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# ARCTIC GRAYLING AND BURBOT STUDIES IN THE FORT KNOX WATER SUPPLY RESERVOIR AND DEVELOPED WETLANDS (2000)

By Alvin G. Ott and William A. Morris

Photo by Alvin Ott, Pond B in Developed Wetlands

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Alaska Department of Fish and Game Habitat and Restoration Division

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## Acknowledgments

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# Executive Summary

This report summarizes data collected on water quality, phytoplankton, zooplankton, Arctic grayling (*Thymallus arcticus*), and burbot (*Lota lota*) in the Fort Knox water supply reservoir (WSR) and developed wetlands. Arctic grayling and burbot population data from 1995 through 2000 and water quality information from 1997 through 2000 are presented and compared.

Water in the WSR continues to show depressed dissolved oxygen concentrations with depth. The Fort Knox WSR inundated an area containing vast amounts of organic material creating the potential for high biological and chemical oxygen demand. Although dissolved oxygen concentrations showed some increase in 1998 and 1999, concentrations are still depressed with depth. Water quality monitoring in the WSR will continue to document changes in water quality over time.

The estimated number of zooplankton in the upper five m of water ranged from 6.1 to 22.25 zooplankton per l. About 85% of the zooplankton were Daphnia and 15% were Copepoda. The phytoplankton standing crop in the WSR was estimated from chlorophyll-a concentrations extracted from filtered samples. The average chlorophyll-a in all sample sites was 2.9 $mg/m^3$. The phytoplankton standing crop in the WSR is similar to that measured in mesotrophic, Chena Lakes.

Arctic grayling >200 mm in length continue to dominate the population. However, small Arctic grayling <150 mm were captured and seen in summers 1999 and 2000. The presence of small Arctic grayling probably is the result of rehabilitation work in the developed wetlands. A channel constructed in early May 1999 provided adult Arctic grayling access to several pond complexes and stream channels for spawning. The wetlands and interconnecting stream channels were used extensively by adult Arctic grayling for spawning. Young-of-the-year and juvenile fish were numerous in this area in summer 2000. The estimated adult population for the WSR in early spring 1999 was 4,123. Our spring 1999 estimate of Arctic grayling population size decreased from our spring 1998 estimate of 5,800 fish. Our estimated Arctic grayling population size (all

size classes) just prior to construction of the freshwater dam was about 6,000. Survival of large or adult Arctic grayling since creation of the WSR appears high.

The burbot population in the WSR has increased substantially and currently is dominated by fish 275 to 325 mm long. Although not numerous, there are individual burbot in the WSR >700 mm long. The preproject estimated burbot population was 825 fish >150 mm. The spring 1999 estimate of abundance for burbot >200 mm was 4,136. The substantial increase in burbot numbers is due to successful spawning and recruitment of burbot less than 300 mm into the population. Small burbot (<150 mm) have not been observed for several years, but this probably is affected by predation in the sample gear types used (hoop traps and fyke-nets).

# Introduction

Fairbanks Gold Mining, Inc. (FGMI) began construction of the Fort Knox hard-rock gold mine in March 1995. The mine is located in the headwaters of the Fish Creek drainage about 25 km northeast of Fairbanks (Figure 1). The project includes an open-pit mine, mill, tailing impoundment, water supply reservoir (WSR), and related facilities. During construction of the WSR, we monitored activities in the field and summarized the various aspects of dam construction that included a stream bypass (Ott and Weber Scannell 1996, Ott and Townsend 1997). Construction of the WSR dam and spillway was complete by July 1996. Rehabilitation, to the extent practicable, has been concurrent with mining activities and natural revegetation of disturbed habitats has been rapid (Figure 2). Development of wetlands between the tailing dam and head of the WSR began in summer 1998 with additional civil work, seeding, and willow sprigging occurring in summers 1999 and 2000.

The projected maximum water surface elevation in the WSR is 1,021 feet. Water levels varied widely in 1996 and 1997, due to water use and winter seepage below the dam that exceeded freshwater input. The WSR reached the projected maximum water level on September 29, 1998 following substantial summer rainfall. Water levels during summers 1999 and 2000 were fairly constant and flow through the low-flow channel in the spillway was present. Seepage flow below the dam remained fairly constant during 1999 at a rate of about 1.16 to 1.82 cfs (geometric mean 1.47 cfs) and from 1.03 to 1.86 cfs (geometric mean 1.38 cfs) in 2000.

