Technical Report No. 21-01

Fish and Water Quality Monitoring at the Fort Knox Mine, 2020

by

Chad E. Bear and Alvin G. Ott

February 2021

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

Symbols and Abbreviations

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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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By

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February 2021

Cover: Floy tagged Arctic grayling in Fish Creek near the Ft. Knox water supply reservoir, May 9, 2020. Photograph by Chad Bear.

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This document should be cited as:
Bear, C.E. and A.G. Ott. 2021. Fish and Water Quality Monitoring at the Fort Knox Mine, 2020. Alaska Department of Fish and Game, Technical Report No. 21-01, Fairbanks, Alaska.

Table of Contents

List of Tables

List of Figures

Acknowledgements

We thank Fairbanks Gold Mining Inc. (FGMI) Bartly Kleven, Mark Huffington, Dave Stewart and William Collingwood for their continued support of our work to monitor fish and wildlife resources in the water supply reservoir, tributaries, and developed wetlands.

We would also like to thank Nik Nichols, Justin Burrows, Maria Wessel, Chelsea Clawson, and Haley Sorensen for their assistance with 2020 fieldwork: and Maria Wessel and Audra Brase for constructive reviews of this report.

Executive Summary

Water Quality

Dissolved oxygen (DO) concentrations were measured in the water supply reservoir (WSR) in early April 2020. For the sixth consecutive year, DO concentrations were some of 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 wetland complex downstream of the tailings dam.

During 2020 RO water discharge continued and was mostly confined to the North Fork Fish Creek drainage before combining with Fish Creek and entering the WSR. The input of warm (6.0°C) RO water raised the North Fork Fish Creek water temperature to 3.01°C at the Pond AB outlet on April 10, 2020 compared to 0.23°C in Fish Creek at Pond F.

Arctic Grayling in the Water Supply Reservoir

Sampling for Arctic graying was conducted from April 24 – May 9, 2020 as fish moved from the WSR into the developed wetlands for spawning. This was 14 days later than sampling began in 2019. The catch per unit of effort (CPUE) and spawning condition increased between April 27 and May 9 as the average water temperature between both creeks rose above 4°C but spawning may have occurred after sampling ended on May 9 as no fish were classified as spent during sampling.

Recruitment is variable among the sampling years but was highest in 2017 (406), with declines in 2018 (241), 2019 (127) and 2020 (41). During the 2020 sampling event 3,865 juvenile Arctic grayling were captured with an average size of 101 mm. These age-1 Arctic grayling demonstrated good success and survival from the 2019 spawning event but are not included in the recruitment estimate.

The spring 2019 population estimate for Arctic grayling $\geq$ 200 mm fork length (FL) was 4,461 fish (95% CI: 4,114 to 4,808 fish).

Burbot in the Water Supply Reservoir

Burbot sampling was conducted during the Arctic grayling sampling event from April 24 to May 9, 2020, and again from September 29 to October 9, 2020. During the two sampling events, 123 burbot were captured in the developed wetlands and WSR. These fish ranged in size from 98 to 825 mm TL. In 2020, 78 of the captured burbot were $\geq$ 400 mm TL with 18 fish having been previously captured and were used for the 2019 population estimate. The spring/fall 2019 population estimate of burbot $\geq$ 400 mm (TL) was 203 fish (95% CI: 142 – 264 fish).

Introduction

Fairbanks Gold Mining Incorporated (FGMI) began construction of the Fort Knox hard-rock gold mine in March 1995. The mine is located about 25 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 impoundment, water supply reservoir (WSR), and related facilities (Figure 1). Construction of the WSR dam and spillway was completed in July 1996. In 2007, permits were issued for the construction, operation, and closure of a valley fill heap leach facility located in Walter Creek upstream of the tailings pond. In 2020, the Barnes Creek Heap Leach was issued an approval to operate and ore continued to be processed through both the mill and Walter Creek valley fill heap leach. Pit mining continued expansion west into land leased from the State of Alaska in 2018.

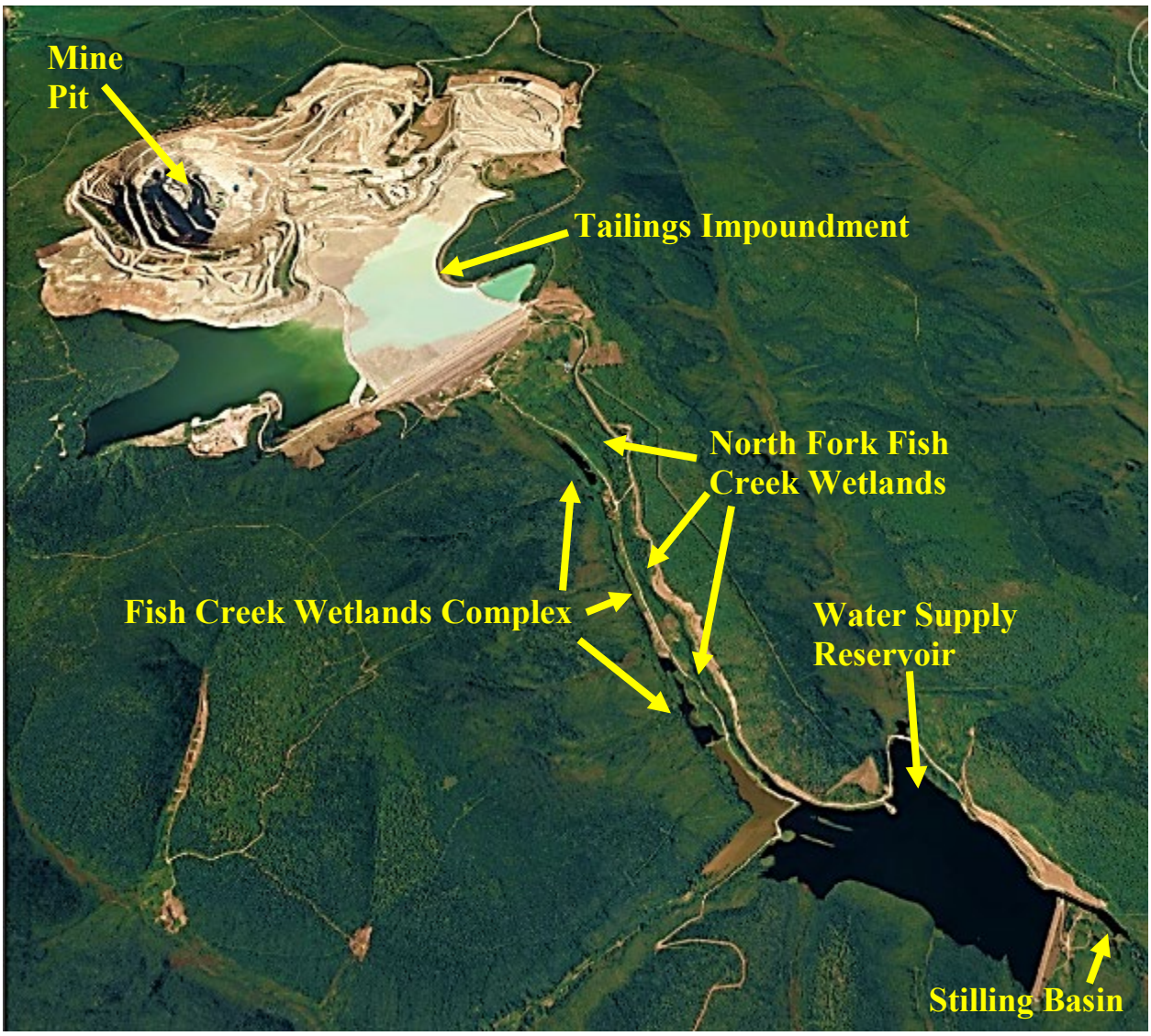

Figure 1. Fort Knox gold mine and associated facilities.

The WSR was constructed to be the primary water supply for mining activities and mill operations at Fort Knox. When full, the WSR contains about 3,363 acre-feet (1.1 billion gallons) of water (Figure 2). Water levels have remained mostly constant since 1998, except during the 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 (Table 1).

Figure 2. Fort Knox Water Supply Reservoir (WSR) October 2020.

Spawning populations of Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) exist in the WSR, and smaller populations of both Arctic grayling and burbot inhabit the Stilling Basin below the WSR outlet spillway. Arctic grayling spawning occurs predominantly in the wetland complex between the WSR and the tailings dam (Figure 1). Burbot spawning, as documented by radio telemetry, likely occurs in Solo Bay where Solo Creek enters the WSR (Figure 6). Arctic grayling recruit into the stilling basin by going over the WSR spillway when the water is high. Burbot recruitment into the stilling basin by passage over the spillway was documented in 2019 when two burbot tagged in the WSR were captured in stilling basin hoop traps during sampling.

Table 1.Winter (October 1 to April 30) water use from the WSR, 1997 to 2020.

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
2015/2016		0		0
2016/2017		0		0
2017/2018		0		0
2018/2019		0		0
2019/2020		0		0

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) filtration into upper Fish Creek. The discharge was authorized by permits issued by the Alaska Department of Environmental Conservation (ADEC). During 2019 FGMI brought two additional RO facilities (RO2 and RO3) online and began discharging from Outfall 002 on January 15, 2019 (Figure 3). Water discharge through the RO systems has been increasing since 2015. The 2018 total discharge was 806 acre-feet. The addition of the two new RO facilities in 2019 increased the total discharge to 6,681 acre-feet of water (Table 2). During 2020 9,663 acre-feet of RO water was discharged into Fish Creek. This influx of RO water is most likely the reason for increased dissolved oxygen (DO) concentrations in the WSR starting in 2015 as documented in the late winter water quality sampling (Figure 16).

Table 2. Total Reverse Osmosis (RO) water discharge from Outfall 001 and 002 into Fish Creek, 2015 - 2020.

Year (Jan 1 to Dec 31)	Acre-Feet of RO Water Discharged from Outfall 001 and 002
2015	163
2016	461
2017	618
2018	806
2019	6,681
2020	9,663

Figure 3. RO Discharge at Outfall 002, March 31, 2020.

The WSR outlet spillway had substancial aufeis built up from the 2019 / 2020 winter (Figure 4). The combination of a colder than average December and January and the increase in water entering the drainage resulted in sheet flow across the spillway which created ice. The aufeis was contained within the spillway walls. Aufeis appeared to be 8 to 9 feet thick near the lower end of the spilway and was within two feet of the top of the spillway walls. Water was flowing under the ice in the center channel during the April 10, 2020 WSR Late Winter Water Quality sampling and no water was flowing on top of the current ice layer.

Figure 4. Spillway at outlet of Water Supply Reservoir on April 10, 2020.

Fort Knox's rehabilitation of the fish and wildlife habitats disturbed during mine operations has been concurrent with permit requirements, to the extent practicable, and natural revegetation of some areas has been rapid. The Fish Creek wetland complex was increased in size and available fish habitat in 2019 when discharged RO water was diverted into the channel on the north side of Centerline Road (Figure 5). 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 during establishment of the main creek channel. Arctic grayling adapt quickly to new spawning and rearing areas and during the April 2020 ADF&G fish sampling event a fyke placed in North Fork Fish Creek captured numerous Arctic grayling moving upriver to utilize the new wetlands during their spring spawning timing.

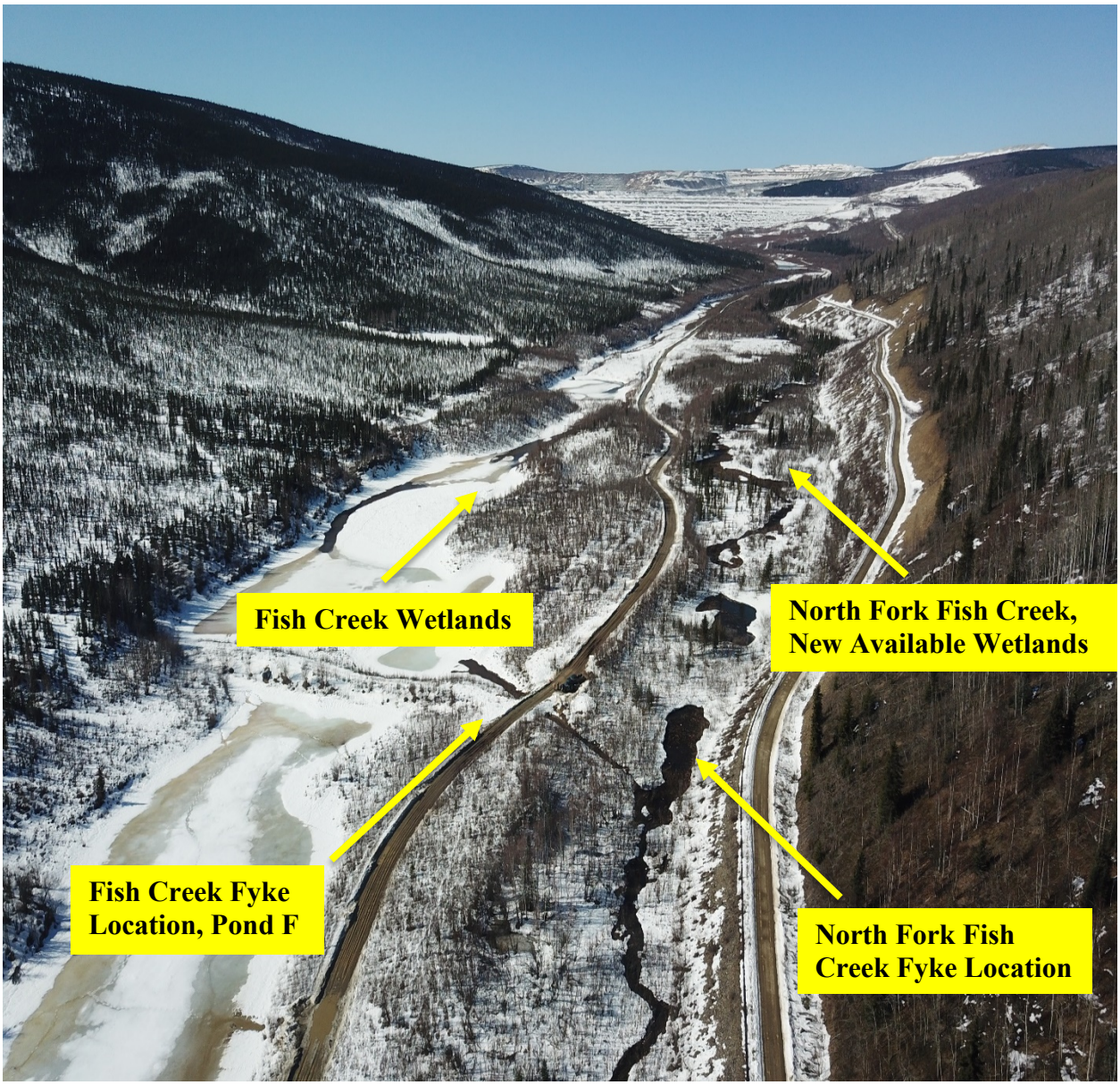

Figure 5. Fish Creek Wetlands (Left) and North Fork Fish Creek Wetlands (Right) April 24, 2020.

Fish monitoring has been performed annually at the Fort Knox mine and related facilities since 1992 and water quality sampling since 1997. This report summarizes fish and water quality data collected during 2020 and discusses these findings in relation to previous work. A chronology of events from 2011 to 2020, with emphasis on biological factors, is presented in Appendix 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). The References section of this report contains a comprehensive list of all technical biological reports for Fort Knox.

Methods

Water Quality

Water quality sampling was conducted on April 10, 2020, when the WSR was ice covered. Six sites in the WSR have been sampled annually since 1998 with two new sites in the wetland complex included starting in 2018 (Figure 6). Measurements of Fish Creek and North Fork Fish Creek were taken to document the effect of increased RO water discharged from Outfall 001 and 002 into the wetlands complex. Vertical profiles of water temperature (°C), 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. Two Hobo temperature loggers were deployed, one in Fish Creek at the Pond F outlet, one in North Fork Fish Creek near the Pond AB culvert below RO Outfall 002 discharge water influence (Figure 6).

