Technical Report No. 23-01

Fish and Water Quality Monitoring at the Fort Knox Mine, 2022

by

Chad E. Bear and Alvin G. Ott

May 2023

Alaska Department of Fish and Game **Habitat Section**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Habitat, Sport Fish, and Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, Technical Reports and Special Publications. 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)

Mathematics, statistics

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

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and
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Cover: Fort Knox water supply reservoir burbot sampling hoop traps, September 6, 2022.
Photograph by Chad Bear.

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Acknowledgements

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Executive Summary

Water Quality

In April 2022 dissolved oxygen (DO) concentrations were measured in the water supply reservoir (WSR). For eight consecutive years, winter DO concentrations have been among the highest since sampling began in 1998. Higher DO concentrations appear to be directly related to the discharge of reverse osmosis (RO) water from mine operations into the Fish Creek wetlands complex just downstream of the tailing's impoundment dam.

During 2022, RO water discharge continued but at a reduced rate compared to 2021. The input of warm (~6.0°C) RO water raised the RO Channel water temperature to 2.69°C on April 14, 2022, compared to 0.84°C in Fish Creek, which receives no direct input of RO water.

In April 2022, FGMI environmental staff reported five dead Arctic grayling recovered from Pond AB. FGMI stopped processing and discharging water from all RO facilities until water test results were analyzed. A wetlands survey was performed to document any issues affecting the wetland habitats. Arctic grayling were observed swimming in Fish Creek and no additional fish moralities were found. Results from receiving water and fish tissue samples showed elevated levels of Weak Acid Dissociable WAD cyanide concentrations, however samples from the outfall discharge were within permit limits (50 ug/L). FGMI reviewed their RO facilities processes and no further fish distress or mortalities were observed.

Arctic Grayling

Sampling for the annual Arctic graying abundance estimate was conducted from May 2 – May 17, 2022 with fyke nets in Fish Creek and the RO Channel to capture fish as they moved from the WSR into the developed wetlands for spawning. The spring 2021 population estimate for Arctic grayling $\geq$200 mm fork length (FL) was 3,090 fish (95% CI: 2,763 to 3,417 fish).

A fyke net was placed in Pond AB, and it captured 165 Arctic grayling with an average length of 173 mm, the first Arctic grayling documented in the uppermost waterbody of the wetlands complex.

Juvenile Arctic grayling recruitment has been variable, with an increase observed between 2020 and 2022. During May, 780 age-2 and age-3 Arctic grayling were captured between 130 and 240 mm showing survival of the thousands of age-1 and age-2 Arctic grayling observed in 2020 and

2021. Of these, 370 fish were 200 -240 mm and classified as 2022 recruitment, the highest recruitment documented in the WSR since 2017.

Burbot

The fall burbot abundance estimate occurred from September 6 - 16, 2022 with hoop traps in the WSR. During the sampling event 123 burbot were captured with 110 being ≥300 mm. The 2020 burbot population estimate used fall 2020 as the mark event and fall 2022 as the recapture event since no fall burbot sampling was conducted in 2021 due to early ice on the WSR. The 2020 WSR population estimate for burbot ≥400 mm was 302 fish (95% CI: 171 to 432 fish).

Pond AB was also sampled in the fall and seven burbot were captured with an average length of 223 mm, the first documented burbot in the uppermost waterbody of the wetlands complex.

Introduction

Fairbanks Gold Mining Incorporated (FGMI) began construction of the Fort Knox hard-rock gold mine in March 1995. The mine is located about 26 road miles (42 km) northeast of Fairbanks, Alaska in the headwaters of the Fish Creek drainage that flows into the Chena River. The project includes an open pit mine, mill, tailings storage facility (TSF), two heap leach facilities, and a water storage reservoir (WSR), these facilities encompass approximately 8,711 acres of land (Figure 1). Construction of the WSR dam and spillway was completed in July 1996, and the first gold pour was in November 1996. In 2021 ore extraction began at the Gil Mine, located approximately 8 miles from Fort Knox. To facilitate hauling ore from Gil to the Fort Knox Mill substantial improvements were made to the Gil Haul Road and causeway in 2021 and 2022 (Figure 2).

Prior to the construction of Fort Knox, the upper Fish Creek valley was extensively placer mined. Rehabilitation of the disturbed habitat has been concurrent with the mining activities at Fort Knox, and natural revegetation continues. Wetlands construction between the tailings dam and WSR began in 1998. A channel connecting wetlands along the south side of the valley was built in 1999. 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 tailings dam and the WSR.

Fish research began in 1992 prior to construction of the Fort Knox mine and related facilities (Weber Scannell and Ott 1993). Arctic grayling *Thymallus arcticus* populations were estimated to determine numbers of fish available to colonize the WSR. Arctic grayling were found throughout the Fish Creek drainage, however these fish were limited to habitat in flooded mine cuts and settling ponds in Last Chance Creek. The Arctic grayling population appeared stunted, fish larger than 220 mm were rare, the average annual growth was 9.0 mm between 1994-95 (Ott and Morris 2000), and the average size of spawners ranged from 160-233 mm (Weber Scannell and Ott 1994).

After completion of the freshwater dam, flooding of the WSR inundated the inlets and outlets of the former mine cuts, thus eliminating the marginal spawning habitat. From 1996 through 1998 few Arctic grayling fry were captured or observed in the WSR and Last Chance Creek (Ott and Morris 2000). In spring 1999, FGMI constructed an outlet channel to connect the Fish Creek developed wetland complex with the WSR. The outlet channel was constructed to bypass a perched

pipe and provide fish access to potential spawning and rearing habitat. Since construction, Arctic grayling have successfully spawned annually in the wetlands complex.

The fish habitat in the wetlands complex was increased in 2019 when discharged RO water from Outfall 002 was routed through Pond AB and into the dry channel on the north side of Centerline Road (Figure 3). From Outfall 002 RO water flows through Pond AB where the relatively warm RO water (~6^{o}C) cools before joining with Fish Creek and entering the WSR. The substantial increase of water to the drainage flooded many low-lying areas creating small ponds. This resulted in 7.9 acres of new wetlands habitat during establishment of the RO channel.

Fish monitoring, including population assessments, has been performed annually at the Fort Knox mine and related facilities since 1992 and water quality sampling since 1997 (winter water quality started in 1998). Viable, self-sustaining populations of both Arctic grayling and burbot *Lota lota* exist in the WSR today. Arctic grayling spawning occurs predominantly in the wetland complex between the WSR and the tailings dam. Burbot spawning, as documented by radio telemetry, likely occurs in Solo Bay where Solo Creek enters the WSR (Ott *et al.* 2013). Both Arctic grayling and burbot recruit into the stilling basin over the WSR spillway (Bear and Burrows 2019).

This report summarizes the fish and water quality data collected during 2022 and discusses these findings in relation to previous work. A chronology of events from 2011 to 2022, with emphasis on biological factors, is presented in Appendix 1.

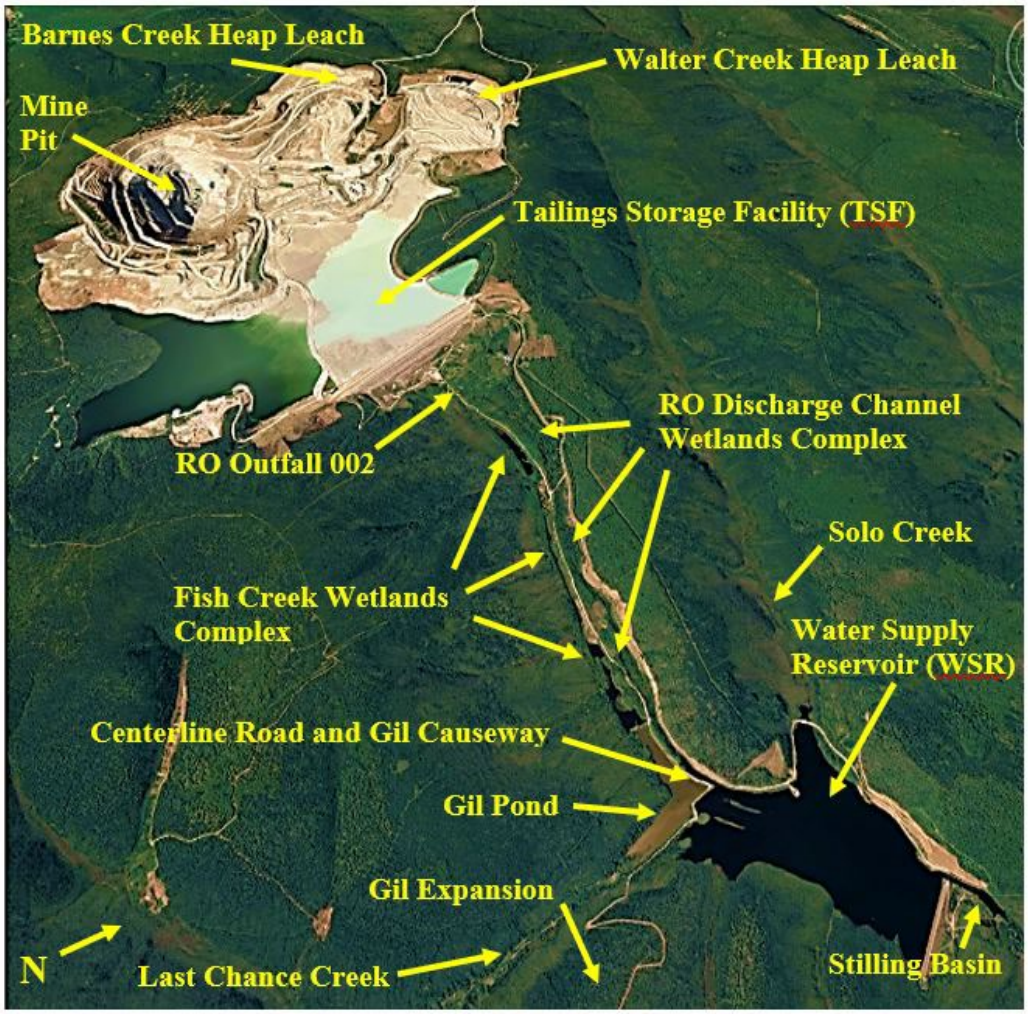

Figure 1. Fort Knox gold mine, and associated facilities.

Figure 2. Fort Knox Water Supply Reservoir (WSR) and Gil Causeway, May 2020 (left) and May 2022 (right).

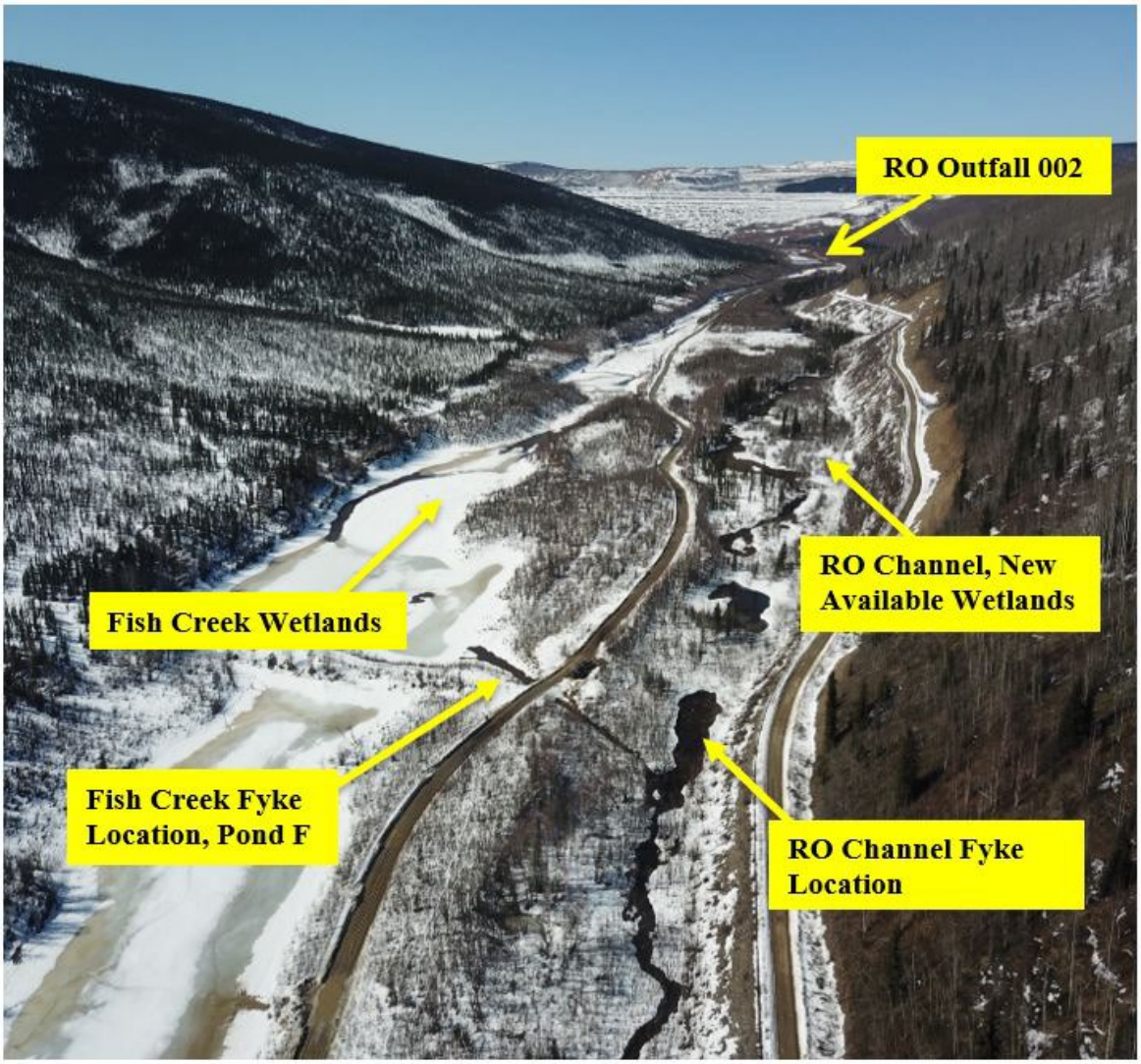

Figure 3. Fish Creek Wetlands Left, RO Channel Wetlands Right.

Structure of Report

This report is presented in several sections as follows:

1) WSR water quality;
2) Arctic Grayling population assessment;
3) Burbot population assessment; and
4) A chronology of events from 2011 to 2022, with an emphasis on biological factors.

Water Quality

The Water Supply Reservoir (WSR) was constructed to be the primary water supply for mining activities and mill operations at Fort Knox. When full, it contains about 3,363 acre-feet (1.1 billion gallons) of water. Water levels have remained mostly constant since 1998, except during winter in certain years when large amounts were removed for mining processes. Since 2015, operational water needs have been satisfied from mine pit and tailings impoundment dewatering wells and no water has been utilized from the WSR. The supply pipeline from the WSR to the Tailings Storage Facility (TSF) was disconnected in 2021 because it was no longer needed.

In spring 2015, FGMI initiated the discharge of non-contact water from dewatering wells around the open pit combined with mine operations water treated by Reverse Osmosis (RO) into the RO Channel wetlands complex from Outfall 001. The discharge was authorized by permits issued by the Alaska Department of Environmental Conservation (ADEC). On January 15, 2019, FGMI brought two additional RO facilities (RO2 and RO3) online and began discharging from Outfall 002 (Figure 4). Discharge from Outfall 001 was routed into Outfall 002 and discharge from Outfall 001 ceased at approximately the same time. Water discharge through the RO systems generally increased from 2015-2021 but declined in 2022 as TSF water balance requirements were met. During 2022, 4,682 acre-feet of RO water were discharged into the RO Channel wetlands, a decline from 8,752 acre-feet in 2021 (Table 1).

The WSR has been annually monitored for late winter/ early spring water quality since 1998. The purpose of this effort is to monitor conditions which may impact aquatic life in the wetlands complex and track changes over time.

Figure 4. Outfall 002, RO water discharge of up to 3,000 gpm into the RO Channel Wetlands.

Table 1. Total RO water discharge from Outfall 001 and 002 into Fish Creek Wetlands Complex, 2015 - 2022.

Year	Acre-Feet of RO Water[1]
2015	163
2016	461
2017	618
2018	806
2019	6,681
2020	9,663
2021	8,752
2022	4,682

[1]RO Water Discharged from Outfall 001 (2015 – 2018) and Outfall 002 (2019 – 2022).

Methods

The 2022 water quality sampling was conducted on April 22 when the WSR was ice covered. Six sites in the WSR have been sampled annually since 1998 with two new sites added in the wetland complex starting in 2018 (Figure 5). Measurements of Fish Creek and the RO Channel were taken to document the effect of increased RO water discharged into the wetlands complex.

Vertical profiles of water temperature (ºC), dissolved oxygen (DO) concentration (mg/L), DO percent saturation (barometrically corrected), pH, specific conductance (µS/cm), oxidation reduction potential (ORP), and depth (m) were measured with a Hydrolab® Minisonde®5 water quality multiprobe connected to a Surveyor® 4 digital display unit. Measurements were taken at 1-meter intervals from just below the ice surface to the bottom of the reservoir at the six WSR sample sites and at 1-meter depth in the two wetlands complex sites. The multiprobe sensors were calibrated in the ADF&G lab prior to field sampling and DO was additionally calibrated on site just prior to data collection.

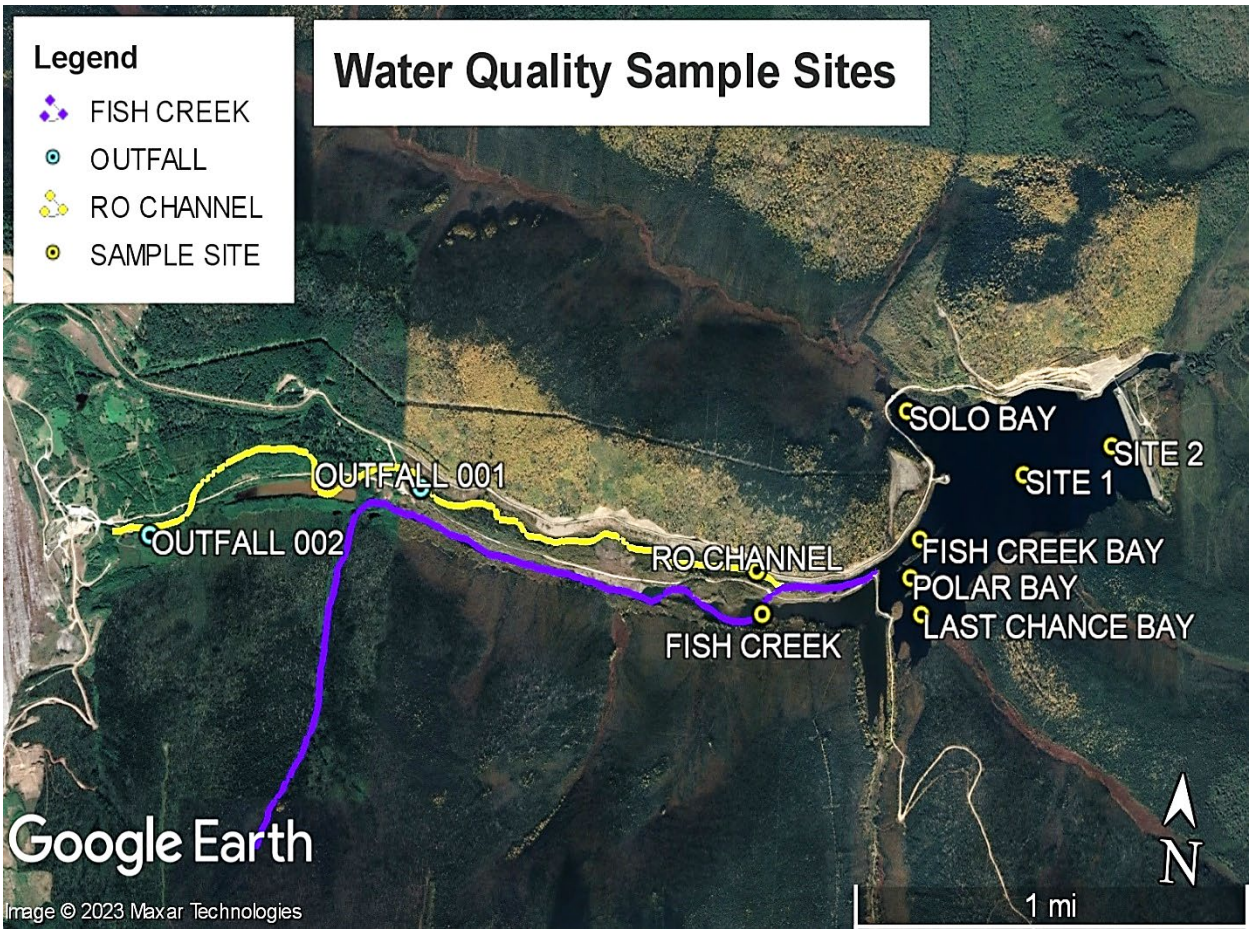

Figure 5. Fort Knox Water Supply Reservoir water quality sample sites, April 14, 2022.