Fish research was initiated in 1992 and focused on streams in and downstream of the project area (Weber Scannell and Ott 1993). In 1993, sampling continued and we began to collect fish data in abandoned settling ponds and mine cuts that would be flooded by the WSR (Weber Scannell and Ott 1994). In 1994, we established and sampled stream reaches above and below the area to be flooded (Ott et al. 1995).

Stream sampling continued in 1995 and we estimated the size of the Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) populations that would be available to

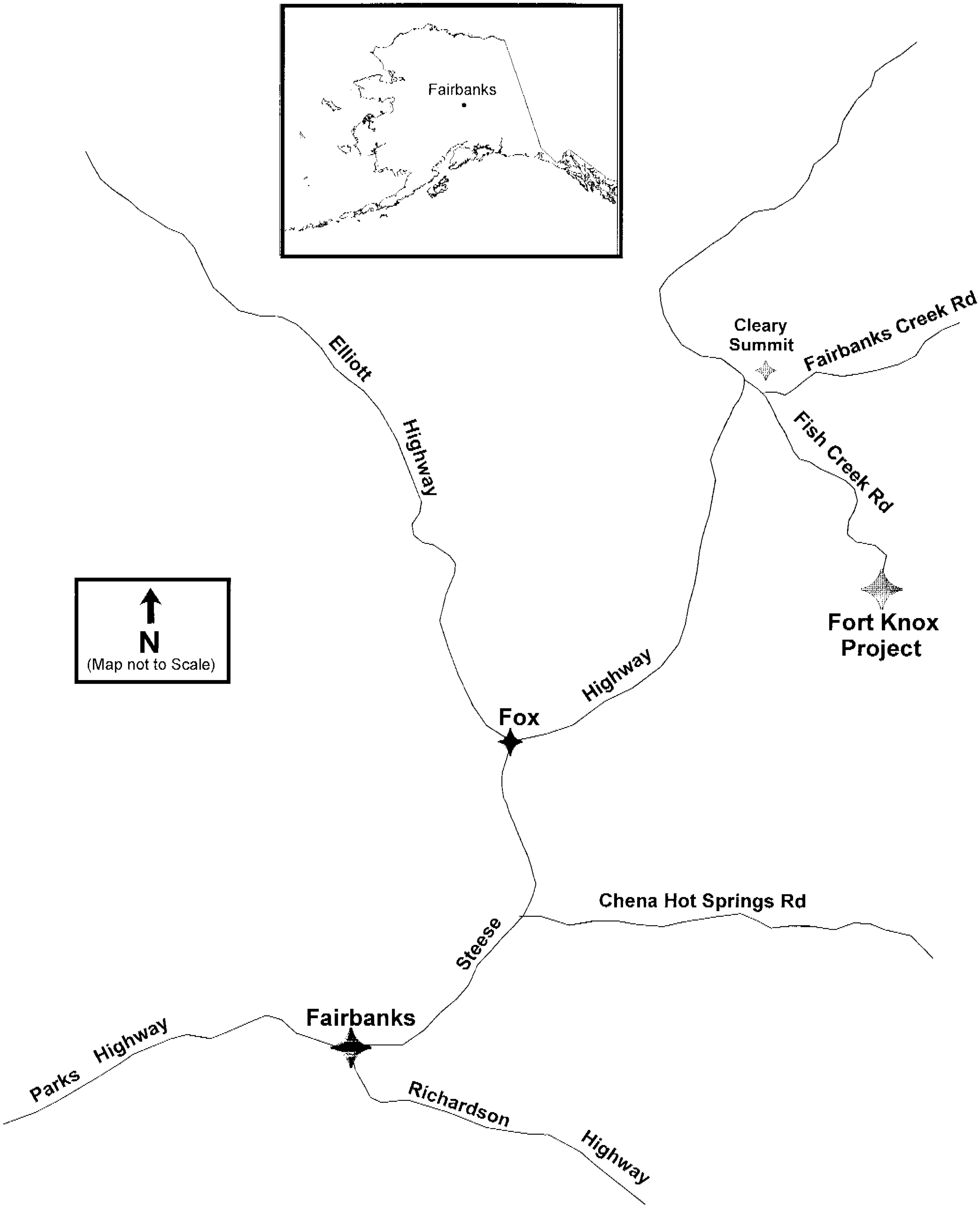



**Figure 1. Fort Knox project location.**

Figure 2. Rehabilitation and natural revegetation of disturbed habitat adjacent to the freshwater dam spillway. Top photograph taken in summer 1997, bottom photograph taken on June 26, 2000.

colonize the WSR (Ott and Weber Scannell 1996). The Arctic grayling population in Fish Creek, upstream of the freshwater dam in 1995 was estimated at 1,700 individuals <150 mm, and 4,350 individuals ≥150 mm. The number of burbot (150 to 331 mm) in the upper Fish Creek drainage was estimated at 825.