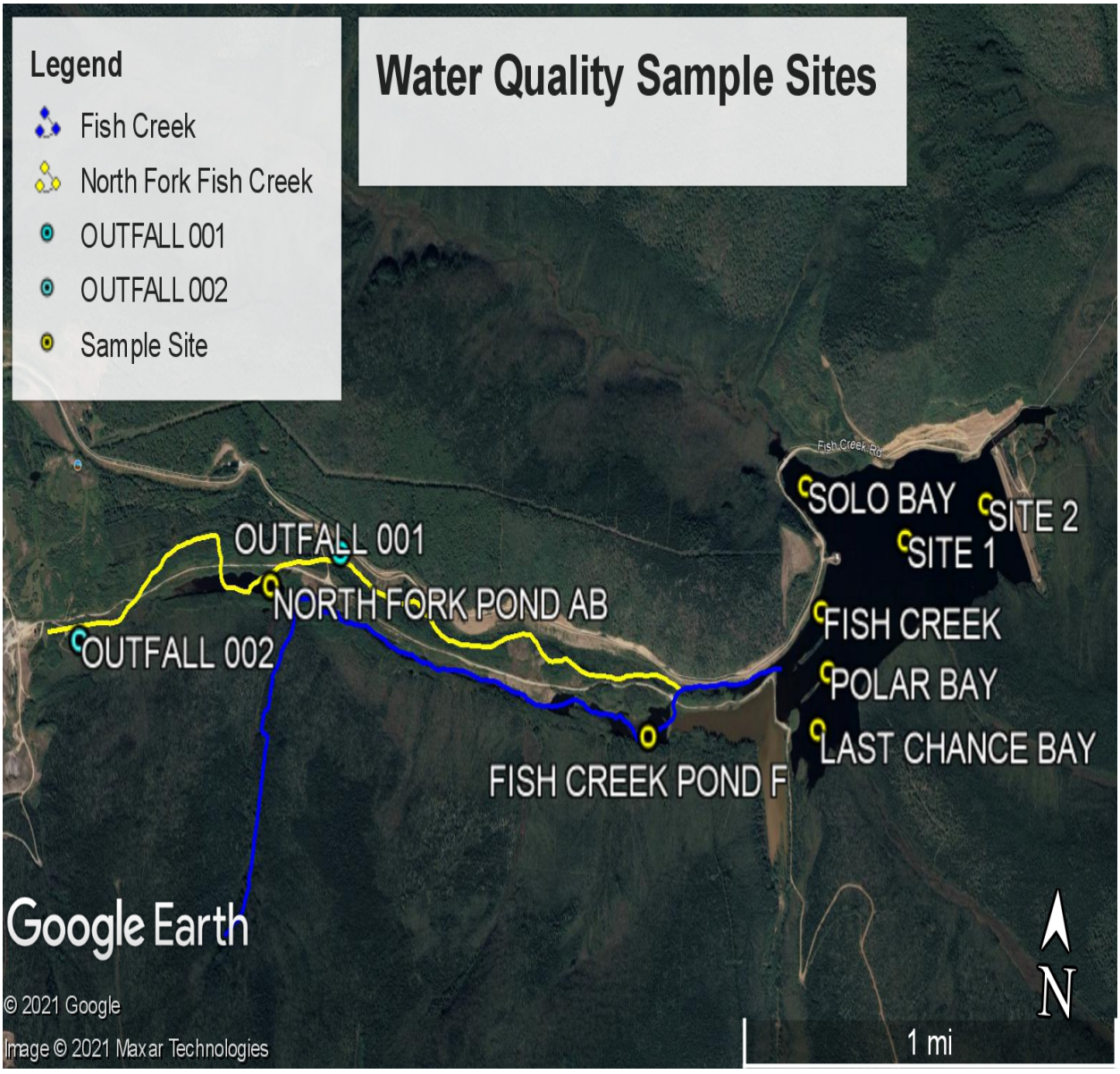

Figure 6. Fort Knox Water Supply Reservoir water quality sample sites, April 10, 2020

Fish

Fish sampling methods included fyke nets, hoop traps, angling, and visual observations. On April 24, 2020, one fyke net was set in Fish Creek near the Pond F outlet (Figure 7). A second fyke net was placed in North Fork Fish Creek on April 28 to determine if Arctic grayling were recruiting into the new available wetland habitat. Fyke nets were fished in the same locations without being moved until May 9. The fyke nets were checked every 1 to 2 days and fished effectively for the sampling period. Thirty hoop traps total were baited with herring and used to capture burbot from September 29 to October 9, 2020. Twenty-four traps were placed in the WSR and six in Gil Pond which is connected to the WSR by several passage culverts (Figure 8).

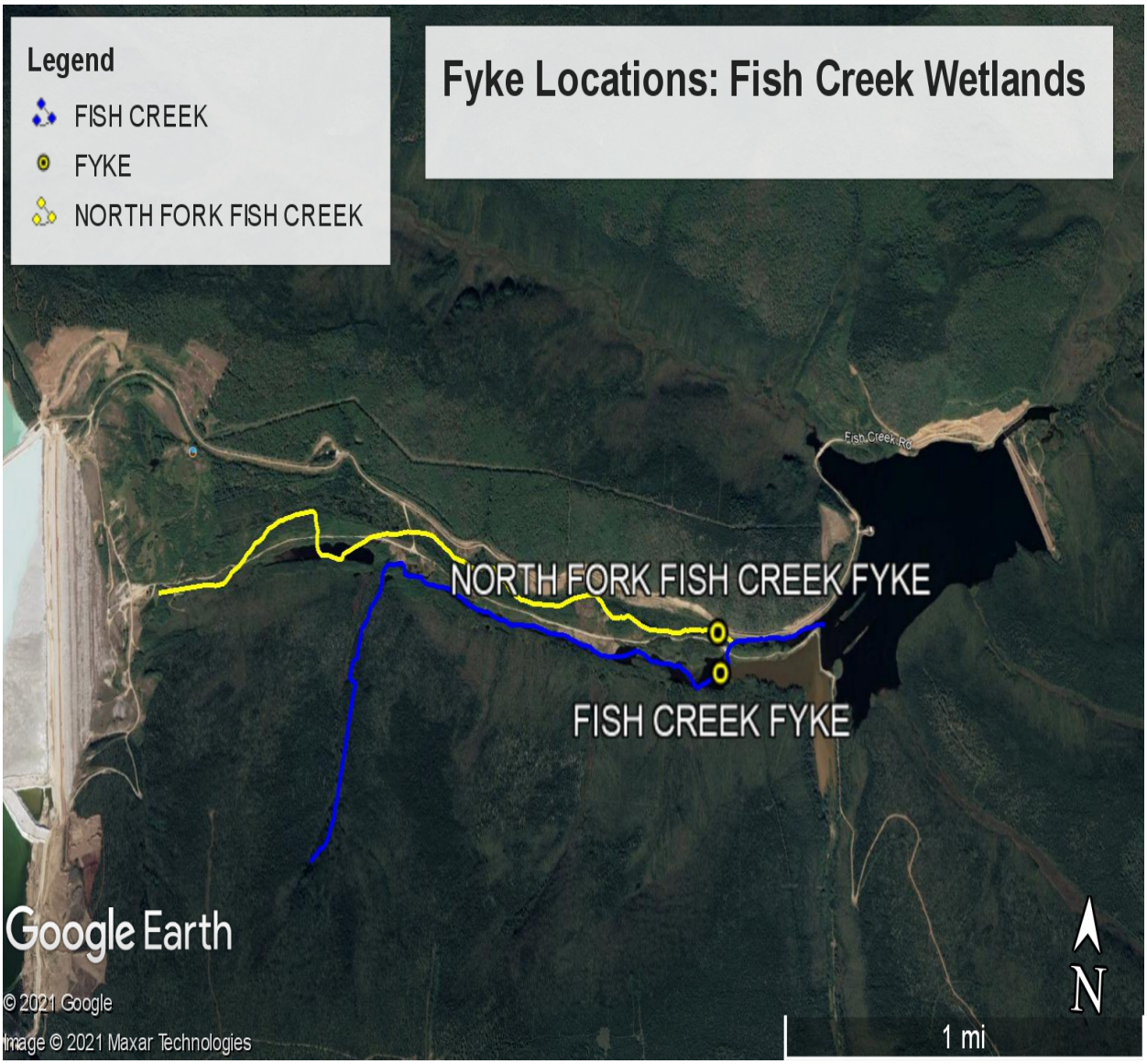

Figure 7. 2020 Fish Creek Wetlands Fyke Locations.

Arctic grayling were measured to fork length (FL, nearest mm), inspected for tags and spawning condition, and released. Burbot were measured to total length (nearest mm), inspected for tags, and released. Un-tagged Arctic grayling ≥ 200 mm and burbot ≥ 300 mm were marked with a numbered Floy® T-bar internal anchor tag. Abundance of Arctic grayling and burbot was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951) and variance was estimated (Seber 1982).

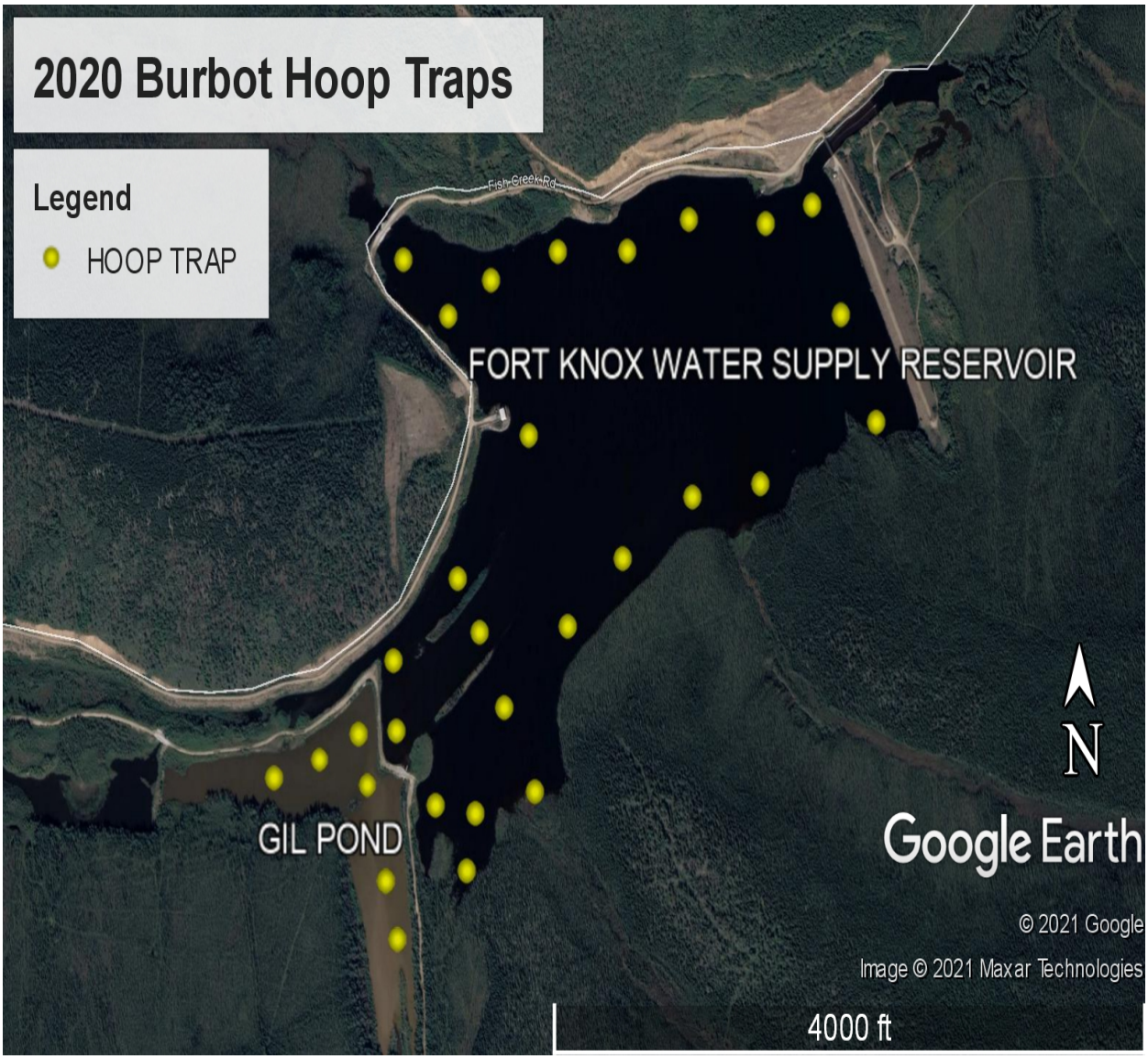

Figure 8. Burbot hoop trap locations in the WSR and Gil Pond, Fort Knox 2020.

Results and Discussion

Water Quality, Water Supply Reservoir

Water quality data were collected on April 10, 2020 (Appendix 2). Ice thickness on the WSR was slightly less than 1 m at each sampling location. There was 1 to 2 inches of slushy snow and up to one foot of overflow on top of the WSR ice near Last Chance Creek (Figure 9). This overflow water did not influence the water quality sampling below the ice. The majority of Fish Creek was frozen with very little exposed flowing water. North Fork Fish Creek had sections of open water but also sections with overflow and glaciated ice in the riverbed. The winter of 2019/20 had above average snowfall and prolonged cold temperatures in December and January. The annual cumulative snowfall between September 1 and April 10 at the Fairbanks International Airport was ~215.9 cm (~85 in) in 2020 compared to ~127 cm (~50 in) in 2019. The water temperature of Fish Creek at Pond F was 0.23 °C and the outlet channel was frozen with 0.6 inches of ice on the surface (Figure 10). North Fork Fish Creek was 3.01 °C taken at open water near Pond AB (Figure 11).

During the 2020 Hydrolab® Minisonde®5 sensor calibration procedures in the ADF&G lab the pH sensor did not respond to the 4.0 or 10.0 pH standard solutions with accurate readings. During sampling of the WSR the ORP sensor readings were very consistent and lower than previouly recorded. The pH and ORP readings for the vertical water colum will not be used for the 2020 data set. Readings of pH were taken at all sites at 1 meter depth wth a Hach HQ40d portable water meter borrowed from Dave Stewart of the Fort Knox envirmonmental department staff and reported in the coresponding figures.

Figure 9. WSR on April 10, 2020. Ice about 1-meter thick with 1-2 inches of overflow.

Figure 10. Deploying Hobo temperature logger in Fish Creek at the mostly frozen Pond F outlet on April 10, 2020.

Figure 11. North Fork Fish Creek at the Pond AB outlet mostly open on April 10, 2020.

Water temperatures recorded in 2020 ranged from 0.09°C to 2.91°C (Figure 12). The minimum temperature of 0.09°C was recorded in Site 1, Site 2 and Solo Bay just below the ice surface. The maximum temperature was recorded in Site 2 at 18 meters just above the reservoir bottom. Temperature at all six sample sites steadily 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.

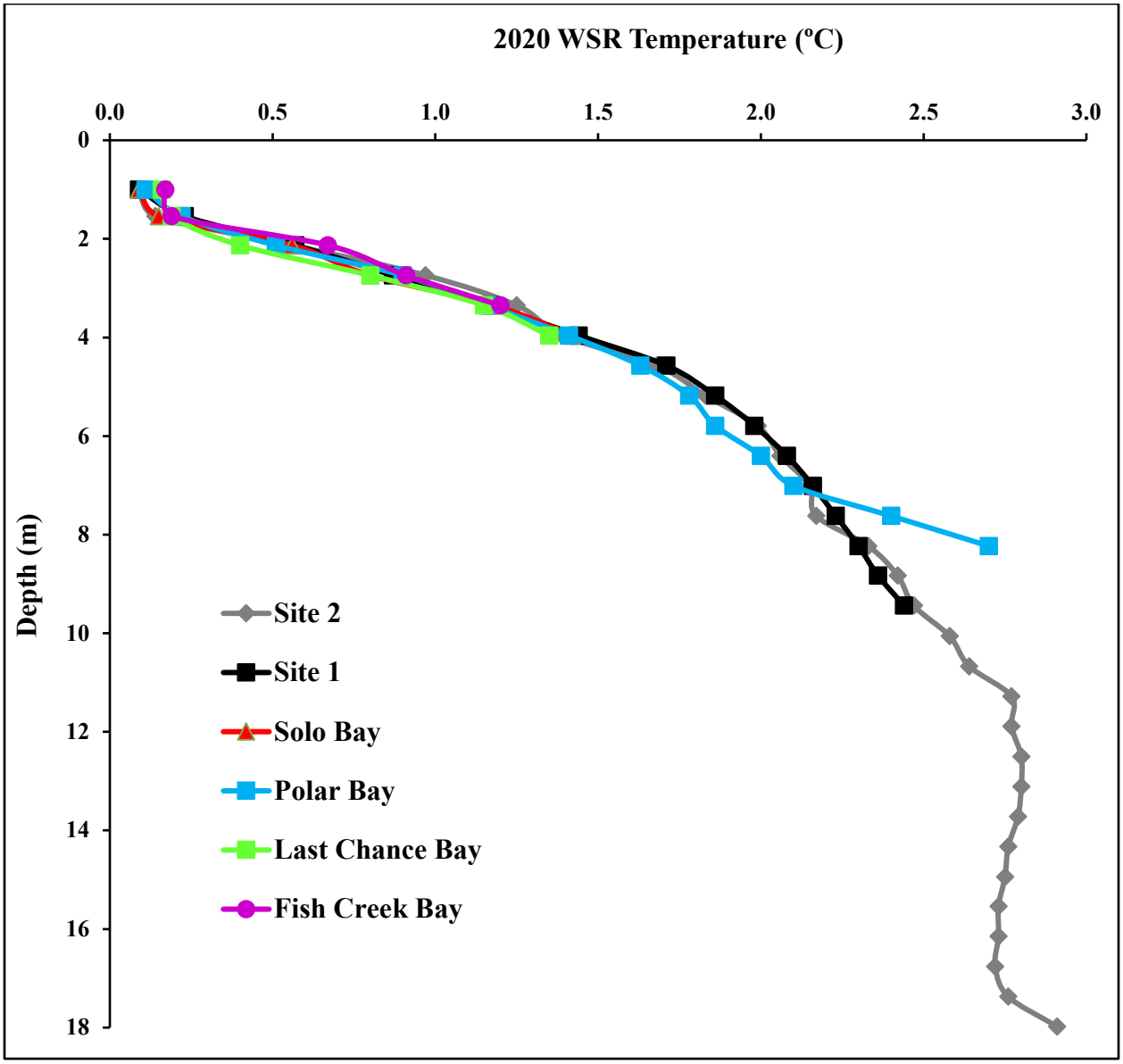

Figure 12. Fort Knox WSR water temperature profile, April 10, 2020.

