

Technical Report No. 24-11

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# Fish and Water Quality Monitoring at the Fort Knox Mine, 2023

by

Chad E. Bear



June 2024

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Alaska Department of Fish and Game

Habitat Section



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<b>Weights and measures (metric)</b>		<b>General</b>		<b>Mathematics, statistics</b>	
centimeter	cm	Alaska Administrative		<i>all standard mathematical</i>	
deciliter	dL	Code	AAC	<i>signs, symbols and</i>	
gram	g	all commonly accepted		<i>abbreviations</i>	
hectare	ha	abbreviations	e.g., Mr., Mrs.,	alternate hypothesis	$H_A$
kilogram	kg		AM, PM, etc.	base of natural logarithm	$e$
kilometer	km	all commonly accepted		catch per unit effort	CPUE
liter	L	professional titles	e.g., Dr., Ph.D.,	coefficient of variation	CV
meter	m		R.N., etc.	common test statistics	(F, t, $\chi^2$ , etc.)
milliliter	mL	at	@	confidence interval	CI
millimeter	mm	compass directions:		correlation coefficient	
		east	E	(multiple)	R
		north	N	correlation coefficient	
<b>Weights and measures (English)</b>		south	S	(simple)	r
cubic feet per second	ft <sup>3</sup> /s	west	W	covariance	cov
foot	ft	copyright	©	degree (angular)	°
gallon	gal	corporate suffixes:		degrees of freedom	df
inch	in	Company	Co.	expected value	$E$
mile	mi	Corporation	Corp.	greater than	>
nautical mile	nmi	Incorporated	Inc.	greater than or equal to	≥
ounce	oz	Limited	Ltd.	harvest per unit effort	HPUE
pound	lb	District of Columbia	D.C.	less than	<
quart	qt	et alii (and others)	et al.	less than or equal to	≤
yard	yd	et cetera (and so forth)	etc.	logarithm (natural)	ln
		exempli gratia		logarithm (base 10)	log
<b>Time and temperature</b>		(for example)	e.g.	logarithm (specify base)	log <sub>2</sub> , etc.
day	d	Federal Information		minute (angular)	'
degrees Celsius	°C	Code	FIC	not significant	NS
degrees Fahrenheit	°F	id est (that is)	i.e.	null hypothesis	$H_0$
degrees kelvin	K	latitude or longitude	lat or long	percent	%
hour	h	monetary symbols		probability	P
minute	min	(U.S.)	\$, ¢	probability of a type I error	
second	s	months (tables and		(rejection of the null	
		figures): first three		hypothesis when true)	$\alpha$
<b>Physics and chemistry</b>		letters	Jan, ..., Dec	probability of a type II error	
all atomic symbols		registered trademark	®	(acceptance of the null	
alternating current	AC	trademark	™	hypothesis when false)	$\beta$
ampere	A	United States		second (angular)	"
calorie	cal	(adjective)	U.S.	standard deviation	SD
direct current	DC	United States of		standard error	SE
hertz	Hz	America (noun)	USA	variance	
horsepower	hp	U.S.C.	United States	population	Var
hydrogen ion activity	pH		Code	sample	var
(negative log of)		U.S. state	use two-letter		
parts per million	ppm		abbreviations		
parts per thousand	ppt,		(e.g., AK, WA)		
	‰				
volts	V				
watts	W				

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**FISH AND WATER QUALITY MONITORING AT THE  
FORT KNOX MINE, 2023**

By

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June 2024

Cover: Bald eagle with burbot carcass at Fort Knox water supply reservoir, October 20, 2023.  
Photograph by Chad Bear.

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## **Executive Summary**

### **Water Quality**

In April 2023 dissolved oxygen (DO) concentrations were measured in the water supply reservoir (WSR). For nine 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 winter 2023, RO water discharged from Outfall 002 continued at a reduced rate similar to winter 2022. The reduced discharge rate resulted in glaciation and aufeis in the lower RO Channel valley near its confluence with Fish Creek. Water temperature was  $-0.8^{\circ}\text{C}$  on April 27 taken in the lower RO channel after water had flowed over the glaciated ice but  $2.69^{\circ}\text{C}$  taken at the outlet of Pond AB. RO Channel water temperature rose to  $3.51^{\circ}\text{C}$  on May 15 but remained cooler than the Fish Creek water temperature of  $6.45^{\circ}\text{C}$  on the same date.

### **Arctic Grayling**

Sampling for the annual WSR Arctic grayling abundance estimate was conducted from May 8 – May 19, 2023, with fyke nets in Fish Creek and the RO channel to capture fish as they moved into the developed wetlands for spawning. The spring 2022 WSR population estimate for Arctic grayling  $\geq 200$  mm fork length (FL<sup>1</sup>) was 4,594 fish (95% CI: 4,066 to 5,121 fish).

A fyke net was placed in the uppermost waterbody on the wetlands complex, Pond AB, and it captured 201 Arctic grayling with an average length of 237 mm FL. One tagged grayling from the lower wetlands and WSR sampling was captured, the first to date, but the population of Pond AB appears to be mostly isolated from the WSR. The 2022 Pond AB population estimate for Arctic grayling  $\geq 200$  mm FL was 241 fish (95% CI: 60 to 422 fish). Continued sampling will determine if the two populations mix or if successful spawning occurs in Pond AB.

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<sup>1</sup> Fork length (FL) is the measurement taken from the tip of head to the fork of the tail.

## **Burbot**

The fall burbot abundance estimate occurred from September 11 - 20, 2023 with hoop traps in the WSR and Gil Pond. During the sampling event 107 burbot were captured with 80 being  $\geq 300$  mm. The 2022 WSR population estimate for burbot  $\geq 400$  mm was 295 fish (95% CI: 144 to 447 fish).

Pond AB was sampled from September 15 – 20, 2023, and 25 burbot were captured with an average length of 306 mm. Fourteen of these burbot were  $\geq 300$  mm and were tagged. Burbot were first documented in this uppermost waterbody of the wetlands complex in 2022. Only one burbot was tagged in 2022 and it was not recaptured in 2023 to generate a Pond AB population estimate. Continued annual sampling will determine if the Pond AB population is isolated from the WSR burbot.

## 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 previously 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 and annual biomonitoring 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 as fish larger than 220 mm FL 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 FL (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° 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. Water quality sampling began in 1997 and winter water quality monitoring of the WSR began 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 2023 and discusses these findings in relation to previous work. A chronology of events from 2011 to 2023, with emphasis on biological factors, is presented in Appendix 1.

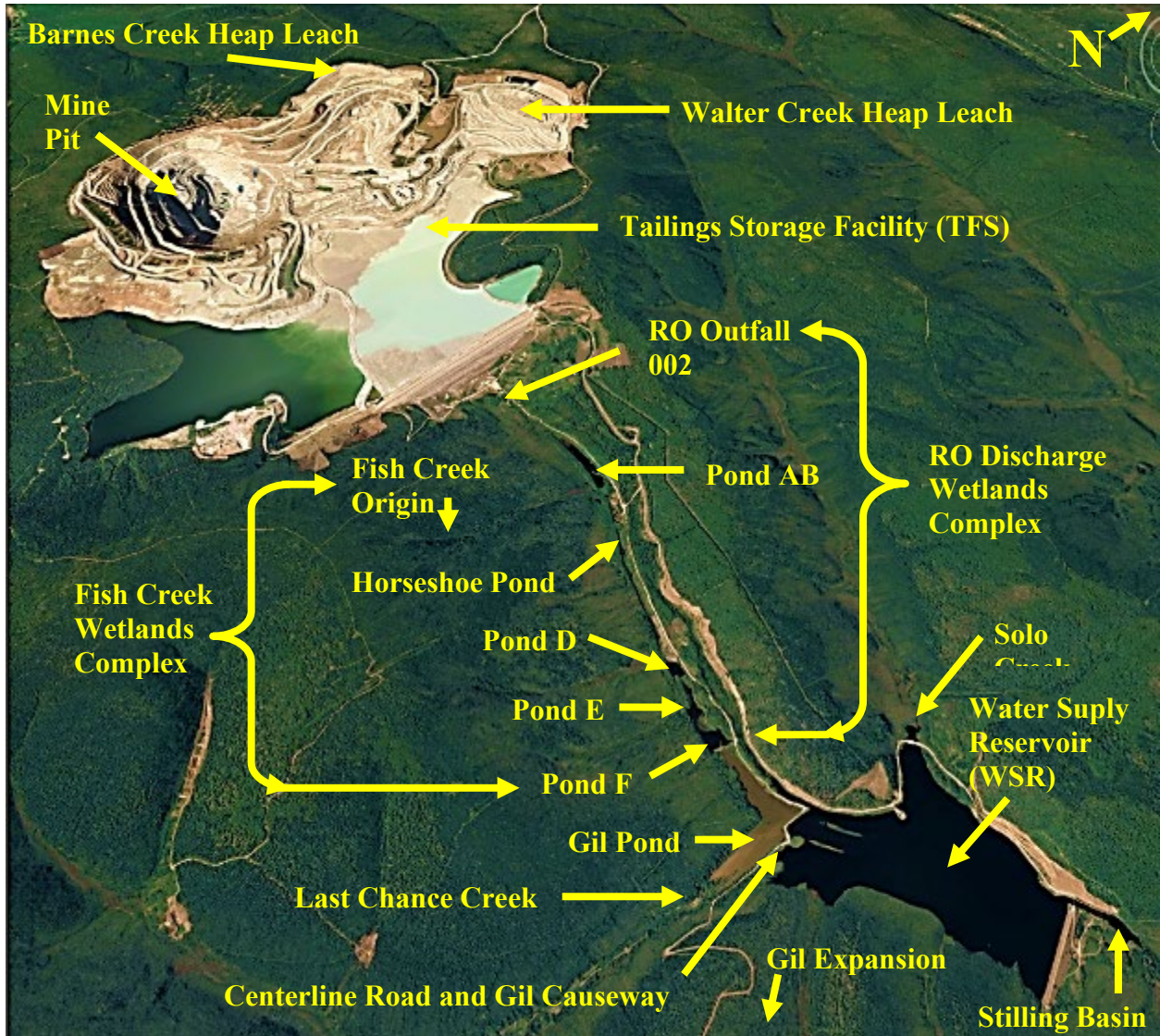


Figure 1. Fort Knox gold mine, and associated facilities.



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

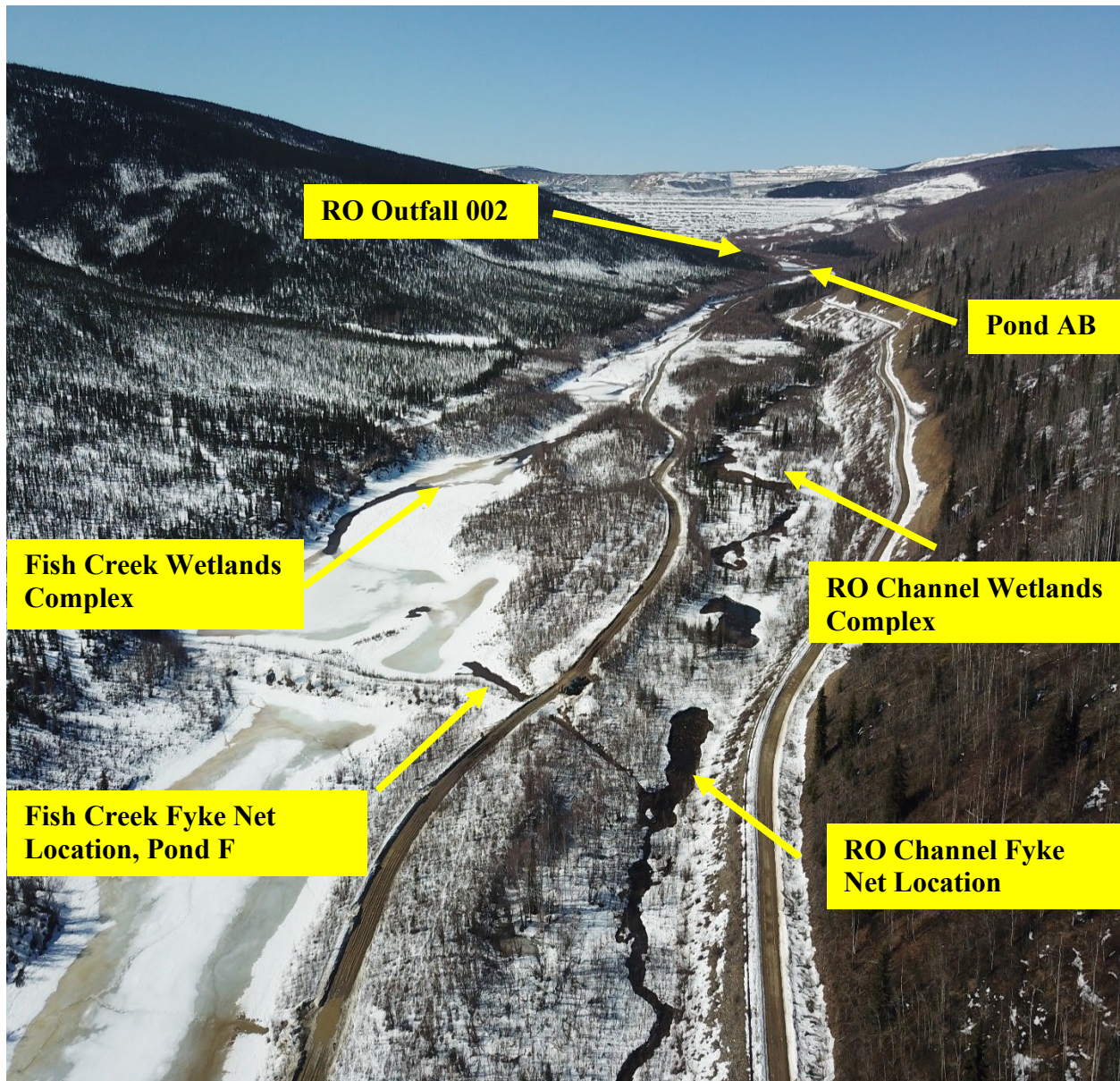


Figure 3. Fish Creek Wetlands (left), RO Channel Wetlands (right), divided by Centerline Road.

## Structure of Report

This report is presented in several sections as follows:

- 1) WSR water quality;
- 2) Arctic grayling population assessment and current issues;
- 3) Burbot population assessment;
- 4) A chronology of events from 2011 to 2023, 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 (Appendix 7). 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 is authorized by the Alaska Department of Environmental Conservation (ADEC) Alaska Pollution Discharge Elimination System (APDES) permit number AK0053643. 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 and 2023 as TSF water balance requirements were met. During 2023, 1,260 acre-feet of RO water were discharged into the RO Channel wetlands, a decline from a peak of 9,663 acre-feet in 2020 (Figure 4 and Appendix 8).

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 (2019 – 2021 left) and reduced to 800 gpm (2022 – 2023 right) into the RO Channel wetlands.

## Methods

The 2023 water quality sampling was conducted on April 14 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 discharge into the wetlands complex.

Vertical profiles of water temperature ( $^{\circ}\text{C}$ ), dissolved oxygen (DO) concentration (mg/L), DO percent saturation (barometrically corrected), pH, specific conductance ( $\mu\text{S}/\text{cm}$ ), oxidation reduction potential (ORP), and depth (m) were measured with a Hydrolab<sup>®</sup> Minisonde<sup>®</sup>5 water quality multiprobe connected to a Surveyor<sup>®</sup> 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.



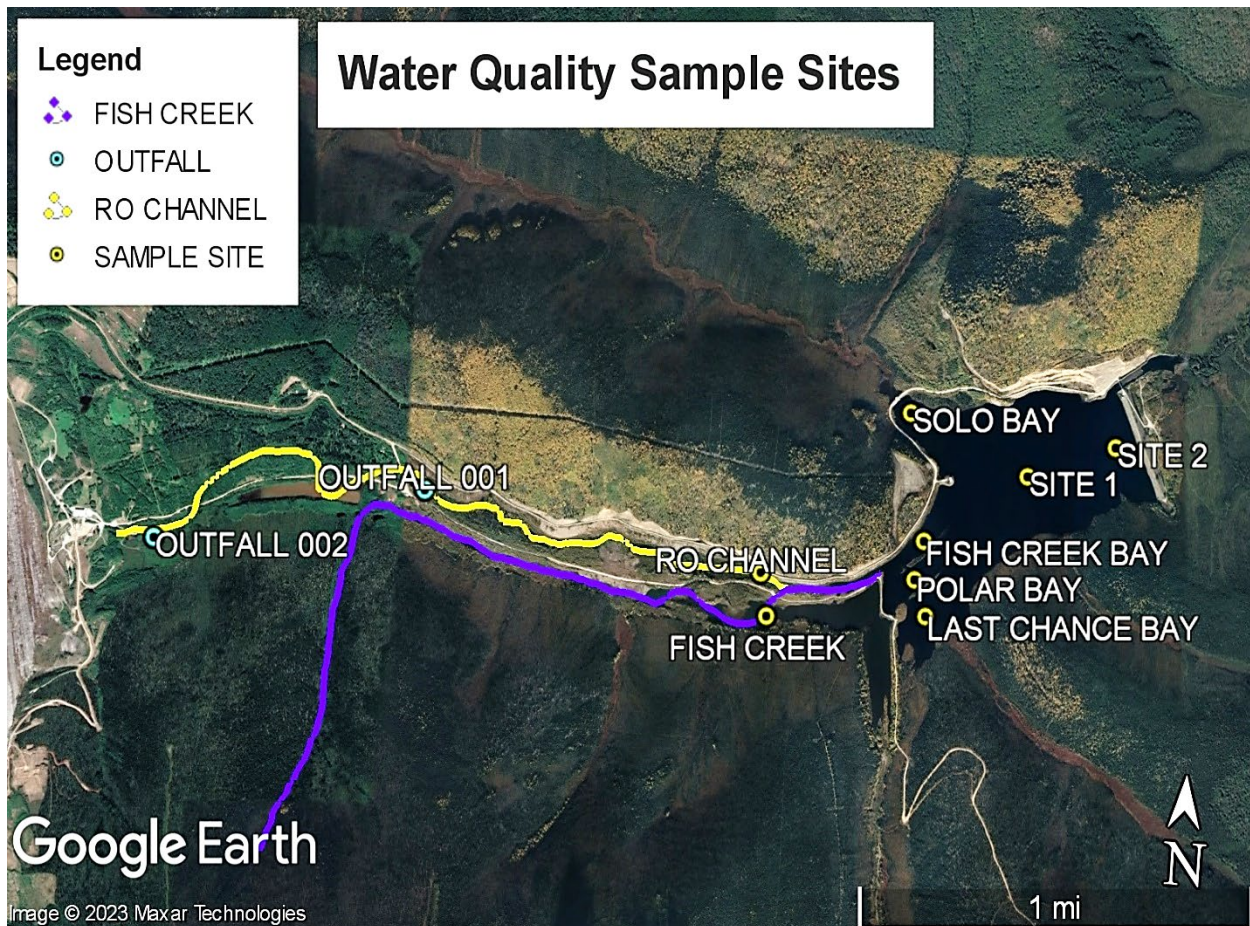


Figure 5. Fort Knox Water Supply Reservoir water quality sample sites, April 14, 2023.