Results and Discussion

In 2022, the ice thickness on the WSR was slightly less than one meter at each of the six annual sampling locations. There was six inches of slushy overflow beneath the two feet of snow on top of the ice. Overflow water may have influenced water quality at the one-meter depth sample from mixing while drilling the test holes, but not the remainder of the water column readings.

WSR water temperatures recorded in 2022 ranged from 0.10°C to 3.01°C (Figure 6). The minimum temperature of 0.10°C was recorded in Polar Bay, just below the ice surface. The maximum temperature of 3.01°C was recorded in Site 2 at 18 meters depth, just above the reservoir bottom. Temperature at all six sample sites increased with water depth. The water temperature profiles at each site are similar when compared to previous years starting in 2015 with the introduction of RO discharge water into the Fish Creek drainage.

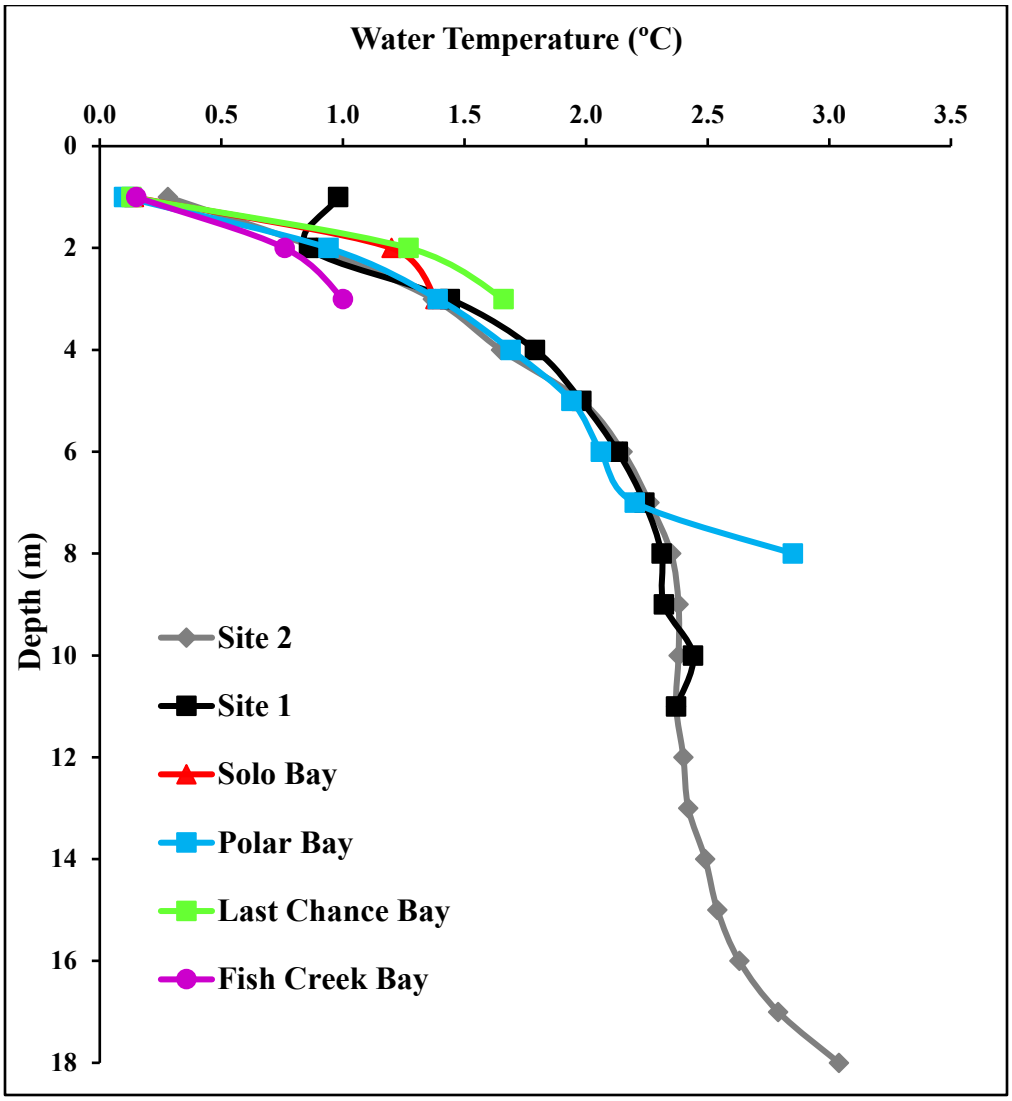

Figure 6. Fort Knox WSR water temperature profiles, April 14, 2022.

Dissolved oxygen (DO) is essential for the survival of fish, aquatic invertebrates, and aquatic plants. In 2022, Solo Bay had the highest recorded dissolved oxygen (DO) at 9.19 mg/L followed by Fish Creek Bay at 8.86 mg/L (Figure 7). These maximums are higher than years prior to 2015 and are likely a result of RO water discharge that began in March 2015. Fish Creek Bay had the highest water column average DO concentration (7.46 mg/L) for the seventh year in a row followed by Solo Bay at 7.23 mg/L. At all six WSR samples sites DO was consistent between the surface and bottom readings showing very little stratification or reduced DO near the bottom of the reservoir. The difference in DO concentration observed in Last Chance Bay is likely due to it being isolated from the water entering the WSR from Fish Creek.

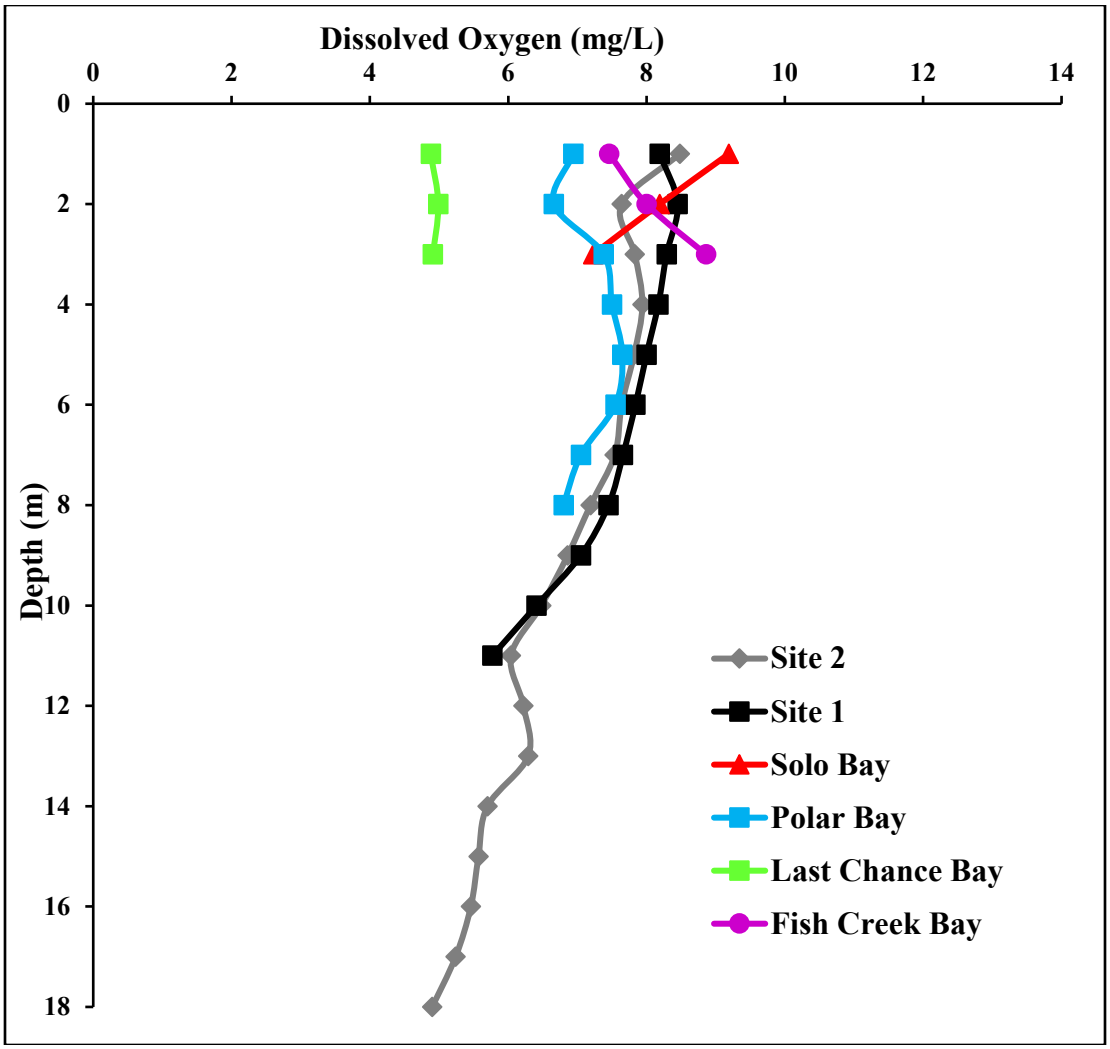

Figure 7. Fort Knox WSR dissolved oxygen (DO) (mg/L) profiles, April 14, 2022.

Temperature specific dissolved oxygen percent saturation DO (%) values were relatively consistent between the surface and bottom readings in 2022 (Figure 8). WSR water is well mixed with very little stratification or reduced DO in deeper areas. DO (%) followed the same pattern as DO (mg/L). At four of the sites DO (%) was between 45 to 65 percent at the surface, increased as it neared 5 m of depth, then reduced to close to its starting values as it approached the reservoir bottom. DO may still become anoxic in the deepest parts of the reservoir. With increased water volume entering the WSR from the RO water discharged into Fish Creek the water is well mixed with consistent DO concentrations among five of the six sites. Last Chance Bay had the lowest average DO for the fourth year in a row and as previously noted, it is not directly mixed by the water entering the WSR from Fish Creek.

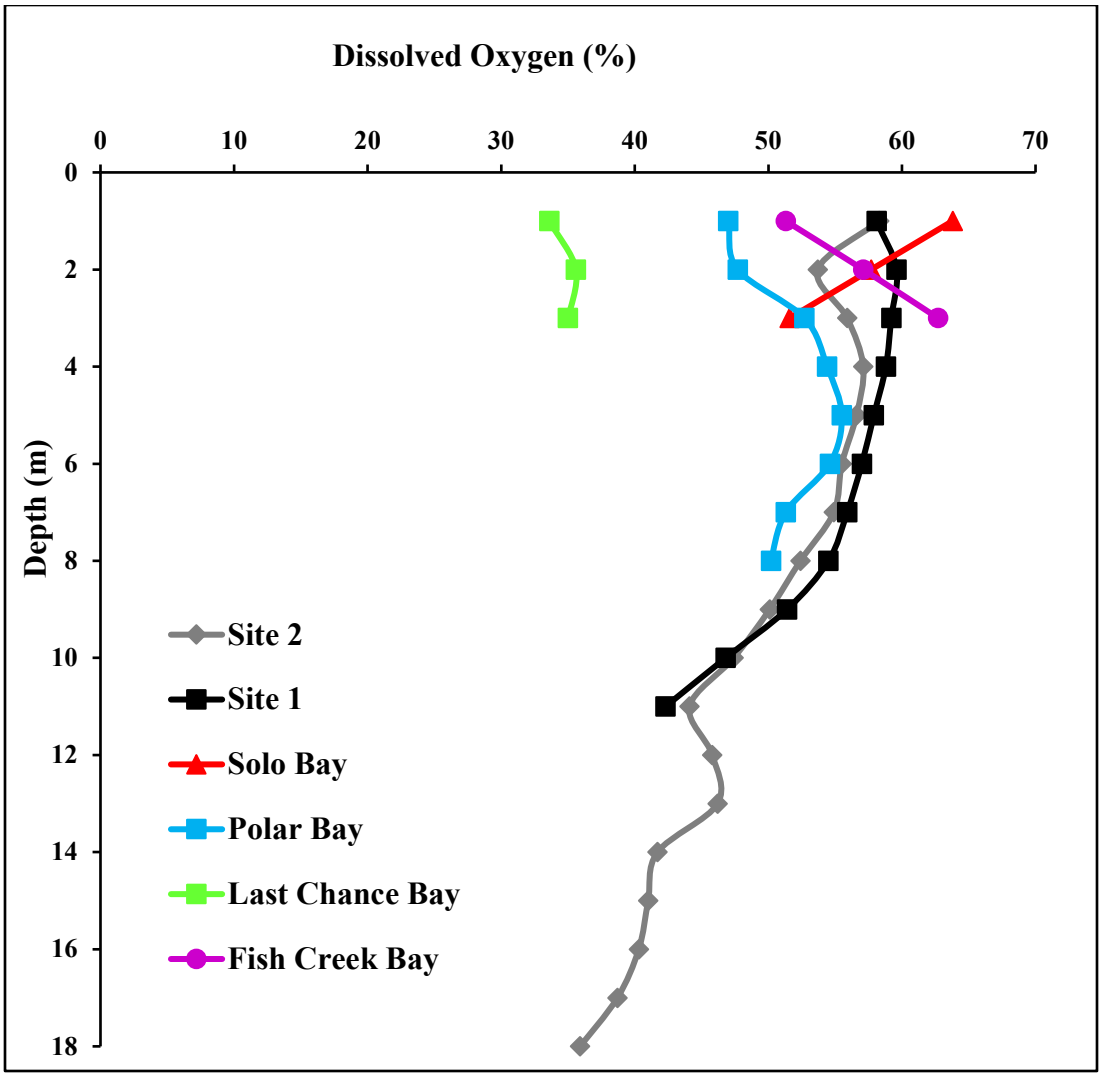

Figure 8. Fort Knox WSR dissolved oxygen (% saturation) profiles, April 14, 2022.

In 2022 the winter water column average dissolved oxygen DO (mg/L) recorded at Site 2 was above the 19-year running average and second highest recorded since 1998 (Figure 9). This is likely a result of the continual discharge of RO water into the Fish Creek drainage entering the WSR. The RO water mixes with the WSR water but may have plumes of highly oxygenated water in different sections of the reservoir at different times. The 2022 total input of 4,682 acre-feet of RO water is more than the total volume of the WSR water of about 3,363 acre-feet. The input of oxygen rich water into Fish Creek has substantially raised the DO in the WSR since 2015.

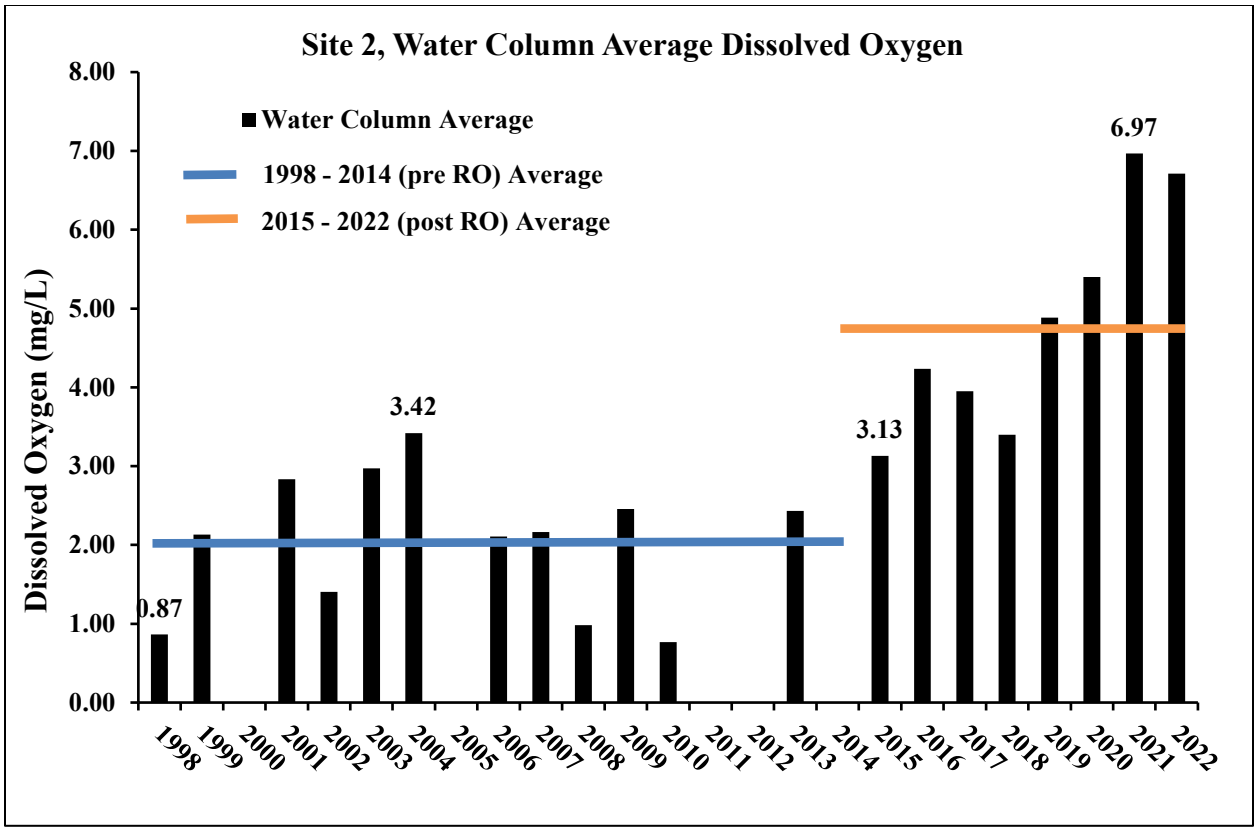

Figure 9. Average water column dissolved oxygen (mg/L) at Site 2, 1998 – 2022.