Dissolved oxygen (DO) is essential for the survival of fish, aquatic invertebrates, and aquatic plants. Fish Creek Bay had the highest recorded dissolved oxygen (DO) at 12.3 mg/L followed by Polar Bay at 11.69 mg/L (Figure 13). These maximums are higher than years prior to 2015 and likely are a result of the non-contact water discharge that began in March 2015 at Outfall 001. On January 15, 2019 Fort Knox began discharging up to 3,000 gpm from a second RO water treatment plant into Fish Creek at Outfall 002. RO water discharges from Outfall 002 flows downgradient through Pond AB and North Fork Fish Creek before combining with Fish Creek and entering the WSR. Fish Creek Bay had the highest water column average DO concentration (9.94 mg/L) for the sixth year in a row followed by Solo Bay at 9.12 mg/L. Similar results were found from 2015 to 2019. The difference in DO concentration observed in Last Chance Bay is likely due to it not being directly mixed by the water entering the WSR from Fish Creek.

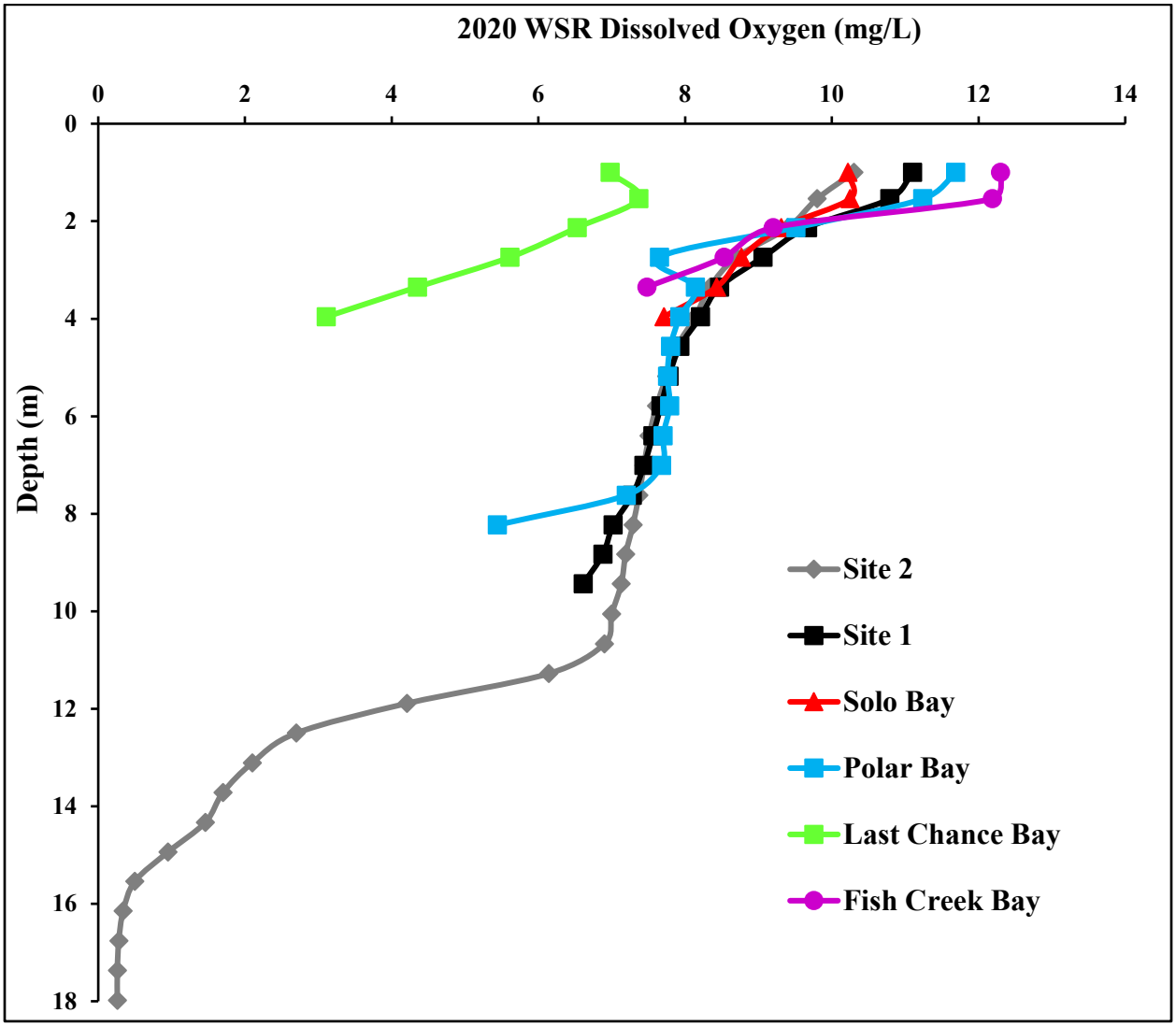

Figure 13. Fort Knox WSR dissolved oxygen (DO) (mg/L), April 10, 2020.

Temperature specific dissolved oxygen percent saturation DO (%) generally decreased with depth at all sites measured (Figure 14). DO (%) followed the same pattern as DO (mg/L) with higher values in the upper WSR near the inlet of Fish Creek and Solo Creek and lower values near the outlet end of the WSR near the spillway, furthest from the fresh water sources. With increased water volume entering the WSR from the combined RO discharges into Fish Creek the water is well mixed with more consistent DO concentrations among five of the six sites. Last Chance Bay had the lowest average DO for the second year in a row and as previously noted, it is not directly mixed by the water entering the WSR from Fish Creek.

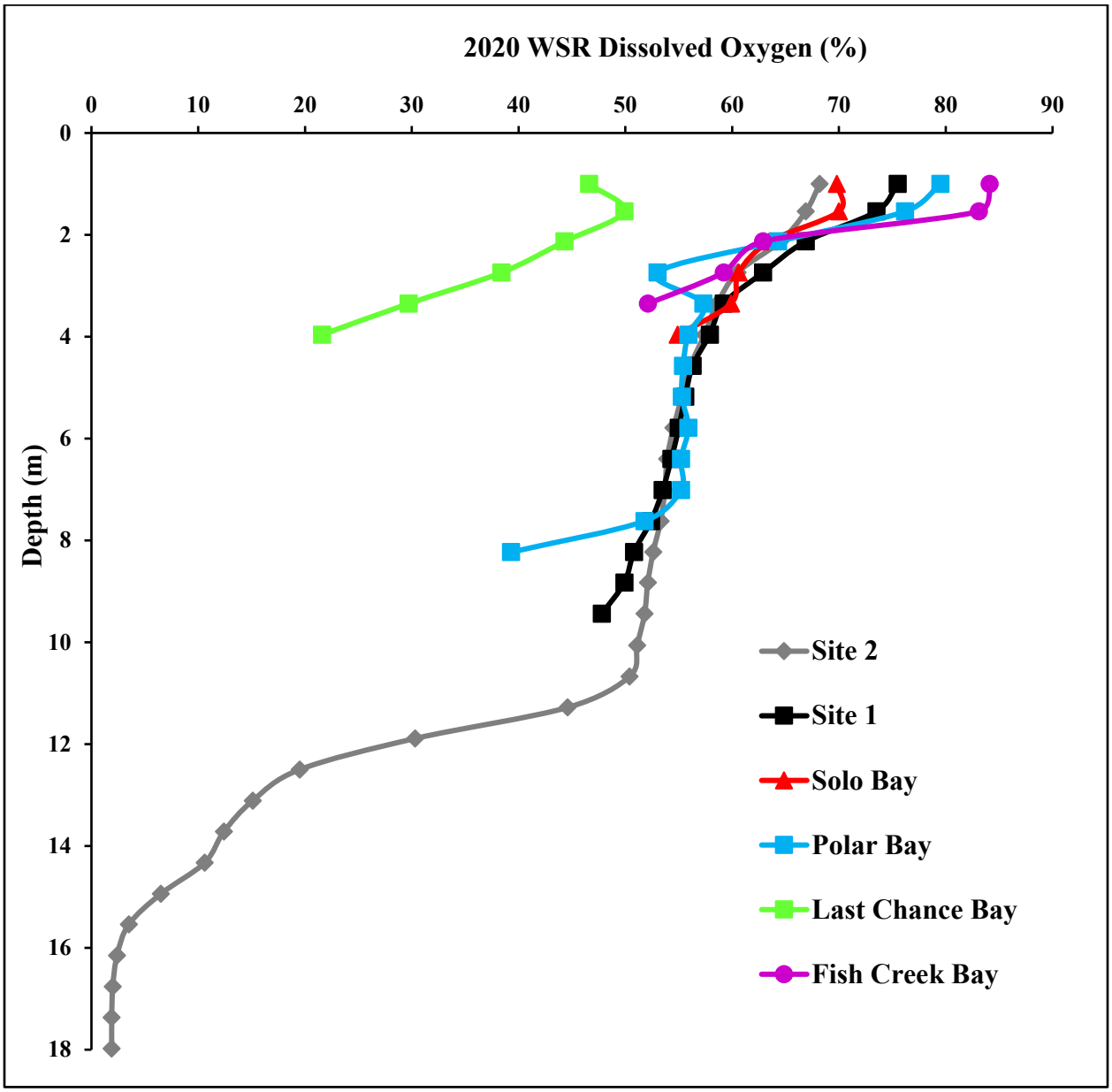

Figure 14. Fort Knox WSR dissolved oxygen (% saturation), April 10, 2020.

Average winter water column dissolved oxygen DO (mg/L), recorded at Site 2 in 2020 was above the 18-year running average and higher than all previous years sampled since 1998 (Figure 15). Similarly, Polar Bay recorded the highest average DO (mg/L) recorded since 2001 (Figure 16). This is likely a result of the continual discharge of RO water into the Fish Creek drainage entering the WSR. The 2020 total input of 9,663 acre-feet of RO water is three times the total volume of the WSR water of about 3,363 acre-feet. The range between the minimum and maximum DO (mg/L) values in 2020 was larger than the previous three years with the highest concentration of DO near the surface and the lowest DO near the bottom. In winter, an ice-covered eutrophic lake will develop a depth stratification of DO. Microorganisms continue to decompose organic materials in the lower water column, and they consume oxygen until the DO is depleted. No oxygen input from the air occurs due to the lake ice cover and snow covers minimizes photosynthesis. The input of oxygen rich water into Fish Creek has substantially raised the DO in the WSR.

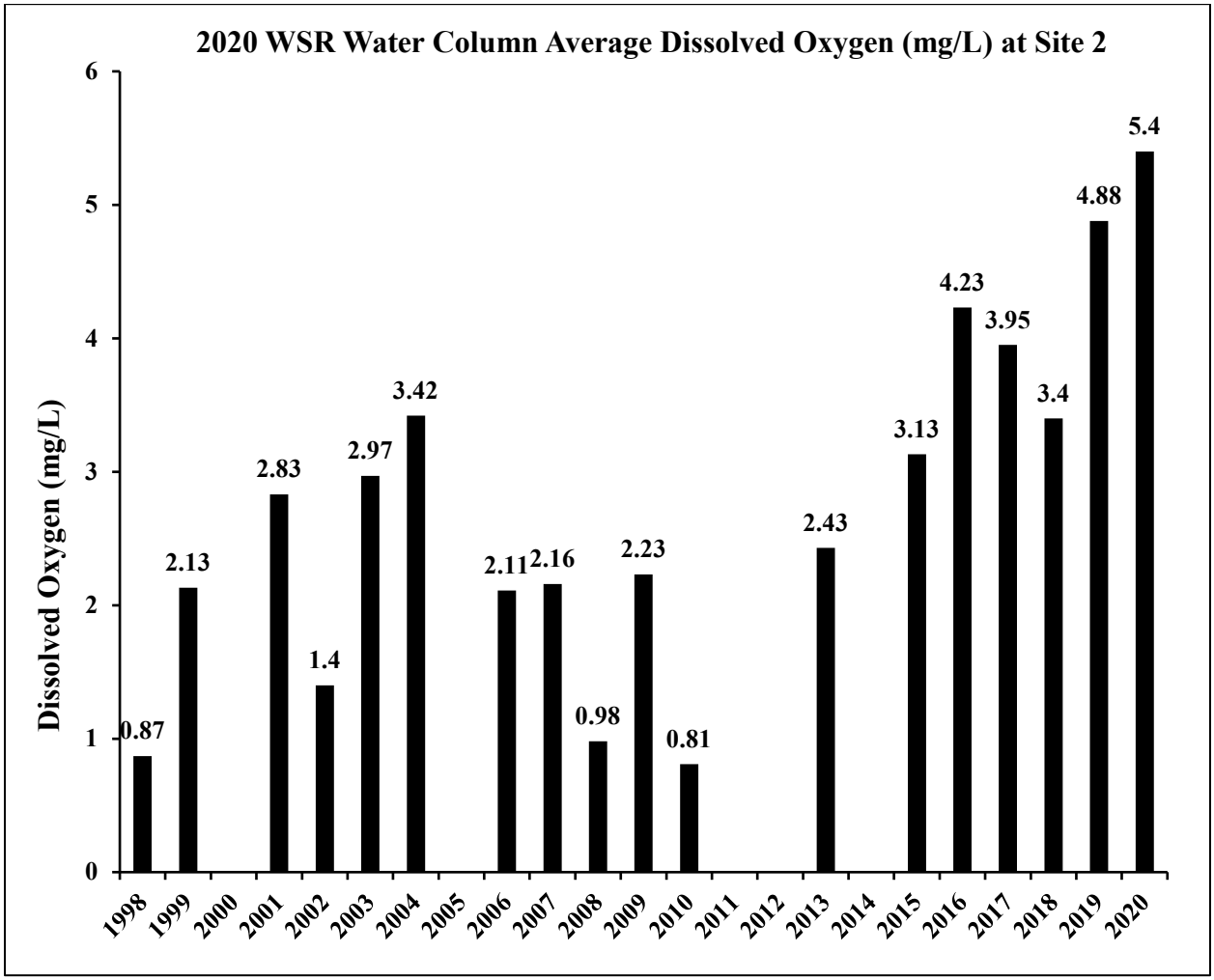

Figure 15. Average water column dissolved oxygen (mg/L) at Site 2, 1998-2020.