## Results and Discussion

In 2023, similar to past years, 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 at most sample locations. Overflow water may have influenced water quality reading at the one-meter depth sample from mixing while drilling the test holes, but not the remainder of the water column.

WSR water temperatures recorded in 2023 ranged from 0.1°C to 4.2°C (Figure 6). The minimum temperature of 0.1°C was recorded in both Fish Creek Bay and Polar Bay, just below the ice surface. The maximum temperature of 4.2°C was recorded at Site 2 at 16 m depth, just above the reservoir bottom. Temperature at all six sample sites increased with water depth. The Site 2 water column average temperature was the warmest recorded since 1997 (Figure 7).

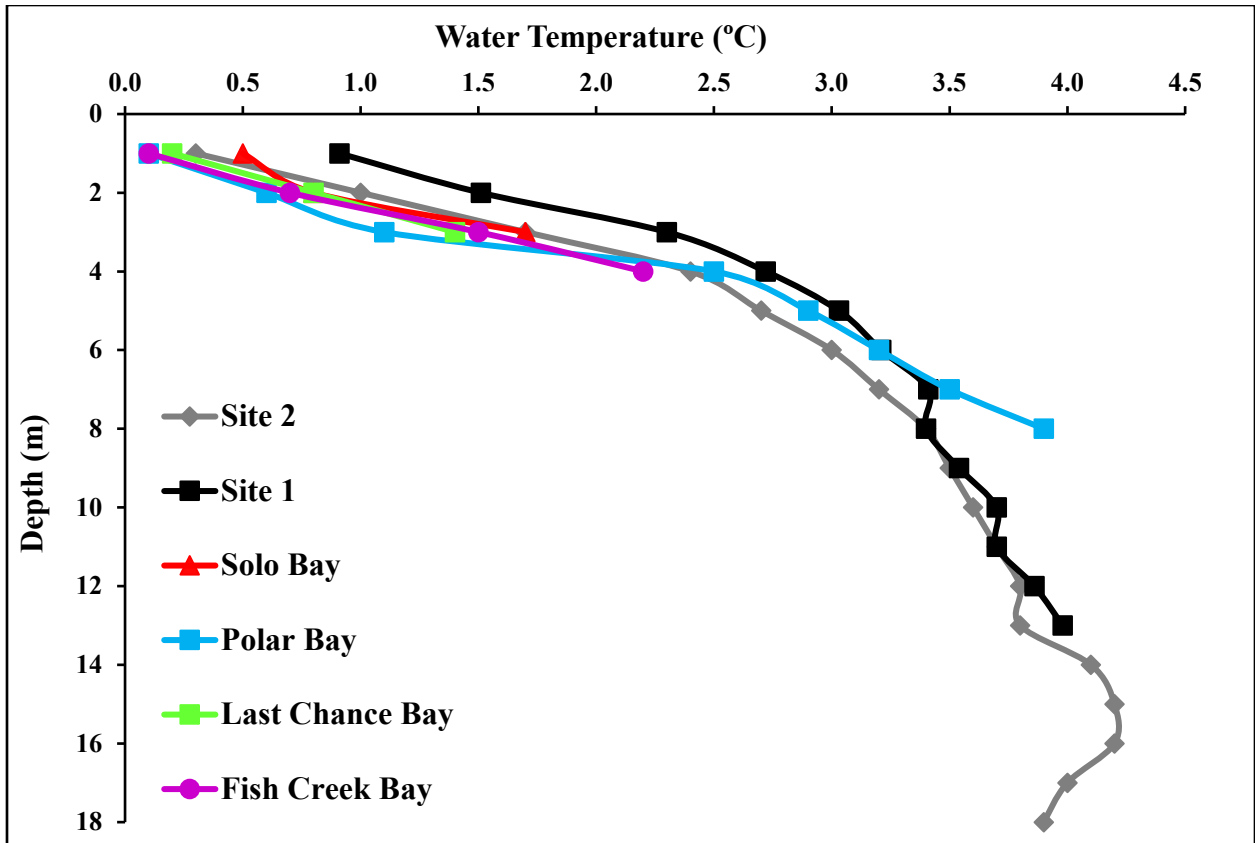


Figure 6. Fort Knox WSR water temperature profiles, April 14, 2023.

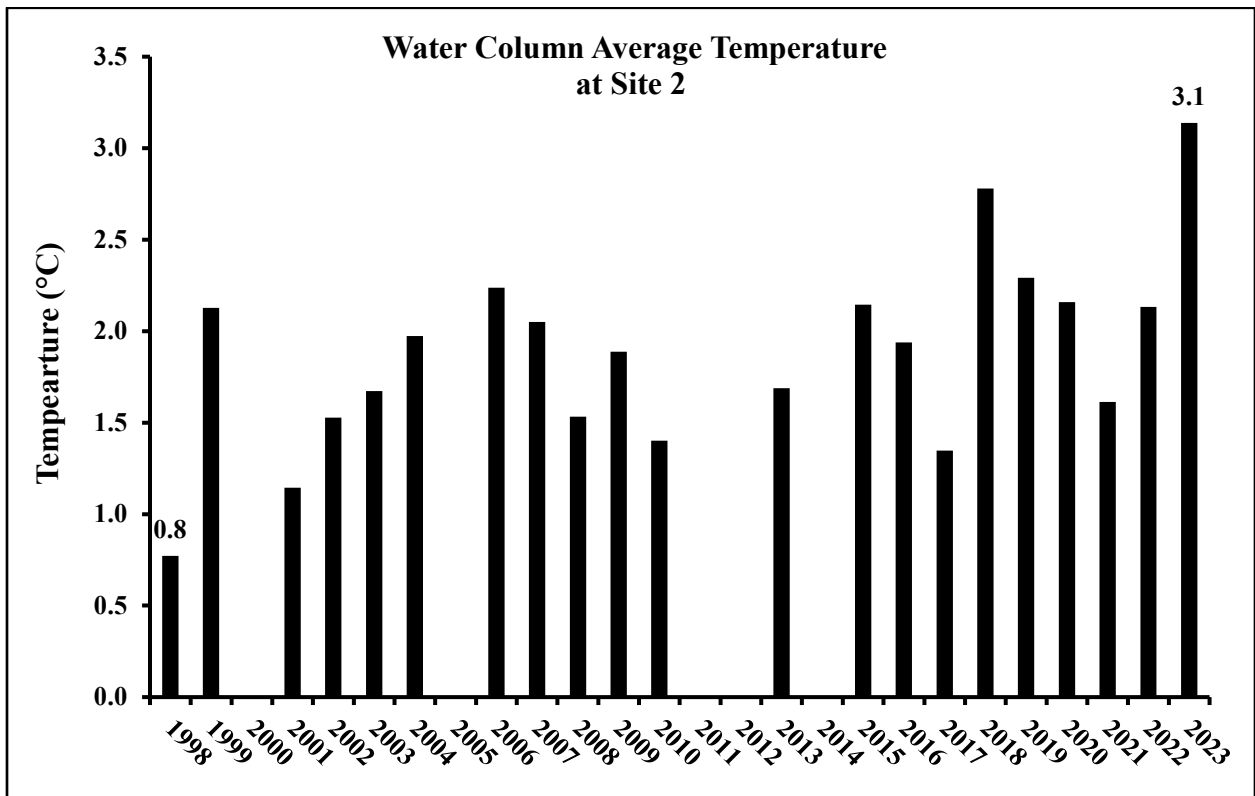


Figure 7. WSR Site 2 annual water column average temperature, 1998-2023.

Dissolved oxygen (DO) is essential for the survival of fish, aquatic invertebrates, and aquatic plants. In 2023, Fish Creek Bay had the highest recorded DO at 11.80 mg/L followed by Polar Bay at 11.20 mg/L (Figure 8). 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 (7.75 mg/L) for the eighth year in a row followed by Solo Bay at 7.73 mg/L. At all WSR samples sites the DO was relatively high in the upper 8 m of the water column, but then dropped rapidly to near 0 mg/L below the 8 m depth.

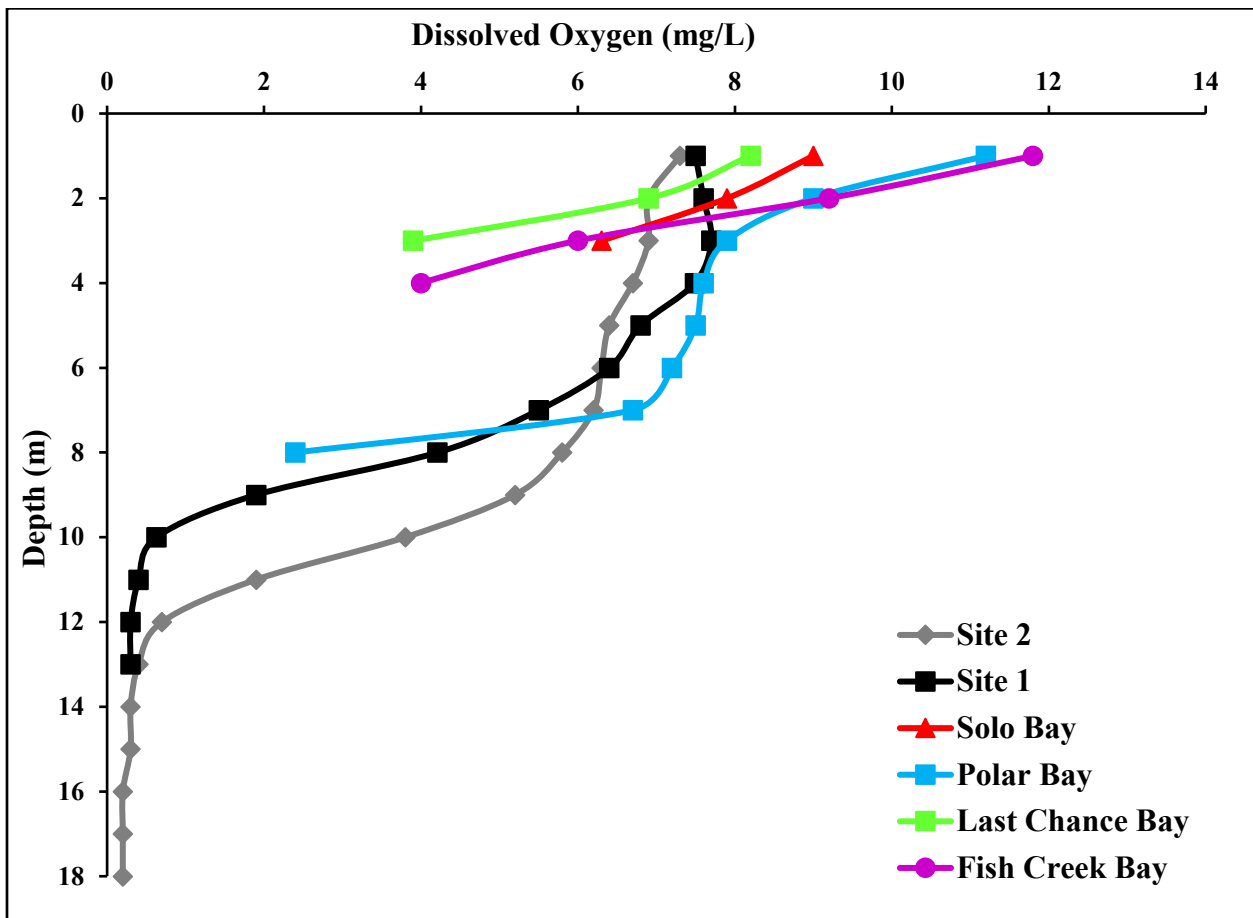


Figure 8. Fort Knox WSR dissolved oxygen (DO) (mg/L) profiles, April 14, 2023.

In 2023 the winter water column average dissolved oxygen DO (mg/L) at Site 2 was above the pre-RO average, but below the post-RO average (Figure 9). This is likely a result of the reduced RO water entering the Fish Creek drainage and WSR in the winter of 2022/23.

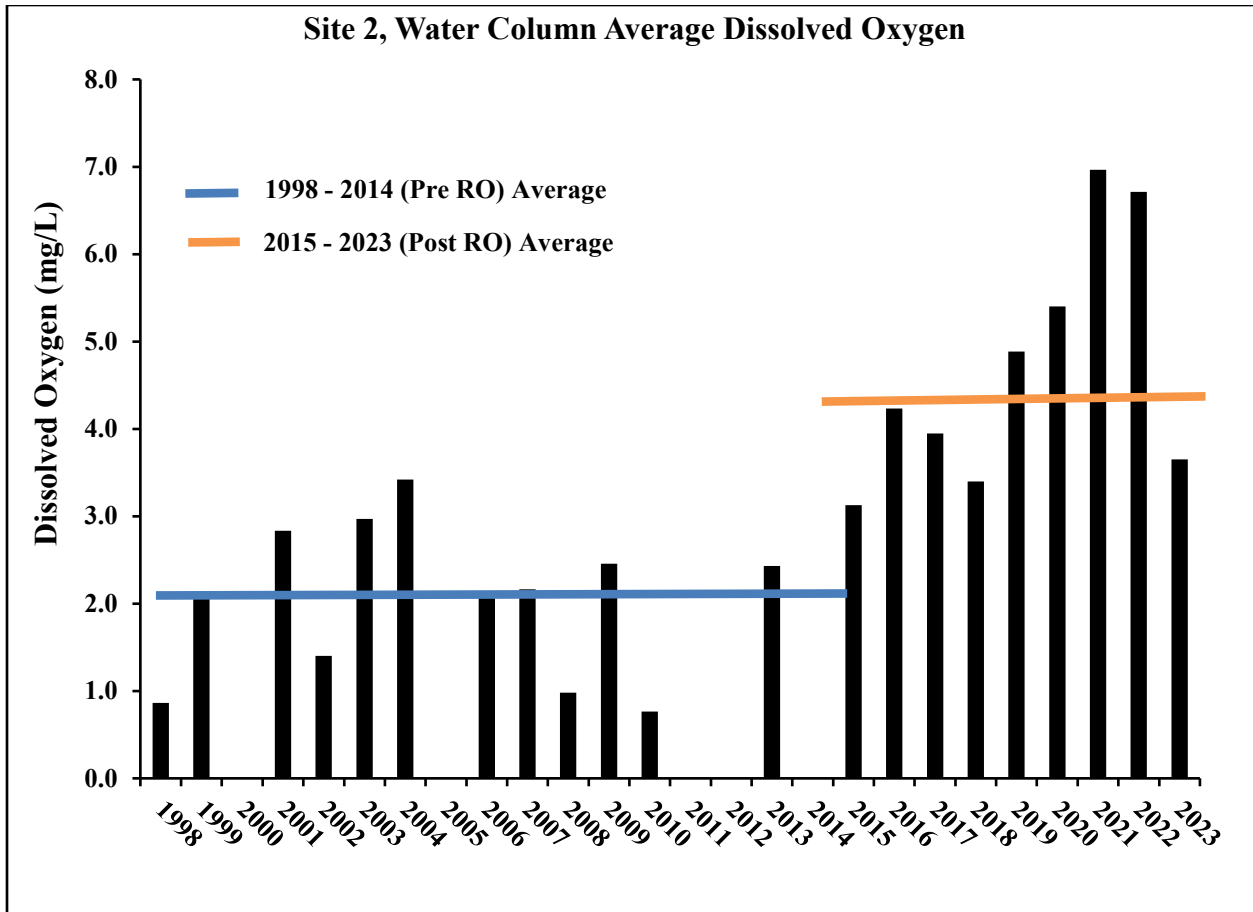


Figure 9. Average water column dissolved oxygen (mg/L) at Site 2, 1998 – 2023.

Temperature specific DO percent saturation (%) values were stratified between the surface and bottom in 2023 (Figure 10). DO (%) showed the same stratification at 8 m as DO (mg/L). This is compared to 2022 where the larger input of RO water mixed the WSR reducing stratification of oxygen (Figure 11). The 2023 water stratification resembles typical lake oxygen profiles that do not have large freshwater input during winter months (Palshin 2021) When DO levels drop below 2 mg/L, the water is described as hypoxic. As DO levels in the reservoir approach 0 mg/L below 10 m depth the water becomes anoxic. With reduced RO water discharge entering the WSR from Fish Creek during the winter of 2022/23, the DO was lower at all sites than in 2022. In 2022 the Last Chance Bay site had lower DO and dissimilar to other sites, as it may not be mixed with and influenced by the RO water input, but in 2023 its profile more closely resembled the rest of the WSR sites (Figure 10 and 11).

