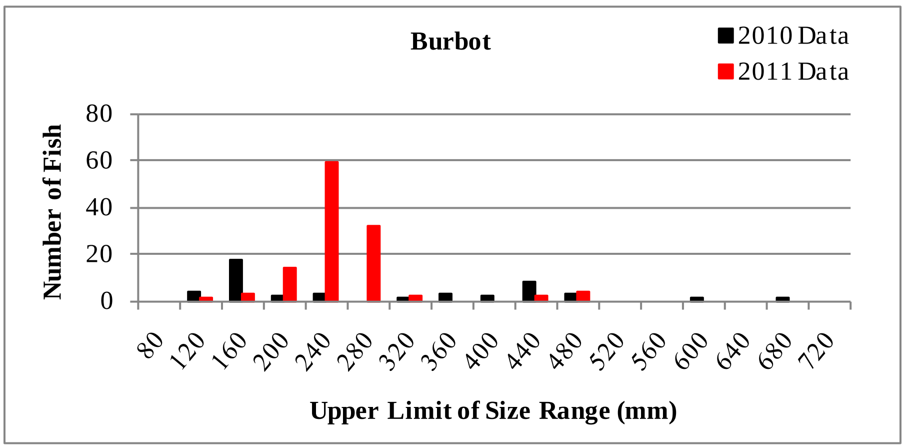

Figure 16. Length frequency of burbot in the WSR in spring 2010 and 2011.

Conclusion

Self-sustaining populations of Arctic grayling and burbot have been established in the Fort Knox WSR. The post-mining goal for the Arctic grayling population was set at 800 to 1,600 fish $\geq$ 200 mm (FGMI 1993). Our spring 2010 estimated population for Arctic grayling $\geq$ 200 mm was 4,346 fish. A goal for the burbot population was not set prior to construction, but a small self-sustaining spawning population exists.

We plan to continue to work cooperatively with FGMI to collect data on fish resources and water quality in the WSR and to implement rehabilitation projects designed to increase fish and aquatic habitat values and terrestrial habitats. Options under consideration include development of a second wetland complex along the north side of the Fish Creek valley, conversion of the existing Gil causeway into re-vegetated islands, civil work in Last Chance Creek to mitigate aufeis, rehabilitation of the road down the valley between the tailing dam and freshwater reservoir, construction of a passive water treatment wetlands below the tailing dam, and removal of beaver dams to maintain Arctic grayling spawning habitat in the developed wetlands.

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Appendix 1. A Summary of Mine Development with Emphasis on Biological Factors

2011

- on February 9, 2011, ADF&G provided input to ADNR on the environmental audit to be conducted in summer 2011. We identified several possible fish and wildlife enhancement projects originally recommended by Buell and Moody (2005).
- on March 4, 2011, the ACOE issued a permit (POA-1992-574-M19) authorizing construction of the modified dam raise and expansion of the Tailing Storage Facility (TSF).
- in April and May several Plan of Operations amendments were issued by ADNR for work associated with the TSF, waste rock dumps, powerline, topsoil storage, and dewatering.
- on May 2, 2011, ADF&G provided input to ADNR on the reclamation and closure plan for Fort Knox. Emphasis was on maintaining the existing developed wetland complex downstream of the TSF.
- our spring sample event for Arctic grayling and burbot ran from May 9 to 24. We caught 1,194 Arctic grayling and 117 burbot in a fyke net set in the WSR.
- the estimated spring 2010 Arctic grayling population was 4,346 fish > 200 mm long and was an increase from the 2009 estimate of 3,223. Recruitment of new fish in spring 2011 was strong with 198 new fish < 230 mm marked.
- Arctic grayling spawned in the wetland complex from Pond D downstream. Beavers had not rebuilt the dams in the wetland complex.
- a constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring 2011 – one chick was seen in August. An active raven nest was observed on the rock cut near the freshwater dam.
- water began flowing over the spillway on May 27, water had not reached the spillway since winter 2009/2010.
- on June 2, 2011, ADF&G provided written comments on the Ft. Knox and True North environmental audit proposals.
- on July 19, 2011, FGMI pumped about 10,440 gallons of water from the “801 Pond” downstream – environmental staff were notified and pumping was immediately stopped – water from the “801 Pond” is supposed to be pumped back into sump below the TSF
- on August 4, 2011, ADNR informed us of planned changes at Fort Knox including expansion of the heap leach facility from 160 to 300 million tons, the need for a ADEC permit to discharge non-contact water, and the long-term need for a permit and water treatment plant for closure.