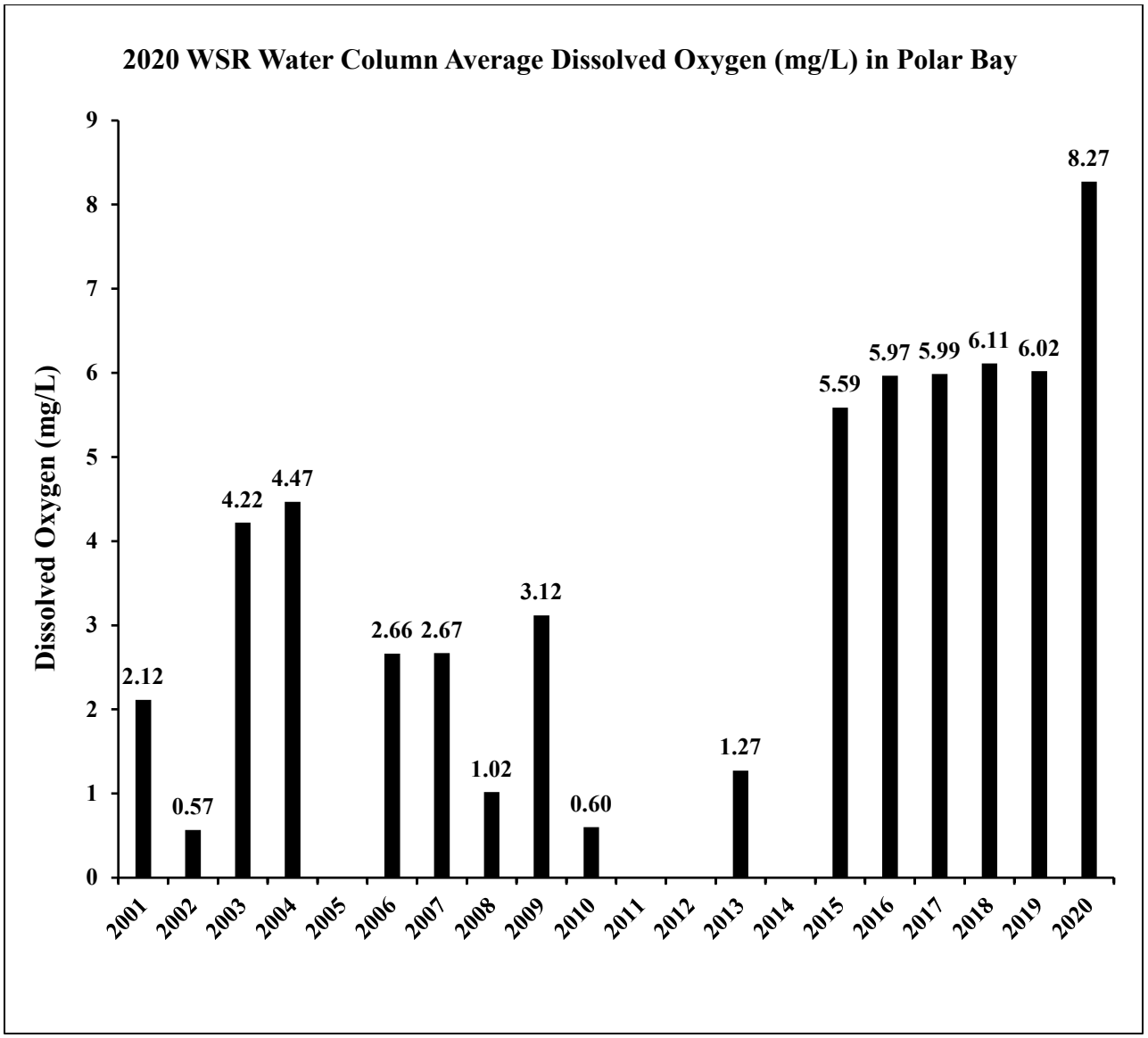

Figure 16. Average water column dissolved oxygen (mg/L) in Polar Bay, 2001 – 2020.

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 ADF&G Hydrolab pH meter was not functioning properly in 2020 and could not be calibrated correctly before sampling, therefore the pH at one-meter intervals in the water column to the WSR bottom was not measured. The winter water pH was taken at one meter of depth, just below the surface of the ice, at all six WSR sample sites and two Fish Creek sites, using a Hach HQ40D portable water meter (Figure 17). The pH meter was calibrated by Fort Knox staff directly before measurements were taken. The pH readings at one-meter deep are just above or below 7.0 at all six sites ranging from 6.86 and 7.56. The pH readings are similar to previous years including 2019. The pH measurements are in the safe range (between 5.5 and 7.5) for freshwater fish including Arctic grayling and burbot.

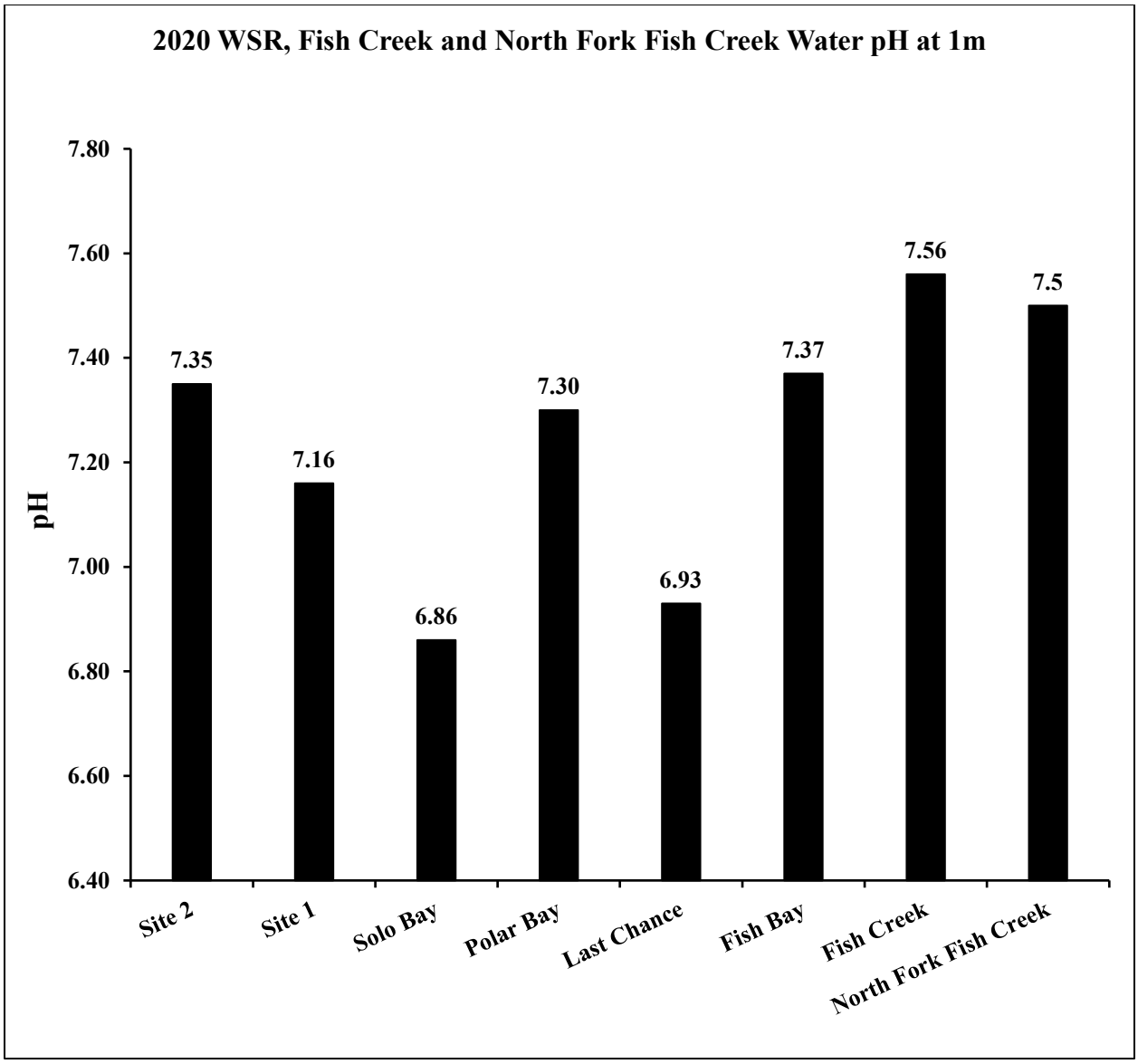

Figure 17. Fort Knox WSR pH at the one-meter depth contour; April 10, 2020.

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 throughout the reservoir (Figure 18). Values generally increased 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 six sample sites. There is a conductance stratification present between two and three meters. The 2020 average from all six sites combined is 178.0 µS/cm and is higher than the 2019 average of 143.0 µS/cm. The specific conductance also is higher than the 2015 to 2019 averages showing an increase in the number of dissolved solids such as chloride, nitrate, phosphate, sodium, magnesium, calcium, and iron present in the WSR water.

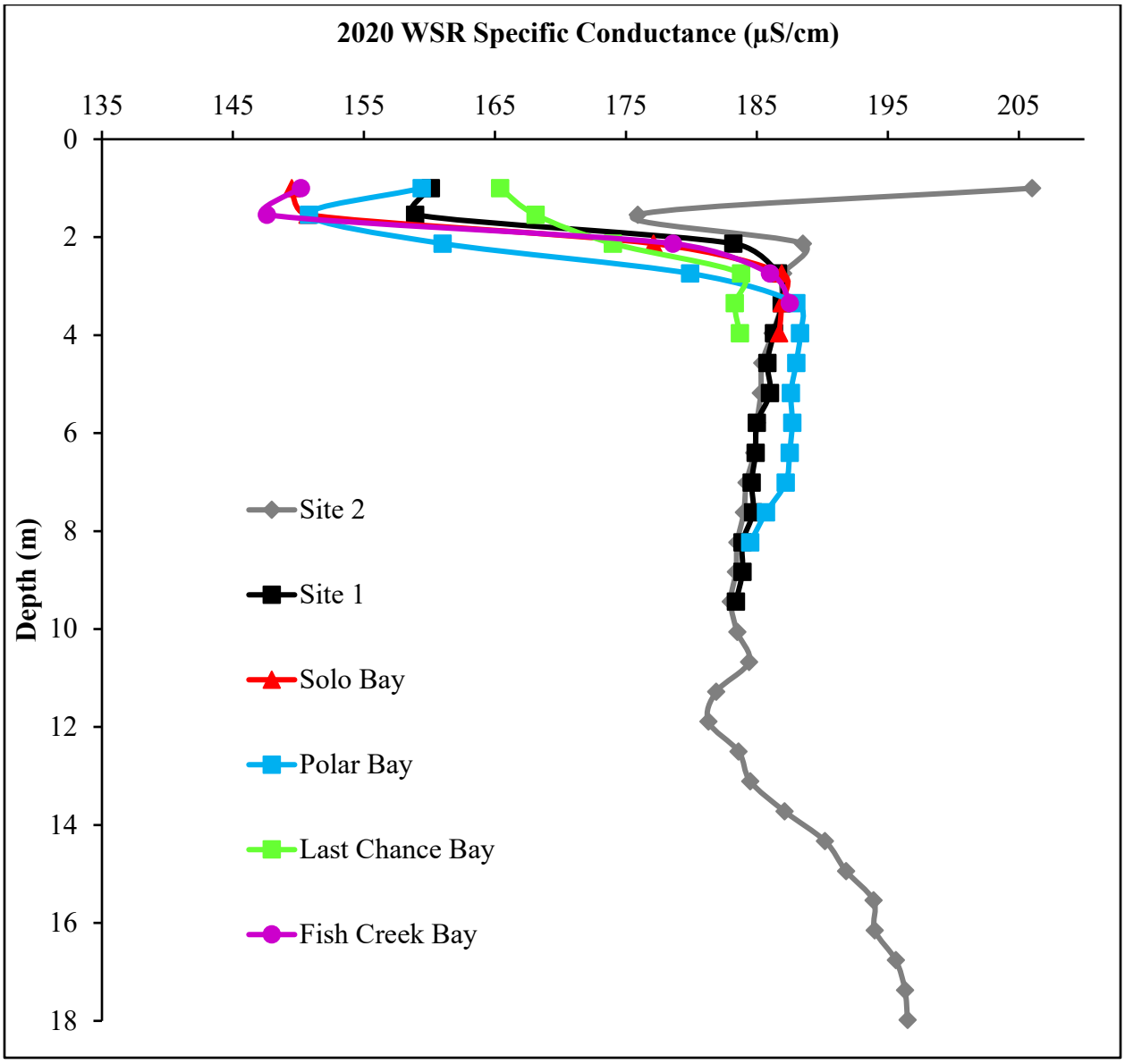

Figure 18. Fort Knox WSR specific conductivity (µS/cm) April 10, 2020.

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. The more oxygen is present in the water, the higher the ORP value. Oxidation reduction potential data was recorded but not used for the 2020 data set. The ORP sensor and pH sensor are combined on the ADF&G Hydrolab Sonde which was malfunctioning during the sampling and did not take accurate measurements.

Water Quality: Fish Creek, North Fork Fish Creek

In 2019 and 2020 water quality data were collected at two new sample sites, Fish Creek at Pond F and North Fork Fish Creek at Pond AB (Figure 6). On April 10, 2020 water temperature in North Fork Fish Creek was 3.01 °C and higher compared to the water temperature in Fish Creek of 0.23 °C and the six WSR sample sites, where average temperatures ranged from 0.63 – 2.14 °C (Figure 19). Typically, the two forks of Fish Creek's water temperature have been similar; however, the influence of warmer RO water discharged from Outfalls 001 and 002 raised the water temperature in North Fork Fish Creek. In comparison, during the 2019 sampling RO water was flowing into Fish Creek because of a beaver dam blocking the Pond AB culvert and Fish Creek water was warmer than North Fork Fish Creek.

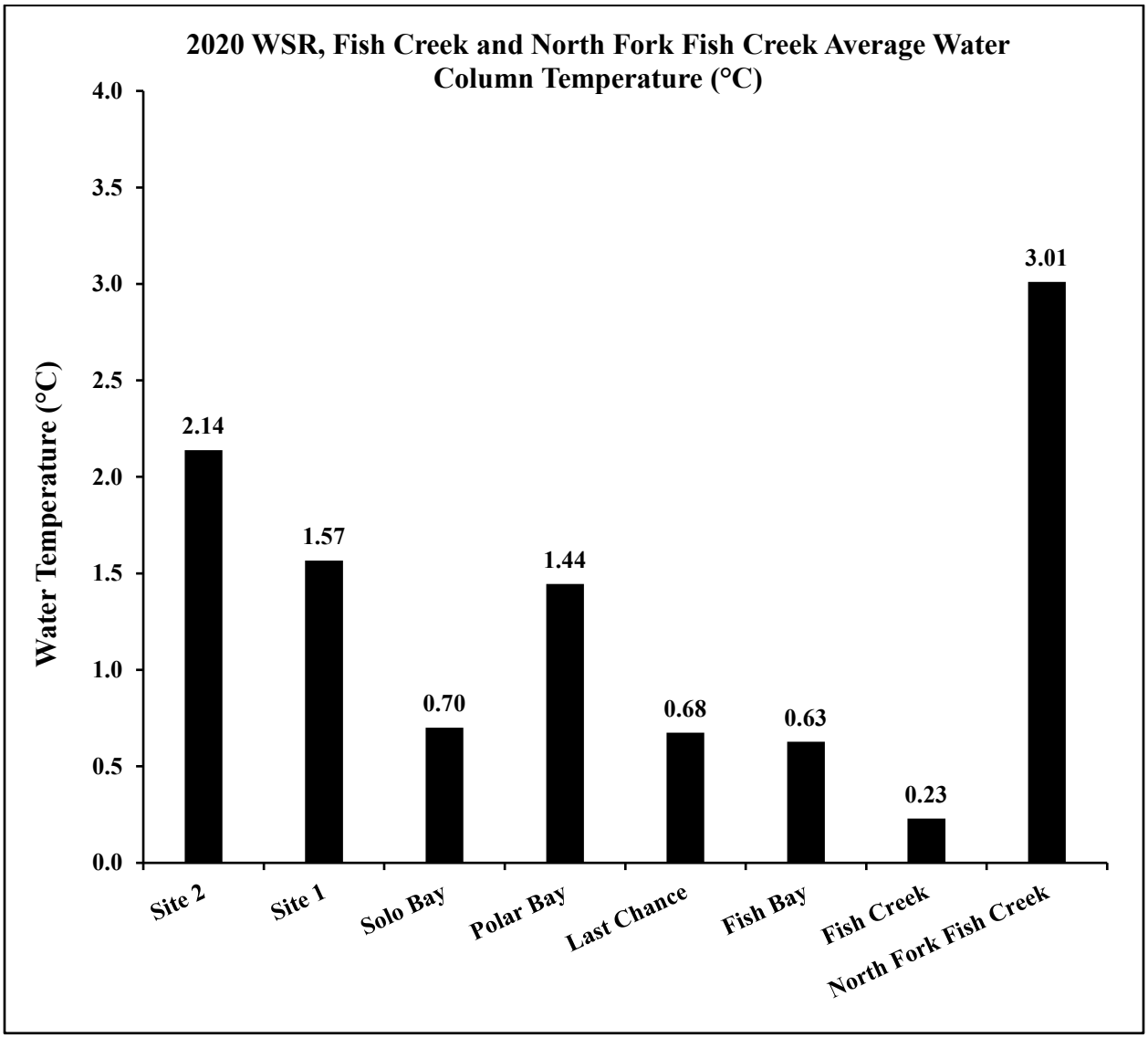

Figure 19. WSR, Fish Creek, North Fork Fish Creek Water Temperature, April 10, 2020.

The DO in North Fork Fish Creek and Fish Creek was higher when compared to the average DO in the six WSR sample sites (Figure 20). RO water discharged from Outfalls 001 and 002 is high in DO and has contributed to the rise in measured WSR DO since 2015. Most of the RO water discharged from outfall 002 flows though Pond AB and into North Fork Fish Creek. In 2020, a small percentage of RO water was flowing out of Pond AB's natural outlet and into Fish Creek despite no culvert blockage from beaver activity. This RO water combined with natural hydraulic agitation during movement contributed to its higher DO concentration when compared to the WSR.