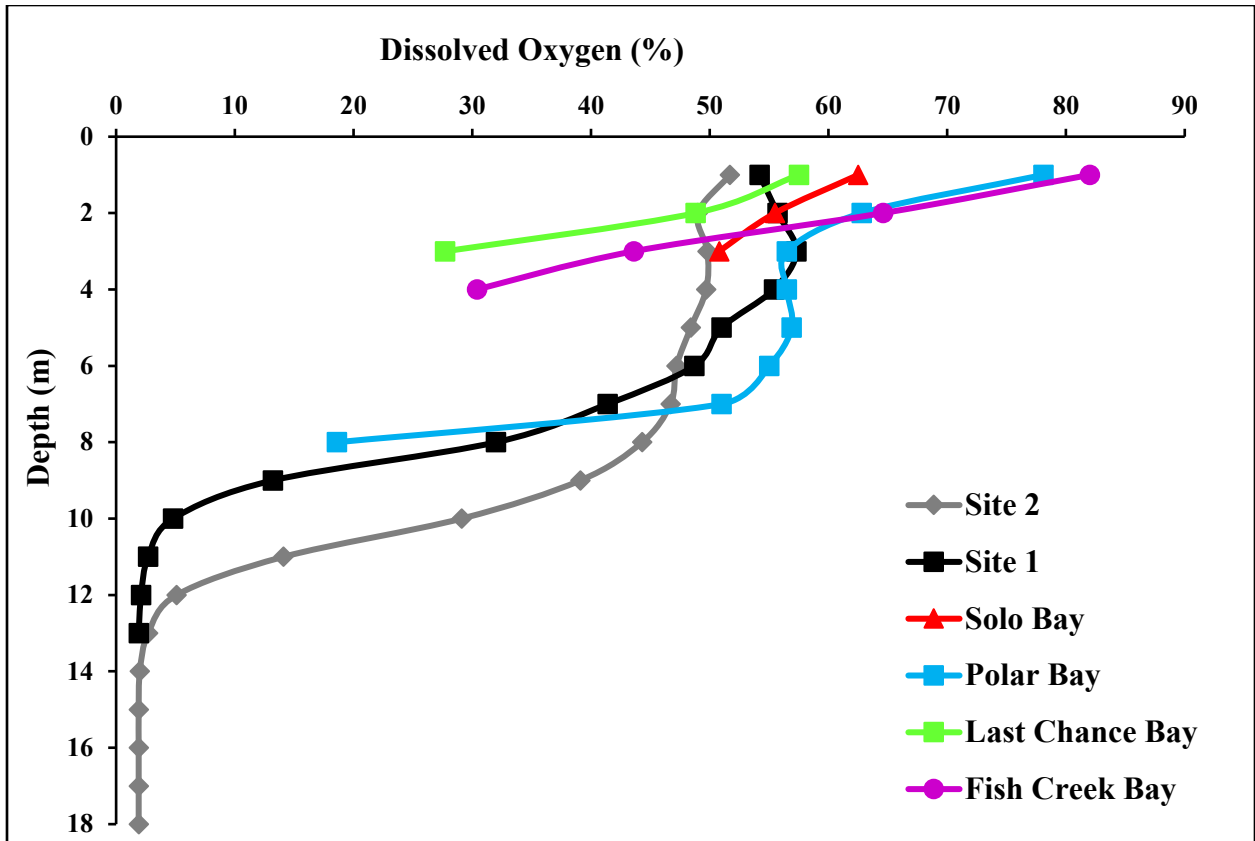


Figure 10. Fort Knox WSR dissolved oxygen (% saturation) profiles, April 14, 2023.

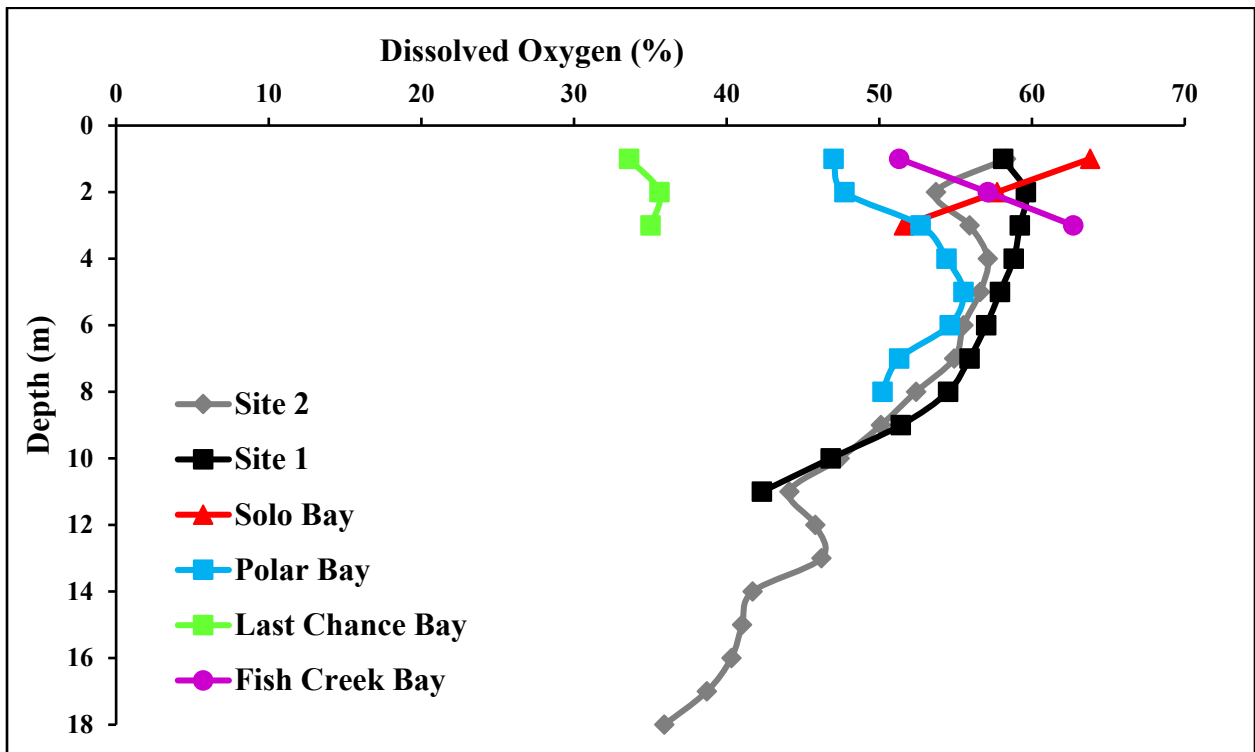


Figure 11. Fort Knox WSR dissolved oxygen (% saturation) profiles, April 14, 2023.

The pH of water has many effects on aquatic plants, aquatic invertebrates, and has the potential to affect reproduction, recruitment, growth rates, and general health of fish. The WSR pH in 2023 was relatively similar across all sites but had a wider range of values compared to prior years. The pH ranged from 6.3 at Solo Bay near the surface to 7.2 in Polar Bay near the surface (Figure 12). Most WSR pH measurements in 2023 met the ADEC standard for aquatic life of 6.5 to 8.5, with Solo Bay and Site 2 pH measurements slightly lower than this standard (Figure 12).

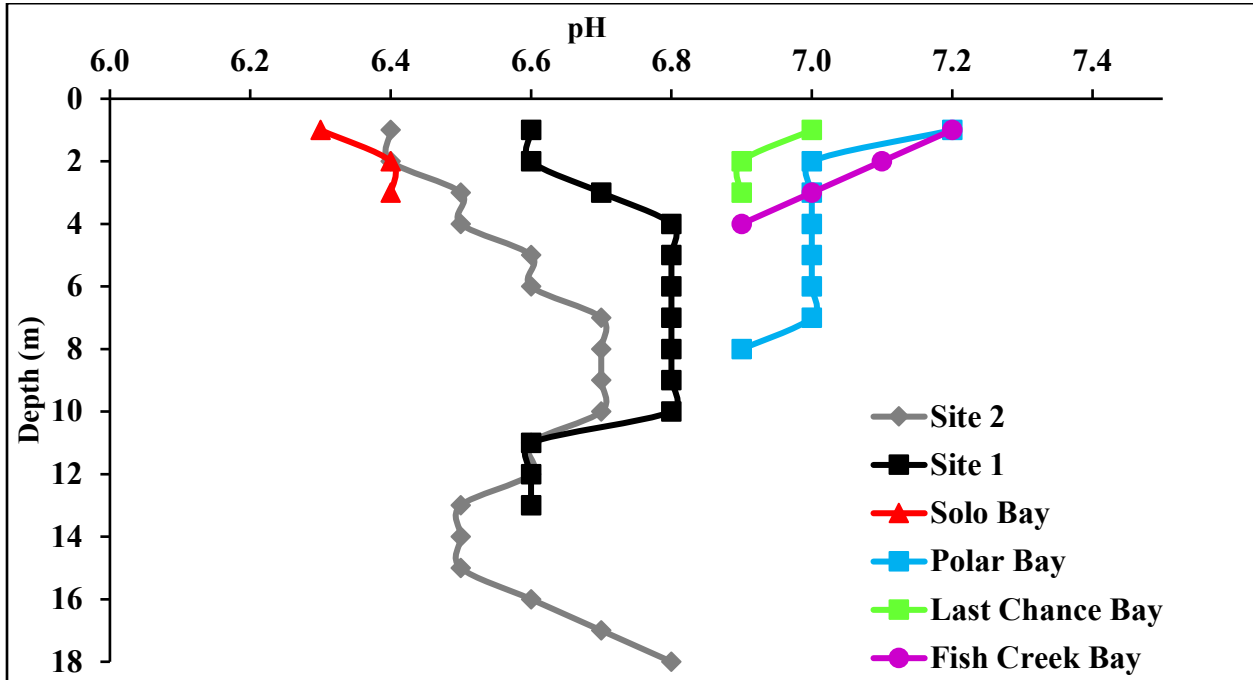


Figure 12. Fort Knox WSR water column pH profiles, April 14, 2023.

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. It can be used as an indicator of water quality. Specific conductance was similar among all six sites in 2023 (Figure 13). Values generally increase with water depth as minerals sink from the surface and settle near the bottom. The measurement at one meter, just below the ice surface, may be influenced by melt water mixing with WSR water while drilling the test hole. The 2023 WSR conductance values ranged between 107.1 and 399.2  $\mu\text{S}/\text{cm}$  with most of the water column reading near 200  $\mu\text{S}/\text{cm}$ . This is lower when compared to 2022 where most of the water column readings were near 400  $\mu\text{S}/\text{cm}$ . The 2023 Site 2 water column average specific conductance was 255.7  $\mu\text{S}/\text{cm}$ , compared to the 2022 average of 427.2  $\mu\text{S}/\text{cm}$ , the highest ever recorded at this site (Figure 14). Higher values indicate an increase in dissolved solids such as chloride, nitrate, phosphate, sodium, magnesium, calcium, and iron.

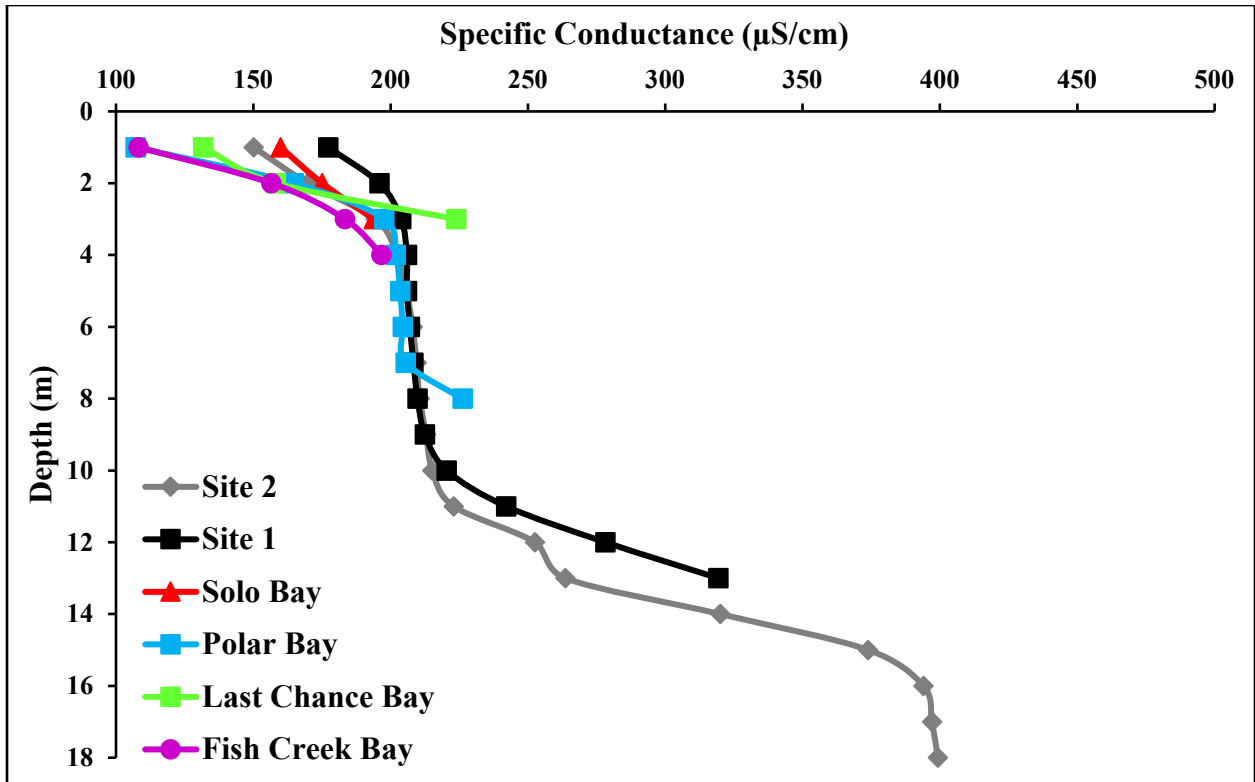


Figure 13. Fort Knox WSR specific conductivity ( $\mu\text{S}/\text{cm}$ ) profiles, April 14, 2023.

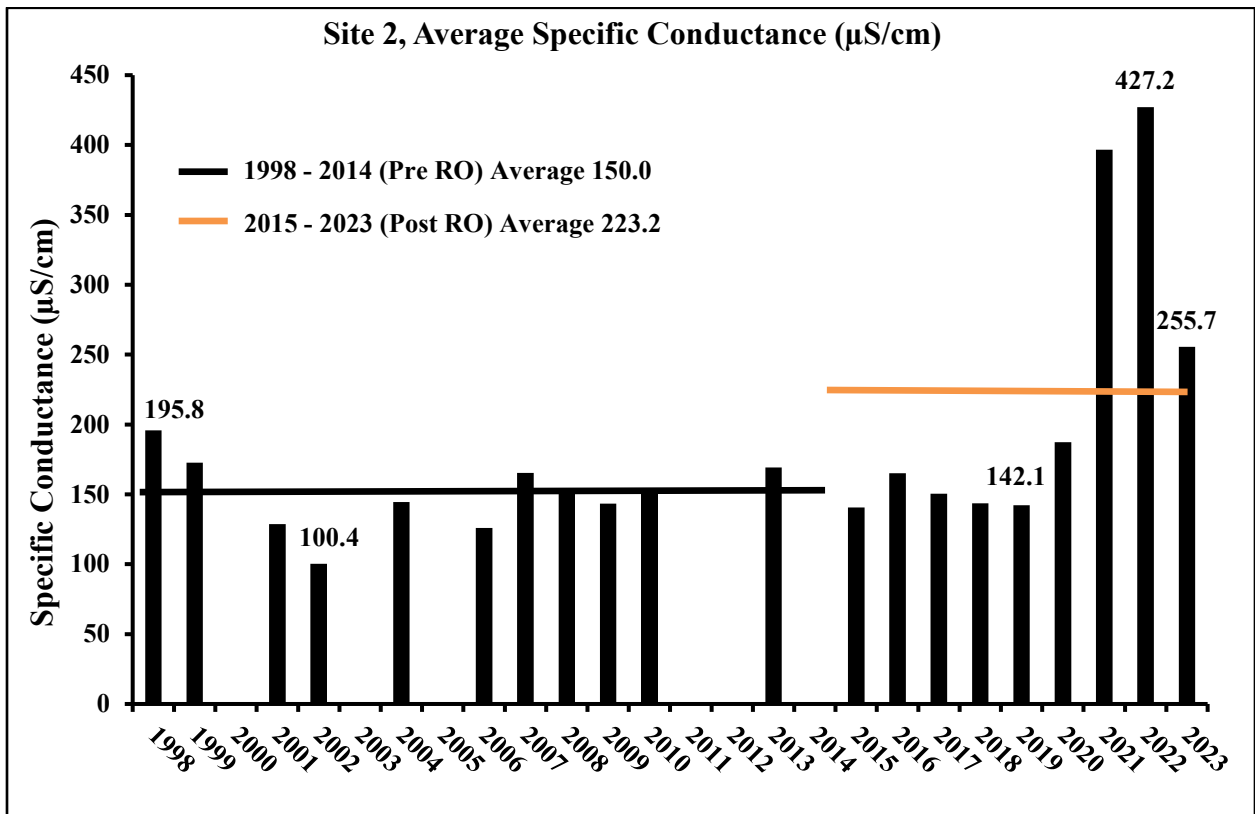


Figure 14. WSR specific conductivity at Site 2, pre-RO (1998-2014) average and post-RO (2015 – 2023) average.

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 sample sites in 2023, ranging from 297 to 385 mV (Figure 15). The 2023 total WSR average of all six sites combined was 337 mV.