The pH of water has many effects on the plants, invertebrates, and fish in a water body, and has the potential to affect reproduction, recruitment, growth rates and general health of fish. The WSR water pH in 2022 was relatively similar compared to prior years. At all six sites, the pH remained between 6.8 and 7.2 at all depths measured (Figure 10). All WSR pH readings met the ADEC standard for aquatic life, which includes freshwater fish such as Arctic grayling and burbot, of 6.5 to 8.5.

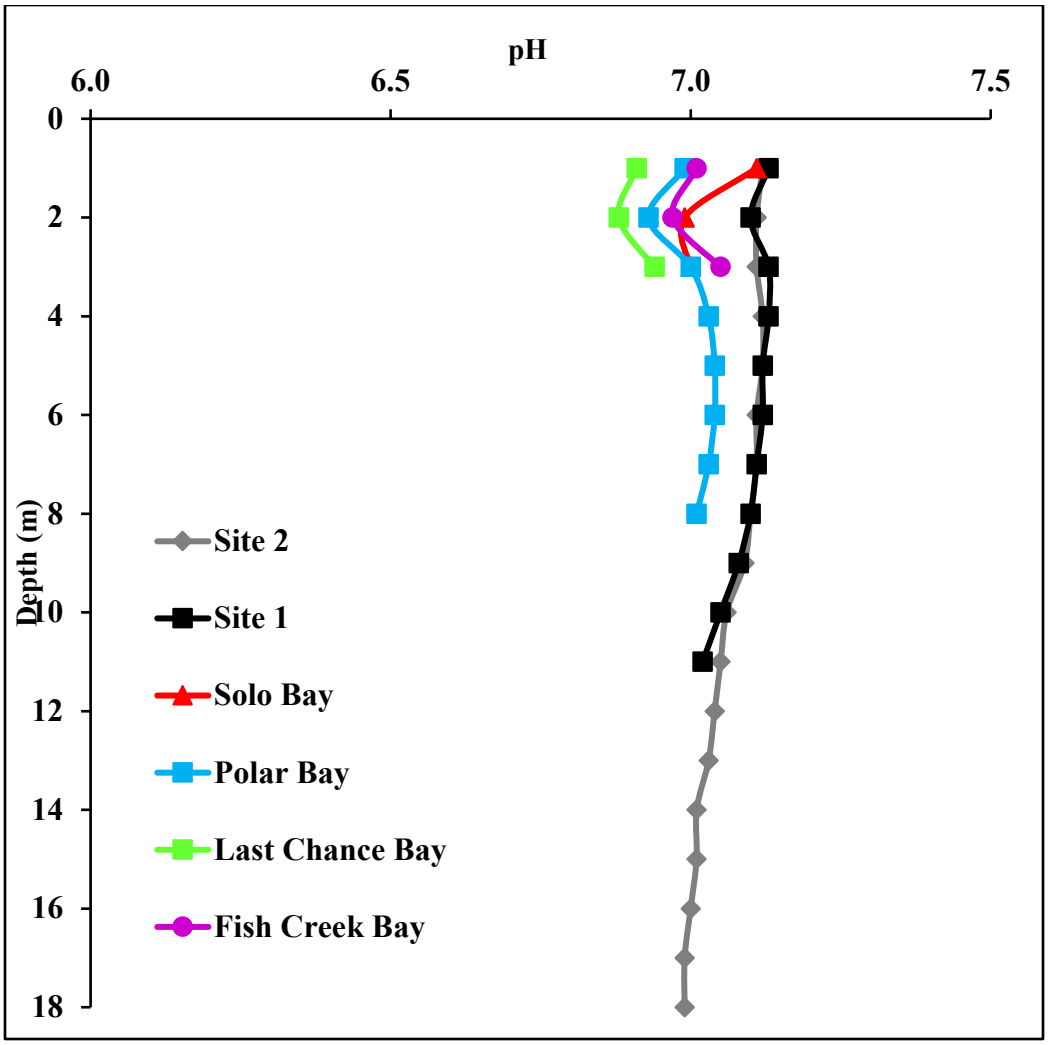

Figure 10. Fort Knox WSR water column pH profiles, April 14, 2022.

Specific conductance is the measure of how well water can conduct an electrical current and increases with increasing amounts and mobility of positively or negatively charged ions and can be used as an indicator of water quality. Specific conductance was similar among all six sites (Figure 11). Values generally increase with water depth as minerals sink from the surface and settle near the bottom. The water in the WSR appears to be mixed with similar measurements at all sample sites. The one-meter reading, just below the ice surface, may be influenced by melting water mixing with WSR water while drilling the test hole. The 2022 Site 2 water column average specific conductance was 427 µS/cm and is the highest ever recorded, indicating an increase in dissolved solids such as chloride, nitrate, phosphate, sodium, magnesium, calcium, and iron present in the WSR water (Figure 12).

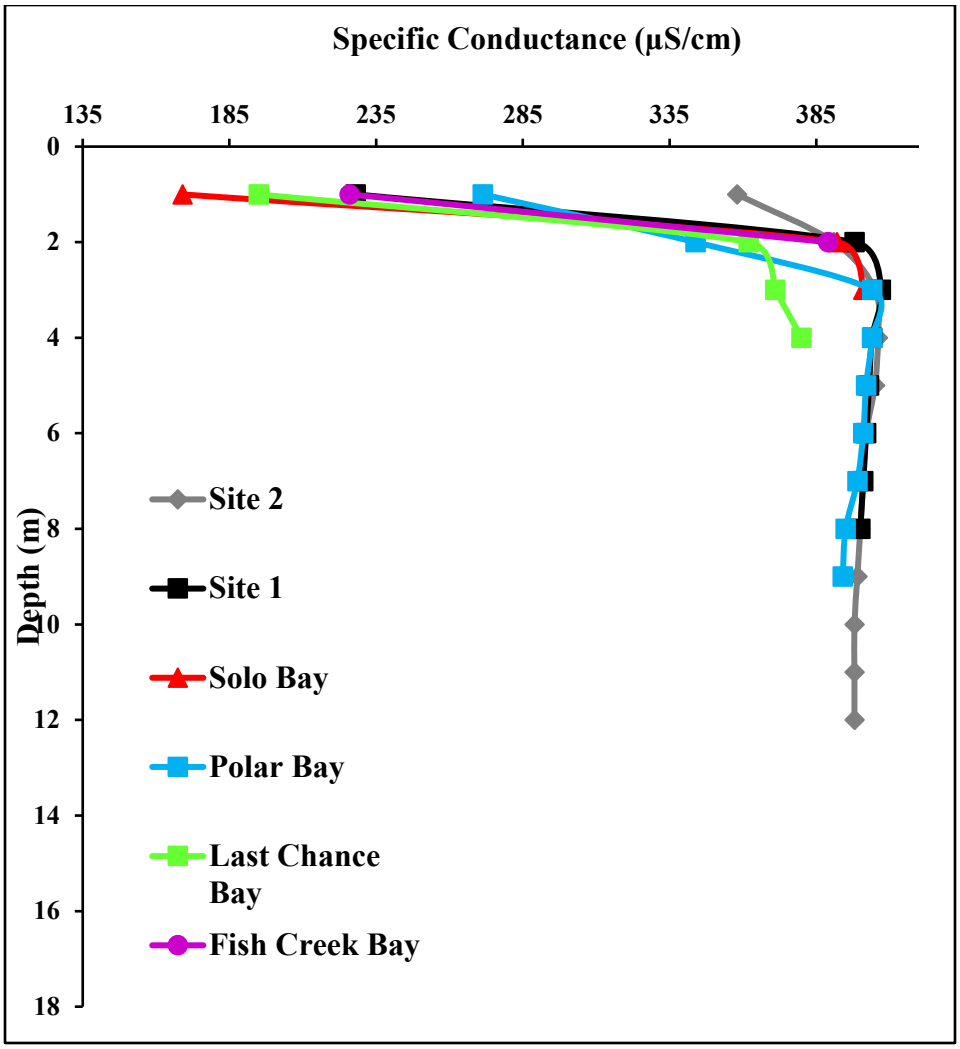

Figure 11. Fort Knox WSR specific conductivity (µS/cm) profiles, April 14, 2022.

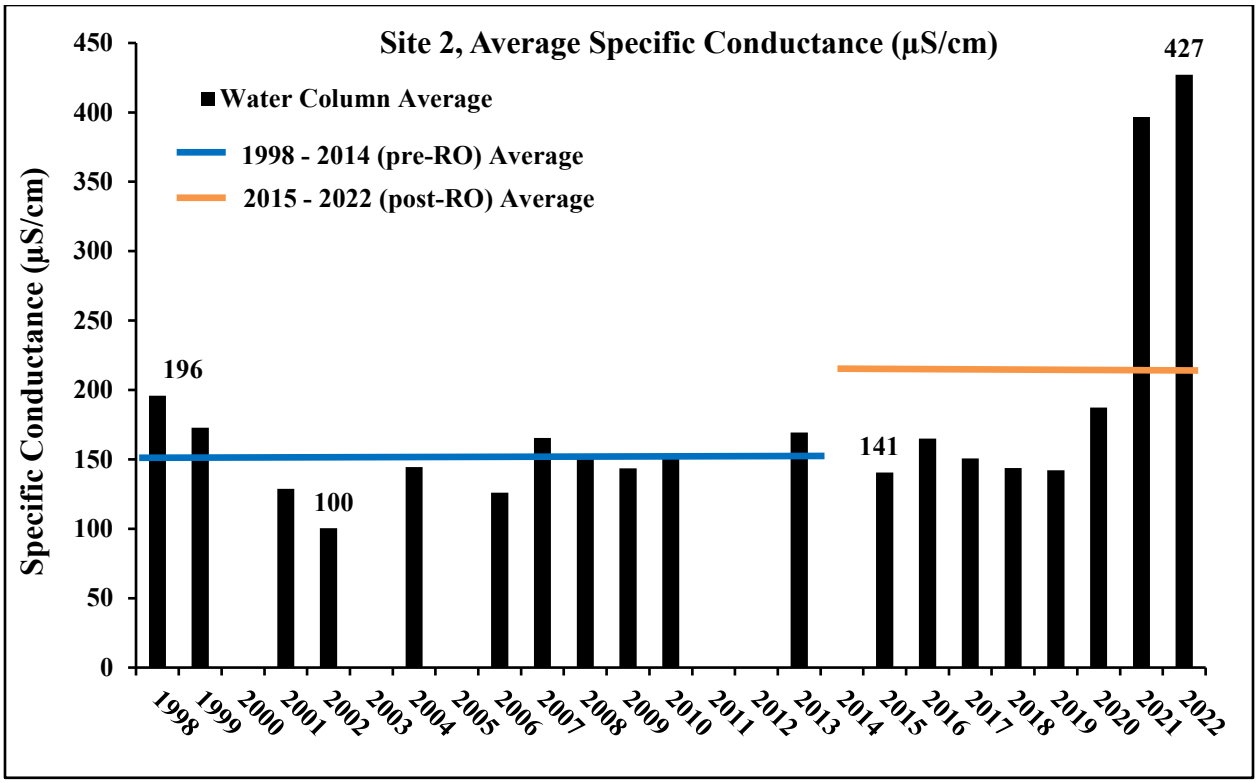

Figure 12. WSR specific conductivity at Site 2, 1998 - 2022.

Oxidation reduction potential (ORP) measures the ability of a lake or river system to break down waste products, such as contaminants and/or dead biological material. ORP was consistent among all sample sites ranging between 308 to 409 mV (Figure 13). The 2022 total WSR average of all six sites combined was 382 mV. This is similar but lower than previous years. The 2021 average was 432 mV. In 2022 ORP values increased with water depth at four of the six sites. This is dissimilar to 2021 where ORP decreased with depth at all six sites (Figure 14).

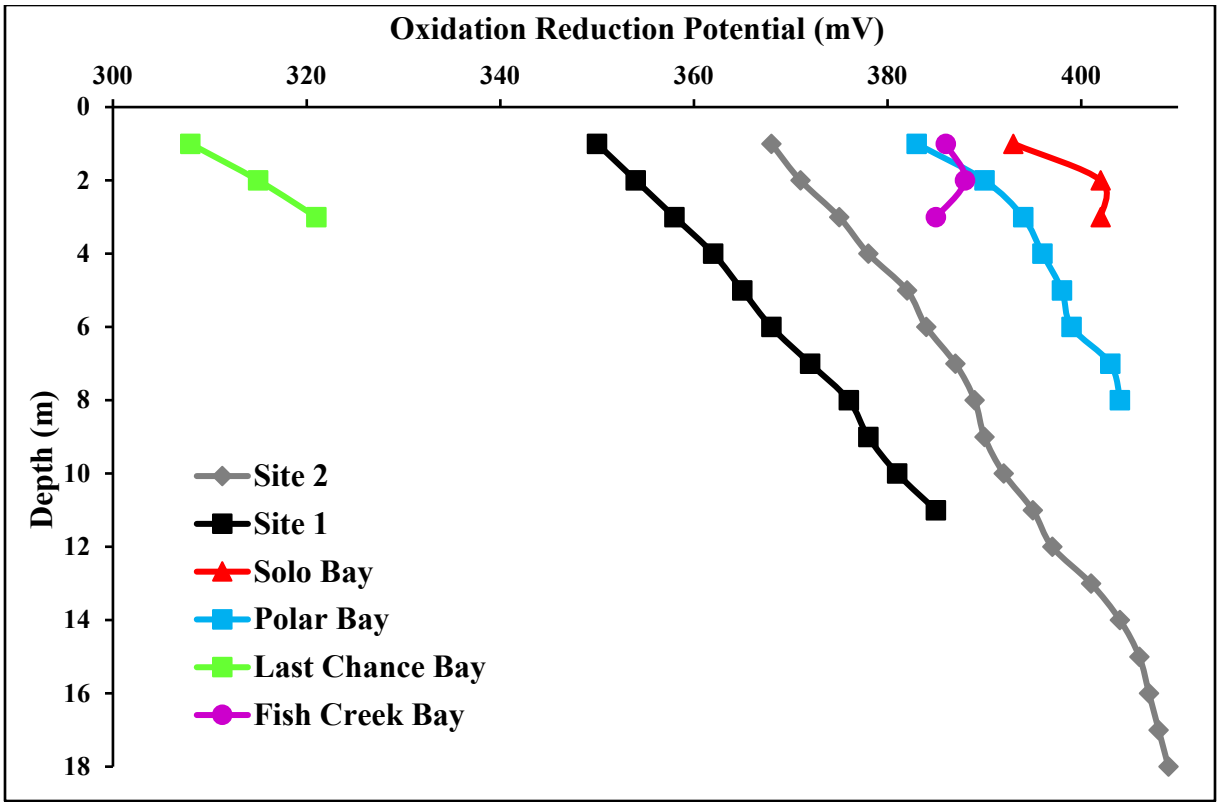

Figure 13. WSR oxidation reduction potential (mV) profiles, April 14, 2022.

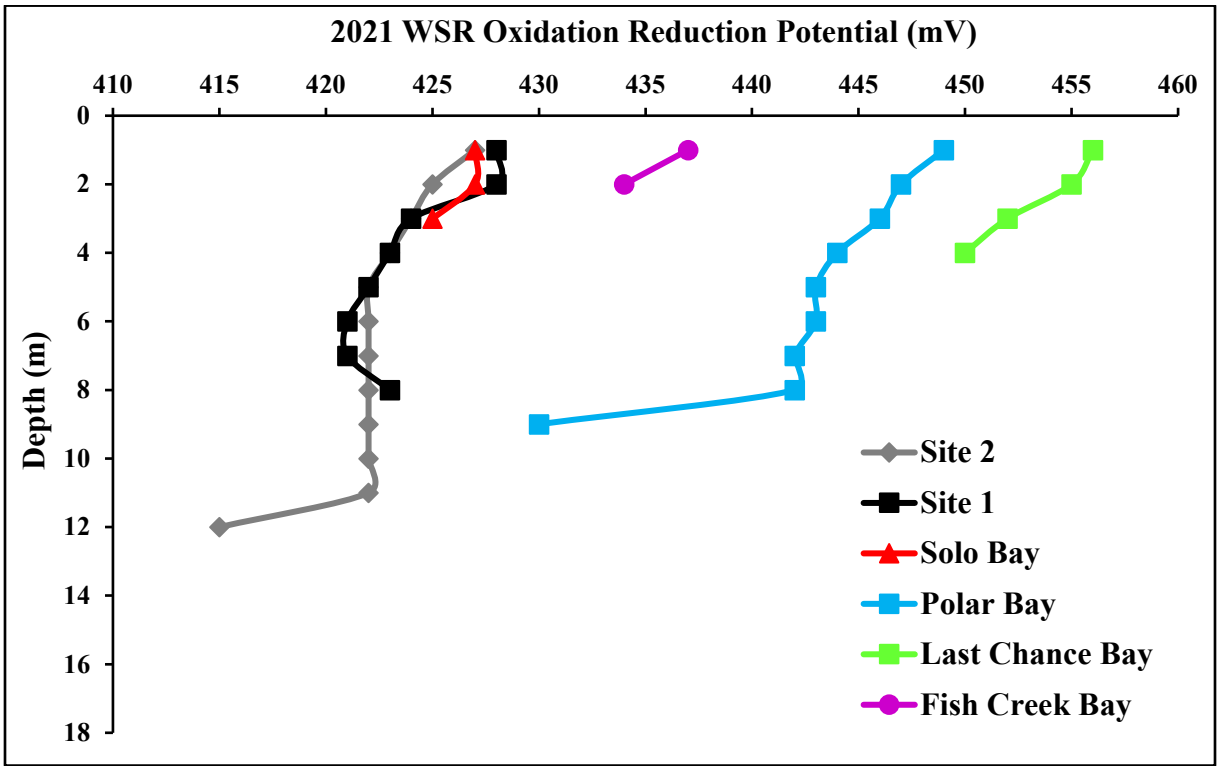

Figure 14. 2021 WSR oxidation reduction potential (mV) profiles for comparison.

From 2019 - 2022 water quality data were collected at two additional sample sites, Fish Creek at Pond F, and the RO Channel downstream of Outfall 002 (Figure 5). On April 14, 2022, the water temperature in the RO Channel was 2.69°C and higher compared to both the water temperature in Fish Creek of 0.84 °C and all the water column averages of the six WSR sample sites (Figure 15). The influence of warmer RO water discharged from Outfall 002 raised the water temperature in the RO Channel.