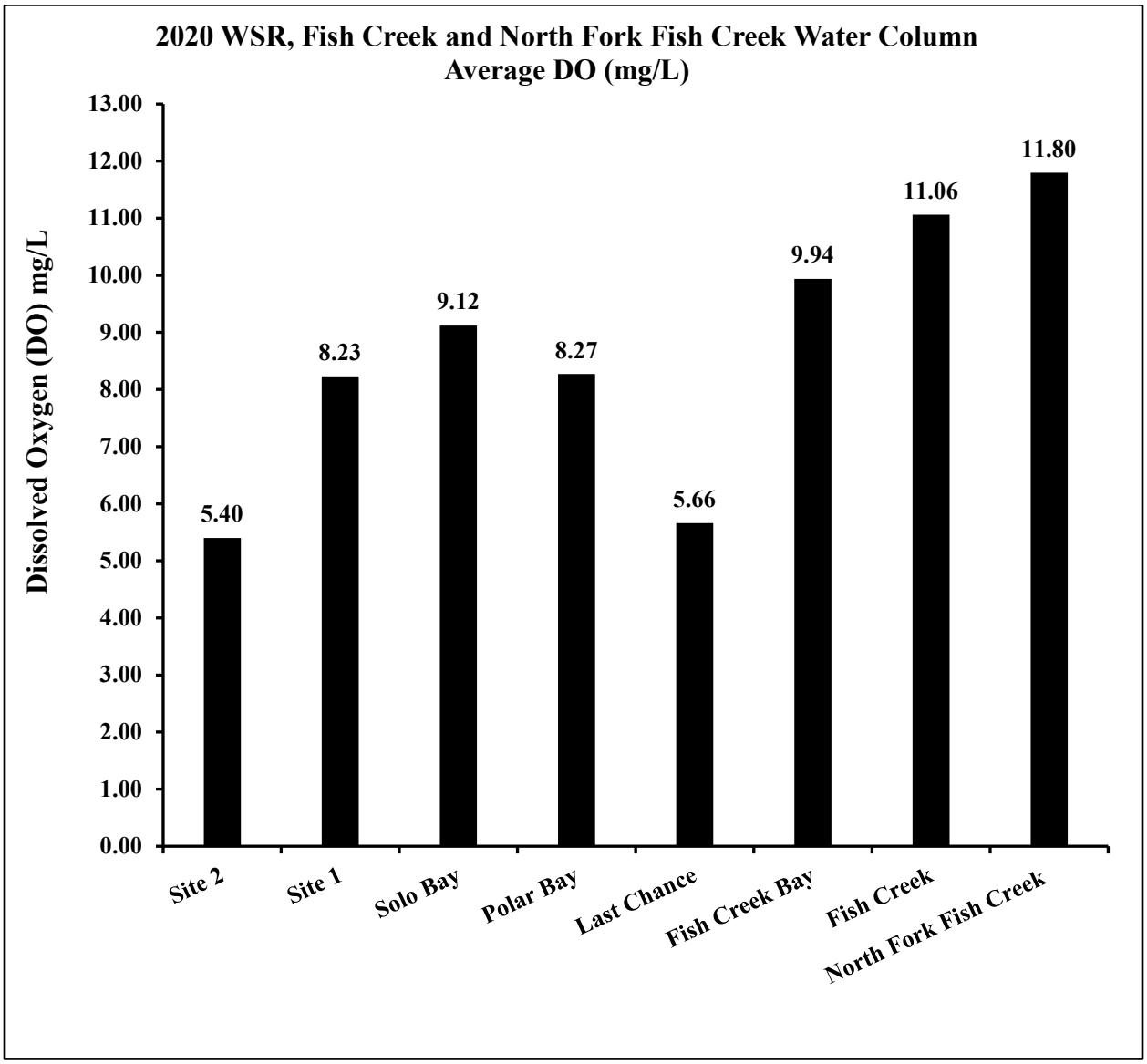

Figure 20. WSR, Fish Creek and North Fork Fish Creek DO (mg/L) April 10, 2020.

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 percentage of non-contact ground water can vary during RO water processing. North Fork Fish Creek Specific Conductance measurements were taken downstream of Outfall 002 and had the lowest recorded values for the WSR and Fish Creek (Figure 21). During the 2019 sampling North Fork Fish Creek's specific conductance was the highest measured during sampling at 187.3 µS/cm.

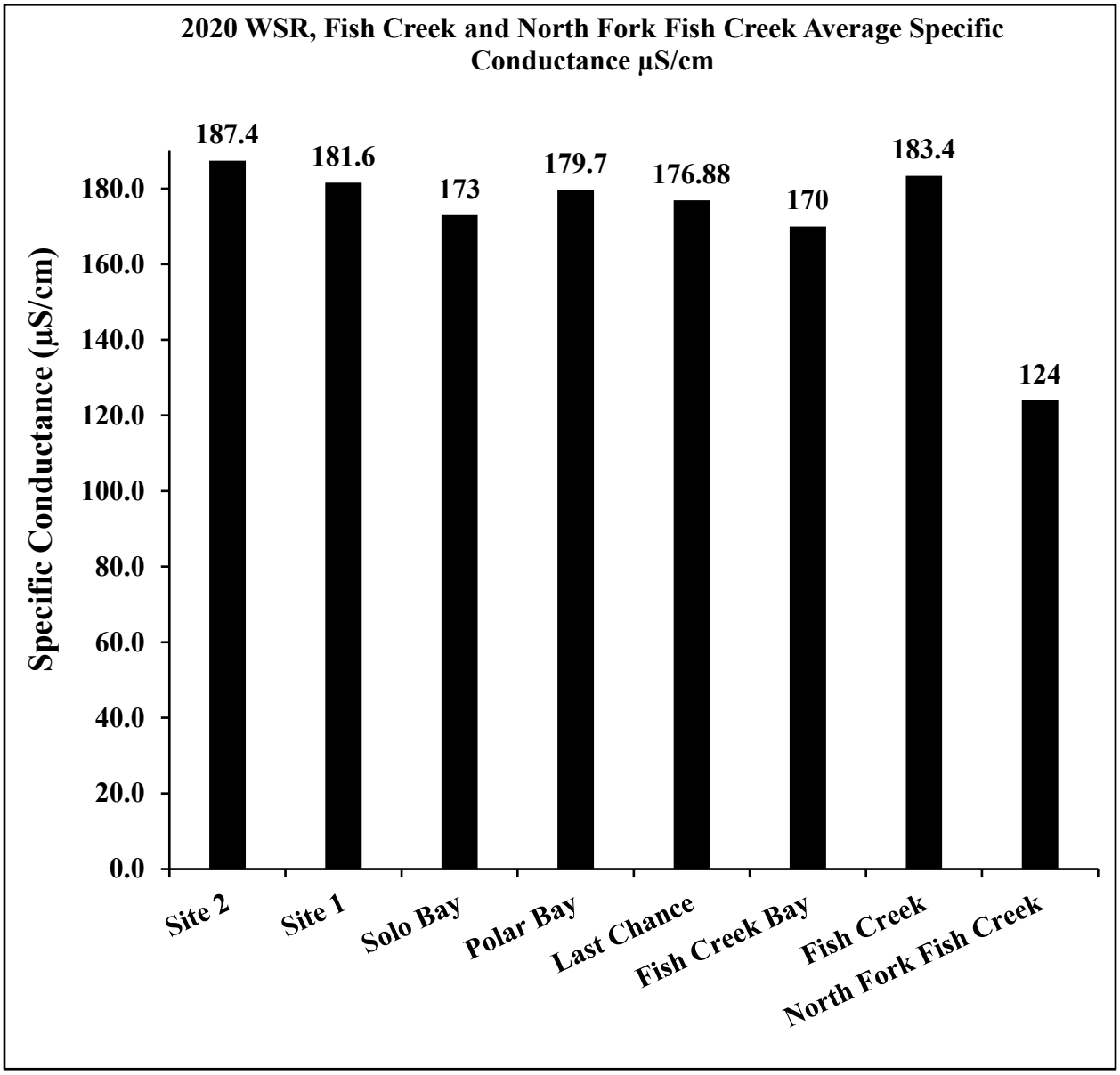

Figure 21. WSR, Fish Creek and North Fork Fish Creek total water column average specific conductance µS/cm, April 2020.

Water Supply Reservoir, Arctic Grayling

Arctic grayling were found throughout the Fish Creek drainage prior to construction of the WSR. However, fish were concentrated in flooded mine cuts in Last Chance Creek. The population appeared stunted: fish larger than 220 mm were rare, average annual growth was 9 mm, and size at maturity was small averaging 148 mm for males and 165 mm for females (Al Ott, Unpublished Data). Successful spawning was limited to inlets and outlets of the flooded mine cuts and upper Last Chance Creek. Flooding of the WSR inundated the inlets and outlets of mine cuts, thus eliminating this spawning habitat. Since flooding of the WSR, aufeis in Last Chance Creek has been substantial. Since 1998, successful spawning by Arctic grayling in Last Chance Creek has only been observed in 2004 and 2005.

After completion of the freshwater dam, very few Arctic grayling fry were captured or observed (< 10 fish) from 1996 through 1998 in the WSR and Last Chance Creek. In spring 1999, FGMI constructed an outlet channel to connect the 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 in the wetland complex.

Arctic grayling have successfully spawned in the wetland complex every year since 1999 (Figure 22). However, in 2002, 2006, and 2007, substantial aufeis and resultant cold-water temperatures in the wetland complex, in addition to beaver dams, limited 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.

Figure 22. Arctic grayling with Floy brand T-Tag.

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

In winter 2020, aufeis in Fish Creek was minimal. North Fork Fish Creek had substantial aufeis and formed glaciers five to six feet deep throughout the drainage. Beaver dams in Pond D and F outlets and in the lower wetland complex had not been rebuilt during winter of 2019/2020. Fort Knox was successful in removing resident beavers from Fish Creek during the spring of 2020 to maintain fish passage for spawning and rearing. Arctic grayling had access to the wetland complex (Ponds D, E and F) for most of the summer, but access was reduced further upstream by a 1 m high natural barrier in the channel connecting Pond D and the Horseshoe ponds. (Figure 23). Several Arctic grayling were observed upstream of the vertical obstruction between Pond E and Horseshoe ponds on May 23, 2018, but no survey was conducted during the summer of 2020.

Figure 23. A hydraulic jump (about 1 m high) formed in the channel connecting Ponds D and E that was a limiting obstacle to the upstream movement of fish, April 12, 2019.

On April 10, during the late winter WSR water quality sampling, water temperature of North Fork Fish Creek at the Pond AB outlet was 3.01°C and approaching the ideal spawning conditions for Arctic grayling (4.0ºC). Fish Creek was colder at 0.23°C. North Fork Fish Creek was partially open and flowing, Most of Fish Creek and Pond F was frozen over including the outlet. Conditions were determined to be appropriate to begin fyke netting Arctic grayling on April 24. This was 14 days later than sampling began in 2019.

The majority of the RO water discharged from Outfall 001 and 002 was confined in the North Fork Fish Creek channel during the winter of 2019/2020. The creek is beginning to form a single channel in some areas. As previously mentioned, the winter of 2019/2020 had below average temperatures in December and January and above average snowfall, ~85 inches compared to ~50 inches in winter 2018/2019. Snow melt was variable with periods of warm and cool weather during the sample period. Water flow varied with the highest flow near May 9, but no significant high-water events affected net efficiency.

One fyke net was set in Fish Creek at the Pond F outlet (Figure 24) on April 24. A second fyke net was placed in North Fork Fish Creek on April 28, after several days of low catches from Pond F, to determine if Arctic grayling were expanding into the new available wetland habitat (Figure 25). Both fyke nets were fished in the same locations without being moved for the duration of the sample period. Beginning on April 24, the fyke nets were checked daily or every other day until they were pulled on May 9. Capture efficiency declined in the North Fork Fish Creek fyke net on May 7 when the weighted lead line of one wing was off the creek bottom, which allowed fish to avoid capture. After the lead line was reset, both fyke nets fished effectively for the remainder of the sampling days.

Figure 24. Fish Creek Pond F fyke net and open water, April 28, 2020.

Figure 25. North Fork Fish Creek fyke net and open water, April 28, 2020.

The 2020 Fish Creek daily peak water temperature taken at the Pond F outlet was colder when compared to previous years during the same time period (Figure 26). Fish Creek water temperature was 0.23°C on April 11 from natural spring melt water entering the drainage. The Fish Creek daily peak water temperature was later than average, but not similar to 2013, the latest spring in recent records (Figure 26). North Fork Fish Creek water temperature was warmer at 3.01°C on April 10. The warmer water temperature resulted from the 3,000 gpm discharge of RO water from Outfall 002 which began in January 2019. The large volume of warm moving water dilutes the influx of cold spring melt water thereby keeping North Fork Fish Creek warmer than Fish Creek (Figure 27). Fyke netting started on April 24 based on the warmer of the two creeks water temperature to avoid missing the Arctic grayling spawning event.

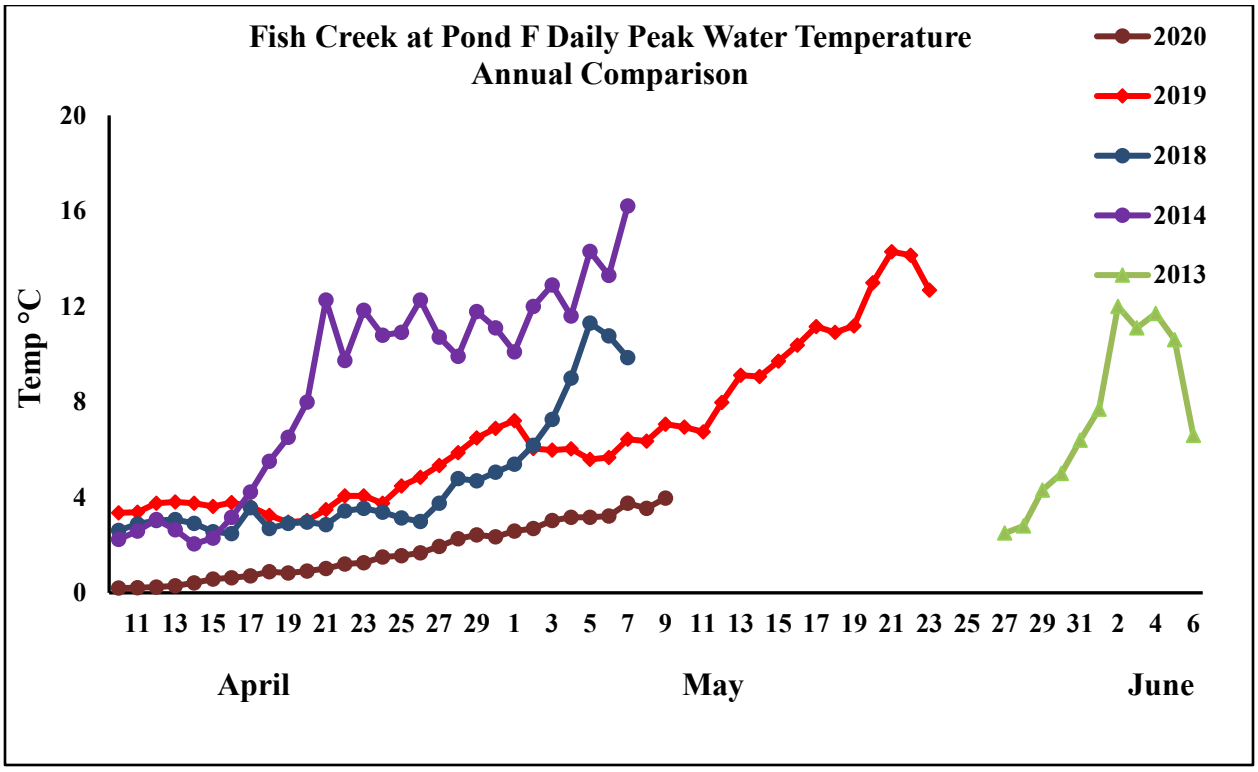

Figure 26. Fish Creek at Pond F outlet daily water temperature maximums; select years for reference.