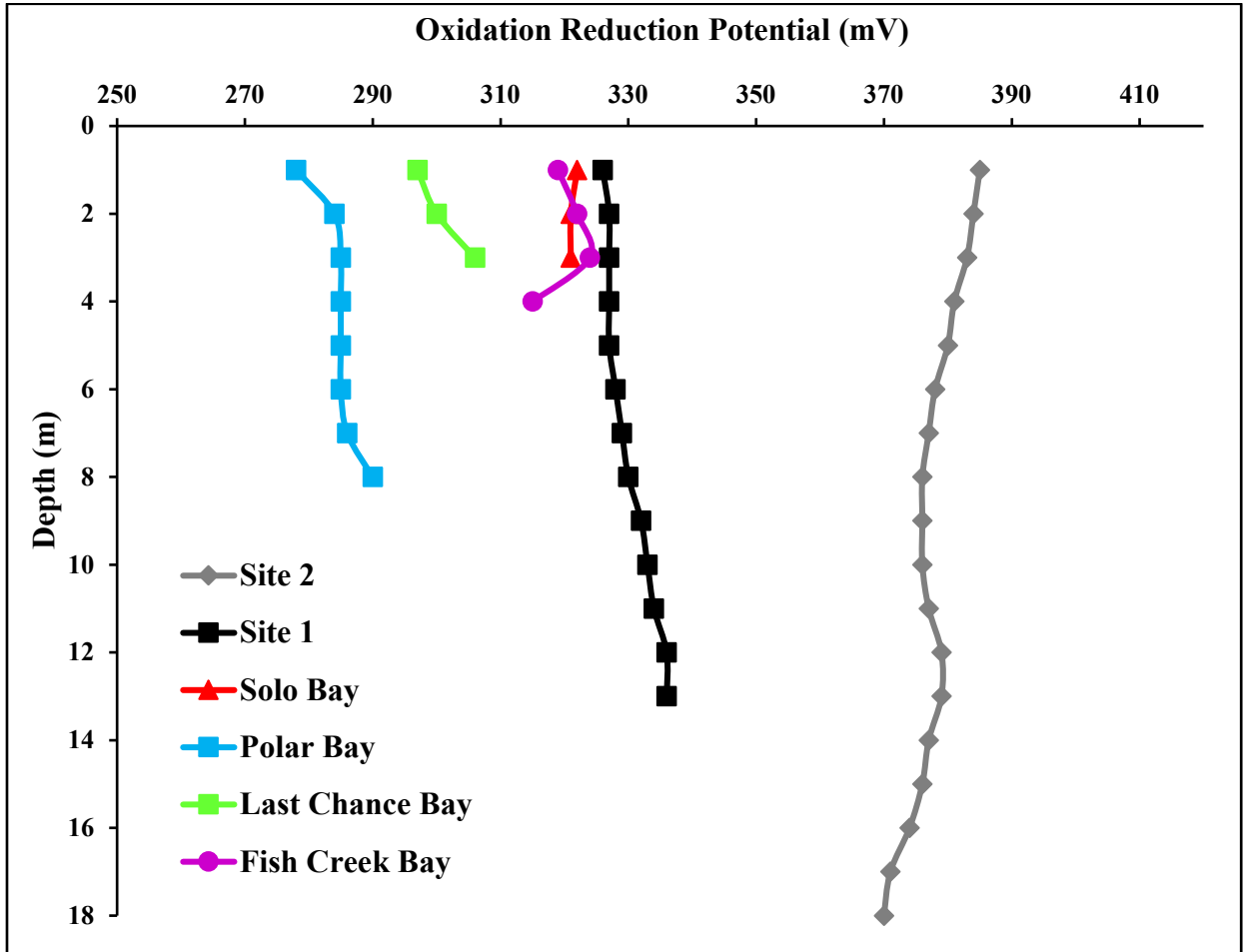


Figure 15. WSR oxidation reduction potential (mV) profiles, April 14, 2023.

From 2019 - 2023 water quality data were collected at Fish Creek at Pond F and the RO Channel downstream of Outfall 002 (Figure 1). On April 14, 2023, the water temperature in the RO Channel was 1.6 °C and the water temperature in Fish Creek was 0.1 °C (Figure 16).



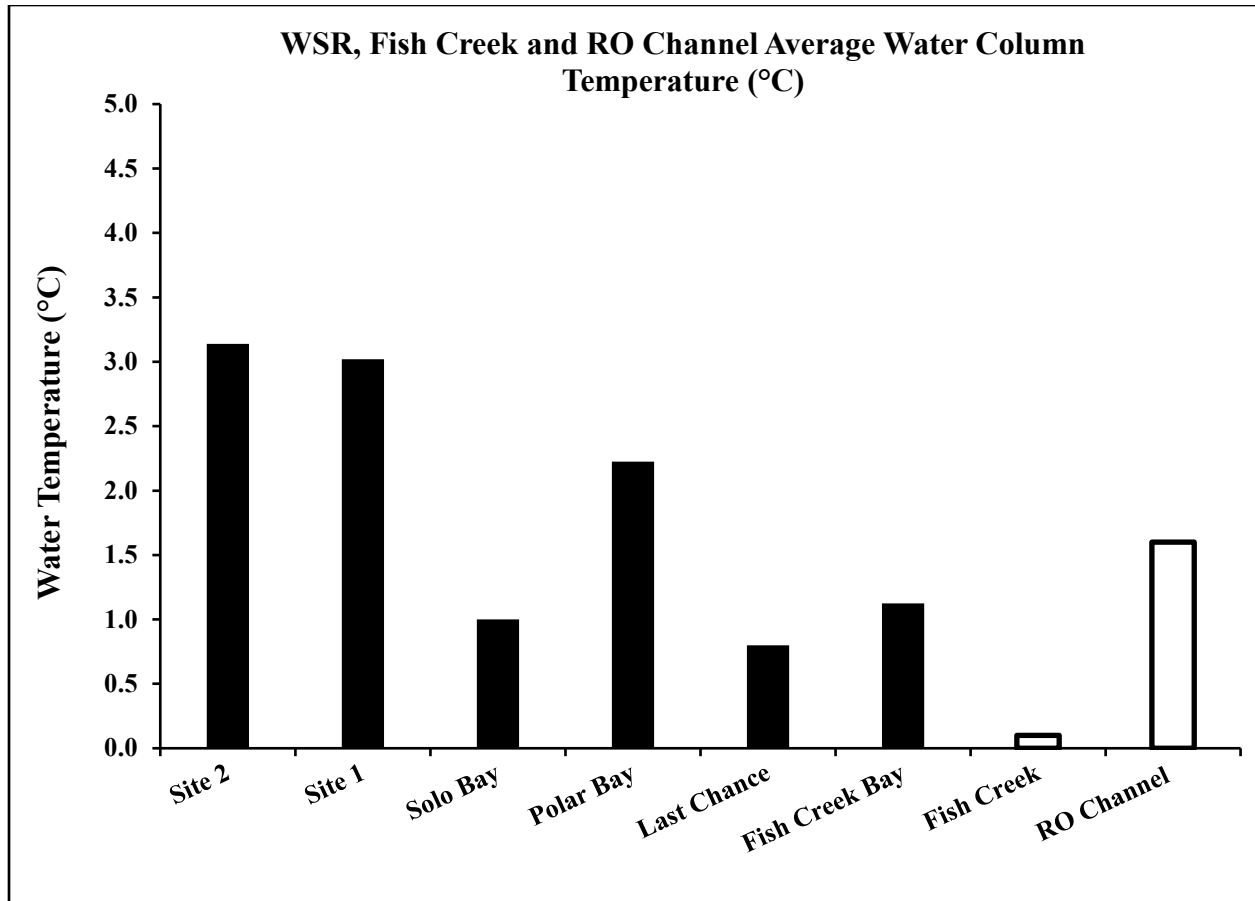


Figure 16. Water temperatures in Fish Creek, RO Channel (1 meter depth) and WSR (average for water column), April 14, 2023.

The DO in Fish Creek and the RO Channel was higher when compared to the average DO in the six WSR sample sites (Figure 17). Generally, most of the RO water discharge flows through Pond AB and into the RO Channel on the north side of Centerline Road. On April 14, 2023, about 10 percent of the RO water discharge was flowing out of Pond AB's natural outlet 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 in Fish Creek.

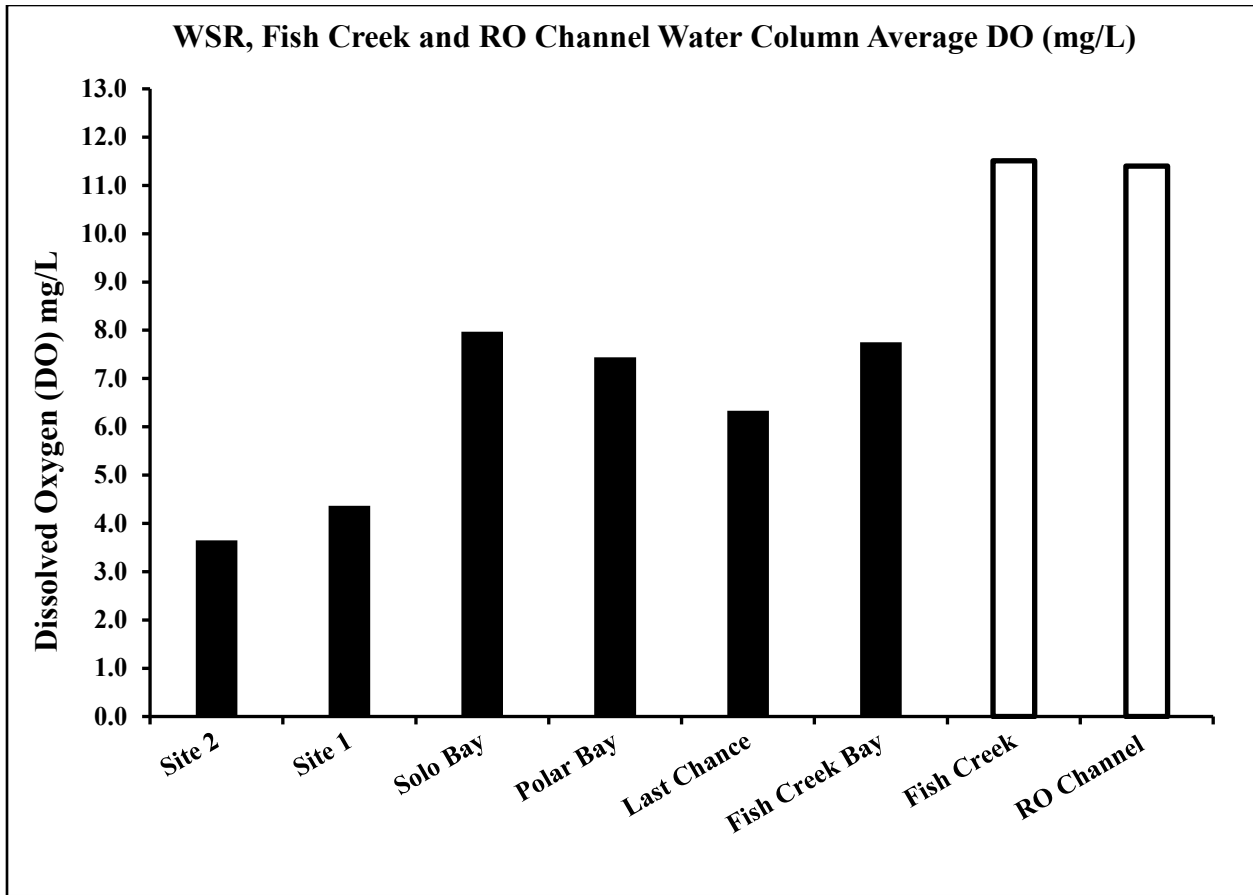


Figure 17. Dissolved oxygen in the WSR (average for water column), Fish Creek and RO Channel (1 meter depth) (mg/L), April 14, 2023.

Reverse osmosis water typically has very low conductivity. The RO water discharge from Outfall 002 is mixed with non-contact ground water from de-watering wells, which adds minerals and raises the specific conductance before it is discharged into the Fish Creek drainage. The 2023 RO Channel specific conductance measurement of 52.1  $\mu\text{S}/\text{cm}$  was taken downstream of Outfall 002 and had the lowest recorded value of all sites in 2023 (Figure 18). During the 2022 and 2021 sampling, the RO Channel specific conductance was measured at 494  $\mu\text{S}/\text{cm}$  and 455  $\mu\text{S}/\text{cm}$  respectively, more than double the specific conductance measured in 2019 and 2020 (Figure 19).

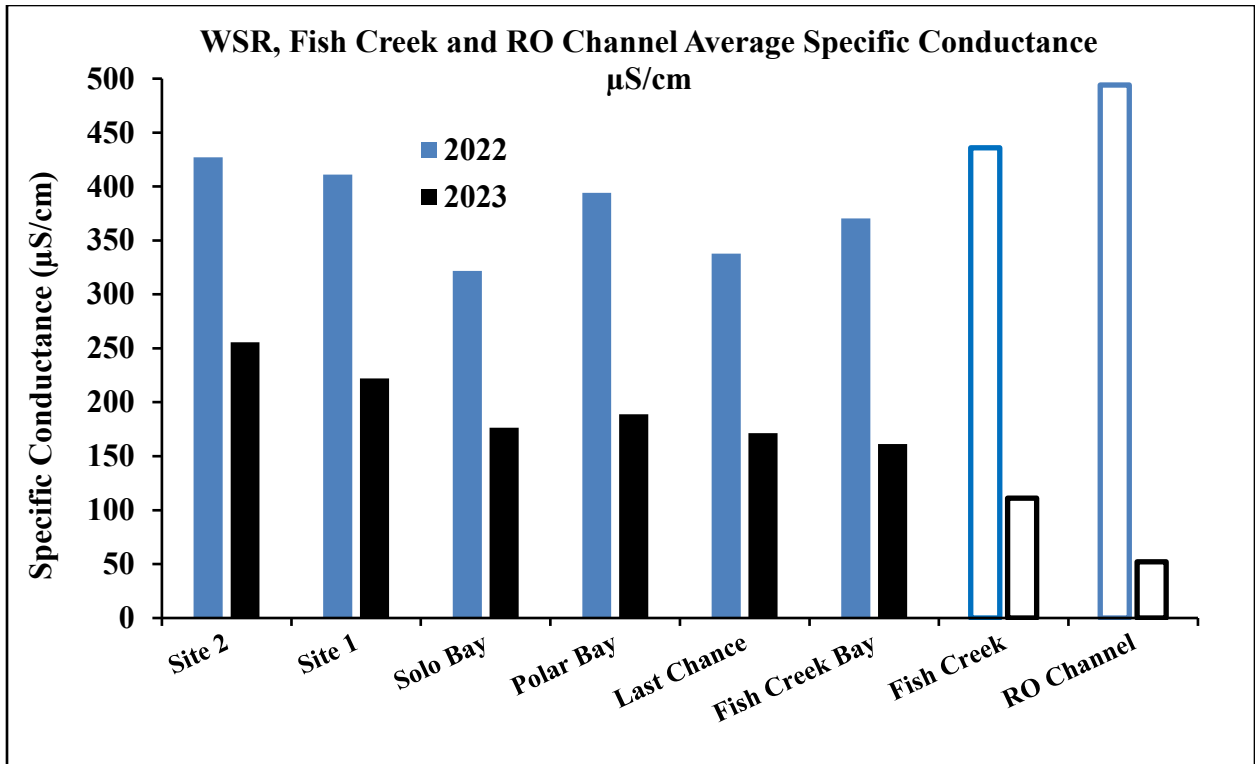


Figure 18. Specific conductance in the WSR (average for water column), Fish Creek and RO Channel (1 meter depth)  $\mu\text{S}/\text{cm}$ .

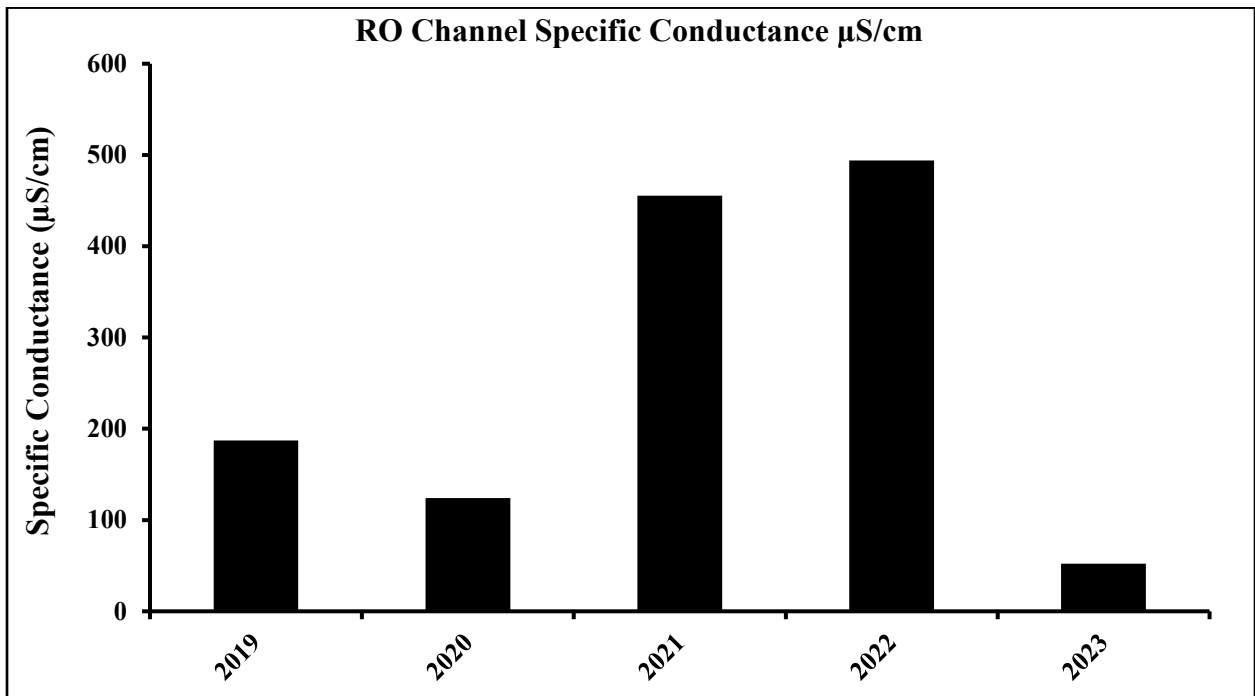


Figure 19. Specific conductance in the RO Channel ( $\mu\text{S}/\text{cm}$ ), taken downgradient of Outfall 002, 2019-2023.

## 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, Fish Creek 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

2023 Arctic grayling sampling methods included fyke nets, angling, and visual observations. One fyke net was set in Fish Creek at the Pond F outlet and one in Pond AB on May 8. The RO Channel fyke net at its confluence with Fish Creek could not be set until the aufeis thawed on May 15 (Figure 20). Fyke nets were checked daily until they were removed on May 19.

Fyke nets in Fish Creek and the RO channel were used to capture Arctic grayling moving from the Water Supply Reservoir (WSR) into the wetlands complex for spawning (Figures 21 and 22). Additionally, the RO Channel net was used to assess Arctic grayling use of the wetland habitats created by the RO discharge waters. The Pond AB fyke was used to determine if fish were residing in the uppermost waterbody in the wetlands complex that was first documented in the 2022 spring Arctic grayling sampling (Bear and Ott 2023).