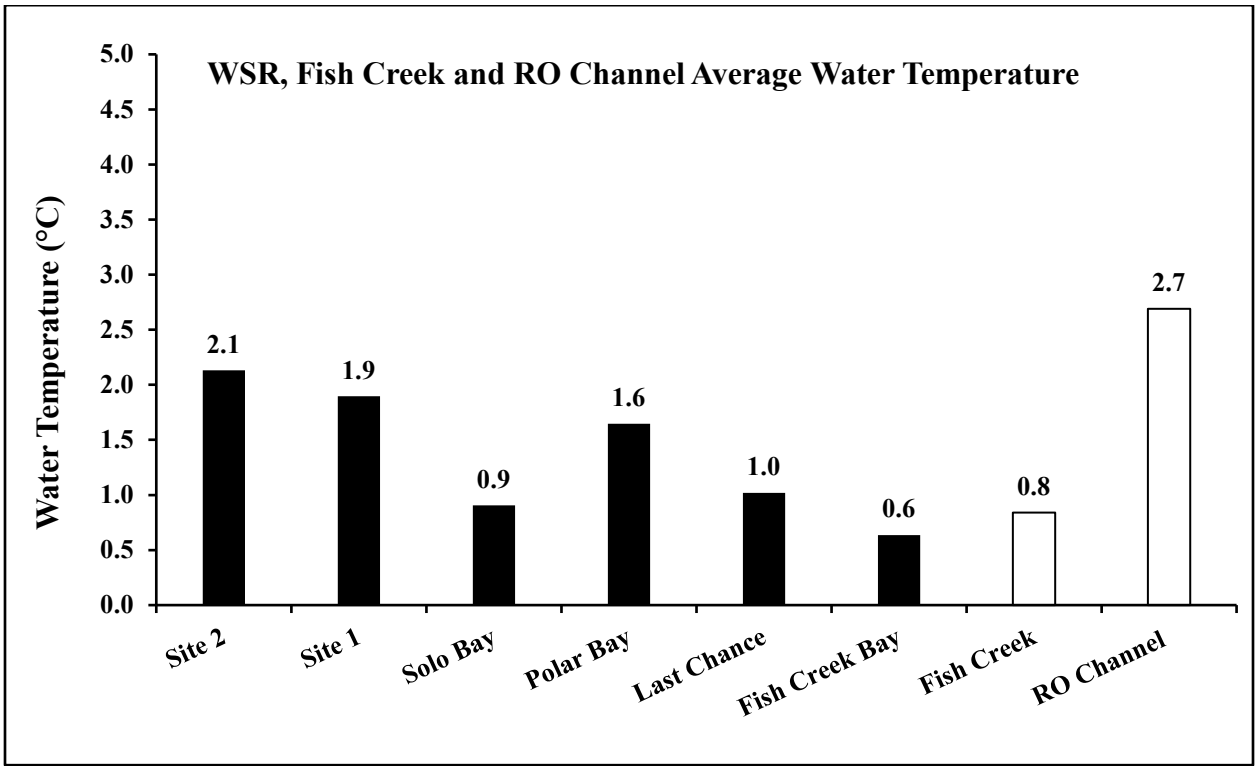

Figure 15. Water temperatures in Fish Creek, RO Channel (1 meter depth) and WSR (average for water column), April 14, 2022.

The DO in Fish Creek and the RO Channel at one meter of depth was higher when compared to the average DO in the six WSR sample sites (Figure 16). Most of the RO water discharged flows though Pond AB and into the RO Channel on the north side of Centerline Road. On Aril 14, 2022, about 10 percent of the discharged RO water was flowing out of Pond AB's natural outlet and into Fish Creek. This RO water combined with natural hydraulic agitation during movement downstream and the exposure to air contributed to its higher DO concentration.

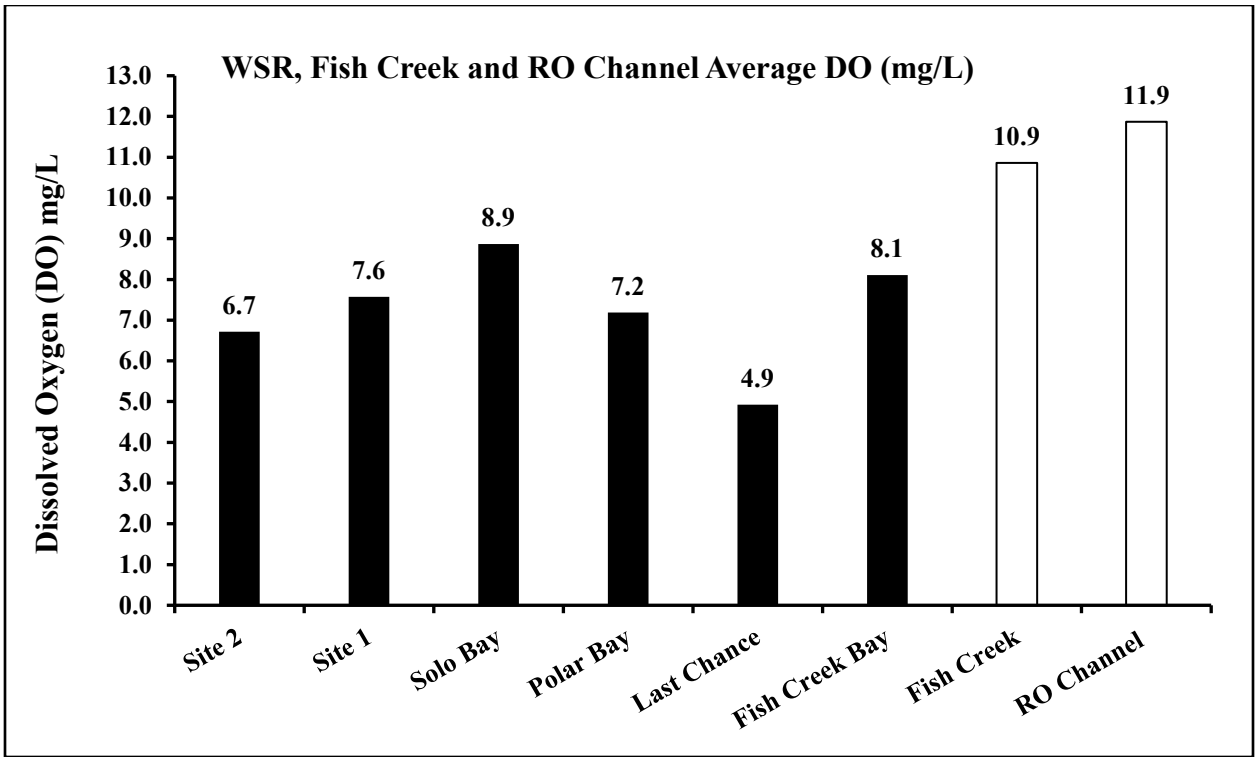

Figure 16. Dissolved oxygen in the WSR (average for water column), Fish Creek and RO Channel (1 meter depth) (mg/L), April 14, 2022.

The RO water discharged from Outfall 002 is mixed with non-contact ground water from de-watering wells that adds minerals and raises the specific conductance before it is discharged into the Fish Creek drainage. The RO Channel specific conductance measurements were taken downstream of Outfall 002 and had the highest recorded values of all sites in 2022 (Figure 17). During the 2022 and 2021 sampling, the RO Channel specific conductance was measured at 494 µS/cm and 455 µS/cm respectively, more than double the specific conductance measured in 2019 and 2020 (Figure 18).

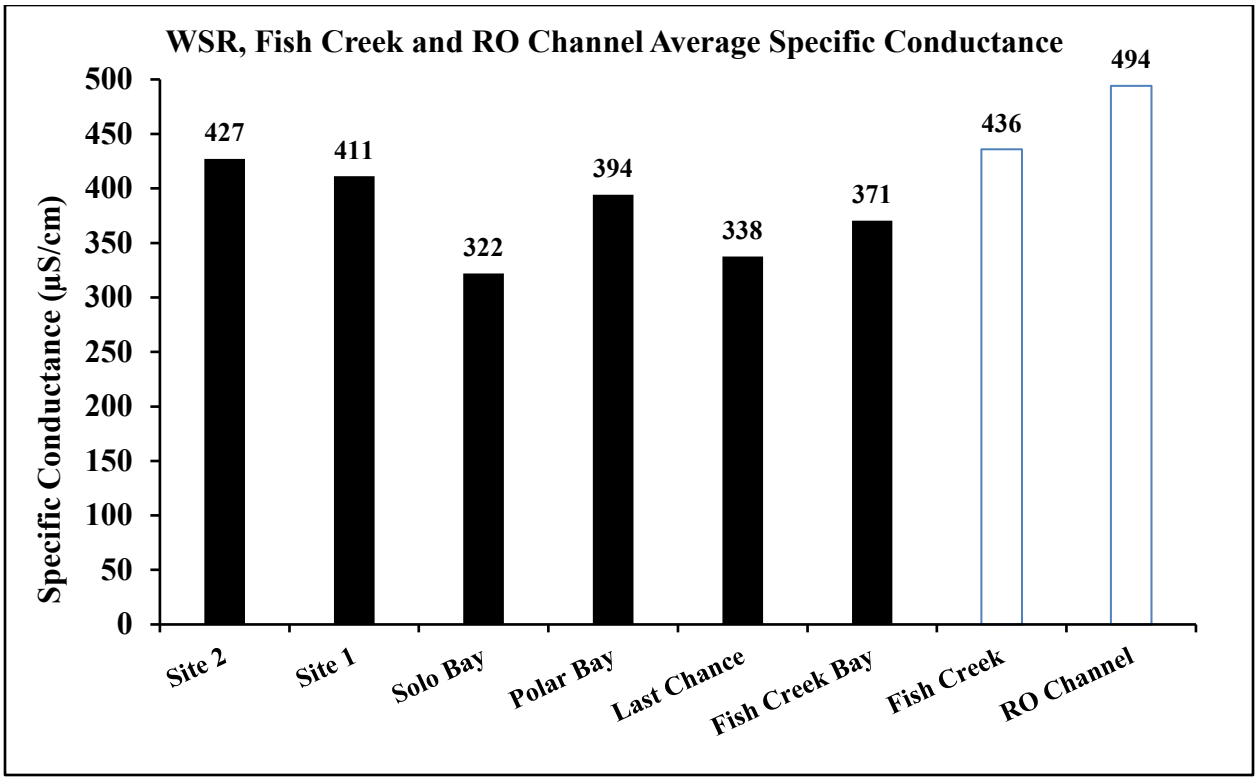

Figure 17. Specific conductance in the WSR (average for water column), Fish Creek and RO Channel (1 meter depth) µS/cm, April 14, 2022.

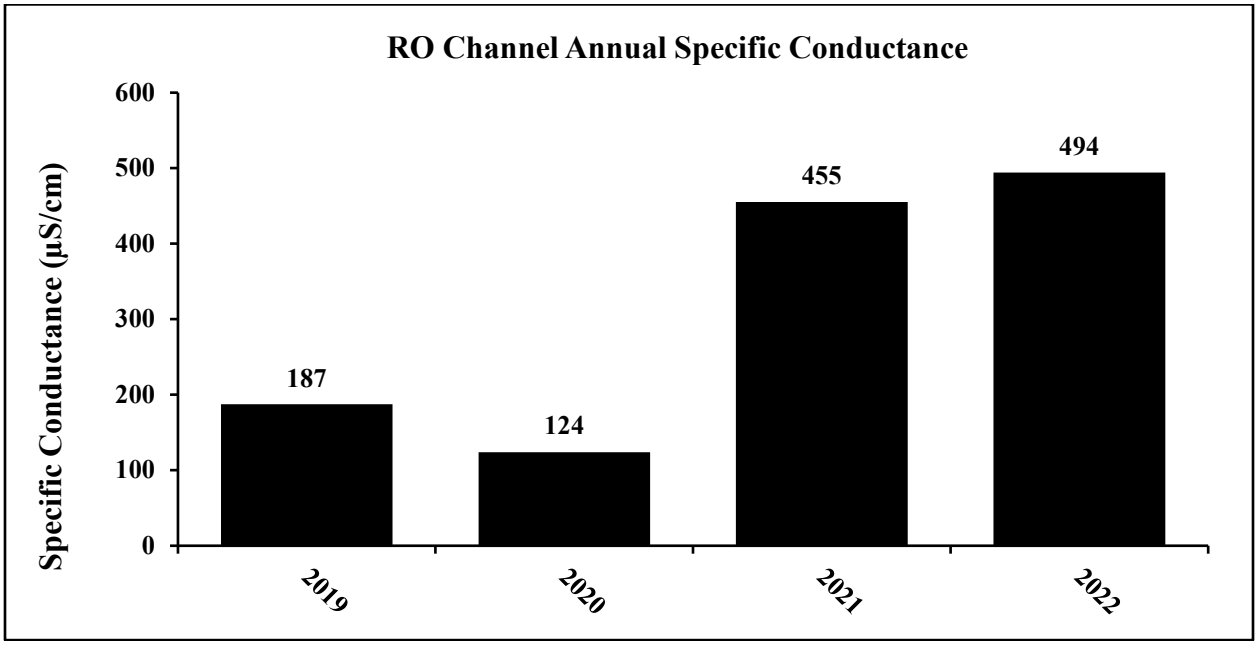

Figure 18. Specific conductance in the RO Channel (µS/cm), taken downgradient of Outfall 002, 2019-2022.

Current Issues

In April 2022, Fort Knox environmental staff submitted a noncompliance notification to ADEC for five dead Arctic grayling recovered from Pond AB (ADEC 2022). As part of their investigation and response efforts, Fort Knox stopped processing and discharging water from all three RO facilities until water test results were analyzed. ADF&G performed a wetlands survey with Fort Knox staff to document any issues that may be affecting wetland habitats. Arctic grayling were observed swimming in Fish Creek and no additional fish moralities were found.

The investigation of the mortalities included water samples from the RO outfall and Pond AB (receiving water) for Weak Acid Dissociable (WAD) cyanide by an outside laboratory. An analysis of the dead Arctic grayling tissues for select chemicals and heavy metals was also performed. The outfall water samples taken on April 13 and 20 showed no exceedances in their permit effluent WAD cyanide limits of 50 ug/L (DEC 2022). The water samples from Pond AB showed WAD cyanide concentrations of 171 and 179 ug/L. The necropsy and fish tissue analysis showed high WAD cyanide within the tissues (Ecotox Consulting 2022). The RO facilities were reviewed by FGMI and restarted on April 27. No further fish distress or mortalities were observed and WAD cyanide levels in receiving waters remained below 50 ug/L.

During fall 2021 and spring of 2022, substantial improvements and widening were made to Centerline Road and the Gil Haul Road causeway across the WSR. Fork Knox broke ground on the Gil Expansion project in the fall of 2021 and began hauling ore eight miles to the Fort Knox mill. Centerline road travels down Fish Creek valley with Fish Creek on the south side and the RO Channel on the north side (Figure 3).

The winter of 2021 / 2022 had heavy snowfall and precipitation that resulted in high surface runoff from Centerline Road entering both Fish Creek and the RO Channel at several locations prior to and during the period of Arctic grayling spawning. No water samples or measurements were taken, but the runoff visually increased the turbidity in Fish Creek. The RO Channel was less impaired by the runoff than Fish Creek since the high influx of RO water diluted the road runoff. Fort Knox staff worked with the road contractors to implement storm water prevention measures during and after the spring thaw to reduce the turbid runoff into Fish Creek and the RO channel.

Arctic Grayling

Arctic grayling have successfully spawned in the wetland complex every year since 1999. However, in some years, substantial aufeis and resultant cold-water temperatures in the wetland complex, in addition to beaver dams, limit the access and availability of spawning habitat. In recent years, aufeis buildup has been relatively minor and more effective beaver management has been implemented, including the annual removal of dams throughout the wetland complex by Fort Knox and ADF&G staff.

Methods

2022 Arctic grayling sampling methods included fyke nets, angling and visual observations. Fyke nets were set in Fish Creek at the Pond F outlet and the RO Channel on May 2 (Figures 19-21). All fyke nets were fished in the same locations without being moved for the duration of the sample period. Beginning on May 3, the fyke nets were checked daily except on May 14 and 15 until they were removed on May 17.

The net in the Fish Creek wetlands near the Pond F outlet was used to capture Arctic grayling moving from the WSR into the wetlands complex. The net in the RO Channel was used to determine if Arctic grayling were recruiting into the newly available wetland habitat and assist in the population estimate. A third fyke net was placed in Pond AB on May 9 to determine if fish were residing in the uppermost waterbody in the wetlands complex (Figures 19 - 21).

Capture efficiency declined in the RO Channel fyke net on May 7 when a new channel thawed around the fyke, which allowed fish to avoid capture. Capture efficiency was reduced in all three nets by numerous holes chewed by muskrats, beaver or other aquatic mammals residing in the wetlands.

Figure 19. Fyke net locations Fish Creek Pond F (left), RO Channel (middle), and Pond AB (right), 2022.

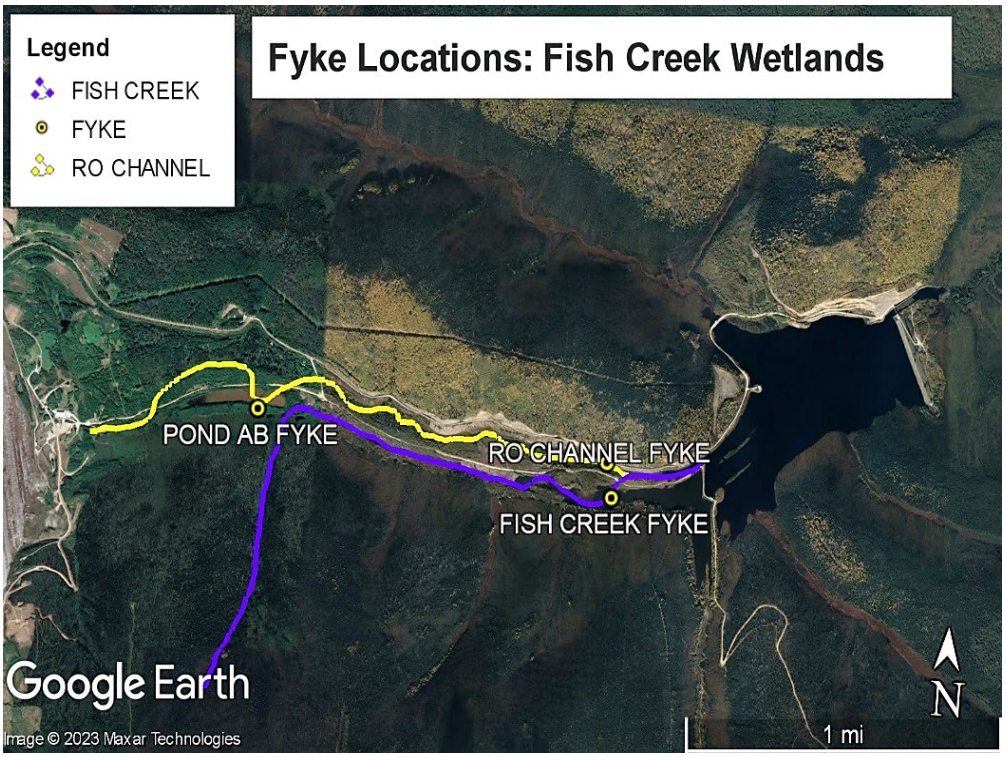

Figure 20. Fish Creek Wetlands Fyke Locations, 2022.