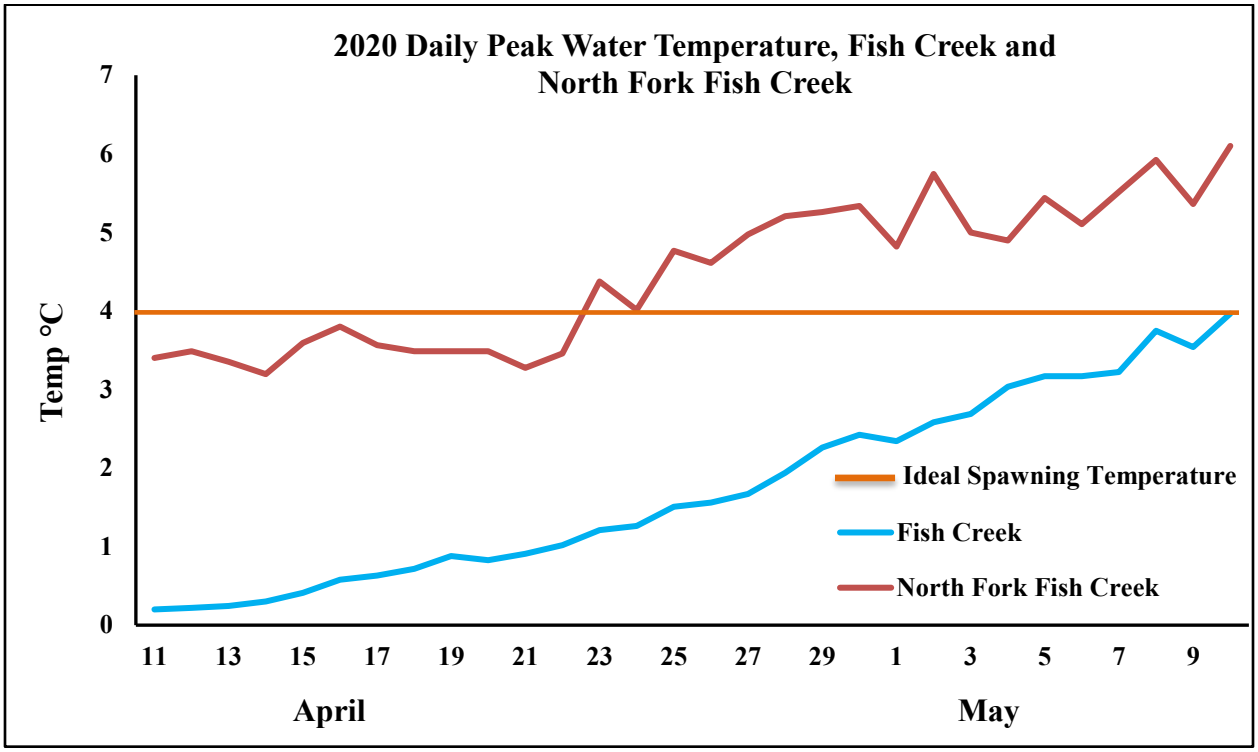

Figure 27. Fish Creek and North Fork Fish Creek daily peak water temperature April 24 - May 9, 2020.

From April 24 to May 9 all fish caught in the fyke nets were sampled with the majority being Arctic grayling. Burbot were also captured and these data is presented in the WSR Burbot section of this report. The Arctic grayling CPUE in Fish Creek was low during the first few days of sampling and increased on May 3 as water temperature rose. A second fyke net was placed in North Fork Fish Creek starting on April 28 to determine if fish were moving into the new available wetlands. Water temperatures were warmer in North Fork Fish Creek, 5.2°C on April 29 compared to 2.4°C in Fish Creek. The CPUE of both creeks followed the same variable pattern, but the number of Arctic grayling caught in North Fork Fish Creek was higher (Figure 28). North Fork Fish Creek CPUE reached a high of 6.5 fish/hour on May 5, the same day Fish Creek peaked at 4 fish/ hour. The fyke nets were pulled on May 8 as the target sample size of 1,000 Arctic grayling had been reached between both Fish and North Fork Fish creeks.

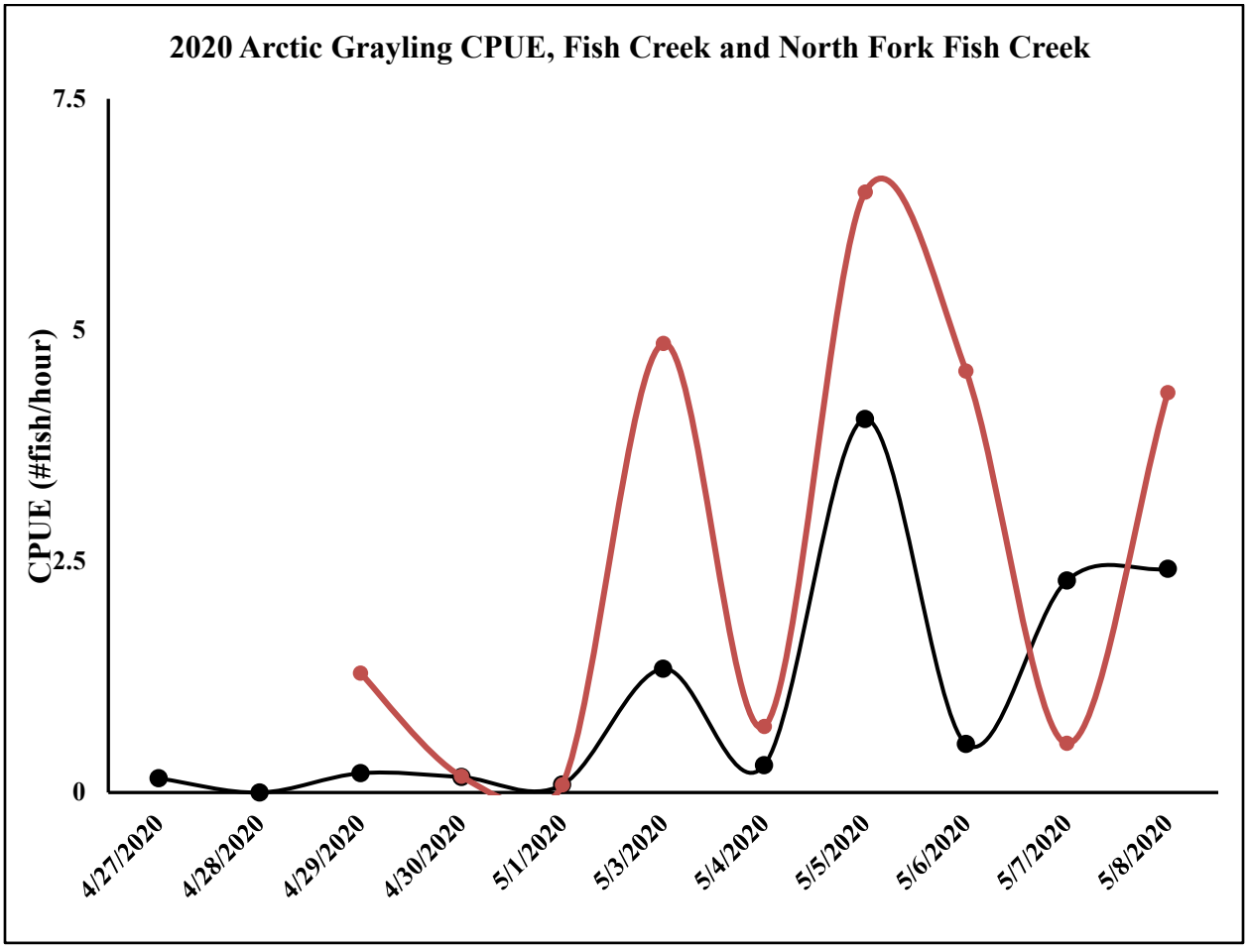

Figure 28. Catch per unit of effort (CPUE) in #fish/hr at the Pond F and North Creek fyke nets in the wetlands complex, 2020.

Female Arctic grayling were categorized as not ripe, ripe, or spent, based on their spawning condition (Figure 29). On the first day of fish capture (April 27), 100% of the female Arctic grayling were categorized as not ripe. The number of not ripe females steadily decreased throughout the sampling period to 2% on May 9. On April 27, 0% of the female Arctic graying were classified as ripe. The number of ripe females steadily increased to 98% on May 9. No fish were classified as spent during the 12 days of the sampling period. The 2020 spawning condition and timing were later than in 2019 where sampling ended on May 3 and 92% of the females were categorized as spent.

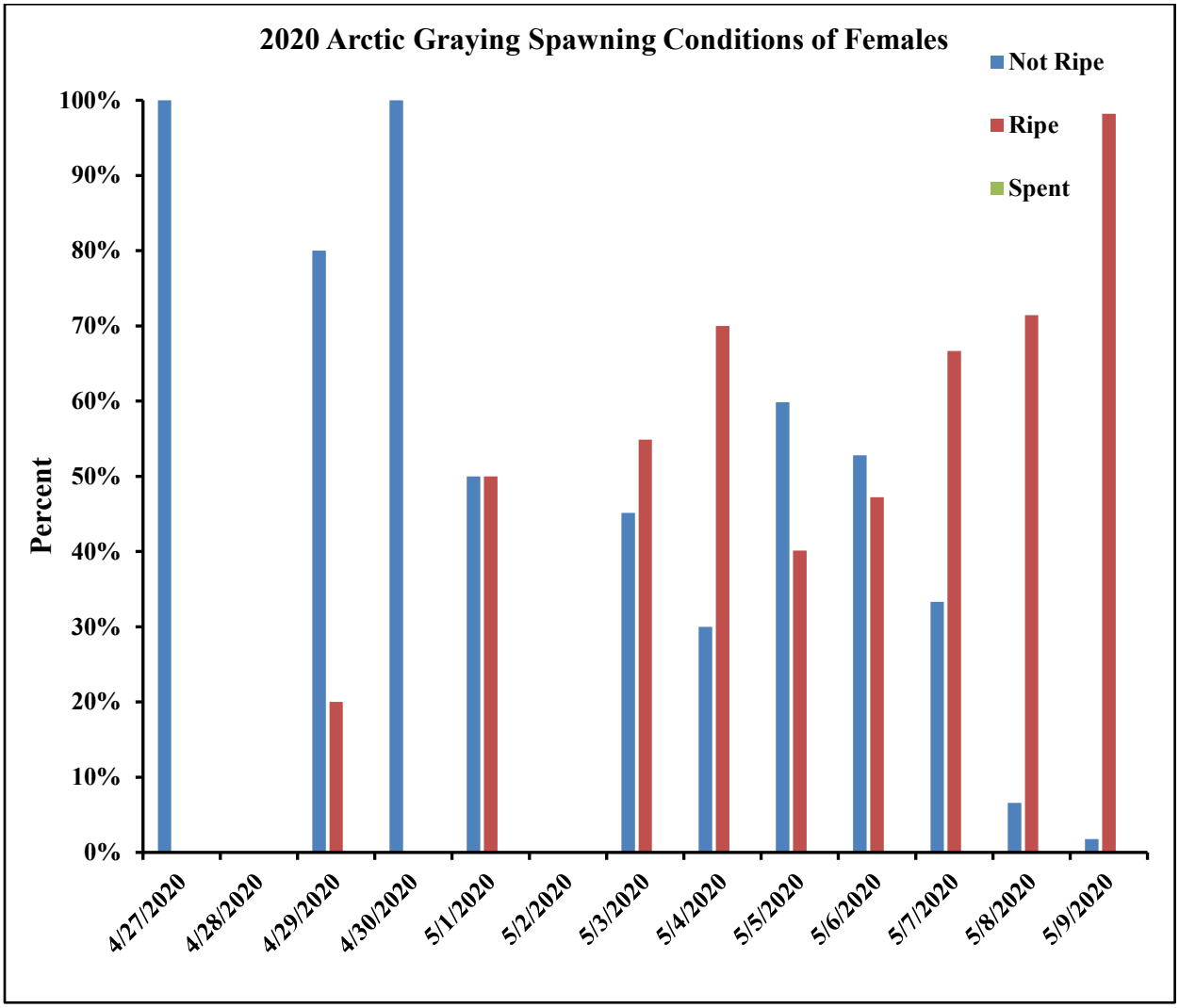

Figure 29. Spawning condition of Arctic grayling females categorized as: not ripe, ripe or spent, 2020.

Arctic Grayling Catches and Metrics

The spring 2019 population abundance estimate for Arctic grayling ≥ 200 mm was 4,461 fish with a 95% CI of 4,114 to 4,808 fish (Figure 30). The population has declined since 2017 but is anticipated to increase in the future with the substantial number of age one juvenile Arctic grayling seen during the spring 2020 sampling event.

The 2019 population abundance estimate of Arctic grayling in the WSR was calculated using spring 2019 as the mark event and spring 2020 as the recapture event. During the spring of 2020 1,067 Arctic grayling ≥ 240 mm were captured, of those 330 were recaptures from the spring 2019 tagging event. For the 2019 population estimate, Arctic grayling population length frequency distributions from 2019 and 2020 were compared to eliminate those fish handled in 2020 that would have been too small (<200 mm) to mark in spring 2019, 41 fish met these criteria and were not included in the population estimate.

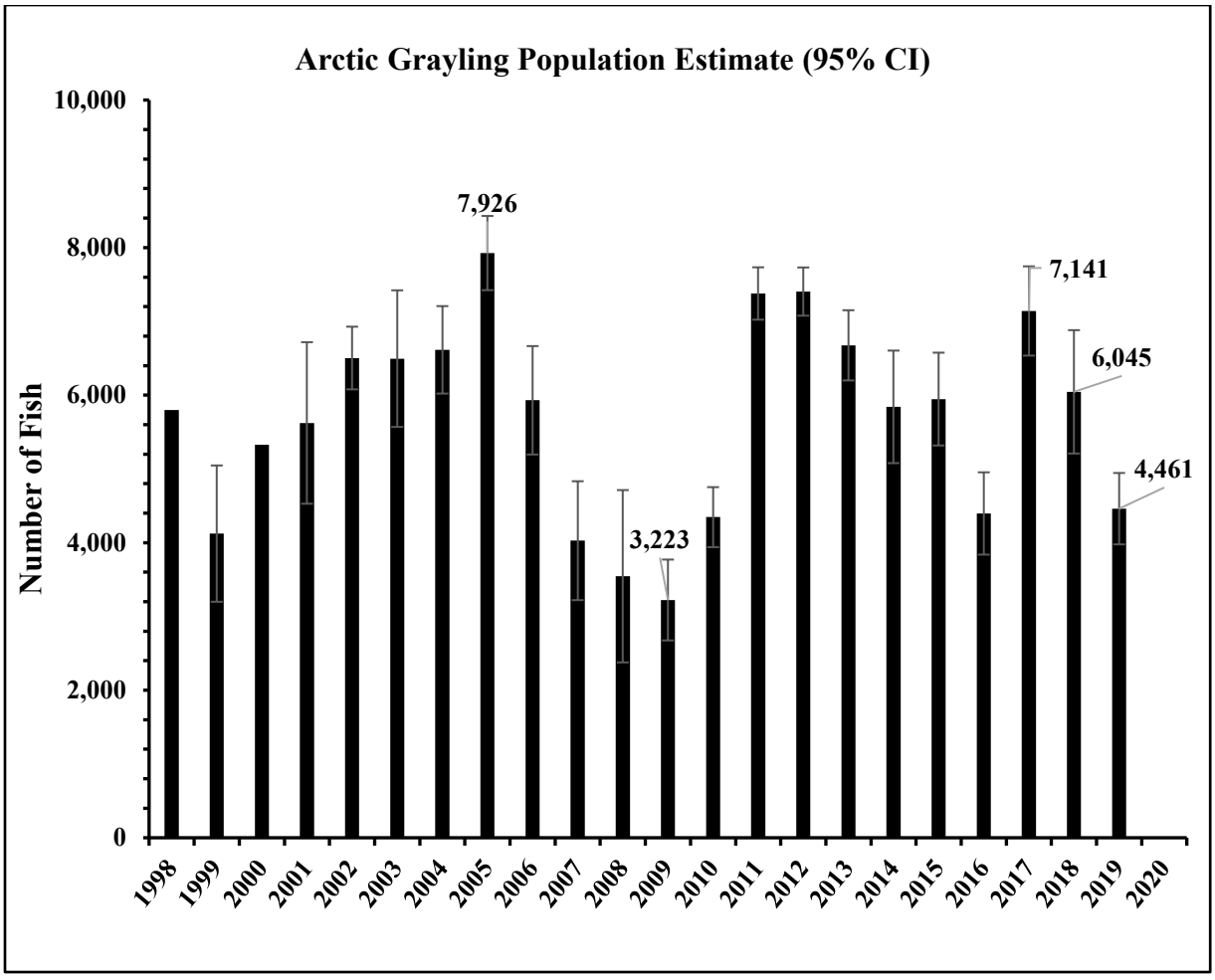

Figure 30. Estimates of the Arctic grayling population in the wetlands and WSR, 1998 – 2019.

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, but was highest in 2017 and declined in 2018, 2019, and 2020 (Figure 31). Substantial recruitment was observed in the spring of 2004, 2010, 2014, and 2017. A substantial recruitment event was defined as >300 fish encountered during a recapture sampling event that were not available for tagging based on size at the mark event (typically fish between 200 and 240 mm). During the 2020 sampling there were thousands of age class one Arctic grayling captured indicating that there was good spawning success and survival from the 2019 spawning event, but these fish are not included in the recruitment estimate (Figure 32 and 33).