Figure 20. Fyke net locations: RO Channel (left), Fish Creek Pond F (middle), and Pond AB (right), 2023.

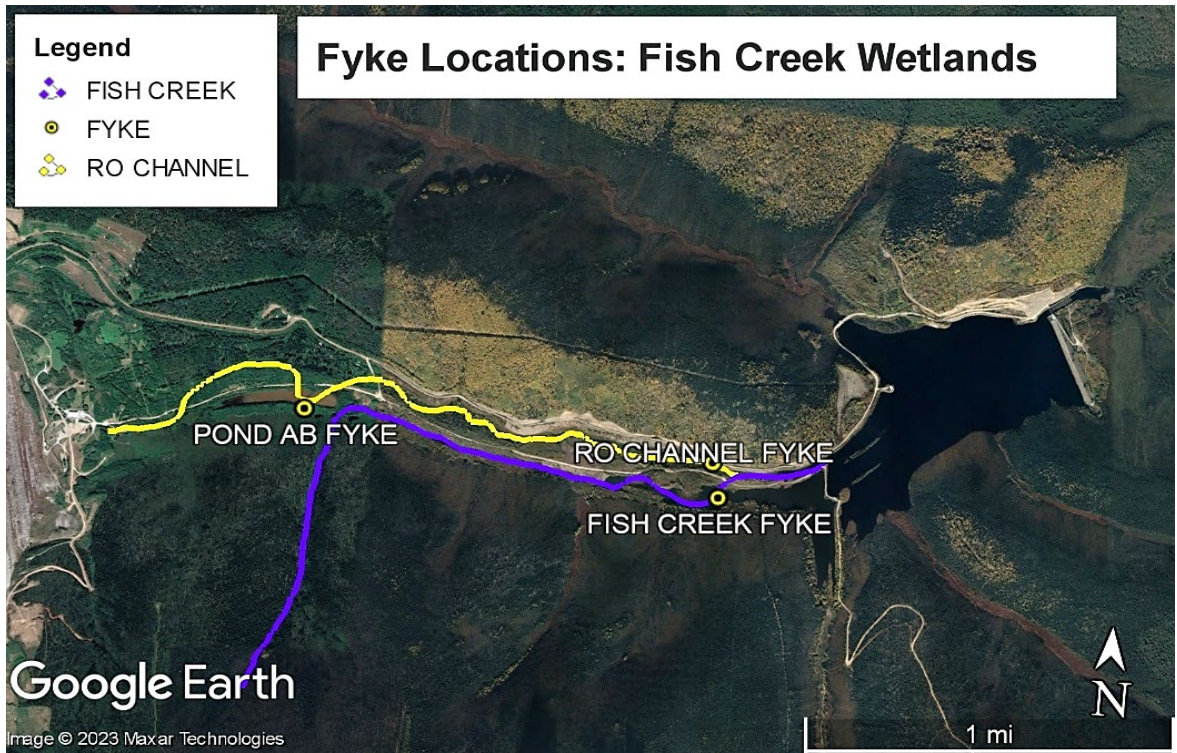


Figure 21. Fish Creek Wetlands Fyke Locations, 2023.

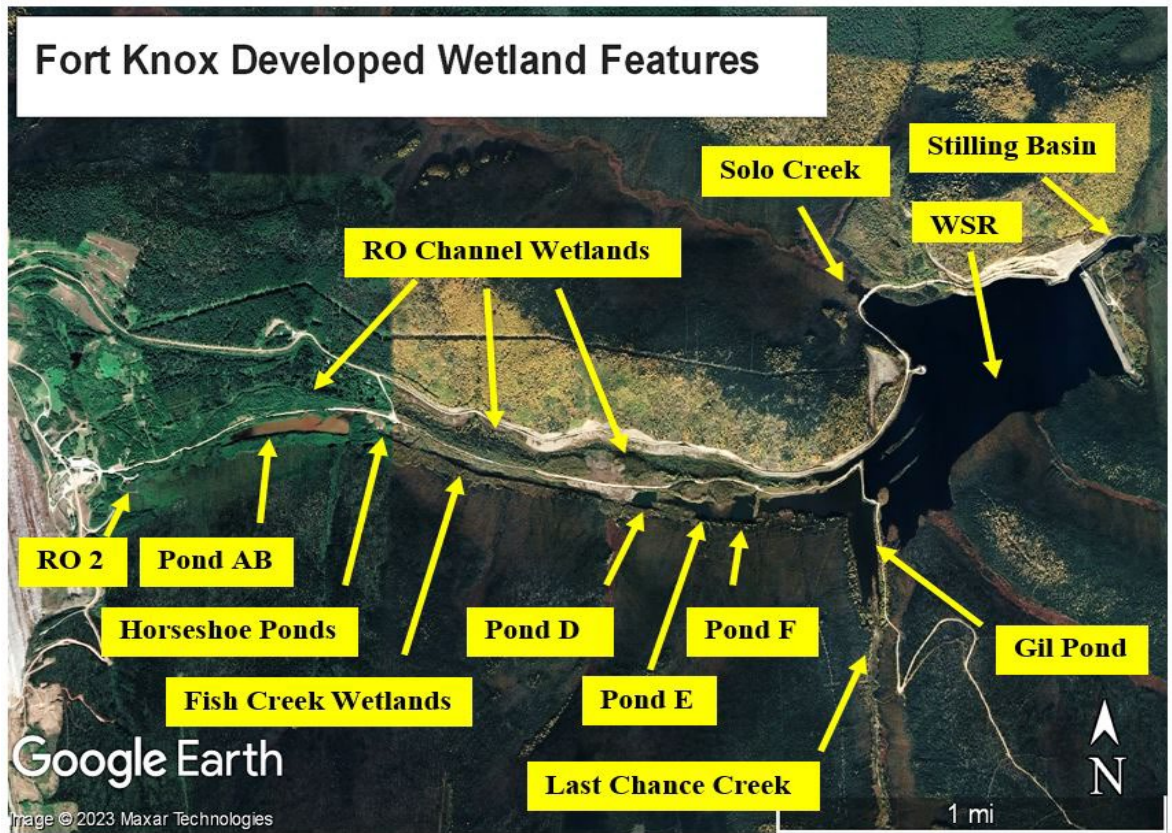


Figure 22. Fish Creek and RO Channel Wetlands Features.

Arctic grayling were measured to fork length (FL, nearest mm), inspected for tags and spawning condition, then released. Un-tagged Arctic grayling  $\geq 200\text{mm}$  and burbot  $\geq 300\text{mm}$  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),

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

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

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

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

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

## Results and Discussion

The 2023 Fish Creek daily peak water temperature taken at the Pond F outlet was similar when compared to previous years during similar timing (Figure 23). Fish Creek water temperature was  $0.33^\circ\text{C}$  on April 27 from natural spring melt water entering the drainage. The RO Channel water temperature was warmer at  $2.98^\circ\text{C}$  taken at Pond AB (Figure 24). The large volume of RO water dilutes the influx of cold spring melt water keeping Pond AB and the RO Channel warmer than Fish Creek in the upper part of the drainage. Lower in the RO Channel aufeis covered the valley floor and water flowing over the ice was near zero Celsius until a channel thawed, and water temperature rose to  $3.5^\circ\text{C}$  on May 15<sup>th</sup> near the confluence with Fish Creek.

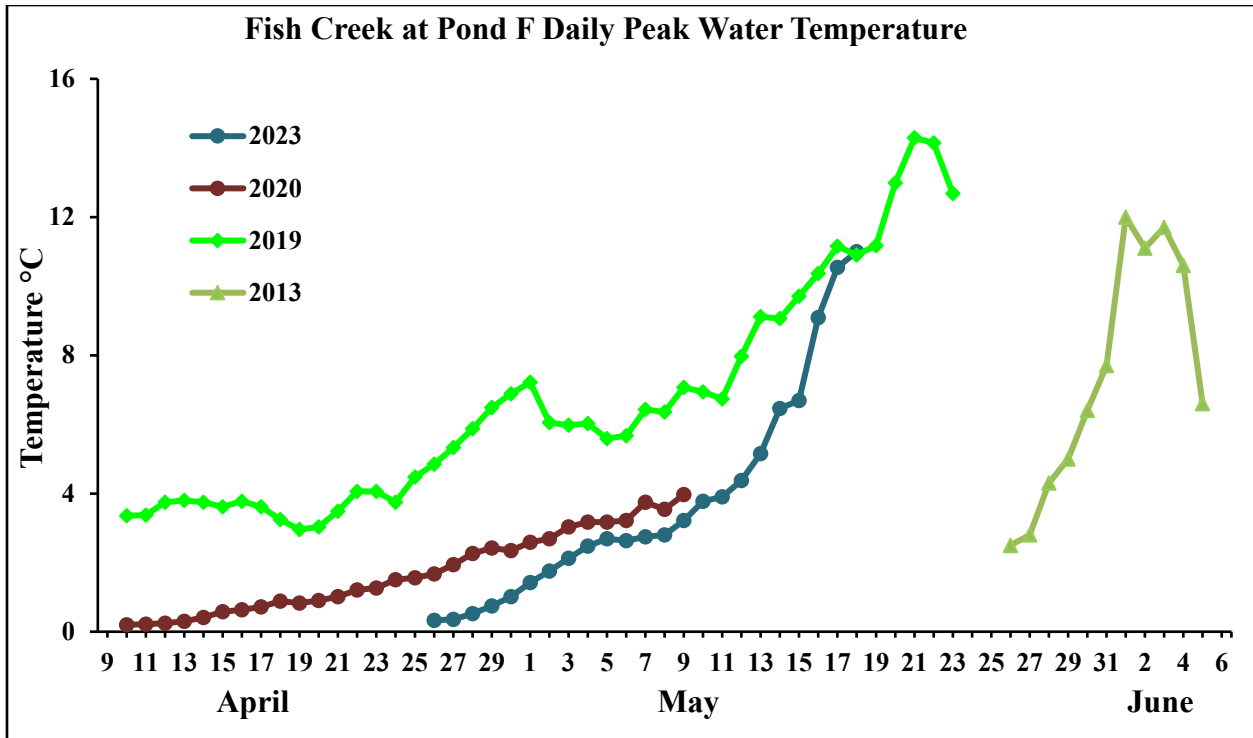


Figure 23. Fish Creek at Pond F daily water temperature maximums; select years for reference.

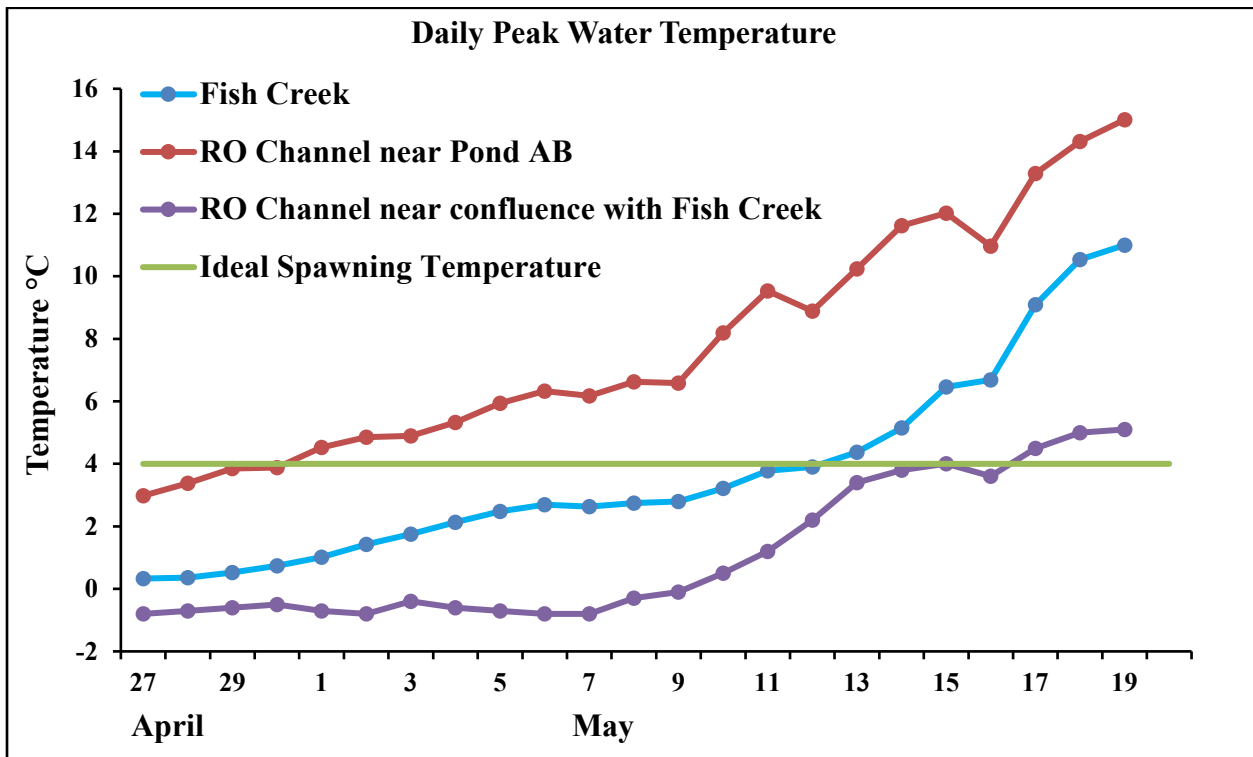


Figure 24. Fish Creek at Pond F, RO Channel at Pond AB and RO Channel near confluence with Fish Creek daily peak water temperature, 2023.

From May 8 - 19, all fish caught in fyke nets were handled with the majority being Arctic grayling. The Arctic grayling catch per unit of effort (CPUE) in Fish Creek varied during the first few days of sampling and peaked at 5.98 fish/hour on May 16. The RO Channel CPUE reached a high of 5.79 fish/hour on May 17 before catch rates declined (Figure 25). Water temperatures remained cool in the lower RO Channel, at 4.0°C on May 19, compared to 10.99°C in Fish Creek. The fyke nets were removed on May 19.

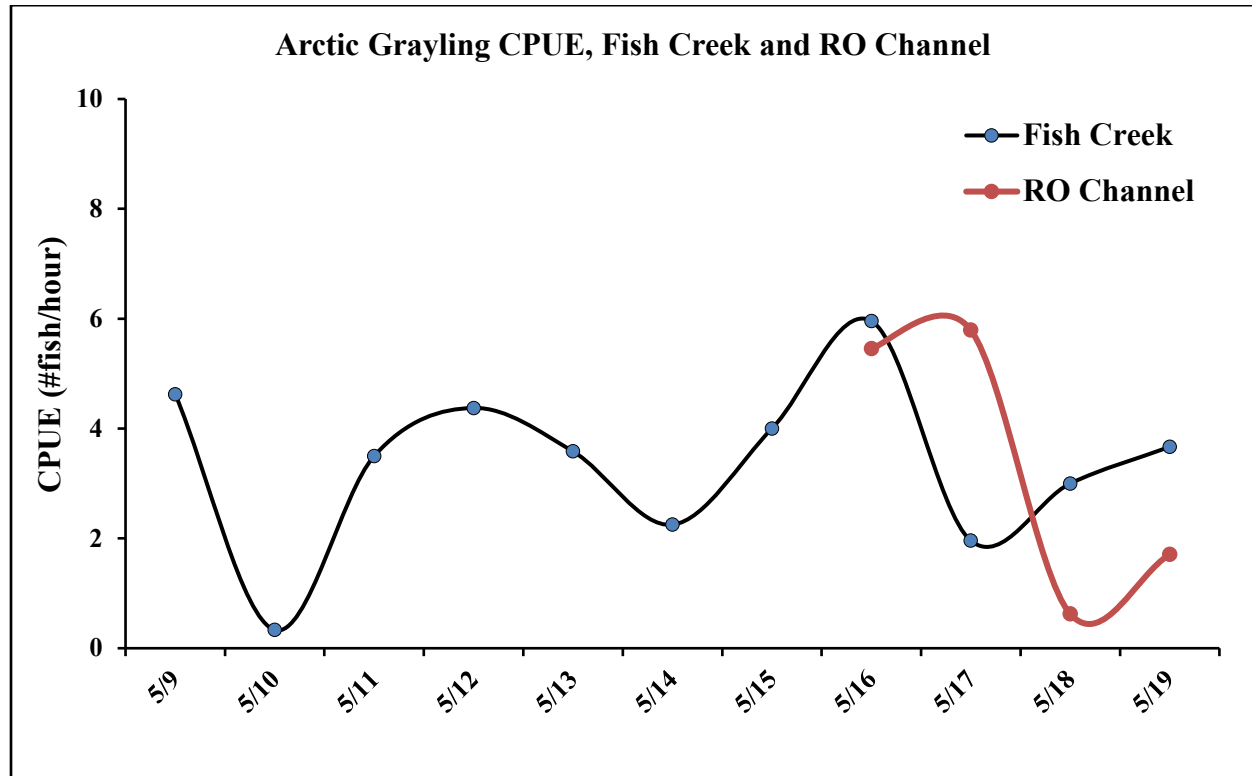


Figure 25. Catch per unit of effort (CPUE) in #fish/hr at the Pond F and the RO Channel fyke nets in the wetlands complex, 2023.

Female Arctic grayling were categorized as not ripe, ripe, or spent, based on their spawning condition (Figure 26). On the first day of fish capture (May 9), 96% of the female Arctic grayling were categorized as not ripe and 4% were classified as ripe. The number of not ripe females decreased throughout the sampling period to 9% on May 19. The number of ripe females increased to 91% on May 19 when sampling concluded. Very few fish were classified as spent during the first eight days of sampling and 13% of females were spent on May 18.