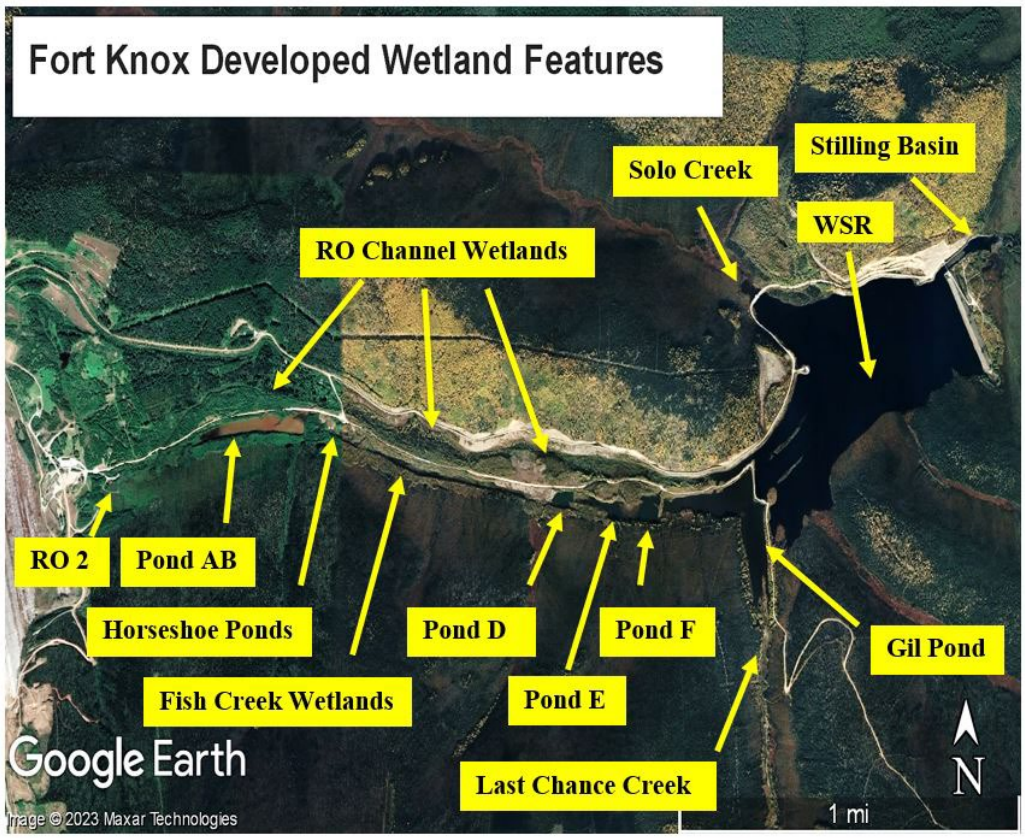

Figure 21. Fish Creek and RO Channel Wetlands Features.

Arctic grayling were measured to fork length (FL, nearest mm), inspected for tags and spawning condition, then released. Un-tagged Arctic grayling ≥200mm and burbot ≥300mm were tagged with a numbered Floy® T-bar internal anchor tag.

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

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

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

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

The 95% C.I. for the population estimate was calculated as:

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

Results and Discussion

The 2022 Fish Creek daily peak water temperature taken at the Pond F outlet was similar when compared to previous years during similar timing (Figure 22). Fish Creek water temperature was 1.83°C on April 22 from natural spring melt water entering the drainage. The RO Channel water temperature data collection began on April 22 and was warmer at 4.79°C compared to Fish Creek temperature of 1.83°C (Figure 23). The large volume of RO water dilutes the influx of cold spring melt water keeping the RO Channel warmer than Fish Creek.

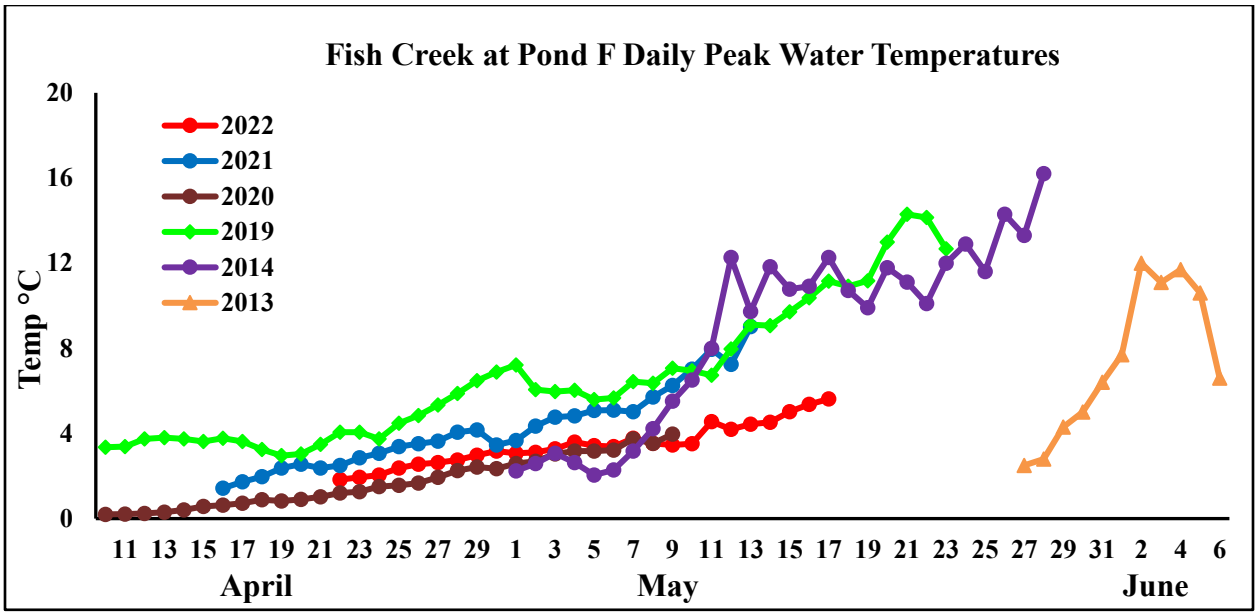

Figure 22. Fish Creek at Pond F daily water temperature maximums; select years for reference.

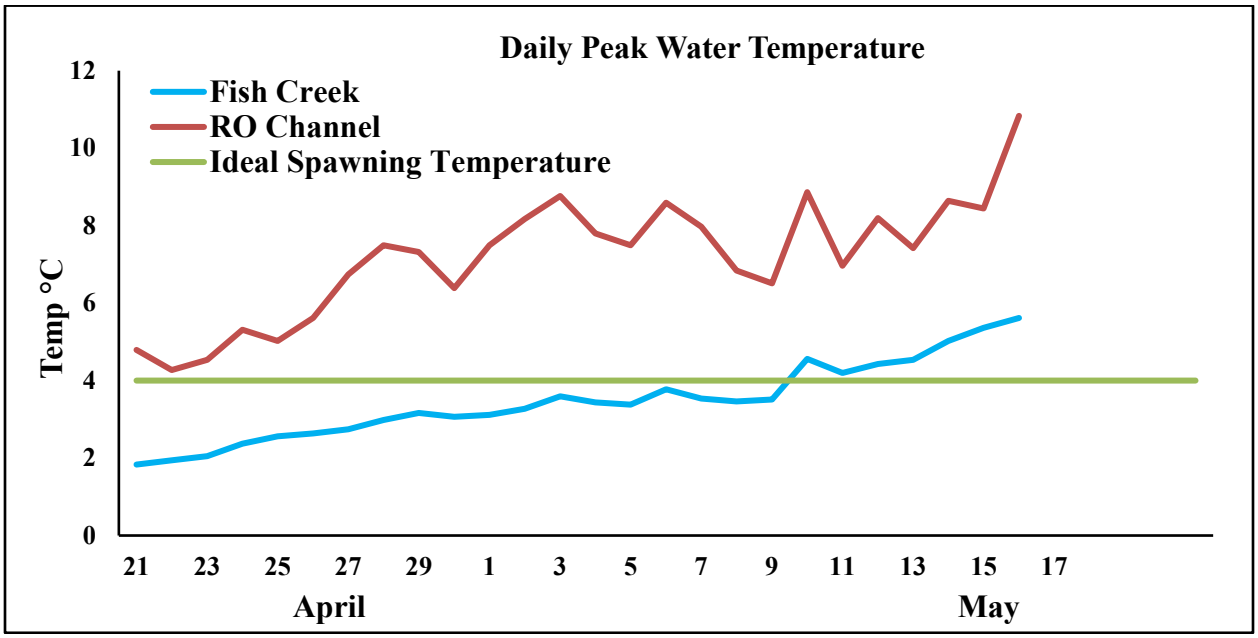

Figure 23. Fish Creek and the RO Channel daily peak water temperature, 2022.

From May 3 - 17, all fish caught in fyke nets were handled with the majority being Arctic grayling. Burbot were also captured and are reported in the burbot section of this report. The Arctic grayling CPUE in Fish Creek varied during the first few days of sampling and peaked at 1.90 fish/hour on May 13 (Figure 24). The RO Channel fyke net CPUE varied greatly during sampling as catches were affected by numerous holes in the fyke net created by aquatic mammals. Days without holes from aquatic mammals had substantially higher numbers of fish. The RO Channel CPUE reached

a high of 5.75 fish/hour on May 6 and catch rates declined in part due to a previously frozen channel that thawed around the fyke net allowing fish an alternate route past the net. Water temperatures were warmer in the RO Channel, 7.49°C on May 2 compared to 3.12°C in Fish Creek. The fyke nets were removed on May 17 as the water temperature increased past the ideal spawning temperature of 4°C in Fish Creek.

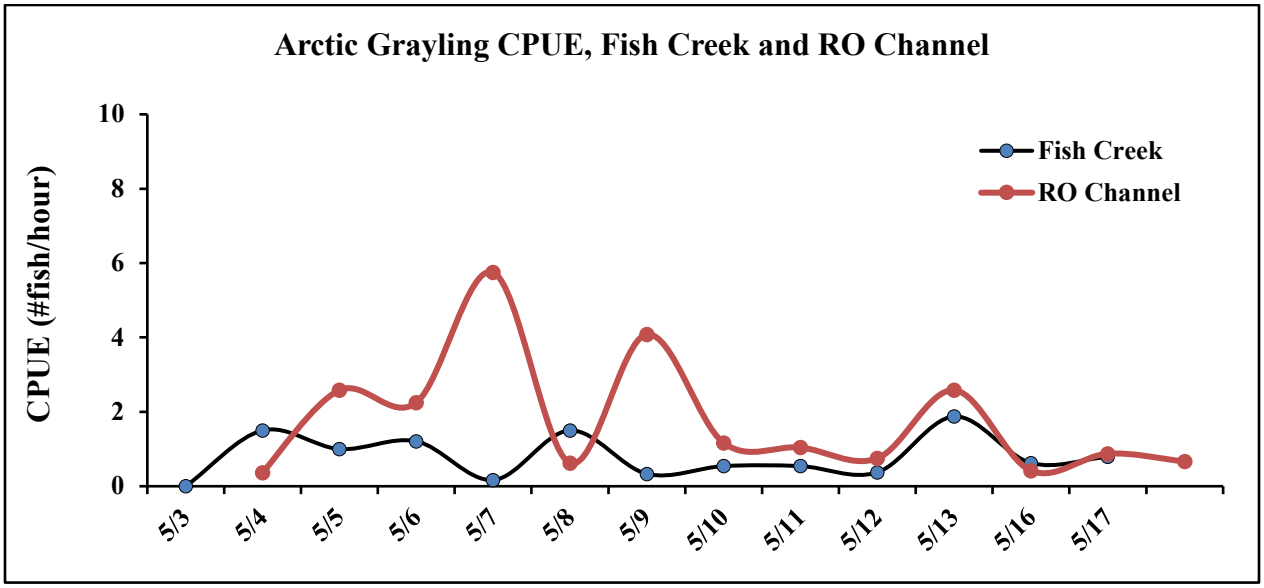

Figure 24. Catch per unit of effort (CPUE) in #fish/hr at the Pond F and the RO Channel fyke nets in the wetlands complex, 2022.

Female Arctic grayling were categorized as not ripe, ripe, or spent, based on their spawning condition (Figure 25). On the first day of fish capture (May 3), 75% of the female Arctic grayling were categorized as not ripe. The number of not ripe females decreased throughout the sampling period to 10% on May 17. On May 3, 16% of the female Arctic graying were classified as ripe. The number of ripe females increased to 79% on May 10 and remained high until sampling concluded. No fish were classified as spent during the first eight days of sampling and 15% of females were spent on May 17.

Recruitment (defined as those fish ≥200 mm that would have been too small to mark in the previous year) is variable among the sampling years. Recruitment was high in 2017, declined from 2018 to 2021, and then increased in 2022 (Figure 26). Substantial recruitment was observed in the spring of 2004, 2010, 2014, 2017 and 2022. A substantial recruitment event was defined as >300 fish encountered during a recapture sampling event that were not available for tagging based on size during the marking event (typically fish between 200 and 240 mm). In 2022 there were 370

Arctic grayling captured between 200 and 240 mm that met the recruitment criteria and were not included in the population estimate.

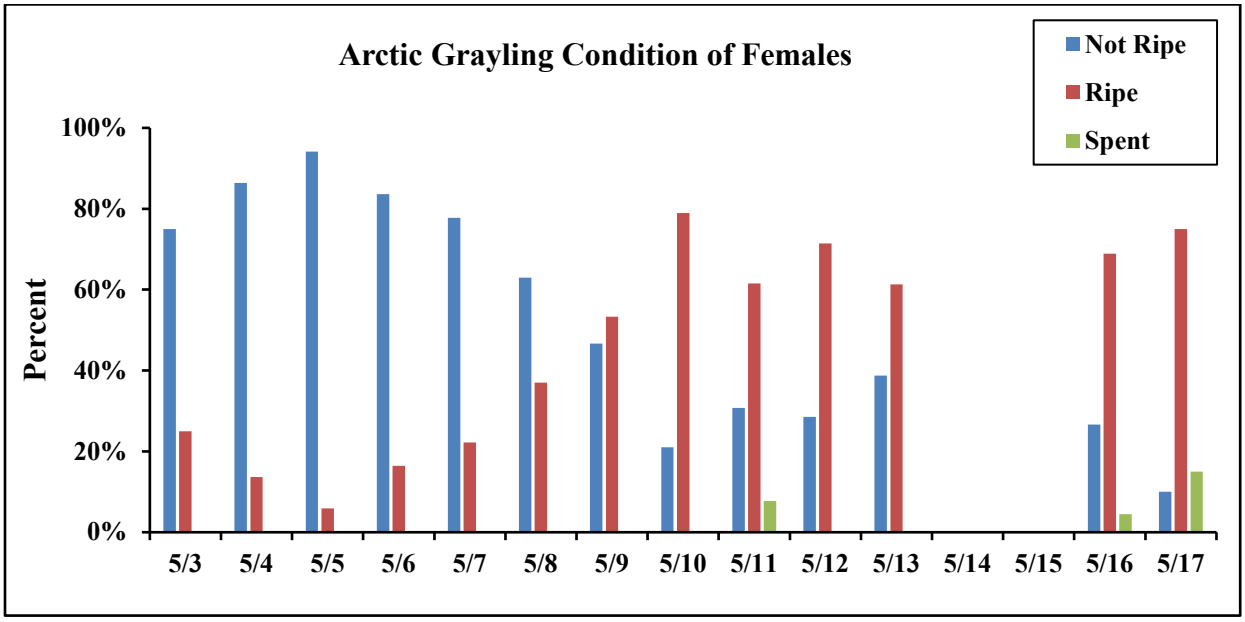

Figure 25. Spawning condition of Arctic grayling females categorized as: not ripe, ripe, or spent, 2022.

The 2021 population abundance estimate of Arctic grayling in the WSR was calculated using spring 2021 as the mark event and spring 2022 as the recapture event. During the spring of 2022 509 Arctic grayling ≥240 mm were captured, of those 182 were recaptures from the spring 2021 tagging event. The 2022 recapture number does not include fish that were less than 235 mm as they were likely too small to tag in 2021.

The spring 2021 population abundance estimate for Arctic grayling ≥200 mm was 3,090 fish with a 95% CI of 2,763 to 3,417 fish (Figure 27). The population has declined since 2017 but remains above the post mining goal of 800 – 1,600 fish ≥200 mm. This Arctic grayling population is anticipated to increase in the future with the substantial number of age-2 and age-3 Arctic grayling captured during the spring 2022 sampling event.

Average growth of Arctic grayling prior to the development of the WSR ranged from 3 to 17 mm per year (Figure 28). Average growth in each size class has increased since the construction of the WSR in 1994. The highest annual average growth in most size classes occurred in 2014, and the lowest occurred in 2015.

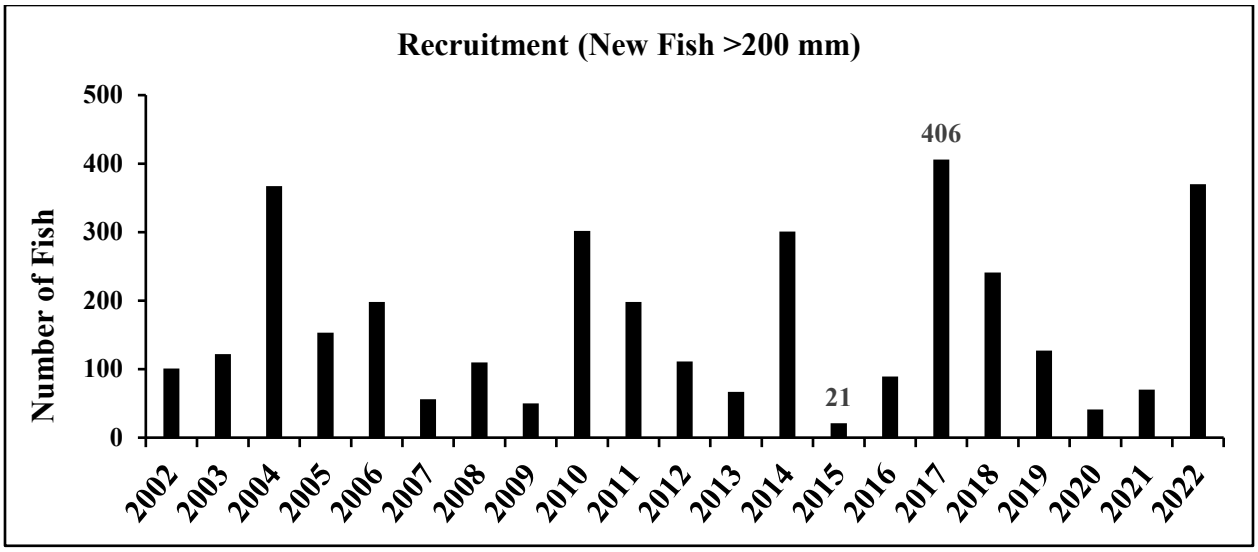

Figure 26. Number of new fish ≥ 200 mm that entered the population but would have been too small to tag in the previous year (generally ~235 mm).