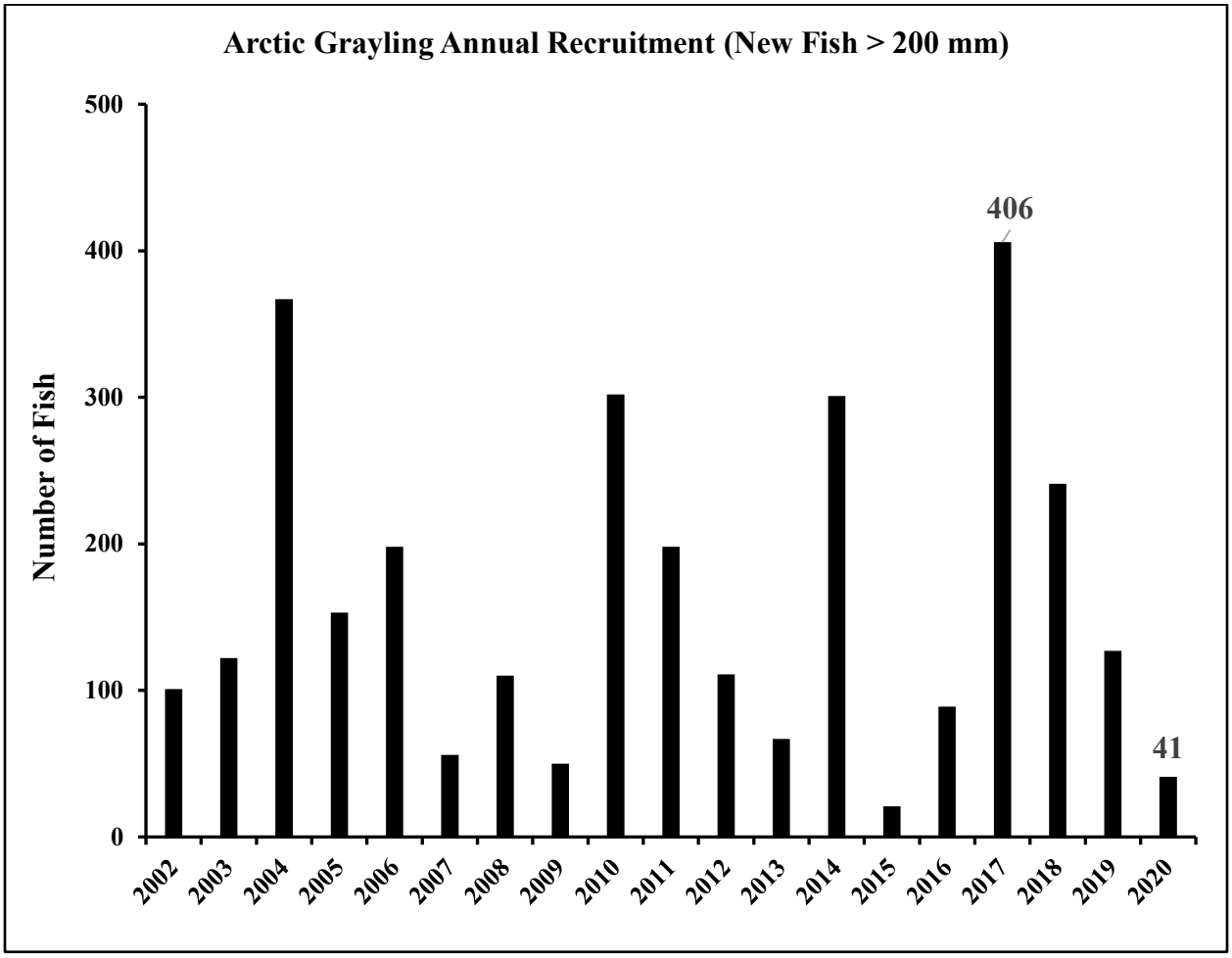

Figure 31. Number of new fish > 200 mm that entered the population but would have been too small to mark in the previous year (based on growth of marked fish).

Figure 32. Example of the juvenile Arctic grayling captured in Fish Creek, April 28, 2020.

Figure 33. Juvenile Arctic grayling (Age-1) captured in Fish Creek, April 28, 2020.

Average growth of Arctic grayling prior to the development of the WSR ranged from 3 to 17 mm per year (Figure 34). 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. Most notable in 2019 was the increase of the average growth rate of large grayling ≥300 mm. For example, Arctic grayling between 300 and 310 mm grew an average of 11 mm in 2019 compared to 3 mm in 2018 and 6 mm in 2017. The increased growth of large Arctic grayling ≥300 mm corresponds to the decrease in recruitment and total population of Arctic grayling in the WSR since 2017.

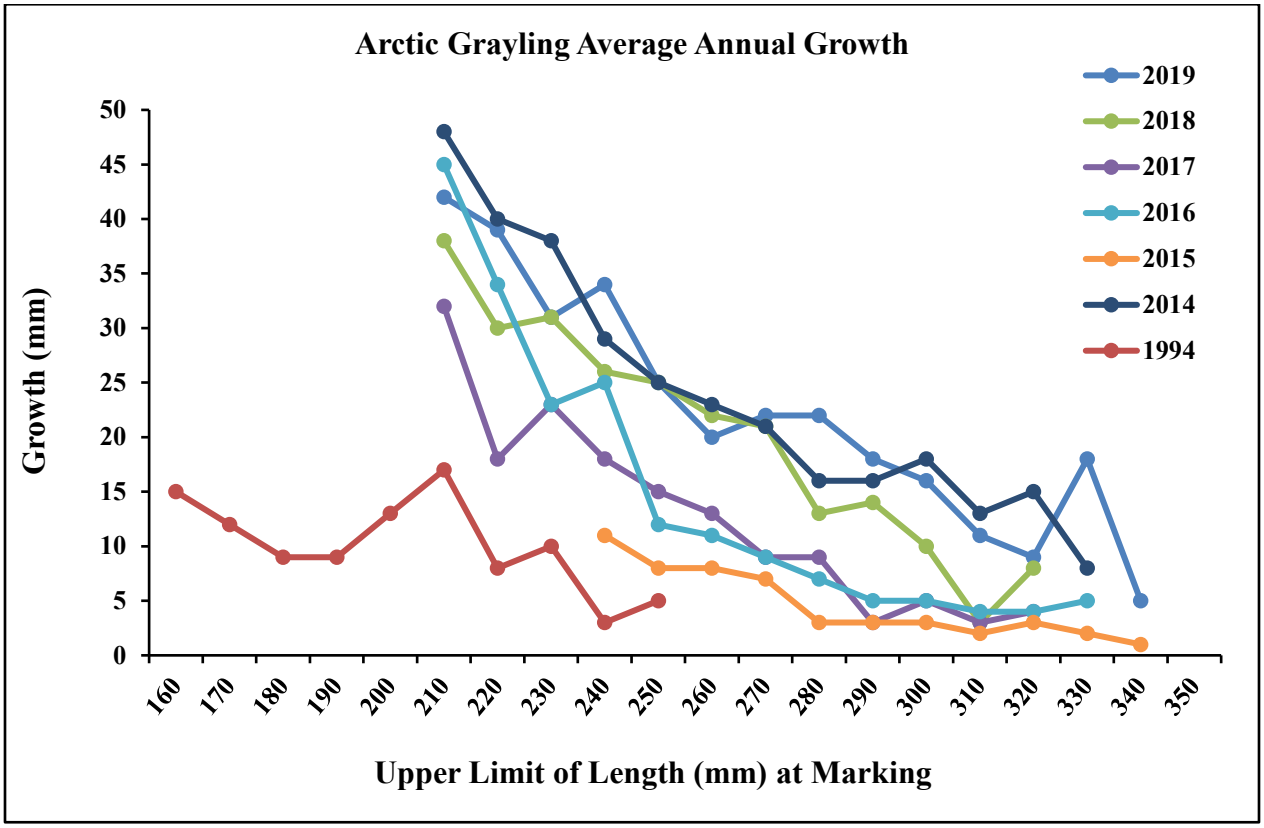

Figure 34. Average annual growth of Arctic grayling by size group in the WSR in selected years including baseline (before WSR) in 1994.

The 2020 length frequency distribution of Arctic grayling caught in the wetlands complex is presented in Figure 35. Data from 1995 are included for comparison to the length of Arctic grayling before the construction of the WSR. The length distribution frequency has increased since 1995. 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 2020 sampling, 3,865 small Arctic grayling were captured <130 mm (Figure 36). A subsample of 425 of these small Arctic grayling were measured and found to have an average length of 101 mm. The subsample measured is presented in Figure 35. Very few Arctic grayling were captured in the 130 to 240 mm size range during 2020.

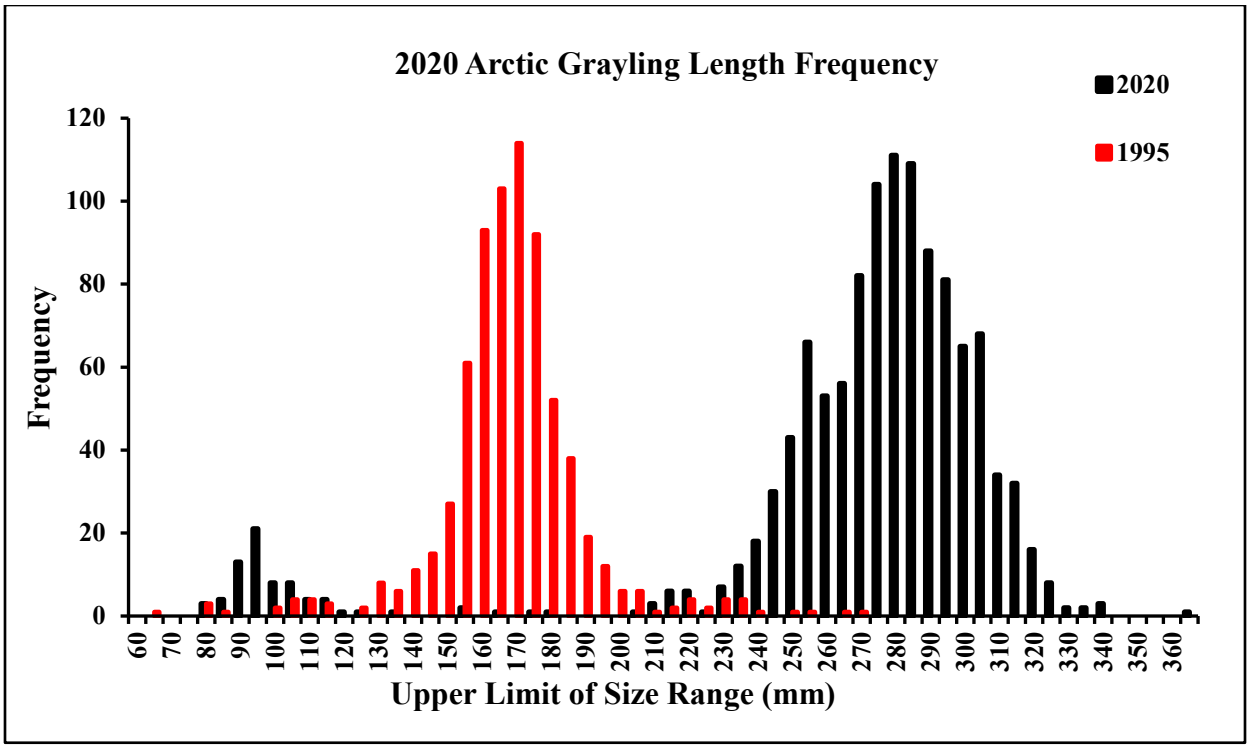

Figure 35. Length frequency distribution of Arctic grayling captured in spring 2020 and 1995 (425 fish subsample of 3,865 juvenile Arctic grayling captured represented in graph)

Figure 36. Juvenile Arctic grayling averaging 101 mm captured in Fish Creek May 9, 2020.

Water Supply Reservoir, Burbot

The 2019 burbot population estimate used 2019 fall hoop trapping as the mark event, and 2020 fall hoop trapping as the recapture event. During September and October 2019, 124 burbot were captured, 105 were ≥300 mm and tagged, 48 of which were ≥400 mm. In the 2020 capture event, 123 burbot were caught, and of these 78 were ≥ 400 mm, and 18 were recaptures from the 2019 mark event. In both events, fish from Gil Pond were included in the population estimate as it is connected to the WSR by access culverts.

The 2019 WSR population estimate for burbot ≥400 mm is 203 fish (95% CI: 142 to 264 fish). Population estimates from 2012 to 2019 have varied from a low of 80 to a high of 402 (Figure 37). A population estimate was not performed for fish between 300 and 399 mm, because we did not catch any fish in this size range that were tagged during the 2019 sampling event.

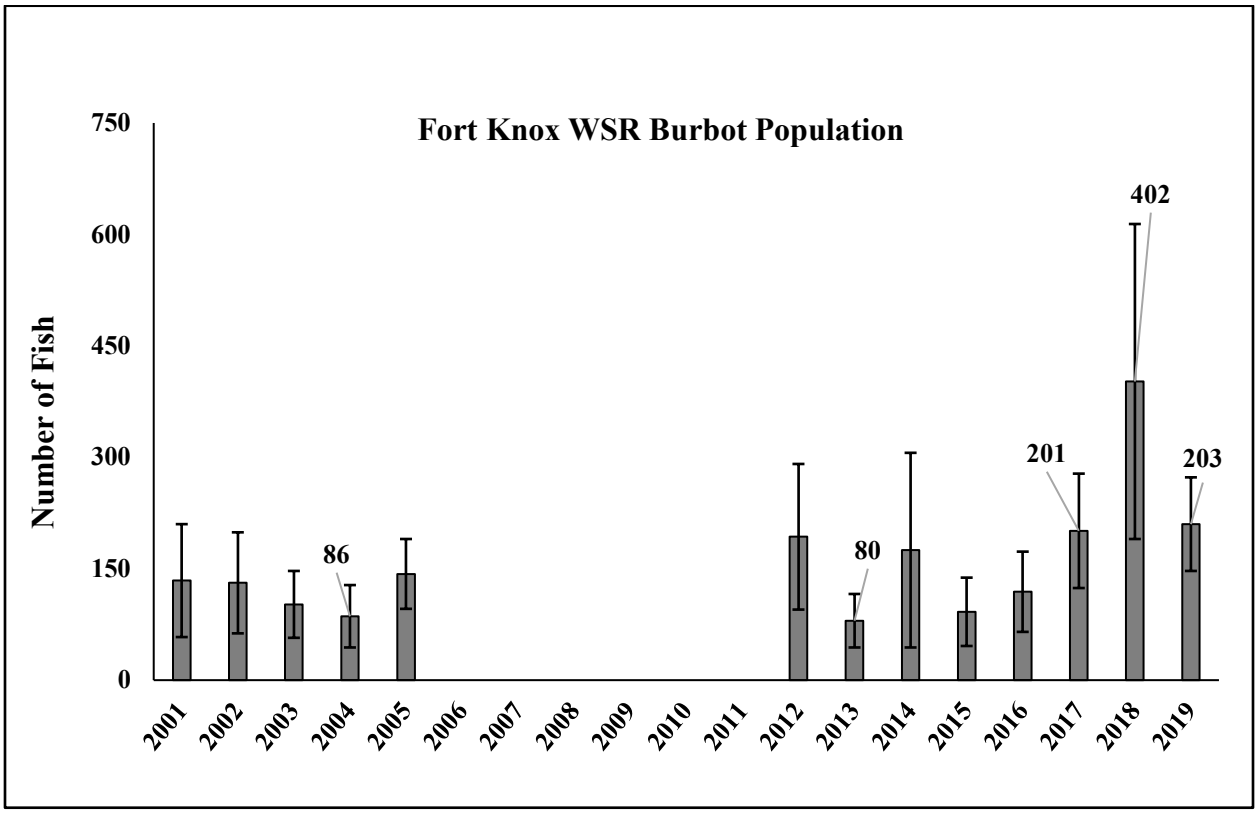

Figure 37. Population estimates of burbot ≥400 mm in the Fort Knox WSR, 2001-2019 (95% Confidence Interval).

Catch Per Unit Effort (CPUE) of all burbot captured in 2020 was 0.4 fish per day per trap (Figure 38). This is identical to the CPUE of 2019, but much lower than 2018's CPUE of 1.1. The 2020 CPUE is tied with 2019 for being the lowest since 1996. CPUE of burbot over 400 mm increased from 0.1 fish per day per trap in 2019 to 0.2 in 2020 (Figure 38).