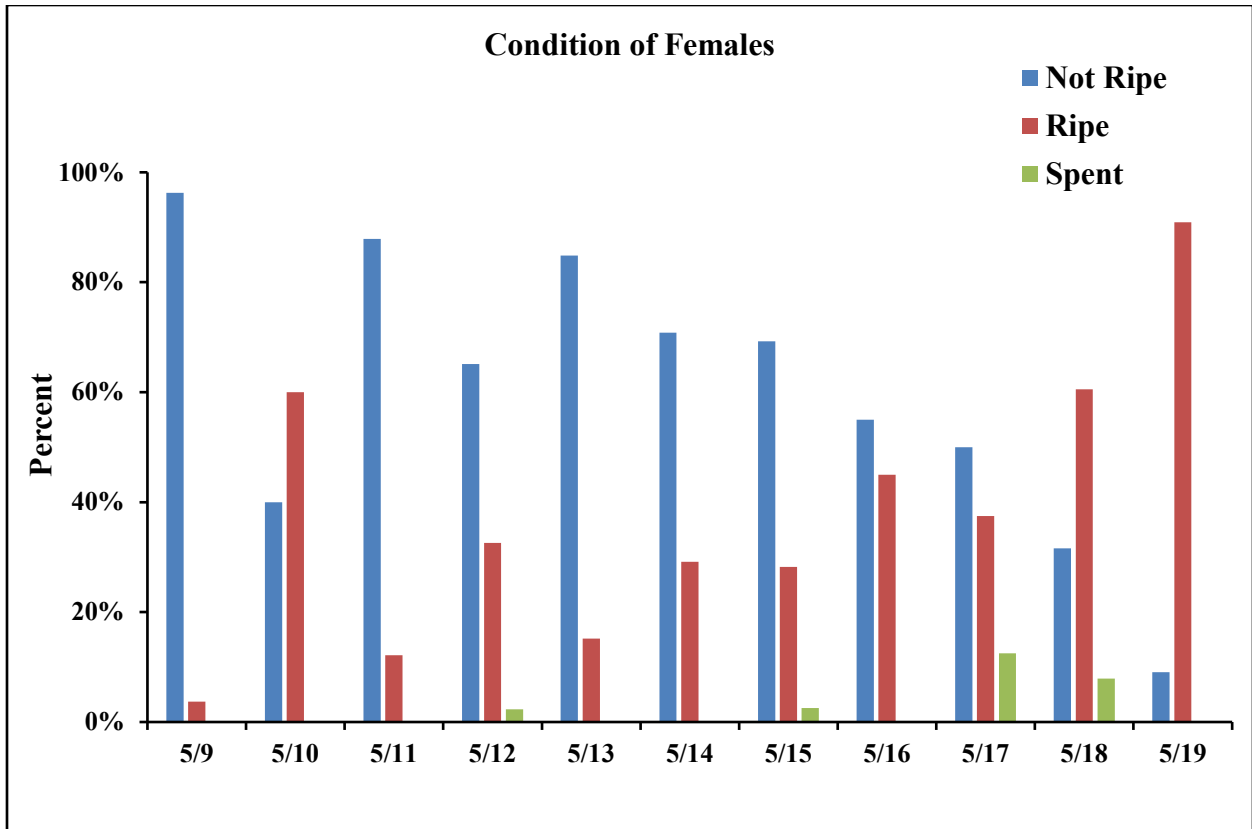


Figure 26. Spawning condition of Arctic grayling females categorized as: not ripe, ripe, or spent, 2023.

Recruitment is defined as those fish  $\geq 200$  mm captured in spring 2023 that would have been too small to mark in 2022. These age-2 and age-3 Arctic grayling are generally between 200 and 240 mm long. Recruitment is variable among the sampling years but follows a peak and decline trend. The highest recorded recruitment of 406 fish was in 2017 then declined from 2018 to 2020. It peaked again in 2022 with 370 fish and began to decline in 2023 (Figure 27). Substantial recruitment was observed in the spring of 2004, 2010, 2014, 2017 and 2022. A substantial recruitment event is defined as  $\geq 300$  fish captured. In 2023, the recruitment was 224 Arctic grayling between 200 to 240 mm long.

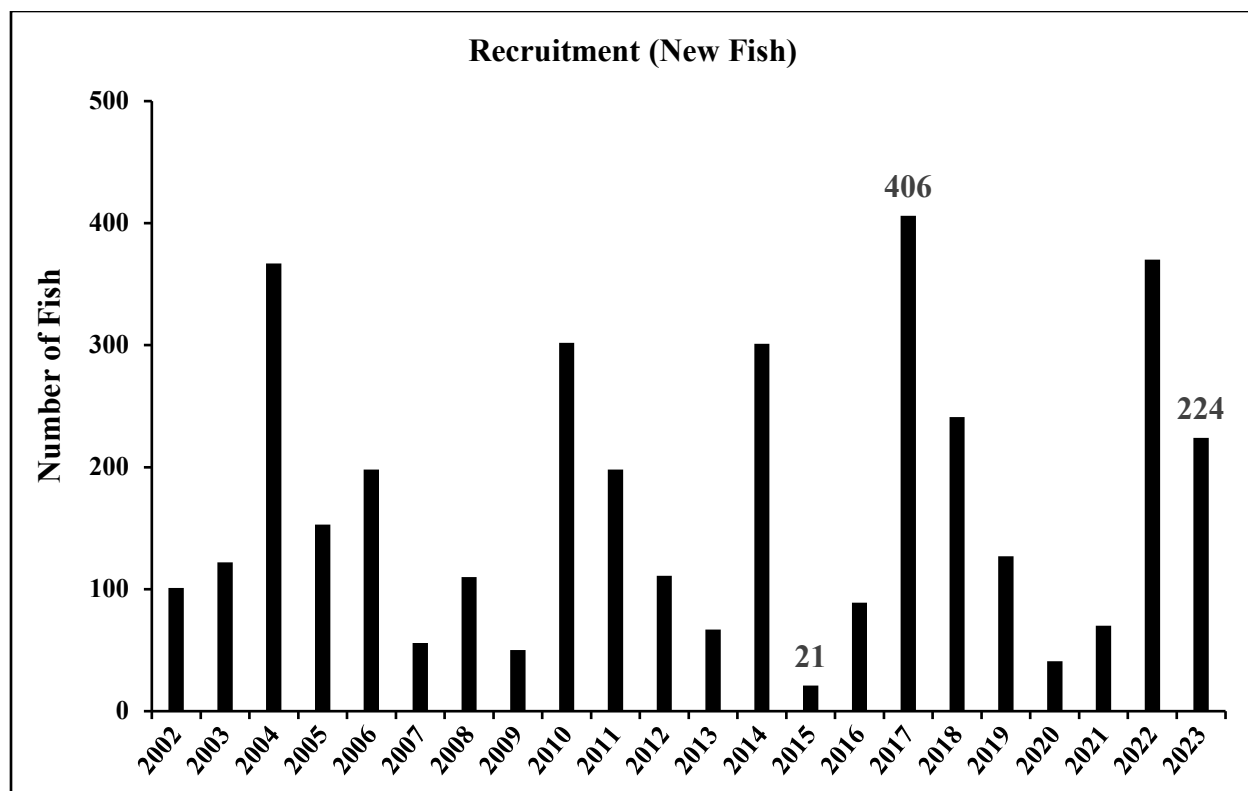


Figure 27. Number of new fish  $\geq 200$  mm that entered the population but would have been too small to tag in the previous year.

The 2022 population abundance estimate of Arctic grayling in the WSR was calculated using spring 2022 as the mark event and spring 2023 as the recapture event. During the spring of 2023 965 Arctic grayling  $\geq 240$ mm were captured, of those 184 were recaptures from the spring 2022 tagging event. The 2023 capture ( $n_2$ ) number does not include fish that were less than 240 mm as they were likely too small to tag in 2022.

The spring 2022 population abundance estimate for Arctic grayling  $\geq 200$  mm was 4,594 fish with a 95% CI of 4,066 to 5,121 fish (Figure 28). The population has declined since 2017 but increased in 2022 and remains above the post mining goal of 800 – 1,600 fish  $\geq 200$  mm. The Arctic grayling population is anticipated to increase in the future based on the substantial number of age-2 and age-3 Arctic grayling captured during the spring 2022 and 2023 sampling events.

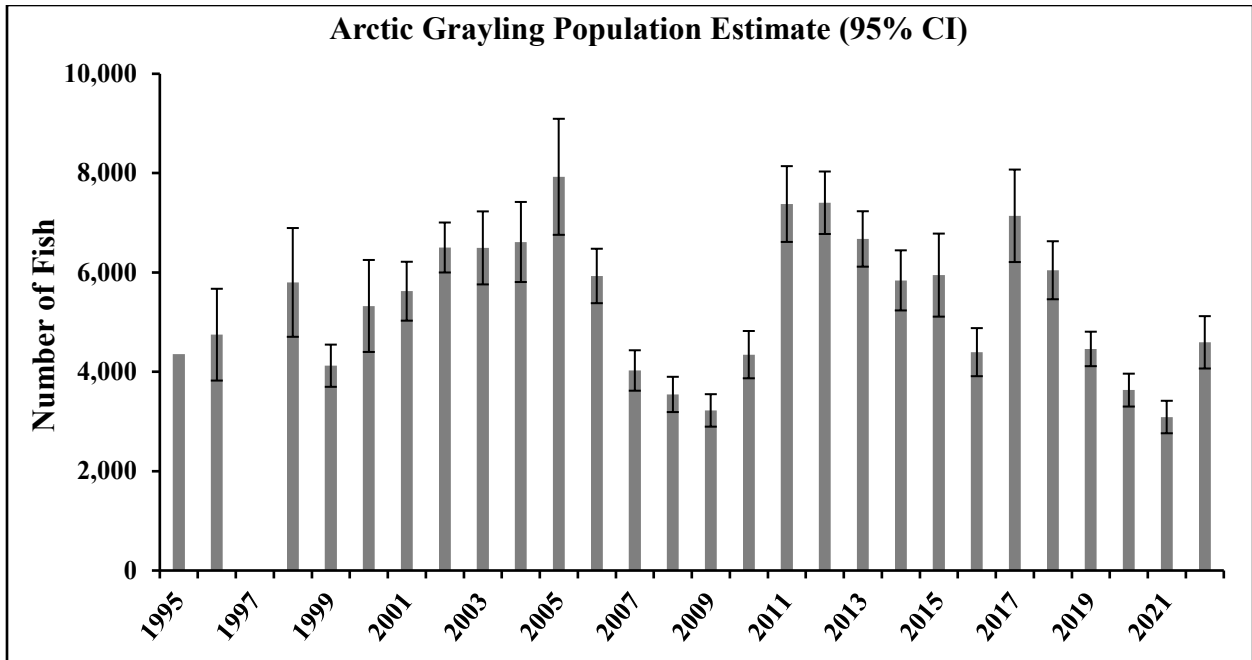


Figure 28. Estimates of the Arctic grayling population in the wetlands and WSR with 95% confidence intervals, 1998 – 2022.

Annual average growth of Arctic grayling in each size class has increased since the construction of the WSR in 1994. Average growth prior to the development of the WSR ranged from 3 to 17 mm per year (Figure 29). In 2023, the average growth rate for fish from 200 to 209 mm at the time of marking was 42 mm (n = 24). For fish from 270 to 279 mm at mark, the average growth was 17 mm (n = 16).

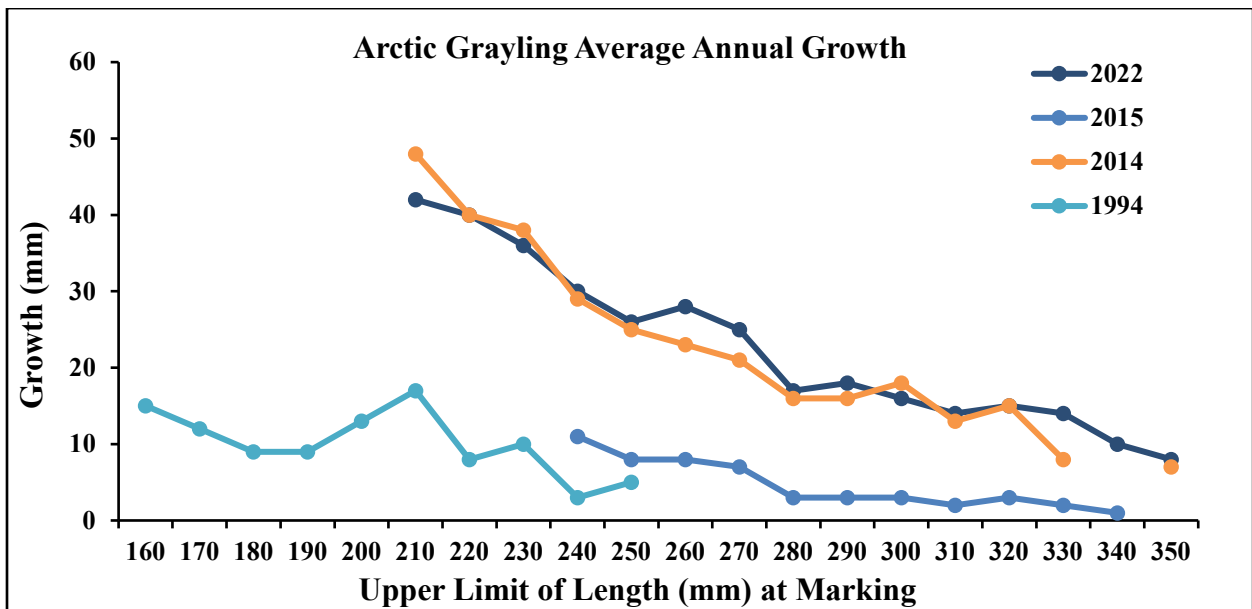


Figure 29. Average annual growth of Arctic grayling by size group in the WSR in selected years including baseline (before WSR) in 1994.

The 2023 length frequency distribution of Arctic grayling caught in Fish Creek and the RO Channel is presented in Figure 30. Data from 1995, before construction of the WSR, are included for comparison. The 1995 data set reflects the stunted condition of the population when growth was limited by available habitat and food sources at that time. The current population has very few large Arctic grayling  $\geq 300$  mm, the oldest fish in the population, but a substantial number of juveniles  $\leq 110$  mm (Figure 30).

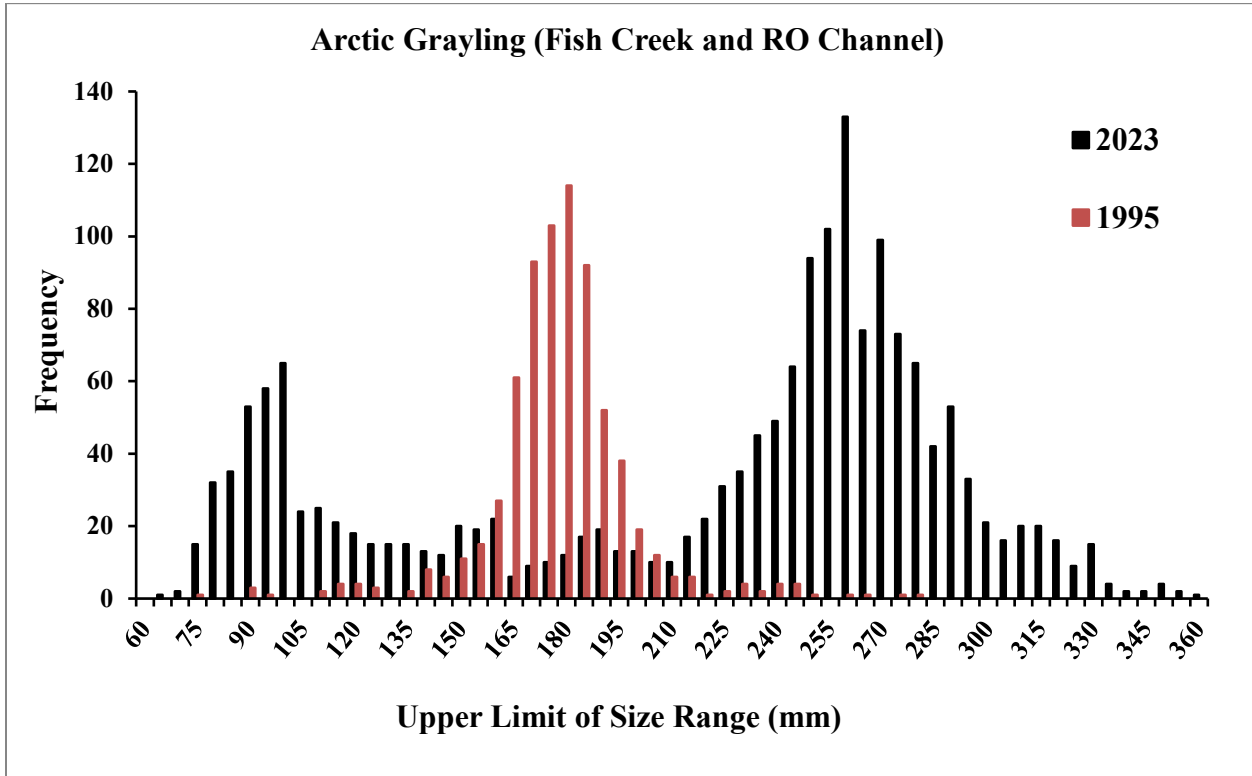


Figure 30. Length frequency distribution of Arctic grayling captured in spring 2023 and 1995. Pond AB is the uppermost waterbody in the wetlands system located immediately downstream of the tailings dam. It is downstream of Outfall 002 in the RO Channel (Figures 21 and 22). The fyke net placed in Pond AB on May 8 captured 201 Arctic grayling of which 189 were of taggable size ( $\geq 200$  mm FL). Captured fish ranged from 101-291 mm FL with an average size of 237 mm (Figure 31). Four Arctic grayling were recaptured from the 2022 sampling event, three of which were tagged in Pond AB. The remaining recapture was initially tagged in the lower Fish Creek wetlands during 2022 sampling. This is the first documented movement of a tagged Arctic grayling from the lower wetlands into Pond AB.

Arctic grayling were able to access Pond AB after RO water discharge from Outfall 002 began in 2019, but access was immediately limited by an increase in beaver activity in the RO Channel.

Some fish can possibly move upstream and downstream through the RO Channel during high water events, but passage is substantially restricted by the numerous beaver dams and vertical obstructions.