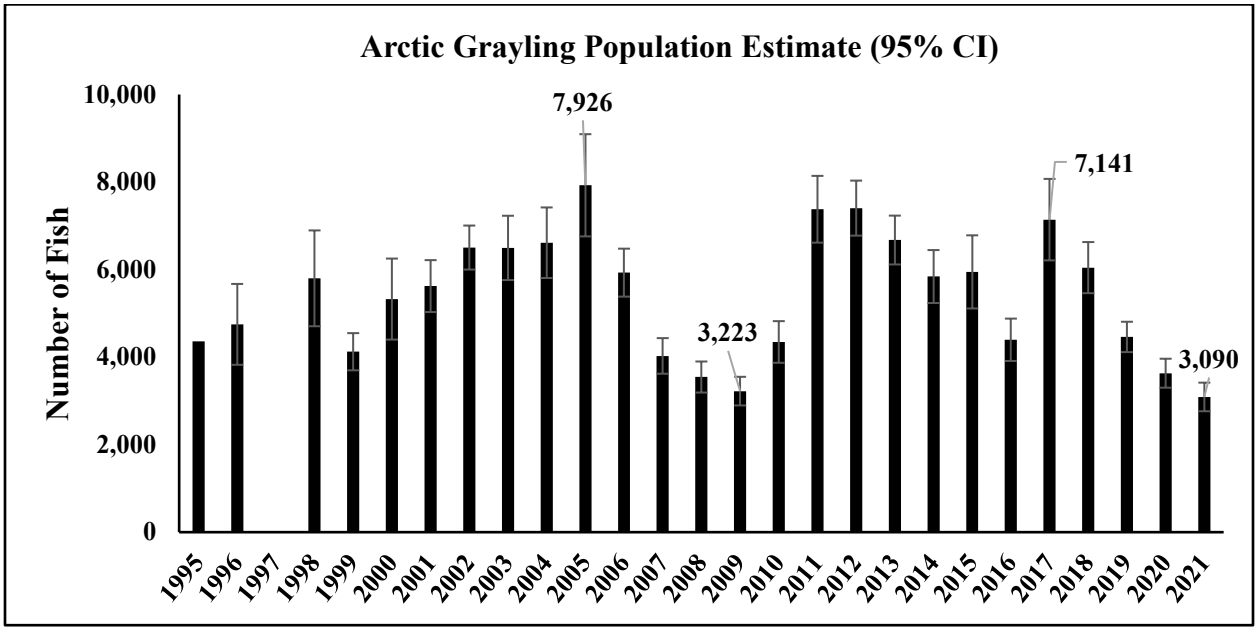

Figure 27. Estimates of the Arctic grayling population in the wetlands and WSR with 95% confidence intervals, 1998 – 2021.

The 2022 length frequency distribution of Arctic grayling caught in the wetlands complex is presented in Figure 29. Data from 1995 are included for comparison to the length of Arctic grayling before the construction of the WSR. The 1995 data set was obtained before construction of the freshwater dam and reflects the stunted condition of the population at that time. During the 2022 sampling, 781 Arctic grayling were captured between 130 and 240 mm, this was an increase over

the 488 fish captured in that same size range in 2021. The current population appears to have fewer large Arctic grayling ≥300 mm but a more even distribution of fish in all size ranges (Figure 29).

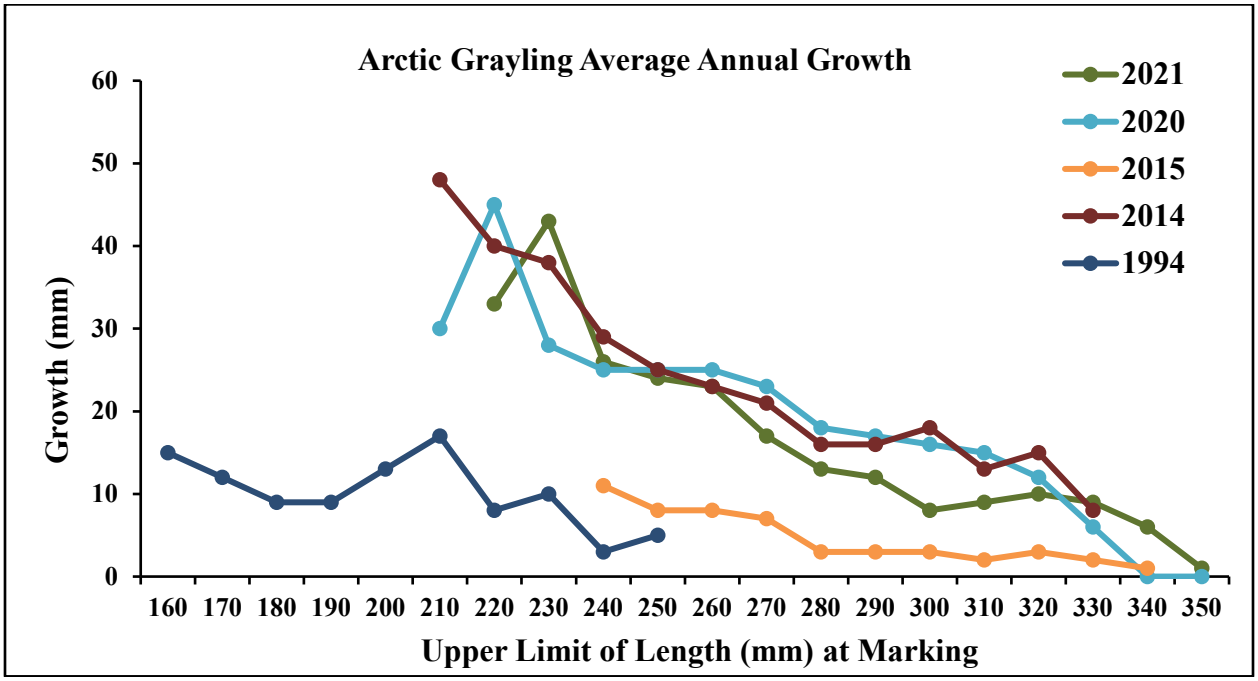

Figure 28. Average annual growth of Arctic grayling by size group in the WSR in selected years including baseline (before WSR) in 1994.

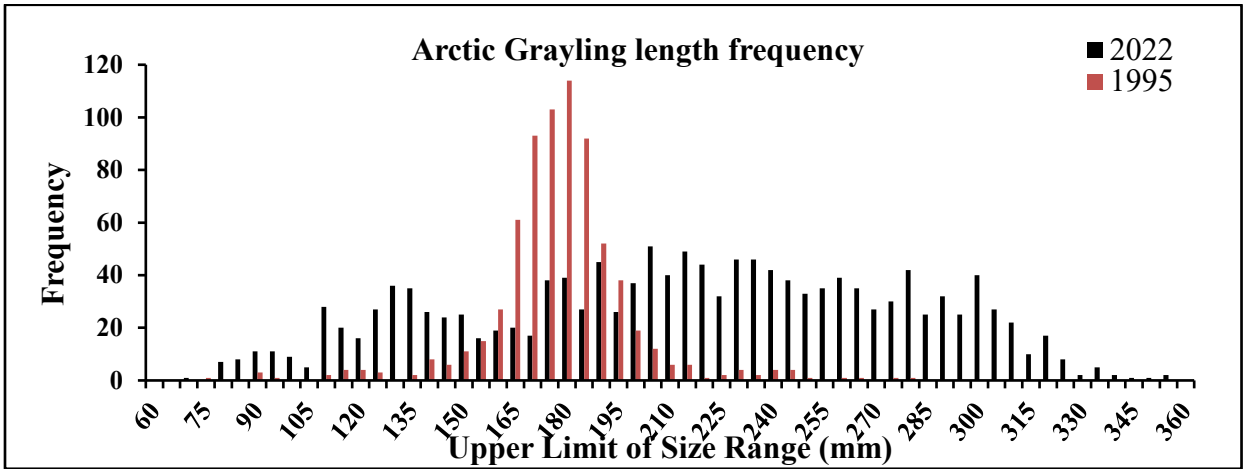

Figure 29. Length frequency distribution of Arctic grayling captured in spring 2022 and 1995.

The uppermost waterbody in the wetlands system located immediately downstream of the tailings dam is referred to as Pond AB. It is located below Outfall 002 in the RO Channel (Figure 21). The fyke net placed in Pond AB on May 9 captured 165 Arctic grayling between 115 and 240 mm with an average size of 173 mm. The 2022 length frequency distribution of Arctic grayling caught in

Pond AB is presented in Figure 30. Eighteen Arctic grayling were ≥200 mm and tagged. No Arctic grayling were captured in Pond AB in 2022 that had been handled and tagged in the two fyke nets located in the lower Fish Creek wetlands during past years sampling events. The population of Arctic grayling in Pond AB may be isolated from the lower wetlands by the beaver dams and vertical obstructions in Fish Creek and the RO Channel. High water events may allow juvenile Arctic grayling to move through the obstructions but no adult Arctic grayling >240 mm were captured during the 2022 sampling.

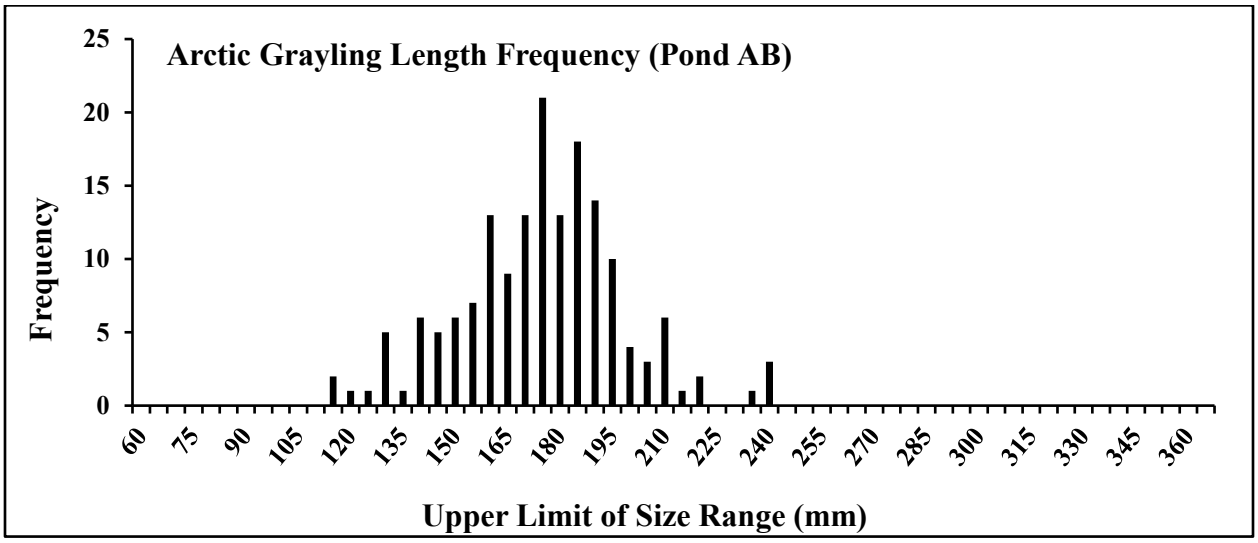

Figure 30. Arctic grayling (n=165) length frequency captured in Pond AB, 2022.

Current Issues

Beaver dams throughout the wetlands complex including the Pond D and F outlets were rebuilt during fall of 2021 or spring of 2022. Fort Knox staff were successful in removing resident beavers from Fish Creek during the summer of 2021 to maintain fish passage, but the remaining beavers reestablished multiple dams. Arctic grayling had access to the Fish Creek wetland complex (Ponds D, E, and F) during most of the summer of 2021, but access was limited by a 3-meter-tall beaver dam in the channel connecting Pond D and the Horseshoe Ponds. No Arctic grayling were observed upstream of this dam during the two weeks of sampling in spring 2022. In the RO Channel, a series of six or more smaller beaver dams created ponds and were partial obstructions to fish in 2022.

Burbot

Methods

The 2022 burbot sampling in the WSR was performed from September 6 - 16, when water temperatures were lower, and handling is less stressful to the fish. Twenty-four hoop traps were set in the WSR, and six in Gil Pond, which is connected to the WSR with a fish passage culvert (Figure 31). Traps were set at depths ranging from five to 15 feet. Deeper areas were avoided to prevent burbot mortality from low dissolved oxygen. Hoop traps were baited with cut herring and checked every two to three days. From September 14 to 16 three hoop traps were set in Pond AB to determine if burbot were inhabiting the uppermost water body in the Fish Creek wetlands complex. The WSR was ice free for the duration of our trapping efforts and water temperatures ranged between 13.6°C on September 6 to 11.9°C on September 16.

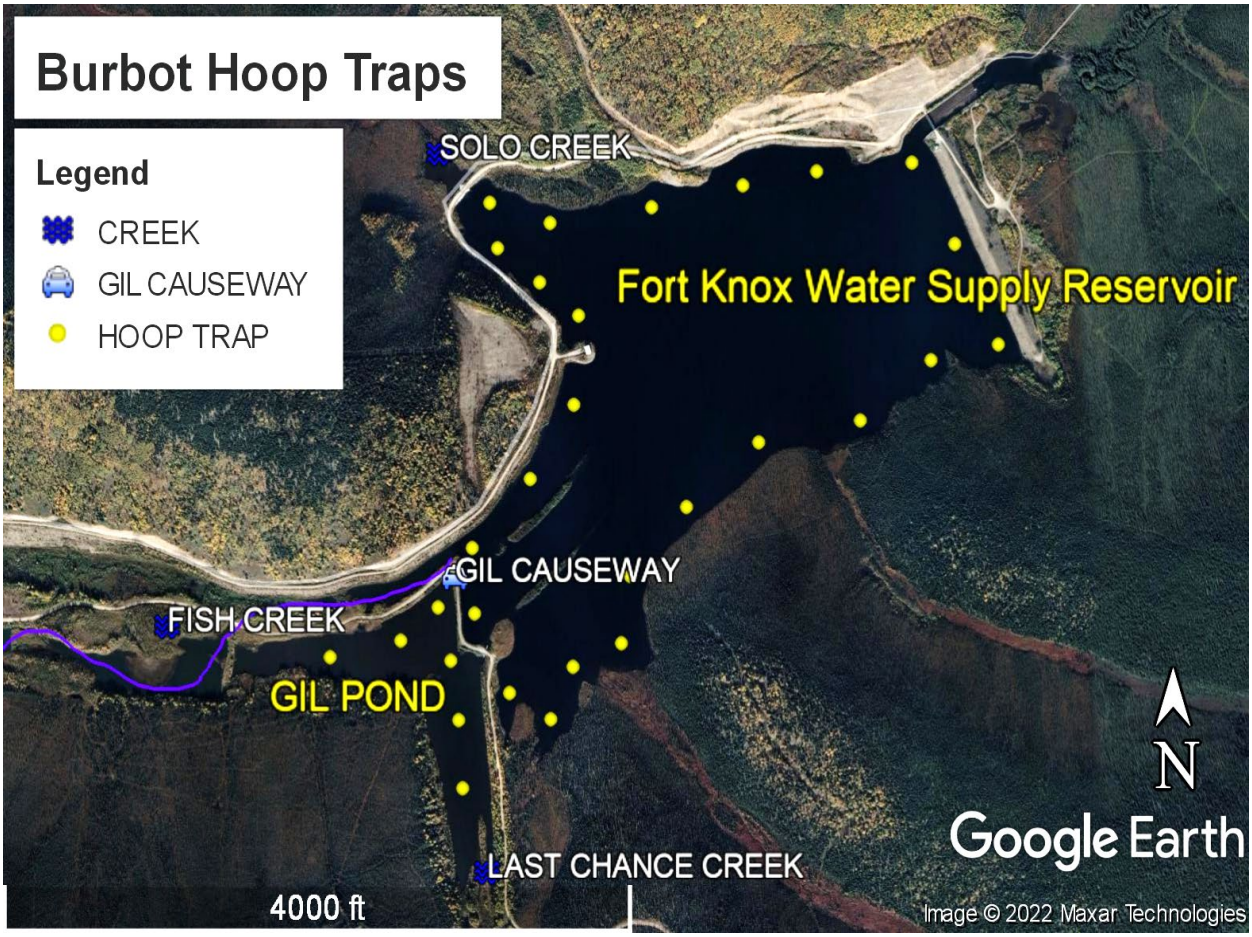

Figure 31. Burbot hoop trap locations in the WSR and Gil Pond.

Burbot were measured to total length (nearest mm), inspected for tags, then released. Un-tagged burbot ≥300 mm were marked with a numbered Floy® T-bar internal anchor tag. Abundance of burbot was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951) and variance was estimated (Seber 1982), see Arctic grayling section of this report for formulas.

Results and Discussion

Burbot residing in the WSR and Fish Creek wetlands were captured during the 2022 spring Arctic grayling fyke netting event. During the 2022 spring sampling event, 35 burbot were captured in Fish Creek and the RO Channel fyke nets. Five of these were ≥300 mm and tagged with a unique numbered Floy tag. Most (32 of 35) burbot were captured in the RO Channel fyke net and <300 mm. One burbot was recaptured that had been tagged in a prior year. No burbot were captured in the Pond AB fyke net during the 2022 spring sampling (May 9 - 17). The five burbot Floy tagged in the spring were not included in the WSR burbot population estimate calculations as only burbot sampled annually from fall to fall are used.

The 2020 burbot population estimate used 2020 fall hoop trapping as the mark event, and 2022 fall hoop trapping as the recapture event. During September 2020, 123 burbot were captured, 110 were ≥300 mm and tagged, 78 of which were ≥400 mm. In the 2022 capture event, 135 burbot were caught, 75 were ≥300 mm and tagged, of these 45 were ≥400 mm, and 11 were recaptures from the 2020-mark event. In both events, fish from Gil Pond were included in the population estimate as it is connected to the WSR by culverts.

A post-mining population goal was not established for the burbot within the WSR, however a small population of fish larger than 400 mm remains present. The 2020 WSR population estimate for burbot ≥400 mm is 302 fish (95% CI: 171 to 432 fish). Population estimates from 2012 to 2020 have varied from a low of 80 to a high of 402 fish (Figure 32). The 2020 WSR population estimate for burbot ≥300 mm was not calculated because there were no recaptures in fall 2022 between 300 and 400 mm.

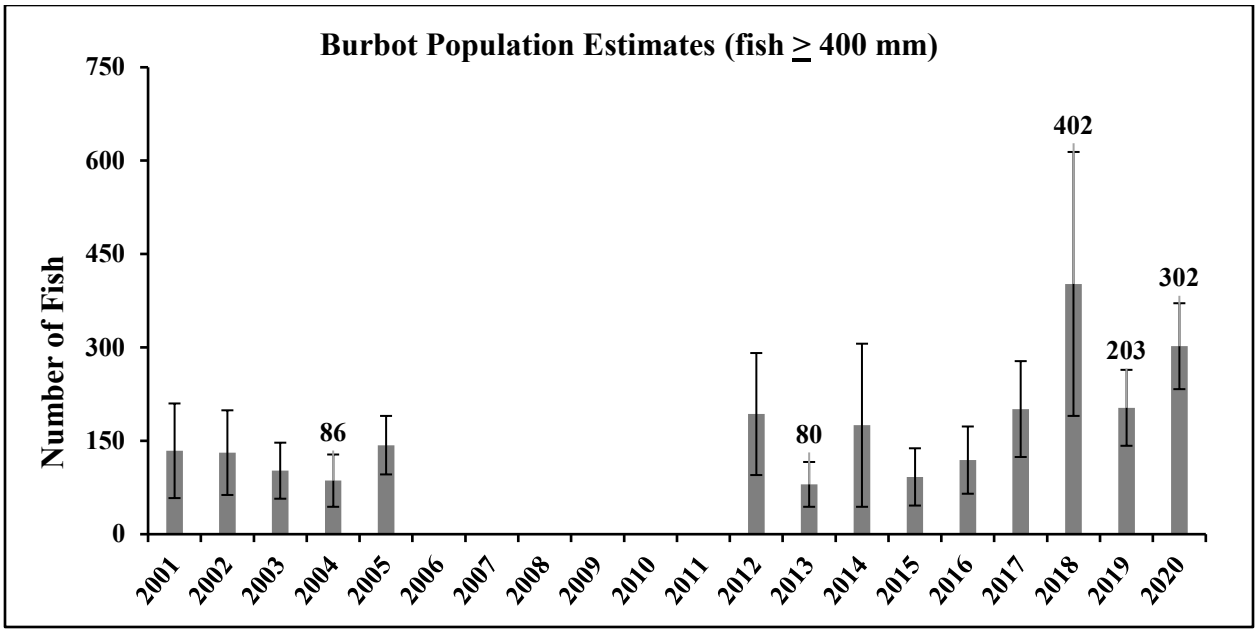

Figure 32. Population estimates of burbot ≥400 mm in the Fort Knox WSR, 2001-2020 (95% Confidence Interval).