Appendix 2. Arctic Grayling Population Estimates in the Stilling Basin.

Year	Minimum Size of Fish in Estimate (mm)	Estimated Size of Population	95% Confidence Interval
2007[1]	200	1,140	748-1,531
2008[1]	200	815	531-1,099
2009[2]	200	1,159	812-1,505
2009[1]	200	1,199	612-1,787

[1]The 2007 through 2009 population estimates were made using a mark event in spring of the year of the estimate, but the recapture event was in spring of the following year.

[2]This 2009 estimate was made capture (spring) and recapture (fall) event in summer 2009.

Appendix 3. Arctic Grayling Population Estimates in the WSR.

Year	Minimum Size of Fish in Estimate (mm)	Estimated Size of Population	95% Confidence Interval
1995[1]	150	4,358	
1996[2]	150	4,748	3,824-5,672
1996[3]	150	3,475	2,552-4,398
1998[4]	200	5,800	4,705-6,895
1999[4]	200	4,123	3,698-4,548
2000[4]	200	5,326	4,400-6,253
2001[4]	200	5,623	5,030-6,217
2002[4]	200	6,503	6,001-7,005
2003[4]	200	6,495	5,760-7,231
2004[4]	200	6,614	5,808-7,420
2005[4]	200	7,926	6,759-9,094
2006[4]	200	5,930	5,382-6,478
2007[4]	200	4,027	3,620-4,433
2008[4]	200	3,545	3,191-3,900
2009[4]	200	3,223	2,896-3,550
2010[4]	200	4,346	3,870-4,823

[1]We used estimates from the ponds and creeks for the Arctic grayling population; a confidence interval was not applicable to the data set.

[2]The 1996 estimate was made with a capture and recapture event in summer 1996.

[3]Gear type for the population estimate was a boat-mounted electroshocker with both capture and recapture events in fall 1996.

[4]The 1998 through 2010 population estimates were made using a mark event in spring of the year of the estimate, but the recapture event was in spring of the following year.

Appendix 4. Arctic Grayling Growth in the WSR.

2010 to 2011 growth grayling (n=196)			
Upper Limit (mm) and Sample Size	Average (mm)	Maximum (mm)	Minimum (mm)
210 (n=9)	38	47	29
220 (n=10)	33	56	19
230 (n=15)	29	36	20
240 (n=12)	28	30	19
250 (n=2)	31	38	24
260 (n=1)	13	13	13
270 (n=4)	9	17	4
280 (n=5)	7	18	0
290 (n=8)	11	24	3
300 (n=20)	5	13	1
310 (n=29)	6	15	0
320 (n=37)	4	11	0
330 (n=26)	5	21	0
340 (n=14)	6	12	0
350 (n=4)	5	6	4

	≤ 250 mm		>250		
Upper Limit (mm) and Sample Size	Average (mm)		Average (mm)	Year	Population Size
210 to 250 (n=15)	10			1994	4,358
210 to 250 (n=3)	15			1995	4,358
210 to 250 (n=9)	28	> 250 (n=22)	25	1998	5,800
210 to 250 (n=10)	33	> 250 (n=131)	18	1999	4,123
210 to 250 (n=0)		> 250 (n=47)	14	2000	5,326
210 to 250 (n=154)	33	> 250 (n=142)	7	2001	5,623
210 to 250 (n=119)	31	> 250 (n=188)	12	2002	6,503
210 to 250 (n=135)	15	> 250 (n=83)	6	2003	6,495
210 to 250 (n=135)	15	> 250 (n=76)	6	2004	6,614
210 to 250 (n=81)	23	> 250 (n=51)	11	2005	7,926
210 to 250 (n=144)	24	> 250 (n=130)	16	2006	5,930
210 to 250 (n=27)	25	> 250 (n=178)	19	2007	4,027
210 to 250 (n=29)	49	> 250 (n=180)	23	2008	3,545
210 to 250 (n=5)	29	> 250 (n=209)	14	2009	3,223
210 to 250 (n=48)	31	> 250 (n=148)	6	2010	4,346