Arctic grayling residing in Pond AB appear to be the same cohort of fish that have grown larger from 2022 to 2023 (Figure 31). This can be seen in the length frequency as they increased from an average length of 173 mm to 237 mm from 2022 to 2023 with very few larger or smaller fish captured. Continued sampling of Pond AB will determine if the population remains isolated and if successful spawning occurs.

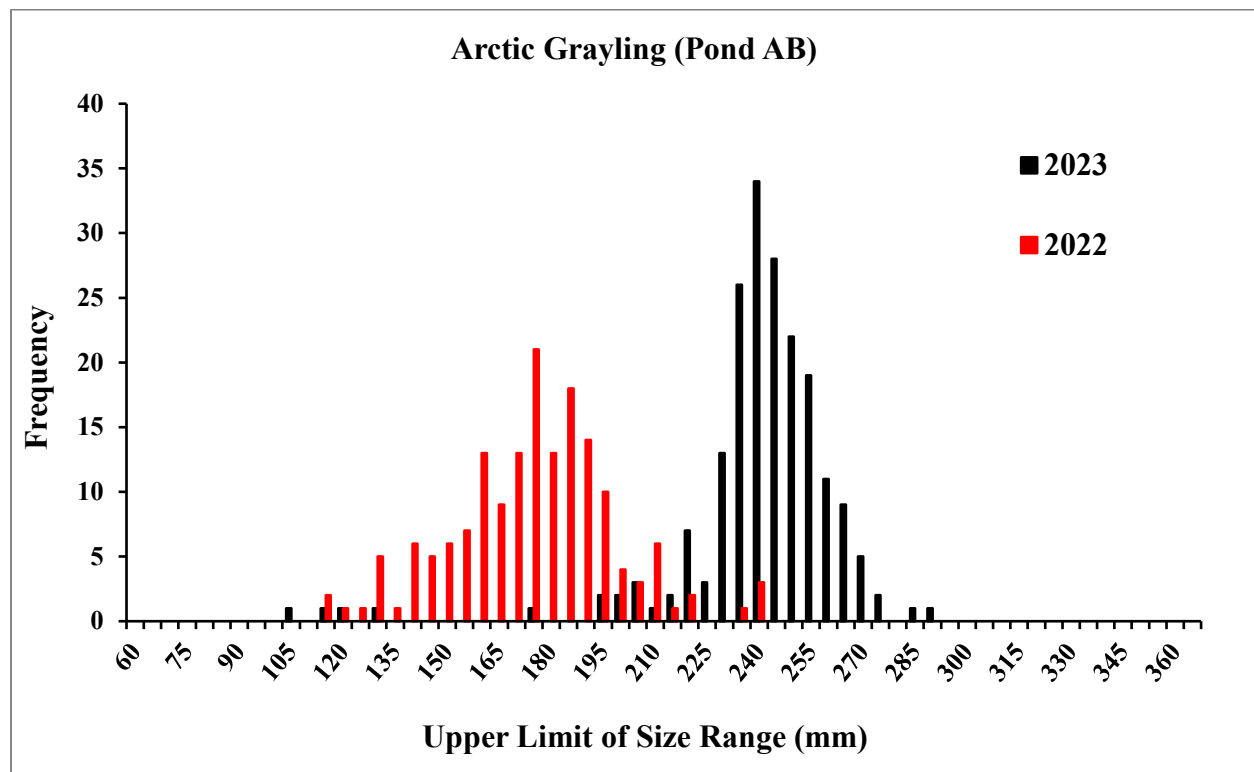


Figure 31. Arctic grayling length frequency captured in Pond AB, 2022 and 2023.

The 2022 population estimate of Arctic grayling in Pond AB was calculated using spring 2022 as the mark event and spring 2023 as the recapture event. During spring 2023, 50 Arctic grayling  $\geq 250$  mm were captured, of those three were recaptures from the spring 2022 Pond AB tagging event. The spring 2022 Pond AB population estimate for Arctic grayling  $\geq 200$  mm was 241 fish with a 95% CI of 60 to 422 fish. This is the first population estimate generated for the potentially isolated Pond AB population.

## Current Issues

Beaver dams throughout the Fish Creek and RO Channel wetlands complex, including the Pond D and F outlets, were rebuilt during 2023. ADF&G staff removed the Pond D beaver dam on May 8, 2023, to allow access into Pond D and further up Fish Creek (Figure 32). Fort Knox staff were successful in removing resident beavers from Fish Creek and the RO Channel during the summer of 2023 to maintain fish passage, but the remaining beavers reestablished multiple dams. Access further up the Fish Creek wetlands is 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 2023.

In the RO Channel, a series of six or more smaller beaver dams created ponds and were partial obstructions to fish passage in 2023. These dams prevent most fish from moving from the WSR into Pond AB. Arctic grayling appear to have adequate areas to spawn and rear when the Fish Creek, specifically the Pond D dam, are consistently removed.



Figure 32. Beaver dam removed by ADF&G from Pond D outlet, May 8, 2023.

In winter 2022/2023, aufeis in Fish Creek was minimal and water was open and flowing by May 8. The RO Channel had substantial aufeis and formed glaciers of frozen overflow two to three feet deep throughout the drainage. No thawed channel with open water was observed on April 27 through May 8. Since 2018, an open channel with warm RO water has been present, but with the reduced discharge of warm RO water from Outfall 002 during the winter of 2023, the lower channel was filled with ice. The RO water cooled and mostly froze in the valley during the winter or went subsurface before connecting with Fish Creek. Water flowing over the ice during the spring remained cold,  $-0.8^{\circ}\text{C}$ , until a channel was thawed on May 15 (Figure 33).



Figure 33. RO Channel remained glaciated with cold water until May 15, 2023.

## **Burbot**

### **Methods**

The annual burbot population assessment in the Fort Knox WSR was performed from September 11 – 20, 2023. Burbot are sampled during the fall when water temperatures are relatively cool to reduce stress during handling. Twenty-four hoop traps were set in the WSR and six in the Gil Pond (Figure 34). The Gil Pond is connected to the WSR with a fish passage culvert (FH15-III-0219-A3). Traps were set at depths ranging from five to 15 feet. Water deeper than 18 meters can be anoxic and was 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 15 to 20 two hoop traps were set in Pond AB to determine if burbot were continuing to inhabit the uppermost water body in the Fish Creek wetlands complex as first documented in 2022 (Bear 2022). The WSR was ice free for the duration of our trapping efforts and water temperatures ranged between 14.9°C on September 11 to 12.8°C on September 20.

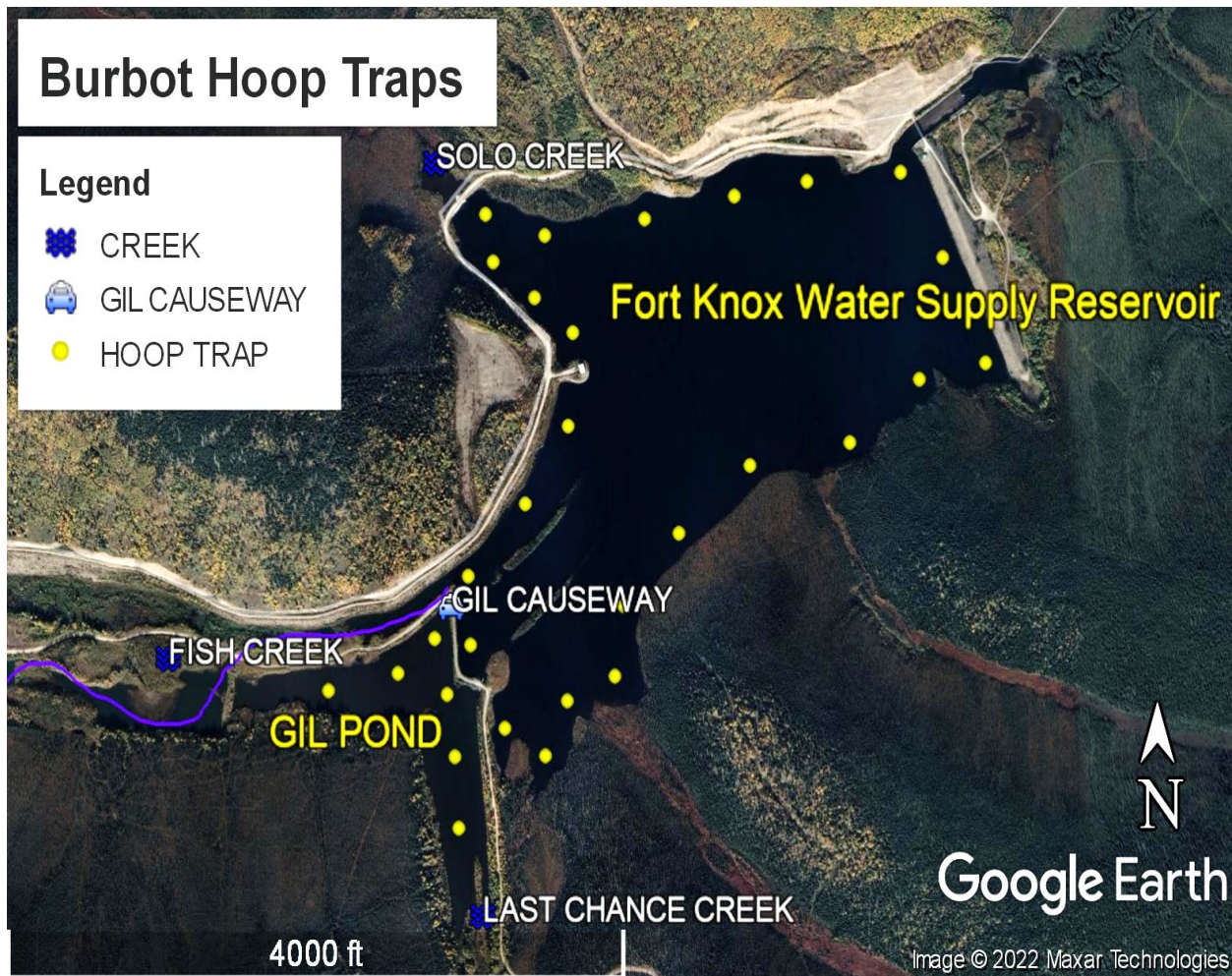


Figure 34. Burbot hoop trap locations in the WSR and Gil Pond.

Burbot were measured to total length (nearest mm), inspected for tags, then released. Un-tagged burbot  $\geq 300$  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 also captured during the 2023 spring Arctic grayling fyke netting event. During the 2023 spring sampling event, 12 burbot were captured and two of these were  $\geq 300$  mm and were tagged with a unique numbered Floy tag. No burbot were captured in the Pond AB fyke net during the 2023 spring sampling (May 8 - 19). The two 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 2022 burbot population estimate used 2022 fall hoop trapping as the mark event, and 2023 fall hoop trapping as the recapture event. During September 2022, 135 burbot were captured, 75 were  $\geq 300$  mm and tagged, 45 of which were  $\geq 400$  mm. In the 2023 capture event, 107 burbot were caught, 80 were  $\geq 300$  mm and tagged, of these 57 were  $\geq 400$  mm, and eight were recaptures from the 2022 marking 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 2022 WSR population estimate for burbot  $\geq 400$  mm is 295 fish (95% CI: 144 to 447 fish). Population estimates from 2012 to 2022 have varied from a low of 80 to a high of 402 fish (Figure 35). The 2022 WSR population estimate for burbot  $\geq 300$  mm was not calculated because there were only one recaptured burbot in fall 2023 between 300 and 400 mm.

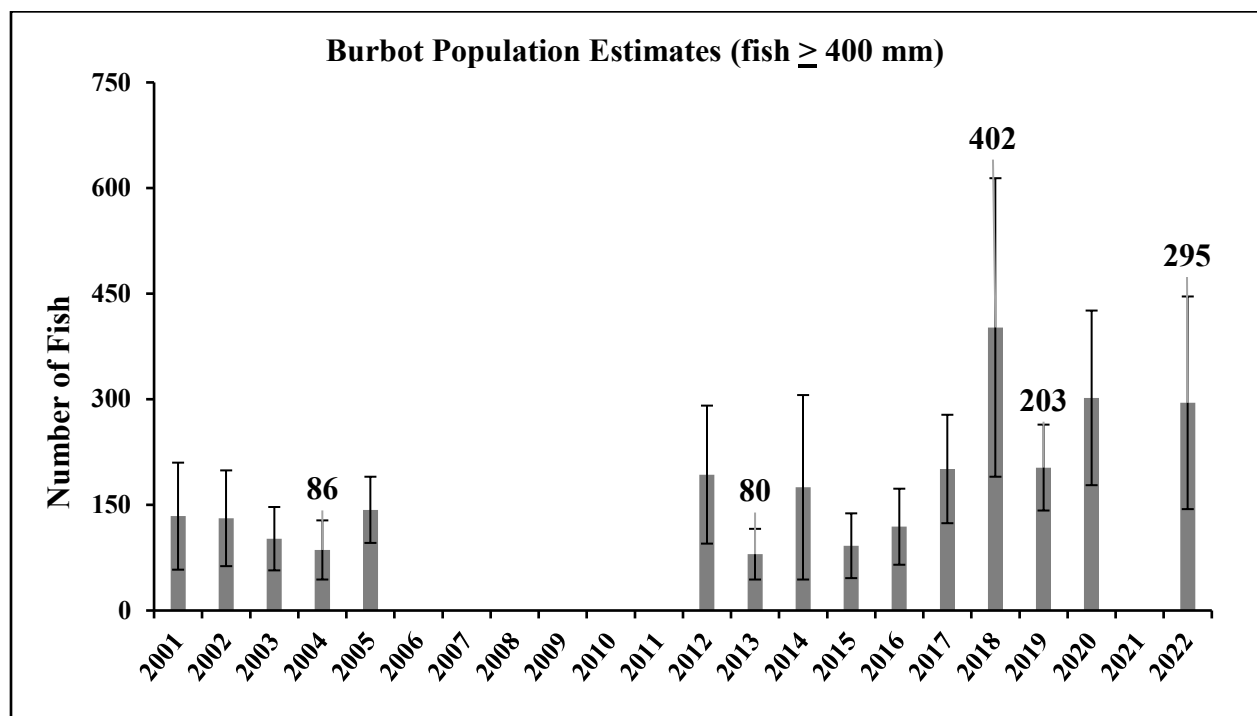


Figure 35. Population estimates of burbot  $\geq 400$  mm in the Fort Knox WSR, 2001-2022 (95% Confidence Interval).

CPUE of all burbot captured in 2023 was 0.40 fish per day per trap (Figure 36). This is similar to the CPUE of 2022, but less than half of the CPUE seen in 2018 (1.1 fish per day per trap). The 2023 CPUE is the third lowest since sampling began in 1996. CPUE of burbot over 400 mm increased from 0.15 fish per day per trap in 2022 to 0.2 in 2023.

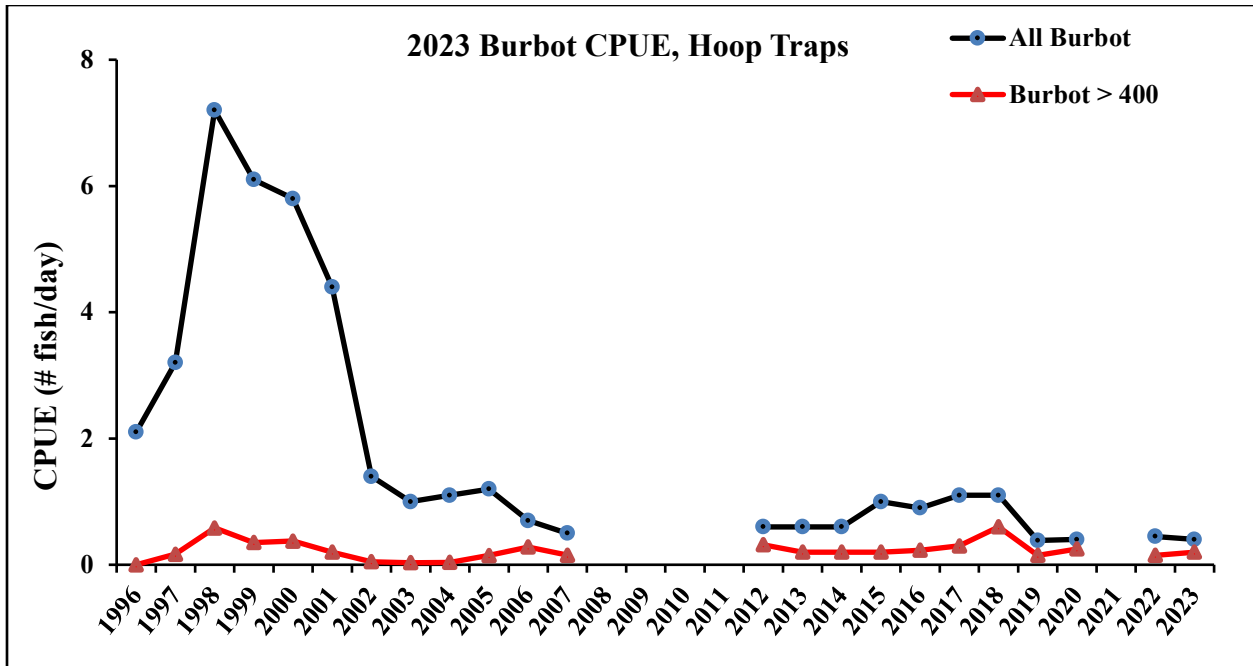


Figure 36. CPUE for all burbot and burbot  $\geq 400$  mm in the Fort Knox WSR.

In 2023, 107 burbot were caught in the WSR with hoop traps. Burbot length ranged from 60 to 980 mm. The burbot length distribution was spread across all size ranges similar to the 2022 length frequency (Figure 37). In 2023, fewer juvenile burbot  $< 200$  mm ( $n = 13$ ) were captured than in 2022 ( $n = 37$ ) (Figure 38).