CPUE of all burbot captured in 2022 was 0.45 fish per day per trap (Figure 33). This is similar to the CPUE of 2020, but less than half of the CPUE seen in 2018 (1.1 fish per day per trap). The 2022 CPUE is the third lowest since sampling began in 1996. CPUE of burbot over 400 mm decreased from 0.3 fish per day per trap in 2020 to 0.2 in 2022 (Figure 33).

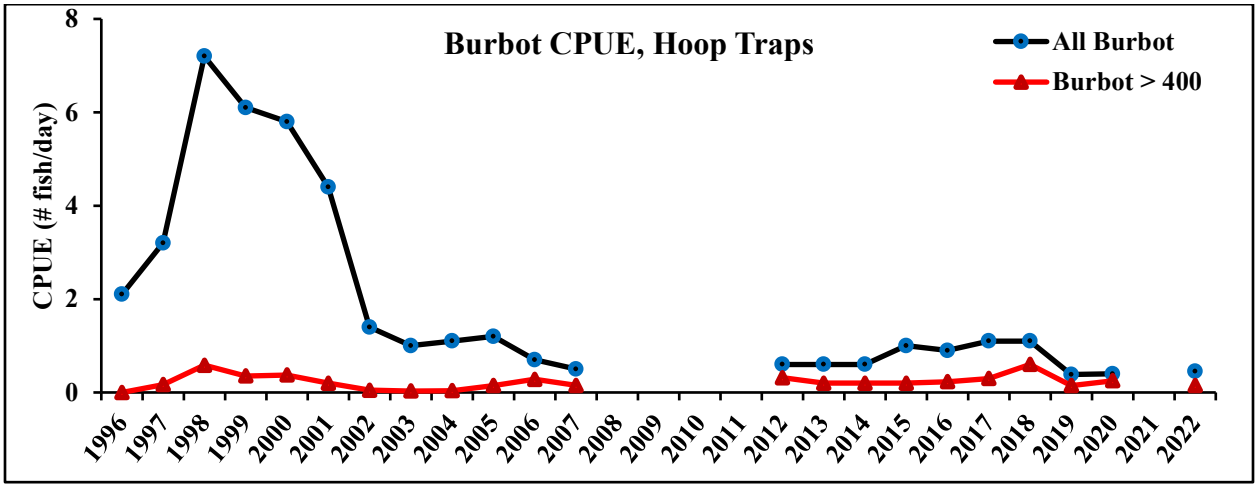

Figure 33. CPUE for all burbot and burbot ≥400 mm in the Fort Knox WSR.

In fall 2022, 135 burbot were caught in the WSR with hoop traps. Burbot length ranged from 67 to 780 mm. The burbot length distribution was more evenly spread across all size ranges compared

to the 2020 length frequency (Figure 34). More juvenile burbot <200 mm were captured than in previous years with 21 of these <100 mm (Figure 35).

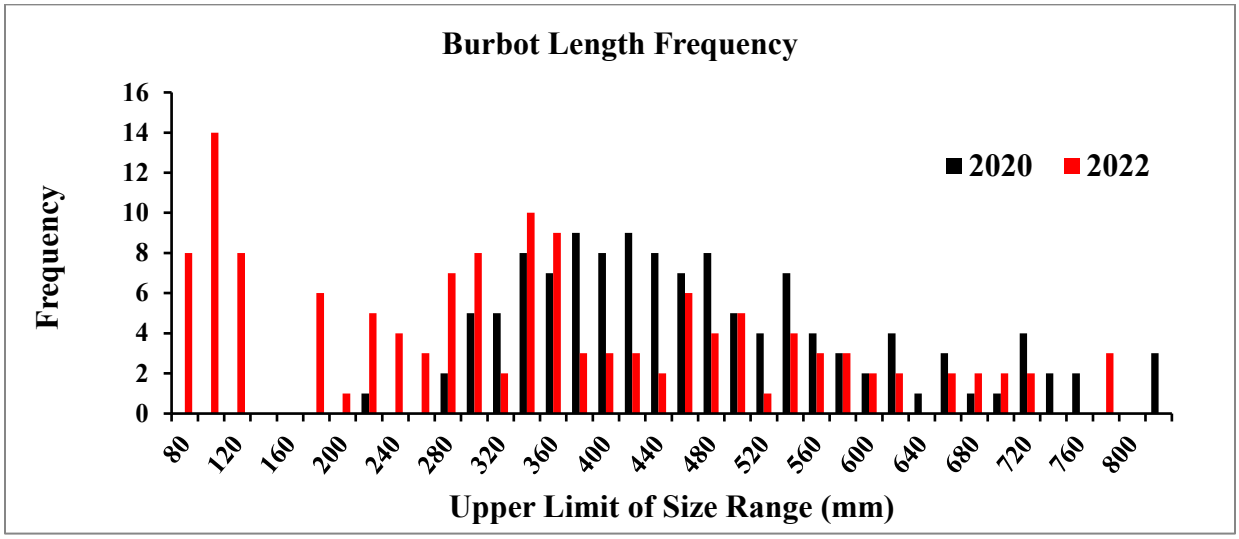

Figure 34. Length-frequency distribution of burbot captured in the Fort Knox WSR, 2020 and 2022.

Figure 35. Juvenile burbot <100 mm captured in Fort Knox WSR, September 2022.

Annual burbot growth in the WSR since 2000 ranges from 24 mm in 2013 to 70 mm in 2016. The average annual growth rate since the year 2000 is 40 mm. The most recent annual growth rate calculated was 2019 with an average of 39.9 mm (Figure 36). The burbot growth rate in the WSR from fall 2020 to fall 2022 was not calculated because two years had passed between sampling events.

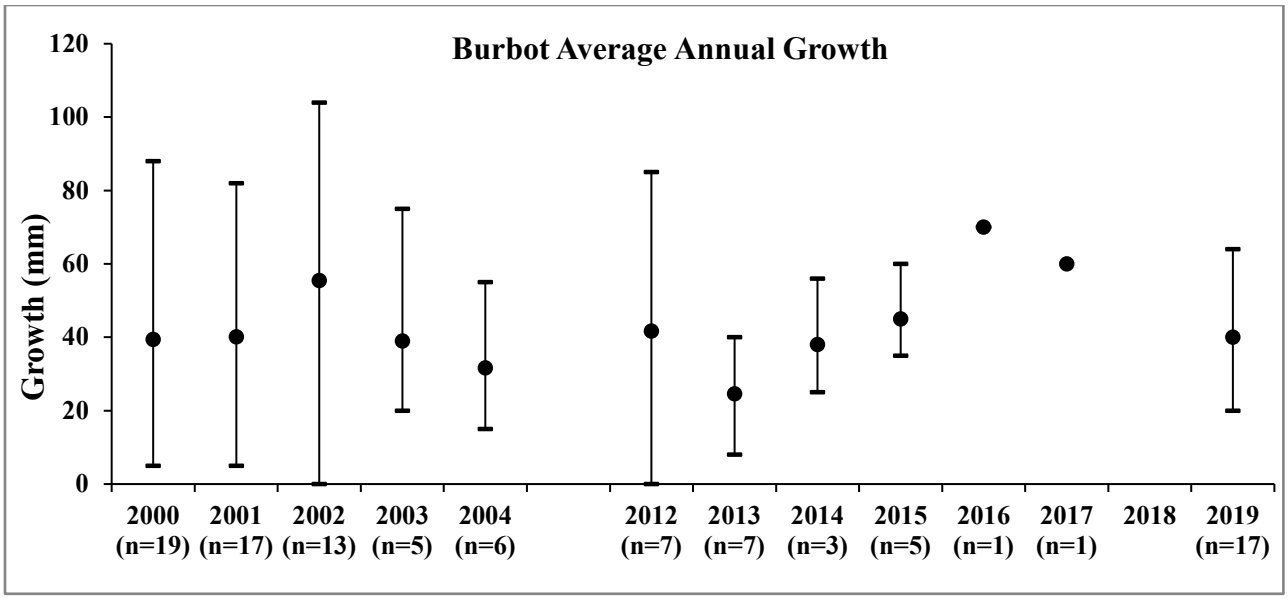

Figure 36. Average annual burbot growth rate in the WSR 2000-2019.

During the 2022 WSR sampling two melanistic burbot were captured. Melanistic animals occur naturally in some animal populations such as wolves and sheep. These all-black burbot have been captured during past years WSR sampling (Bear and Ott 2020). Melanism is a hereditary genetic trait and passed to new generations of burbot. These burbot are in an isolated population with interbreeding and melanism may occur at a higher percentage than in larger populations in open systems.

Seven burbot were captured in the Pond AB hoop traps in the 48 hours they were fished and are the first burbot documented in the upper most part of the wetlands complex. Burbot lengths ranged from 170 mm to 301 mm with an average of 229 mm. The 301 mm burbot was not included in the WSR burbot population estimate.

Current Issues

There are no current issues with the burbot population residing in the WSR.

Conclusion

The post-mining population goal for Arctic grayling in the WSR was set at 800 to 1,600 fish ≥200 mm. The spring 2021 population estimate of 3,090 fish ≥200 mm (95% CI: 2,763 to 3,417 fish) was a decrease from the estimated 2020 population of 3,632 fish but still well above the post-mining population goal. It is unclear if the lower Arctic grayling population estimate is due to fish mortalities, net inefficiencies, or higher numbers of Arctic grayling leaving the WSR during draw down events. The spillway relief valve was open for maintenance and inspection events in 2021 and 2022 for at least 55 days total. It is likely that at least some fish were flushed out of the WSR during these time periods.

A post-mining population goal was not established for burbot within the WSR, however a small population of fish larger than 400 mm remains present. In 2020 that population was estimated to be 302 fish (95% CI: 171 to 432 fish).

During spring 2022 the Pond AB fyke net captured 165 Arctic grayling with an average length of 173 mm. During fall 2022 burbot sampling seven burbot were captured in Pond AB with an average length of 229 mm. These are the first Arctic grayling and burbot captured in the uppermost waterbody of the wetlands complex.

Pond AB is connected to the WSR by the RO channel. Numerous beaver dams present in the RO channel limit fish movement between the WSR and Pond AB. Movement into Pond AB has periodically been possible during period of increased RO water discharge or before beaver dams were present in the drainage.

ADF&G plans 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. Active management of beaver populations within the developed wetlands appears to remain a critical component to ensure Arctic grayling have access to spawning areas within the developed wetlands. The WSR remains a critical component to the productive capacity of the wetland complex by providing overwintering and rearing habitat for both Arctic grayling and burbot.

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Appendix 1. A Summary of Mine Development with Emphasis on Biological Factors, 2011-2022[1]

2011

- February 9, ADF&G provided input to ADNR on the environmental audit to be conducted in summer 2011. ADF&G identified several possible fish and wildlife enhancement projects originally recommended by Buell and Moody (2005).
- March 4, the ACOE issued a permit (POA-1992-574-M19) authorizing construction of the modified dam raise and expansion of the Tailings Storage Facility (TSF).
- 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.
- May 2, 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. ADF&G 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.
- A constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring – 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.
- June 2, ADF&G provided written comments on the Fort Knox and True North environmental audit proposals.
- July 19, 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.
- August 4, 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.

[1] The chronology for the previous years 1992 to 2010 can be found in ADF&G Technical Report No. 10-5, *Arctic grayling and burbot studies at the Fort Knox Mine, 2010* (Ott and Morris, 2010).

Appendix 1 (continued)

- September 13, ADNR approved the drilling of two monitoring wells in the headwaters of Victoria Creek. The purpose of these monitoring wells is to ensure water in Victoria Creek is not impacted by the increased elevation of tailings in the Pearl Creek drainage.
- September 28, ADF&G met with FGMI to discuss plans to discharge non-contact water from the Fort Knox pit to the WSR.

2012

- ADF&G spring sample event (Arctic grayling and burbot) began on May 7 and ended on May 30. The estimated spring 2011 Arctic grayling population was 7,378 fish $\geq$ 200 mm long which was an increase of 3,032 from the 2010 estimate. Recruitment of new fish in spring 2012 was strong with 111 new fish < 230 mm marked.
- ADF&G caught 140 burbot (175 to 950 mm long) in spring 2012 in hoop traps and fyke nets.
- Arctic grayling spawned throughout the wetland complex, including the upper portion of Channel C, in spring 2012. 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 2012.
- July 13, ADF&G provided input to ADEC on the APDES draft permit for discharge of non-contact water. The discharge point has been changed to the old Fish Creek channel just downstream of Ponds A and B. The ADEC permit was issued on August 15, 2012.
- September 27, ADF&G confirmed that a culvert in the road down the Fish Creek valley had been removed. In our trip report to FGMI, ADF&G recommended some additional civil work to ensure that the discharge water stays on the north side of the valley.

2013

- February 20, FGMI received a Notice of Violation from the ACOE for the unauthorized discharge of fill material into 0.28 acres of wetlands.
- March 1, ADF&G informed FGMI that their 2012 Annual Report was extremely well done and FGMI's report was distributed to all habitat offices in the state.
- March 11, the ACOE issued an After-the-Fact authorization covering the 0.28 acres of wetland fill.
- April 25, water quality data (temperature, dissolved oxygen, etc.) were collected in the WSR under ice cover.
- May 4, the ADNR transmitted comments on the December 2012 reclamation and closure plan.

Appendix 1 (continued)

- The spring sample event (Arctic grayling and burbot) began on May 20 and ended on June 10. The estimated spring 2012 Arctic grayling population was 7,404 fish ≥200
- mm long. Recruitment of new fish in spring 2013 was strong with 114 new fish <230 mm marked.
- ADF&G caught 96 burbot (89 to 697 mm long) in spring 2013 in hoop traps and fyke nets.
- Arctic grayling spawned throughout the wetland complex, including the upper portion of Channel C, in spring 2013. Beavers had rebuilt the dams in the wetland complex, but the dams were notched to allow fish passage.
- A constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring 2013.
- Water was not flowing over the spillway when ADF&G began sampling, but by May 27 water had begun to flow out of the WSR and over the spillway.
- June 25, ADF&G observed Arctic grayling fry (numerous) in the upper portion of Channel C. Very few fry were observed in Pond F and the Pond F outlet.
- October 14, ADF&G submitted comments on the Fort Knox 2013 reclamation plan – eight recommendations were made.
- November 27, ADF&G distributed the Fork Knox technical report for work done in 2013.

2014

- In early April, emails were exchanged to determine when Fish Creek was removed from the list of impaired waterbodies – it was on the 1992 list but was removed from the 1994 list because FGMI had bought out all the existing placer operations and was planning on building the freshwater dam.
- April 2014, the decision was made not to collect winter water quality due to unsafe ice conditions and overflow.
- In spring 2014, ADF&G fished a fyke net in the developed wetlands just upstream of the WSR from April 29 until May 9 and then again from May 12 to 15. Arctic grayling spawned throughout the wetland complex in spring 2014. The only beaver dam present was in the upper end of C Channel.
- Our estimated population of Arctic grayling (> 200 mm) for spring 2013 was 6,675 – a slight reduction from the 2011 and 2012 estimates.
- Our estimated population of large burbot (≥ 400 mm) for spring 2013 was 80 – a substantial reduction from the spring 2012 estimate of 193.
- September 29, FGMI notified state agencies that the new Environmental Manager was Bartly Kleven.

Appendix 1 (continued)

- September 4, ADF&G were notified that the road across Solo Creek had failed – FGMI will determine a proper fix – this is the second time the road has failed at the culvert crossing.
- September 26, the developed wetlands and lower Last Chance Creek were inspected. No beaver dams were observed in Ponds D and F and in lower Last Chance Creek (dams had been removed by FGMI during summer).
- October FGMI and ADF&G discussed a draft design for the Solo Creek culvert replacement, conducted a field inspection, and continued discussions to decide what remedial work will be done.
- October 28, ADF&G distributed the Fork Knox technical report for work done in 2014.
- November 12, FGMI submitted a permit application to replace the Solo Creek culvert. ADF&G had several questions regarding the culvert design specifications and FGMI addressed these questions and a permit was issued on November 20, 2014 to install the new 10-foot diameter pipe.

2015

- March 2, ADF&G conducted a field visit to observe the discharge point for non-contact mine water to the old Fish Creek channel, which is dry, except for breakup and periods of heavy rain.
- FGMI initiated the discharge of non-contact water (about 250 gallons per minute) in mid-March and the discharge has been continuous except for a few shutdowns. The discharge was authorized by a permit issued by the ADEC.
- April 8 and 9, ADF&G collected water quality data in the WSR which was ice covered, high DO concentrations were found in Fish Creek Bay.
- April 17, ADF&G collected water quality data in the old Fish Creek channel downstream from where the non-contact mine water was being discharged and found very high

  DOs in the water – leading us to conclude that the discharge of non-contact mine water resulted in increased DOs in the WSR.
- Early May, ADF&G field inspected the culvert replacement in Solo Creek and concluded that it had been installed in accordance with the Fish Habitat Permit.
- Spring 2015, ADF&G fished a fyke net in the developed wetlands just upstream of the WSR from May 4 to 8 and then again from May 10 to 13. Arctic grayling spawned throughout the wetland complex in spring 2015.
- Our estimated population of Arctic grayling ($\geq$ 200 mm) for spring 2014 was 5,841 – a slight reduction from the 2011 and 2012 estimates.

Appendix 1 (continued)

- The estimated population of large burbot (≥ 400 mm) for spring 2014 was 175 – a substantial increase from the spring 2013, but with a large 95% CI.
- June 19 and July 23, ADF&G collected Arctic grayling fry in the wetland complex, average size on June 19 was 29.7 mm and on July 23 it was 57.3 mm.
- June 19, ADF&G inspected the Last Chance culvert in the Gil Causeway. Material at the east end of the pipe has slumped and the road was blocked with cones and flagging.
- October 28, ADF&G distributed the Fork Knox technical report for work done in 2015.