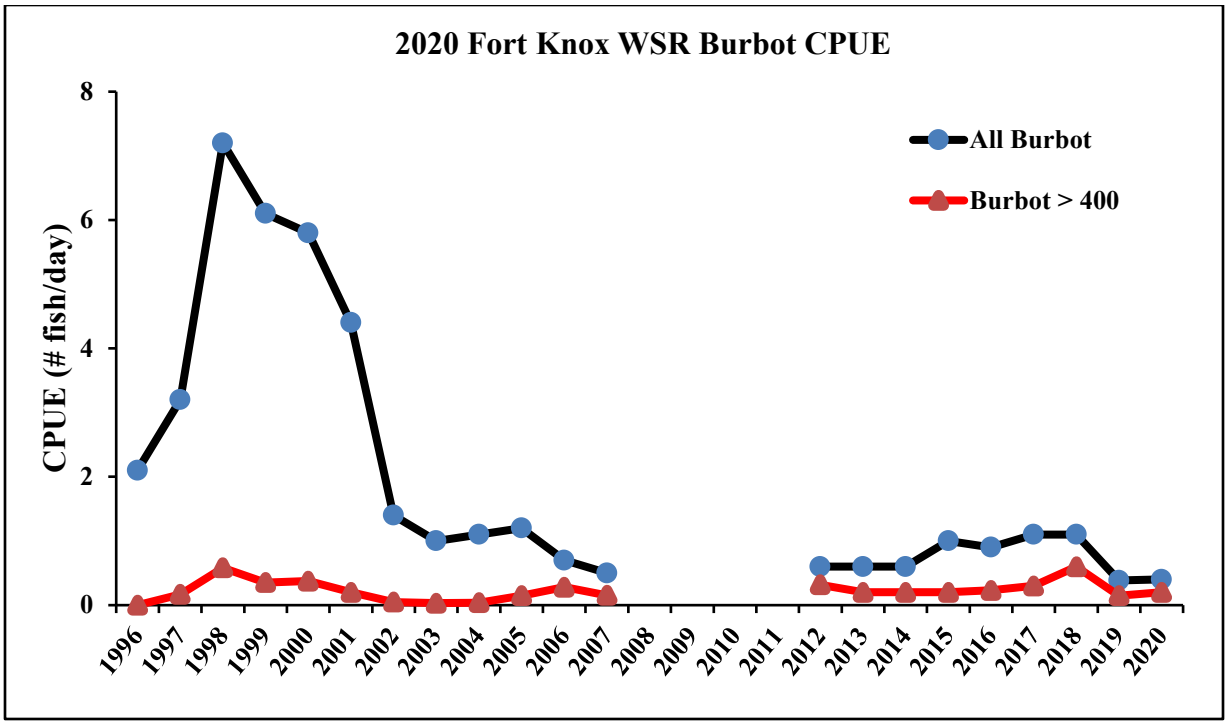

Figure 38. CPUE for all burbot and burbot ≥ 400 mm in the Fort Knox WSR.

In 2020, 123 burbot were caught in the WSR with hoop traps. Burbot length ranged from 98 to 825 mm (Figure 39).

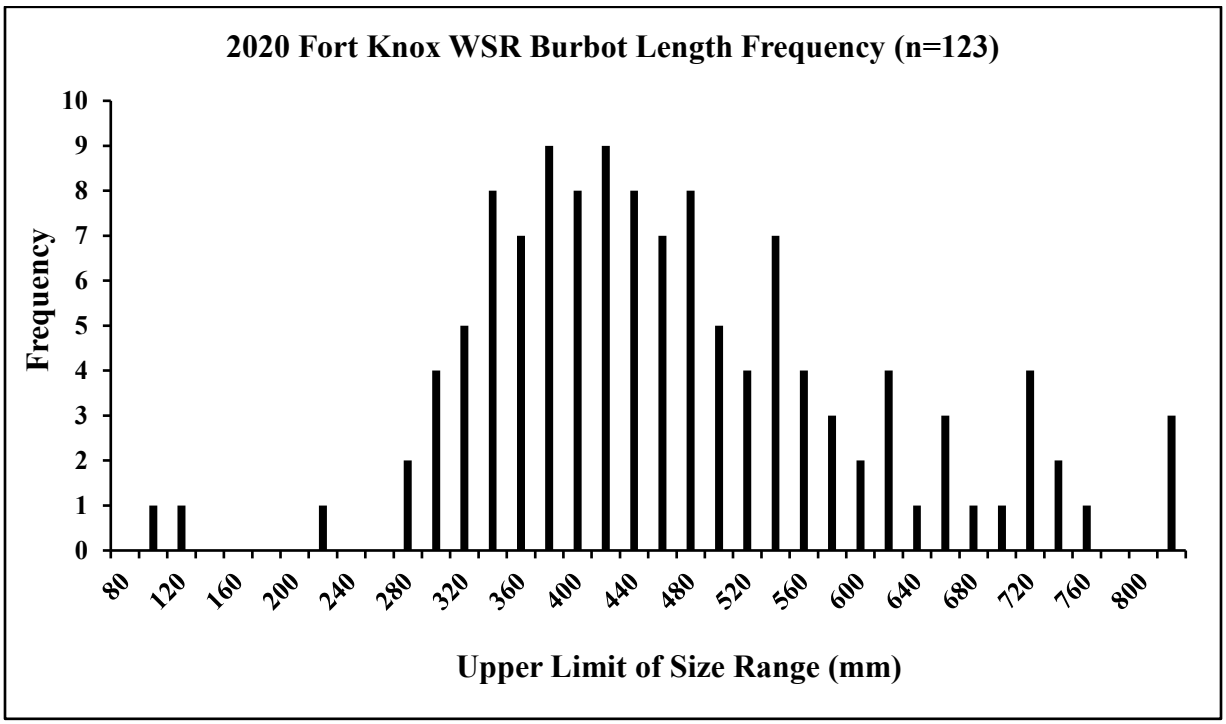

Figure 39. Length-frequency distribution of burbot captured during September and October of 2020, Fort Knox WSR.

The burbot growth rate from fall 2019 to fall 2020 in the WSR averaged 40 mm, which is consistent with the growth rates seen since 2000 (Figure 40). Several large burbot >700 mm were captured that had not been previous tagged by ADF&G (Figure 41).

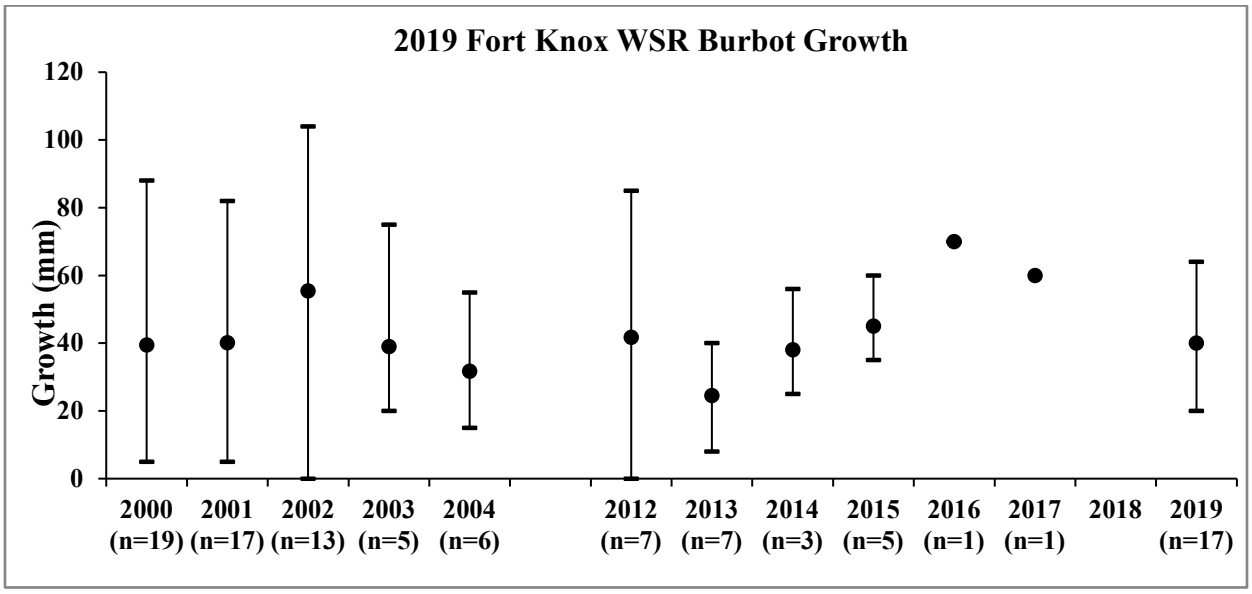

Figure 40. Burbot growth in years with data from 2000 to 2019, Fort Knox WSR. Mean with min/max shown.

Figure 41. A large (>700 mm) newly tagged burbot, October 2020, Fort Knox WSR.

Conclusion

Populations of Arctic grayling and burbot have been established and remain in the Fort Knox WSR. The post-mining population goal for the Arctic grayling in the WSR was set at 800 to 1,600 fish ≥ 200 mm. The spring 2019 population estimate of 4,461 fish ≥200 mm was a decrease from the estimated 2018 population of 6,045 fish but still well above the post-mining population goal. 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. In 2019 that population was estimated to be 203 fish.

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 appears to remain 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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Technical Reports summarizing field work can be found on the Alaska Department of Fish and Game, Division of Habitat Web Page:

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

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

2011

- February 9, ADF&G provided input to ADNR on the environmental audit to be conducted in summer 2011. We identified several possible fish and wildlife enhancement projects originally recommended by Buell and Moody (2005).
- 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. We caught 1,194 Arctic grayling and 117 burbot in a fyke net set in the WSR.
- The estimated spring 2010 Arctic grayling population was 4,346 fish > 200 mm long and was an increase from the 2009 estimate of 3,223. Recruitment of new fish in spring 2011 was strong with 198 new fish < 230 mm marked.
- Arctic grayling spawned in the wetland complex from Pond D downstream. Beavers had not rebuilt the dams in the wetland complex.
- A constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring – 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.
- 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.

Appendix 1 (continued)

2011

- September 28, we met with FGMI to discuss plans to discharge non-contact water from the Fort Knox pit to the WSR.

2012

- Our 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.
- We 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.
- Water was flowing over the spillway when we began sampling in the spring of 2012 – water was still overflowing in late October.
- 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, we 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)

2013

- Our 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.
- We 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 we began sampling, but by May 27 water had begun to flow out of the WSR and over the spillway.
- June 25, we 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, we 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)

2014

- September 4, we 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, we 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, we collected water quality data in the WSR which was ice covered, high DO concentrations were found in Fish Creek Bay.
- April 17, we 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, we field inspected the culvert replacement in Solo Creek and concluded that it had been installed in accordance with the Fish Habitat Permit.
- Spring 2015, we 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)

2015

- Our 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, we 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, we 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, we 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, we 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, we 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)

2017

- In spring 2017, we 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 (≥200mm) 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 Fish Creek.
- 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 North Creek diverting the 3000 gpm of RO water from Outfall 002 into Fish Creek instead of North Fork Fish Creek.
- 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. Fish Creek sites had higher water temperature (6.0 °C) compared to WSR sites.
- April 12 to May 03, we 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 North Creek.
- June 25 to 27, we 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, we 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 from outfall 002 into Fish Creek drainage. Outfall 001 not operated in 2020. Outfall 002 discharged 9,663 acre-feet of RO water.
- Majority of discharged RO water confined to North Fork Fish Creek before combining with Fish Creek and entering the WSR.

Appendix 1 (continued)

- March 2020, FGMI implemented Covid-19 precautions in response to 2020 pandemic when working on FGMI property. ADF&G habitat 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 North Fork Fish Creek 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 North Fork Fish Creek 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.
- November 20, Barns Creek Heap Leach (BCHL) was issued Certificate of Approval to Operate for Stage 1 by ADNR Dam Safety.

Appendix 2. Water Quality Data, from the Fort Knox Water Supply Reservoir (WSR), April 10, 2020.

Site Number (Name)	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (µ S/cm)	pH	ORP
1 (Middle WSR)	4/10/2020	1	0.09	75.5	11.10	160.1	7.16	
		1.54	0.23	73.5	10.79	158.9		
		2.13	0.57	66.9	9.67	183.2		
		2.74	0.87	62.9	9.06	186.6		
		3.35	1.17	59.2	8.47	186.9		
		3.96	1.44	57.9	8.21	186.3		
		4.57	1.71	56.3	7.93	185.8		
		5.18	1.86	55.6	7.78	186.0		
		5.79	1.98	55.0	7.67	185.0		
		6.4	2.08	54.3	7.56	184.9		
		7.01	2.16	53.5	7.44	184.6		
		7.62	2.23	52.4	7.28	184.7		
		8.23	2.30	50.8	7.02	183.9		
		8.83	2.36	49.9	6.88	183.9		
		9.44	2.44	47.8	6.61	183.4		
2 (WSR Near Dam)	4/10/2020	1	0.09	68.2	10.30	206.0	7.35	
		1.54	0.14	66.9	9.80	175.9		
		2.13	0.56	64.5	9.40	188.5		
		2.74	0.97	60.5	8.70	187.0		
		3.35	1.25	58.6	8.34	186.9		
		3.96	1.39	57.4	8.14	186.2		
		4.57	1.68	56.1	7.89	185.4		
		5.18	1.83	55.3	7.75	185.3		
		5.79	1.99	54.5	7.61	185.0		
		6.4	2.06	53.9	7.51	184.8		
		7.01	2.15	53.7	7.44	184.2		
		7.62	2.17	53.3	7.37	184.0		
		8.23	2.33	52.6	7.29	183.5		
		8.83	2.42	52.1	7.19	183.4		
		9.44	2.47	51.8	7.13	183.0		
		10.06	2.58	51.1	7.00	183.5		
		10.67	2.64	50.4	6.90	184.4		
		11.28	2.77	44.6	6.14	181.9		
		11.89	2.77	30.3	4.21	181.3		
		12.5	2.80	19.5	2.70	183.6		
		13.11	2.80	15.1	2.10	184.5		
		13.72	2.79	12.4	1.70	187.1		

		14.33	2.76	10.6	1.46	190.2		
		14.94	2.75	6.5	0.95	191.8		
		15.54	2.73	3.5	0.50	193.9		
		16.15	2.73	2.4	0.34	194.0		
		16.76	2.72	2.0	0.28	195.6		
		17.37	2.76	1.9	0.26	196.3		
		17.98	2.91	1.9	0.26	196.5		
3 (Solo Bay)	4/10/2020	1	1.39	62.2	10.22	149.5	6.86	
		1.54	1.79	58.0	10.25	150.7		
		2.13	1.82	55.5	9.31	177.1		
		2.74	1.82	55.0	8.77	186.9		
		3.35	1.84	54.7	8.43	186.9		
		3.96	1.86	53.7	7.71	186.7		
7 (Last Chance Bay)	4/10/2020	1	0.16	50.1	6.87	165.4	6.93	
		1.54	0.19	46.4	6.27	168.1		
		2.13	0.40	45.3	6.07	174.0		
		2.74	0.80	44.2	5.91	183.8		
		3.35	1.15	43.2	5.79	183.3		
		3.96	1.35	42.0	5.66	183.7		
11 (Polar Bay)	4/10/2020	1	0.11	79.5	11.69	159.4	7.30	
		1.54	0.22	76.2	11.24	150.8		
		2.13	0.51	64.3	9.51	161.0		
		2.74	0.90	53.0	7.65	179.9		
		3.35	1.16	57.3	8.14	188.0		
		3.96	1.41	55.9	7.93	188.3		
		4.57	1.63	55.4	7.80	188.0		
		5.18	1.78	55.3	7.76	187.6		
		5.79	1.86	55.9	7.79	187.7		
		6.4	2.00	55.2	7.70	187.5		
		7.01	2.10	55.2	7.68	187.2		
		7.62	2.40	51.8	7.20	185.7		
		8.23	2.70	39.3	5.44	184.5		
12 (Fish Creek Bay)	4/10/2020	1	0.17	84.1	12.30	150.2	7.37	
		1.54	0.19	83.1	12.19	147.6		
		2.13	0.67	62.9	9.20	178.6		
		2.74	0.91	59.2	8.53	186.0		
		3.35	1.20	52.1	7.48	187.5		

Appendix 3. Population estimates of Arctic Grayling ≥ 200 mm in the Fort Knox Water Supply Reservoir (WSR), 1995-2019.

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		5,800	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

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

[2]In 1995, we 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 2017 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, 2019-2020.

Upper Limit (mm)	Average (mm)	Maximum (mm)	Minimum (mm)	Sample Size
210	42	55	33	5
220	39	50	27	5
230	31	52	17	13
240	34	73	15	23
250	25	54	0	39
260	20	43	0	58
270	22	58	0	55
280	22	46	0	60
290	18	44	0	42
300	16	32	0	20
310	11	16	8	5
320	9	18	3	3
330	18	18	18	1
340	5	5	5	1
350	0	0	0	0

Appendix 5. Population Estimate of Burbot (≥ 400mm) in the Fort Knox Water Supply Reservoir (WSR), 2001-2019.

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