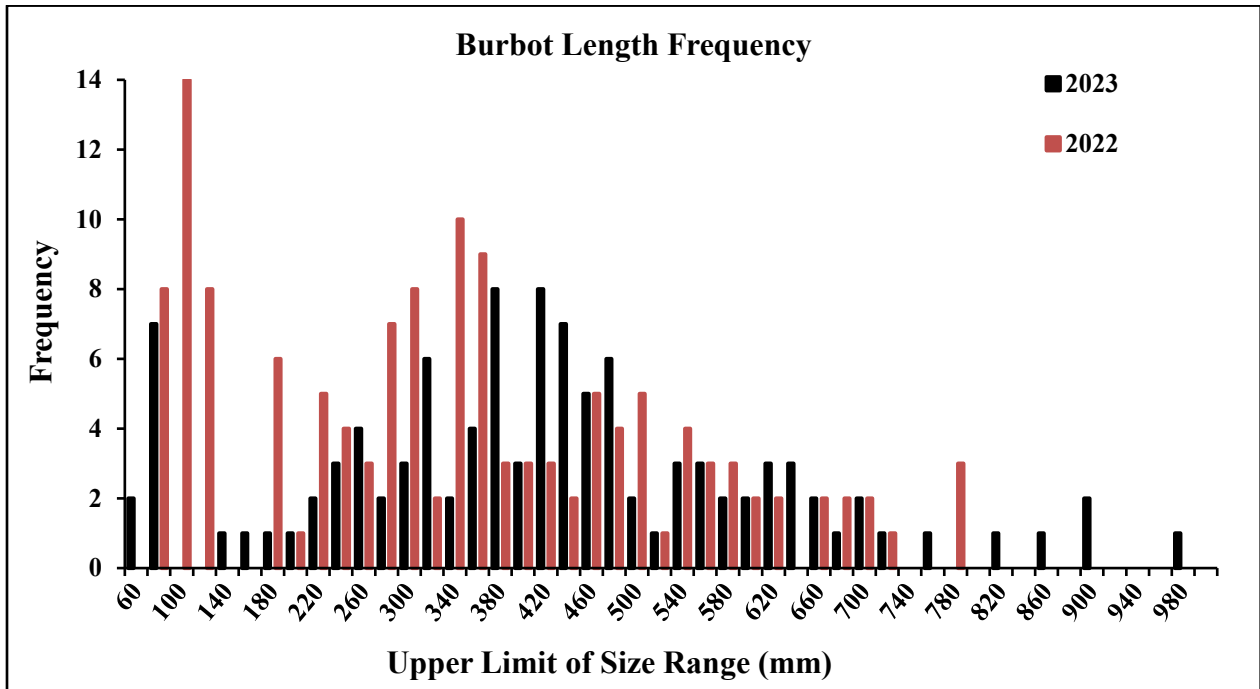


Figure 37. Length-frequency distribution of burbot captured in the Fort Knox WSR, 2022 and 2023.



Figure 38. Juvenile burbot <100 mm captured in WSR, September 2023.

Average annual burbot growth in the WSR has ranged from 24 mm in 2013 to 70 mm in 2016. The 2022 annual growth rate was 51 mm and the overall average annual growth rate since 2000 was 45.5 mm (Figure 39).

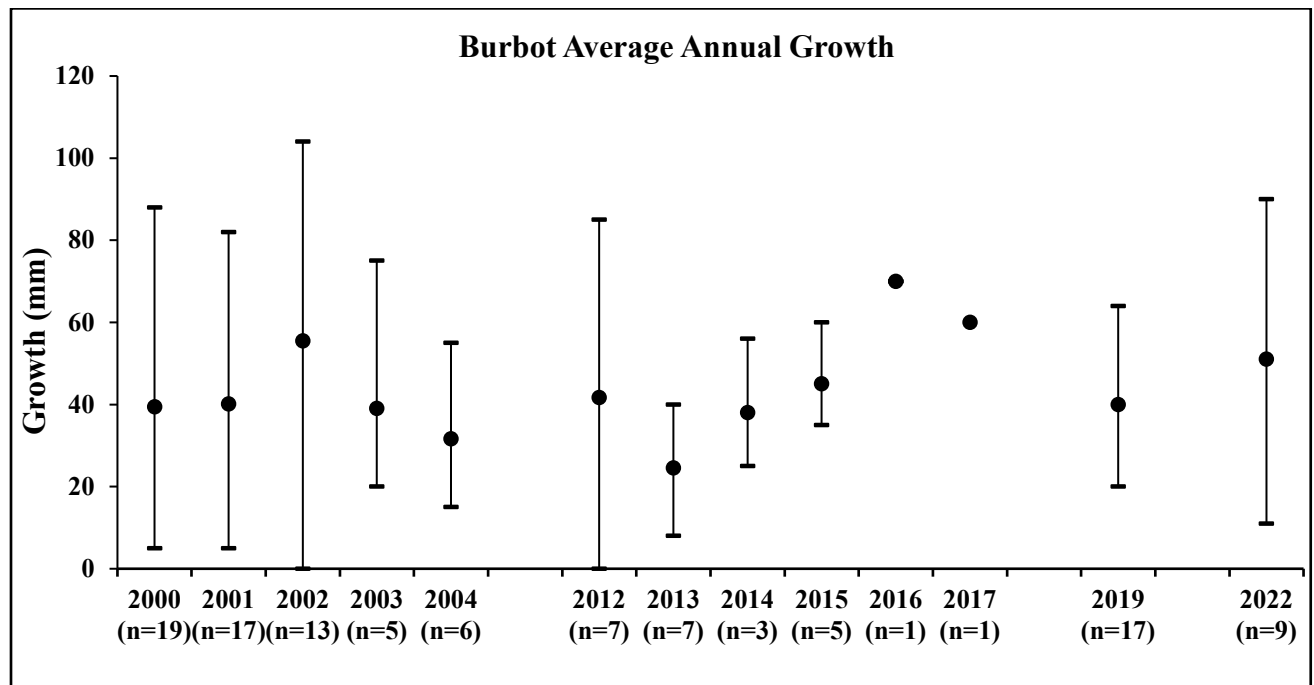


Figure 39. Minimum, median and maximum annual burbot growth (mm) in the WSR 2000-2022.

## **Pond AB Burbot**

Burbot were first documented in Pond AB during 2022 when seven fish were captured during the fall sampling. During the 2023 sampling event, 25 burbot were captured in the Pond AB hoop traps, but sampling time and effort was increased from 2022. In 2023, burbot lengths ranged from 280 to 355 mm with an average of 306 mm, and 14 of these burbot were >300 mm and were tagged. In 2022 the average length was 229 mm, with one fish >300 mm. The one burbot tagged in Pond AB during the 2022 sampling was not recaptured in 2023. It is likely that the fish captured in 2023 were part of the same isolated population of burbot that were residing in Pond AB in 2022. The RO Channel connecting Pond AB to the WSR has numerous beaver dams that may prevent fish passage during typical water levels. These burbot were not included in the WSR burbot population estimate and a separate population estimate for Pond AB cannot be calculated without sufficient recaptured burbot from previous sampling events.

## **Discussion**

The post-mining population goal for Arctic grayling in the WSR was set at 800 to 1,600 fish  $\geq 200$  mm. The spring 2022 population estimate of 4,594 fish  $\geq 200$  mm (95% CI: 4,066 to 5,121 fish) was an increase from the estimated 2021 population of 3,090 fish and above the post-mining population goal. 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 and 2023 sampling events. However other factors such as net capture efficiency and project timing can influence the estimate. The spring 2022 Pond AB population estimate for Arctic grayling  $\geq 200$  mm was 241 fish (95% CI of 60 to 422 fish). This is the first population estimate generated for the potentially isolated Pond AB population.

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 2022 that population was estimated to be 295 fish (95% CI: 144 to 447 fish). A Pond AB burbot population estimate could not be generated for 2022 without sufficient recaptures in 2023 however fourteen burbot  $\geq 300$  mm were tagged during the fall sampling event.

During spring 2023 the Pond AB fyke net captured 201 Arctic grayling with an average length of 237 mm. During fall 2023 burbot sampling 25 burbot were captured in Pond AB with an average length of 306 mm. The average length of both the Arctic grayling and burbot increased from the 2022 Pond AB sampling. The Pond AB fish appear to be in the same cohort as captured in 2022

just one year's average annual growth larger. One Arctic grayling was captured in Pond AB during 2023 sampling had been handled and tagged in the two fyke nets located in the lower Fish Creek wetlands during 2022. This is the first tagged Arctic grayling documented to move from the lower wetlands into Pond AB. Movement into Pond AB is limited but may periodically be possible during period of increased RO water discharge, natural high-water events, or before beaver dams were present in the RO Channel.

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, 2011-2023<sup>2</sup>

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.

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<sup>2</sup> 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).

- 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.



- 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  $\geq 200$  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 ( $\geq 400$  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.

- 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.
- The estimated population of large burbot ( $\geq 400$  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 ( $\geq 200$  mm) for spring 2015 was 5,947 – a slight increase from the 2014 estimate.
- Our estimated population of large burbot ( $\geq 400$  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.

- 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 ( $\geq 200$  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 ( $\geq 200$  mm) for Spring 2017 was 7,141, which is an increase of 2,745 over 2016.
- Our estimated population of large burbot ( $\geq 400$  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.

## 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 Barnes 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 at 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 than 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 ( $\geq 200$  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 ( $\geq 400$  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.

- 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 ( $\geq 200$  mm) for Spring of 2019 was 4,461 fish with a 95% CI from 4,414 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 ( $\geq 400$  mm) is 203 fish with a 95% CI from 142 to 264 fish.
- October 2020, Fort Knox began hauling ore to Barnes Creek Heap Leach (BCHL) and began leaching processes.
- On November 20, Barnes 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.

- 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 ( $\geq 200$  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  $\geq 300$  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 auffs built up during the 2021 / 2022 winter, similar to what was observed in April 2020 and 2021.

- 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 wildlife mortality report for three 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 mortalities 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 to May 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 to 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 ( $\geq 200$  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  $\geq 300$  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 alimy aculpin 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.



- 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.

## 2023

- Fort Knox continued discharge of RO water from outfall 002 into the RO Channel Wetlands. Outfall 001 not operated in 2021. Outfall 002 discharged 1,260 acre-feet of RO water.
- 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 lower than recorded in 2021/2022 from the reduced RO discharge winter 2022/2023.
- April 14, the water temperature in the RO Channel near Pond AB was 1.66 °C from warm RO discharge water compared to 0.01 °C in Fish Creek near Pond F from natural spring thawing.
- The WSR outlet spillway had substantial aufeis built up during the 2022 / 2023 winter, similar to what was observed in April 2022.
- April 27, ADF&G Habitat deployed two hobo temperature loggers into Fish Creek at Pond F and the lower RO Channel near its confluence with Fish Creek.
- April 27, The lower RO Channel had aufeis filling the valley with water flowing over the glaciated ice. The water temperature near its confluence with Fish Creek was -0.08 °C compared to 2.69 °C in 2022. The reduced RO discharge rate allowed water to cool and freeze in the RO Channel. In years with high RO Water discharge a thawed channel and flowing water was present.
- From May 8 to 19 ADF&G sampled with a fyke net placed in Fish Creek and from May 15 to 19 a fyke net in the RO Channel (after it thawed) to capture Arctic grayling and burbot moving into developed wetlands.
- The 2022 WSR and Fish Creek wetlands population estimate of Arctic grayling ( $\geq 200$  mm) was 4,594 fish with a 95% CI of 4,066 to 5,121 fish.
- From May 8 to 19 a fyke net was placed in Pond AB, the uppermost waterbody in the Fish Creek wetlands. It captured 201 Arctic grayling with an average size of 237 mm.
- The 2022 Pond AB population estimate of Arctic grayling ( $\geq 200$  mm) was 241 fish with a 95% CI of 60 to 422 fish. This is the first population estimate generated for the potentially isolated Pond AB fish. However, one tagged Arctic grayling from the WSR was captured in Pond AB, the first documented to move through the RO channel.

- September 11 – 20, ADF&G staff sampled burbot in the WSR with hoop traps. The 2022 WSR population estimate for burbot  $\geq 400$  mm is 295 fish (95% CI: 144 to 447 fish).
- September 11 - 20, hoop traps were set in Pond AB and 25 burbot were captured between 280 mm to 355 mm with an average of 306 mm. A population estimate could not be generated with sufficient recaptures from the 2022 sampling event.
- October 1, 2023 – April 2024, winter discharge rate of RO water was reduced and maintained during the winter.

**Appendix 2. Water Quality Data, from the Fort Knox Water Supply Reservoir (WSR), April 14, 2023.**

Site Number (Name)	Depth (m)	Temperature (°C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	ORP (mV)
1 (Middle WSR)	1	0.9	54.2	7.5	177.3	6.6	326
	2	1.5	55.7	7.6	195.9	6.6	327
	3	2.3	57.3	7.7	203.8	6.7	327
	4	2.7	55.4	7.5	205.9	6.8	327
	5	3.0	51.0	6.8	205.9	6.8	327
	6	3.2	48.7	6.4	207.0	6.8	328
	7	3.4	41.4	5.5	208.3	6.8	329
	8	3.4	32.0	4.2	209.8	6.8	330
	9	3.5	13.2	1.9	212.5	6.8	332
	10	3.7	4.8	0.6	220.4	6.8	333
	11	3.7	2.7	0.4	242.1	6.6	334
	12	3.9	2.1	0.3	278.2	6.6	336
	13	4.0	1.9	0.3	319.3	6.6	336
2 (WSR Near Dam)	1	0.3	51.7	7.3	150.1	6.4	385
	2	1.0	49.0	6.9	169.8	6.4	384
	3	1.7	49.8	6.9	194.5	6.5	383
	4	2.4	49.7	6.7	202.3	6.5	381
	5	2.7	48.4	6.4	205.8	6.6	380
	6	3.0	47.2	6.3	208.0	6.6	378
	7	3.2	46.7	6.2	209.4	6.7	377
	8	3.4	44.3	5.8	210.6	6.7	376
	9	3.5	39.1	5.2	212.9	6.7	376
	10	3.6	29.1	3.8	215.2	6.7	376
	11	3.7	14.1	1.9	223.0	6.6	377
	12	3.8	5.1	0.7	252.5	6.6	379
	13	3.8	2.7	0.4	263.6	6.5	379
	14	4.1	2.0	0.3	320.0	6.5	377
	15	4.2	1.9	0.3	373.9	6.5	376
	16	4.2	1.9	0.2	394.0	6.6	374
	17	4.0	1.9	0.2	397.1	6.7	371
	18	3.9	1.9	0.2	399.2	6.8	370

3 (Solo Bay)	1	0.50	62.5	9.00	159.9	6.30	322
	2	0.80	55.5	7.90	175.1	6.40	321
	3	1.70	50.8	7.00	193.8	6.40	321
7 (Last Chance Bay)	1	0.20	57.5	8.20	131.7	7.00	297
	2	0.80	48.8	6.90	158.2	6.90	300
	3	1.40	27.7	3.90	223.9	6.90	306
11 (Polar Bay)	1	0.10	78.1	11.20	107.1	7.20	278
	2	0.60	62.8	9.00	164.7	7.00	284
	3	1.10	56.5	7.90	197.7	7.00	285
	4	2.50	56.5	7.60	201.9	7.00	285
	5	2.90	56.9	7.50	203.5	7.00	285
	6	3.20	55.0	7.20	204.4	7.00	285
	7	3.50	51.0	6.70	205.5	7.00	286
	8	3.90	18.6	2.40	226.2	6.90	290
12 (Fish Creek Bay)	1	0.10	82.0	11.80	108.2	7.20	319
	2	0.70	64.6	9.20	156.6	7.10	322
	3	1.50	43.6	6.00	183.4	7.00	324
	4	2.20	30.4	4.00	196.6	6.90	315

**Appendix 3. Population estimates of Arctic Grayling > 200 mm in the Fort Knox Water Supply Reservoir (WSR), 1995-2022.**

Year	<sup>1</sup>	Population Estimate	95% Confidence Interval
1995	<sup>2</sup>	4,358	
1996	<sup>3</sup>	4,748	3,824 - 5,672
1996	<sup>4</sup>	3,475	2,552 - 4,398
1998	<sup>5</sup>	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
2022		4,594	4,066 - 5,121

<sup>1</sup>Population estimates from 1995-1996 include fish  $\geq 150$  mm, in all other years fish  $\geq 200$  mm.

<sup>2</sup>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.

<sup>3</sup>The 1996 estimate was made with a capture and recapture event in summer 1996 using fyke nets.

<sup>4</sup>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.

<sup>5</sup>Starting in 1998 through 2022 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, 2021-2023.**

<b>Upper Limit of Size (mm)</b>	<b>Average (mm)</b>	<b>Maximum (mm)</b>	<b>Minimum (mm)</b>	<b>Sample Size</b>
210	42	68	21	24
220	40	56	17	20
230	36	56	7	19
240	30	41	6	14
250	26	40	6	15
260	28	50	0	19
270	25	37	11	8
280	17	37	1	16
290	18	31	4	14
300	16	26	4	11
310	14	25	0	15
320	15	31	0	4
330	14	14	14	1
340	10	16	0	4
350	8	8	8	1

**Appendix 5. Population Estimate of Burbot ( $\geq 400$  mm) in the Fort Knox Water Supply Reservoir (WSR), 2001-2022.**

<b>Year</b>	<b>Population Estimate</b>	<b>95% Confidence Interval</b>
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
2021	No Population Estimates Performed	
2022	295	144 - 447

**Appendix 6. Population estimates of Arctic Grayling > 200 mm in the Fort Knox Pond AB, 2022.**

<b>Year</b>	<b>Population Estimate</b>	<b>95% Confidence Interval</b>
2022	241	60 - 422

**Appendix 7. Winter (October 1 to April 30) water use from the WSR, 1997 to 2015.**

<b>Year (Oct 1 to April 30)</b>	<b>Acre-Feet of Water Removed</b>	<b>Percent of Water Removed</b>
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		

**Appendix 8. Total RO water discharge from Outfall 001 and 002 into RO Channel Wetlands Complex, 2015 - 2023.**

<b>Year</b>	<b>Acre-Feet of RO Water<sup>1</sup></b>
2015	163
2016	461
2017	618
2018	806
2019	6,681
2020	9,663
2021	8,752
2022	4,682
2023	1,260

<sup>1</sup>RO Water Discharged from Outfall 001 (2015 – 2018) and Outfall 002 (2019 – 2023).