2016

- March 29 and 31, water quality data were collected at six sites in the WSR, five of which have been sampled nearly annually since 1998. Average winter water column dissolved oxygen at Site 2 (middle of the WSR) was the highest on record and likely the result of the near continuous discharge of non-contact water into the old Fish Creek channel just upstream of the wetland complex.
- In spring 2016, ADF&G fished two fyke nets in the developed wetlands just upstream of the WSR and in Pond F from April 25 to May 4. Based on the fyke net catches, most of Arctic grayling spawned in the wetland complex downstream of Pond F.
- Our estimated population of Arctic grayling (≥ 200 mm) for spring 2015 was 5,947 – a slight increase from the 2014 estimate.
- Our estimated population of large burbot (≥ 400 mm) for spring 2015 was 92 - a substantial decrease from spring 2014.
- In early October, hoop traps fished in the WSR captured 26 burbot ranging in size from 200 to 630 mm long.
- October 12, ADF&G met with ADEC and FGMI to discuss plans to design and install a new water treatment plant just downstream of the tailings dam with an estimated discharge of 2,000 to 6,000 gallons per minute.
- October 28, ADF&G were notified by FGMI that beaver dams at Pond D outlet and downstream of Pond F had been removed.
- December 21, ADF&G sent a summary of our meeting on the new water treatment plant to FGMI.

2017

- April 12 and 19, water quality data were collected at six sites in the WSR, five of which have been sampled nearly annually since 1998. Average winter water column dissolved oxygen at Site 2 (middle of the WSR) was above the 15 year running average and the second highest on record, behind 2016.

Appendix 1 (continued)

- In spring 2017, ADF&G fished two fyke nets in the developed wetlands just upstream of the WSR and in Pond F from early May to May 18. Based on the fyke net catches and observations, most Arctic grayling spawned in the wetland complex downstream of Pond F.
- About 100 Arctic grayling adults were moved from the Pond F fyke net and released into Pond D upstream of a barrier. These fish successfully spawned in Pond D as fry were captured on June 29.
- Our estimated population of Arctic grayling (≥ 200 mm) for spring 2016 was 4,396, a decrease of about 1,500 fish from 2015.
- May 26, ADEC issued Waste Management Permit 2014DB002 (Modification #1).
- May 26, ADNR issued a permit amendment for the construction of the Barnes Creek heap leach.
- July 19, ADNR issued a Certificate of Approval to construct a dam for the Barnes Creek heap leach (#AK00315).
- October 12, a site visit was conducted to check on the status of beaver dams in the wetland complex that had been removed recently by FGMI.
- October 24, historic information was provided to FGMI on the status of Fish Creek and why it was taken off the impaired waterbody list in 1994.
- December 12, FGMI, ADF&G, ADNR, and ADEC met to discuss alternatives for tailings disposal, closure configuration for the tailing dam at elevation 1557, and a new water treatment plant.
- December 13, FGMI acquired a new parcel of land that contains an estimated 2.1 million ounces of gold.

2018

- March 14, ADNR approved a POA amendment request to replace the power line trail.
- April 3, 5, and 6, water quality data were collected at six sites in the WSR, five of which have been sampled nearly annually since 1998.
- May 3-May 14, two fyke nets were fished in the developed wetlands just upstream of the WSR and in Pond F.
- Our estimated population of Arctic grayling (≥200 mm) for Spring 2017 was 7,141, which is an increase of 2,745 over 2016.
- Our estimated population of large burbot (≥400 mm) was 201 fish, which is an increase of 82 fish over 2016.
- October 9, 2018, the Pond D beaver dam was removed to allow the downstream movement of grayling into the WSR.

Appendix 1 (continued)

2019

- January 15, Fort Knox began the discharge of up to 3000 gpm of Reverse Osmosis (RO) from Outfall 002 into the RO Channel.
- February 20, environmental compliance and management systems audit performed by SRK Consulting found FGMI to be in compliance with all State of Alaska permitting requirements.
- April 3, FGMI requested modification 16 to Plan of Operations (POO) for clearing/grubbing of 15.5 acres of land to stockpile subbase for the Barns Creek Heap Leach facility.
- Between January 15 and April 10, a beaver blocked the Centerline Road culvert between Pond AB and the RO Channel diverting the 3000 gpm of RO water from Outfall 002 into Fish Creek instead of the RO Channel.
- April 10, water quality data were collected as six sites in the WSR, and three new sites in Fish Creek. Average dissolved oxygen (DO) at Site 2, (Middle of the WSR) was higher that all previous year's data. The RO Channel site had higher water temperature (6.0 °C) compared to WSR sites.
- April 12 to May 03, ADF&G set one fyke net in Fish Creek near the Pond F outlet to capture Arctic grayling and burbot moving into the developed wetlands.
- Our estimated population of Arctic grayling (≥200 mm) for spring of 2018 was 6,045 fish with a 95% CI of 5,461 to 6,629 fish.
- June 15, FGMI received a Fish Habitat Permit to lower Centerline Road culvert to improve flow of RO water from Pond AB into the RO Channel.
- June 25 to 27, ADF&G captured seventy-one Arctic grayling from 160-315 mm FL and nine burbot from 320 – 615 mm tail length in the stilling basin. Bathymetric measurements were taken in the stilling basin and WSR seepage pond.
- August 27 to 29, WSR water level lowered 1.70 vertical feet for required spillway structural inspection. Water discharged through stilling basin into lower Fish Creek.
- September 25 to October 9, ADF&G fished twenty-one hoop traps in the WSR and captured 124 burbot for the 2018 population estimate.
- Our estimated population of large burbot (≥400 mm) for spring of 2018 was 402 fish (95% CI: 190 to 613 fish).

2020

- Fort Knox continued discharge of RO water into the RO Channel wetlands. Outfall 001 not operated in 2020. Outfall 002 discharged 9,663 acre-feet of RO water.

Appendix 1 (continued)

- The majority of discharged RO water confined to the RO Channel before combining with Fish Creek and entering the WSR.
- March 2020, FGMI implemented Covid-19 precautions in response to 2020 pandemic when working on FGMI property. ADF&G Habitat Section deployed HOBO temperature loggers on March 31.
- April 10, water quality data were collected at six sites in the WSR and two sites in Fish Creek. Average dissolved oxygen at Site 2 (middle of the WSR) was higher than all previous year's data.
- April 10, water temperature in the RO Channel was 3.01°C from warm RO discharge water compared to 0.23°C in Fish Creek from natural spring thawing.
- From April 24 to May 9 ADF&G sampling with two fyke nets placed in Fish Creek and the RO Channel to capture Arctic grayling and burbot moving into developed wetlands.
- Our estimated population of Arctic grayling (≥200 mm) for Spring of 2019 was 4,461 fish with a 95% CI from 4,4114 to 4,808 fish.
- September 29 to October 9, twenty-six hoop traps were set in the WSR and six in Gil Pond. 123 burbot were captured and used for the 2019 population estimate.
- The 2019 populations estimate of large burbot (≥ 400 mm) is 203 fish with a 95% CI from 142 to 264 fish.
- October 2020, Fort Knox began hauling ore to Barns Creek Heap Leach (BCHL) and began leaching processes.
- On November 20, Barns Creek Heap Leach (BCHL) was issued Certificate of Approval to Operate for Stage 1 by ADNR Dam Safety.

2021

- Fort Knox continued discharge of RO water from outfall 002 into the RO channel wetlands. Outfall 001 not operated in 2021. Outfall 002 discharged 8,752 acre-feet of RO water.
- The majority of discharged RO water confined to the RO Channel before combining with Fish Creek and entering the WSR.
- April 13, ADF&G Habitat Section collected water quality data at five gravel pit sites in lower Fish Creek below Fairbanks Creek as part of the Gil Expansion base line survey work.
- April 15, ADF&G Habitat Section deployed HOBO temperature loggers into upper Fish Creek and the RO Channel.

Appendix 1 (continued)

- On April 15, water quality data were collected at six sites in the WSR and two sites in the Developed wetlands. Average dissolved oxygen at Site 2 (middle of the WSR) was higher than all previous year's data.
- On April 15, water temperature in the Ro Channel was 4.63 °C from warm RO discharge water compared to 0.98 °C in Fish Creek from natural spring thawing.
- From April 30 to May 12 ADF&G spring sampling with two fyke nets placed in Fish Creek and the RO Channel to capture Arctic grayling and burbot moving into developed wetlands.
- Our estimated population of Arctic grayling (≥200 mm) for Spring of 2020 was 3,632 fish with a 95% CI of 3,301 to 3,963 fish.
- From April 30 to May 12, 48 burbot were captured in the Fish Creek and the RO Channel fyke nets. Six of these were ≥ 300 mm and tagged with a unique numbered floy tag. No burbot were captured that had been previously tagged during past year's Wetlands or WSR burbot sampling.
- June 4, Fort Knox initiated a WSR water drawdown to perform a required spillway inspection. Relief valve was closed on Jun 9 and WSR water levels returned to normal.
- July – September, Gil Haul Road improvements cross Fish Creek and Gil Causeway. Three culverts in Fish Creek extended under FH15-III-0218-A1, FH15-III-0219-A1, FH18-III-0039-A1 and FH21-III-0076.
- August 2, Fort Knox initiated a WSR water drawdown to perform spillway repairs. Construction was delayed due to COVID and contractor availability. Repairs were completed on September 29 and the relief valve was closed refilling the WSR.
- Fresh water supply line from WSR to Tailings Storage Facility (TSF) removed during Gil Haul Road improvements.
- September, groundbreaking ceremony for Gil expansion.

2022

- Fort Knox continued discharge of RO water from outfall 002 into the RO Channel Wetlands. Outfall 001 not operated in 2021. Outfall 002 discharged 4,682 acre-feet of RO water.
- April 5, ADF&G Habitat Section collected water quality data at five gravel pit sites in lower Fish Creek below Fairbanks Creek as part of the Gil Expansion base line survey work.
- April 14, ADF&G Habitat Section deployed HOBO temperature loggers into upper Fish Creek and the RO Channel.
- The WSR outlet spillway had substantial aufeis built up during the 2021 / 2022 winter, similar to what was observed in April 2020 and 2021.

Appendix 1 (continued)

- April 14, water quality data were collected at six sites in the WSR and two sites in the developed wetlands. Average dissolved oxygen at Site 2 (middle of the WSR) was the second highest year recorded at 6.71 mg/L.
- April 14, water temperature in the RO Channel was 2.69 °C from warm RO discharge water compared to 0.84 °C in Fish Creek from natural spring thawing.
- April 21, Fort Knox environmental staff submitted a noncompliance notification to ADEC for five dead Arctic grayling recovered from Pond AB. As part of their investigation and response efforts, Fort Knox stopped processing and discharging water from all three RO facilities until water test results were analyzed.
- April 22, ADF&G and FGMI staff performed wetlands survey to document any issues that may be affecting habitats. Arctic grayling were observed swimming in Fish Creek and no additional fish moralities were found.
- April 22, Heavy snowfall during winter 2021/2022 resulted in runoff entering Fish Creek creating turbidity, Fort Knox staff worked on stormwater diversion improvements during summer 2022.
- From May 2 - 17 ADF&G spring sampling with two fyke nets placed in Fish Creek and the RO Channel to capture Arctic grayling and burbot moving into developed wetlands.
- From May 9 - 17 a fyke net was placed in Pond AB, the uppermost waterbody in the Fish Creek wetlands, and captured 165 Arctic grayling with an average size of 173 mm. These are the first documented grayling in Pond AB.
- Our estimated population of Arctic grayling (≥200 mm) for spring of 2021 was 3,090 fish with a 95% CI of 2,763 to 3,417 fish.
- From May 2 to May 17, 35 burbot were captured in the Fish Creek and the RO Channel fyke nets. Five of these were ≥300 mm and tagged with a unique numbered floy tag. One burbot was captured that had been previously tagged during past year's wetlands or WSR burbot sampling.
- August 22, Fort Knox initiated a WSR water drawdown to extend a culvert under FH permit FH15-III-0219-A2. The relief valve was closed on August 24 and WSR water levels returned to normal by September 16.
- August 26, Slippery Creek and Fish Creek near the Gil Project mine pits were sampled for fish presence. 41 Arctic grayling and 39 slimy sculpin were captured.
- September 6, during the Fort Knox WSR water drawdown two upland areas along the WSR were excavated and shallow water aquatic habitat was created within the WSR.
- Gil Causeway and Haul Road improvements and widening continue throughout the year including using excavated gravel from the WSR as road fill and berm stabilization.

Appendix 1 (continued)

- September 6 – 16, ADF&G staff sampled burbot in the WSR with hoop traps. The 2020 WSR burbot population is 302 fish (95% CI: 171 to 432 fish).
- September 14 - 16, hoop traps were set in Pond AB and seven burbot were captured between 170 mm to 301 mm. These are the first burbot documented in Pond AB.
- October 1, 2022 – April 2023, winter discharge rate of RO water was reduced to 1600 gpm and maintained during the winter.

Appendix 2. Water Quality Data, from the Fort Knox Water Supply Reservoir (WSR), April 14, 2022.

Site Number (Name)	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (µ S/cm)	pH	ORP
1 (Middle WSR)	1	0.98	58.1	8.19	326	7.13	350
	2	0.86	59.6	8.45	413	7.10	354
	3	1.44	59.2	8.29	420	7.13	358
	4	1.79	58.8	8.17	419	7.13	362
	5	1.98	57.9	8.00	419	7.12	365
	6	2.13	57.0	7.84	418	7.12	368
	7	2.24	55.9	7.66	417	7.11	372
	8	2.31	54.5	7.45	417	7.10	376
	9	2.32	51.4	7.05	419	7.08	378
	10	2.44	46.8	6.41	420	7.05	381
	11	2.37	42.3	5.77	435	7.02	385
2 (WSR Near Dam)	1	0.28	58.3	8.48	363	7.12	368
	2	0.89	53.7	7.64	406	7.11	371
	3	1.37	55.9	7.83	417	7.11	375
	4	1.65	57.1	7.94	416	7.12	378
	5	1.98	56.6	7.82	416	7.12	382
	6	2.15	55.5	7.64	415	7.11	384
	7	2.26	54.9	7.54	414	7.11	387
	8	2.35	52.4	7.19	413	7.10	389
	9	2.38	50.1	6.86	417	7.09	390
	10	2.38	47.4	6.48	425	7.06	392
	11	2.37	44.1	6.04	434	7.05	395
	12	2.40	45.8	6.22	446	7.04	397
	13	2.42	46.2	6.29	452	7.03	401
	14	2.49	41.7	5.70	452	7.01	404
	15	2.54	41.0	5.57	452	7.01	406
	16	2.63	40.3	5.46	452	7.00	407
	17	2.79	38.7	5.24	451	6.99	408
	18	3.04	35.9	4.90	450	6.99	409
3 (Solo Bay)	1	0.14	63.8	9.19	160	7.11	393
	2	1.20	57.7	8.19	403	6.99	402
	3	1.38	51.6	7.23	403	7.00	402

7 (Last Chance Bay)	1	0.13	33.6	4.88	218	6.91	308
	2	1.27	35.6	4.99	395	6.88	315
	3	1.66	35.0	4.91	401	6.94	321
11 (Polar Bay)	1	0.10	47.0	6.94	226	6.99	383
	2	0.94	47.7	6.66	418	6.93	390
	3	1.39	52.7	7.38	418	7.00	394
	4	1.69	54.4	7.50	422	7.03	396
	5	1.94	55.5	7.65	420	7.04	398
	6	2.06	54.6	7.55	419	7.04	399
	7	2.20	51.3	7.05	417	7.03	403
	8	2.85	50.2	6.80	414	7.01	404
12 (Fish Creek Bay)	1	0.15	51.3	7.46	277	7.01	386
	2	0.76	57.1	8.00	412	6.97	388
	3	1.00	62.7	8.86	423	7.05	385

Appendix 3. Population estimates of Arctic Grayling > 200 mm in the Fort Knox Water Supply Reservoir (WSR), 1995-2021.

Year	[1]	Population Estimate	95% Confidence Interval
1995	[2]	4,358	
1996	[3]	4,748	3,824 - 5,672
1996	[4]	3.475	2,552 - 4,398
1998	[5]	5,800	4,705 - 6,895
1999		4,123	3,698 - 4,548
2000		5,326	4,400 - 6,253
2001		5,623	5,030 - 6,217
2002		6,503	6,001 - 7,005
2003		6,495	5,760 - 7,231
2004		6,614	5,808 - 7,420
2005		7,926	6,759 - 9,094
2006		5,930	5,382 - 6,478
2007		4,027	3,620 - 4,433
2008		3,545	3,191 - 3,900
2009		3,223	2,896 - 3,550
2010		4,346	3,870 - 4,823
2011		7,378	6,616 - 8,141
2012		7,404	6,775 - 8,033
2013		6,675	6,217 - 7,333
2014		5,841	5,235 - 6,446
2015		5,947	5,111 - 6,783
2016		4,396	3,913 - 4,880
2017		7,141	6,176 - 8,018
2018		6,045	5,461 - 6,629
2019		4,461	4,114 - 4,808
2020		3,632	3,301 - 3,963
2021		3,090	2,763 - 3,417

[1]Population estimates from 1995-1996 include fish ≥ 150 mm, in all other years fish ≥ 200 mm.

[2]In 1995, ADF&G used estimates from the ponds and creeks for the Arctic grayling population; a confidence interval was not applicable to the data set.

[3]The 1996 estimate was made with a capture and recapture event in summer 1996 using fyke nets.

[4]In 1996, Arctic grayling were captured with a boat-mounted electro shocker for both the capture and recapture events in fall 1996 by Sport Fish Division.

[5]Starting in 1998 through 2021 the population estimates were made using a mark event in the spring of the year of the estimate, and the recapture event in spring of the following year.

Appendix 4. Arctic Grayling Growth in the WSR, 2021-2022.

Upper Limit (mm)	Average (mm)	Maximum (mm)	Minimum (mm)	Sample Size
210				0
220	33	34	32	2
230	43	51	37	3
240	26	36	8	8
250	24	33	8	10
260	23	34	9	17
270	17	27	5	19
280	13	29	0	27
290	12	30	0	28
300	8	22	0	29
310	9	25	0	19
320	10	20	0	12
330	9	25	0	5
340	6	12	0	2
350	1	1	1	1

Appendix 5. Population Estimate of Burbot (≥ 400 mm) in the Fort Knox Water Supply Reservoir (WSR), 2001-2020.

Year	Population Estimate	95% Confidence Interval
2001	134	58 - 210
2002	131	63 - 199
2003	102	57 - 147
2004	86	44 - 128
2005	143	96 - 191
2006-2011	No Population Estimates Performed	
2012	193	95 - 290
2013	80	44 - 117
2014	175	44 - 305
2015	92	46 - 138
2016	119	65 - 173
2017	201	124 - 278
2018	402	190 - 613
2019	203	142 - 364
2020	302	171 - 432

Appendix 6. Winter (October 1 to April 30) water use from the WSR, 1997 to 2015.

Year (Oct 1 to April 30)		Acre-Feet of Water Removed		Percent of Water Removed
1997/1998		660		19.6
1998/1999		605		18.0
1999/2000		577		17.2
2000/2001		1,464		43.5
2001/2002		320		9.5
2002/2003		337		10.0
2003/2004		279		8.3
2004/2005		716		21.3
2005/2006		659		19.6
2006/2007		299		8.9
2007/2008		1,176		35.0
2008/2009		817		24.3
2009/2010		1,167		34.7
2010/2011		187		5.6
2011/2012		59		1.8
2012/2013		1,837		54.6
2013/2014		1,399		41.6
2014/2015		104		3.1
No water was withdrawn from the WSR after 2014/15				