In 1996, we began to monitor Arctic grayling and burbot use of the WSR, gathering information on growth, production of age-0 fish, and catch per unit of effort (CPUE) (Ott and Weber Scannell 1996). The Arctic grayling population estimate for fish ≥150 mm in summer 1996 was 4,748. We estimated the Arctic grayling population in the WSR with two event mark-recapture experiments using spring 1998 as the mark event ($n_1$ = 355) and spring 1999 as the recapture event. Our estimate of abundance for the spring 1998 Arctic grayling population for fish >200 mm was 5,800 (95% CI 4,705 to 6,895) (Ott and Morris 2000).

In 1996, few age-0 Arctic grayling were captured; however, age-0 burbot were abundant (Ott and Townsend 1997). In May 1997, we estimated the burbot population (fish ≥250 mm) at 622 fish. Age-0 burbot were abundant in fall 1997, while age-0 Arctic grayling were virtually absent (Ott and Weber Scannell 1998). In spring 1998, we conducted a mark/recapture effort to estimate burbot abundance. Our population estimate in 1998 for burbot ≥300 mm was 703 (95% CI 499 to 907) with an unknown number <300 mm (Ott and Morris 1999). We estimated the burbot population in the WSR using spring 1998 as the mark event ($n_1$ = 305) and spring 1999 as the recapture event. Our spring 1998 estimate of abundance for burbot >200 mm was 3,609 (95% CI 2,731 to 4,485) (Ott and Morris 2000). The substantial discrepancy between the two estimates is due to the large abundance of burbot 200 to 300 mm in length not included in the former estimate.

We began water quality monitoring in the WSR in September 1997 and found anaerobic conditions in the middle of the lake (Ott and Weber Scannell 1998). Water quality conditions, specifically dissolved oxygen concentrations, improved in summer 1998 but were still depressed with depth (Ott and Morris 1999). Dissolved oxygen concentrations generally were higher in 1999 in the upper portion of the water column (Ott and Morris 2000). This report summarizes fish and water quality data collected during 2000 and discusses these findings in relation to previous work.

# Methods

## Sampling Sites

Water quality sampling began in fall 1997 in the WSR and in summer 1999 in the developed wetlands. Seven fyke-net sampling sites in the WSR were established in 1996, two sites were added in 1998 (#9 and #10), two stations were established in the developed wetlands in 1999 (#11 and #12), and a new site was fished in the WSR in 2000 (#13) (Figures 3 and 4). In summer 2000, fyke-nets were fished at six sites: #2 (Lower Last Chance Bay), #12 (Pond E), #13 (Outlet Channel from Pond F), #10 (Upper Last Chance Bay), #1 (Solo Creek Bay), and #9 (Spillway). The general area for each net site is fixed but exact location varies with water level. Hoop traps were fished throughout the WSR east of the new road.

## Water Quality

Temperature (°C), dissolved oxygen concentration (mg/L), dissolved oxygen percent saturation (thermally and barometrically corrected), pH, conductivity (*u* S/cm), and depth (m) were measured with a Hydrolab® Minisonde® water quality multiprobe connected to a Surveyor® 4 water quality display unit. The meter was calibrated to suggested specifications prior to use in the field. The dissolved oxygen concentration was calibrated using the open-air method. Conductivity and pH were calibrated with standard solutions. Water quality measurements were made at the surface, at 1 m depth intervals, and at the bottom. In the developed wetlands, measurements were made near the shoreline at a depth of about 0.5 m.

## Zooplankton and Phytoplankton

Zooplankton samples were collected using a 130 mm diameter Wisconsin Plankton Net and Bucket. A single vertical tow through the top 5 m of the water column was made at each of the five water quality sample sites in the WSR. The net sampled 63.3 l of water. The vertical plankton net was lowered to a depth of 5 m, slowly pulled to the

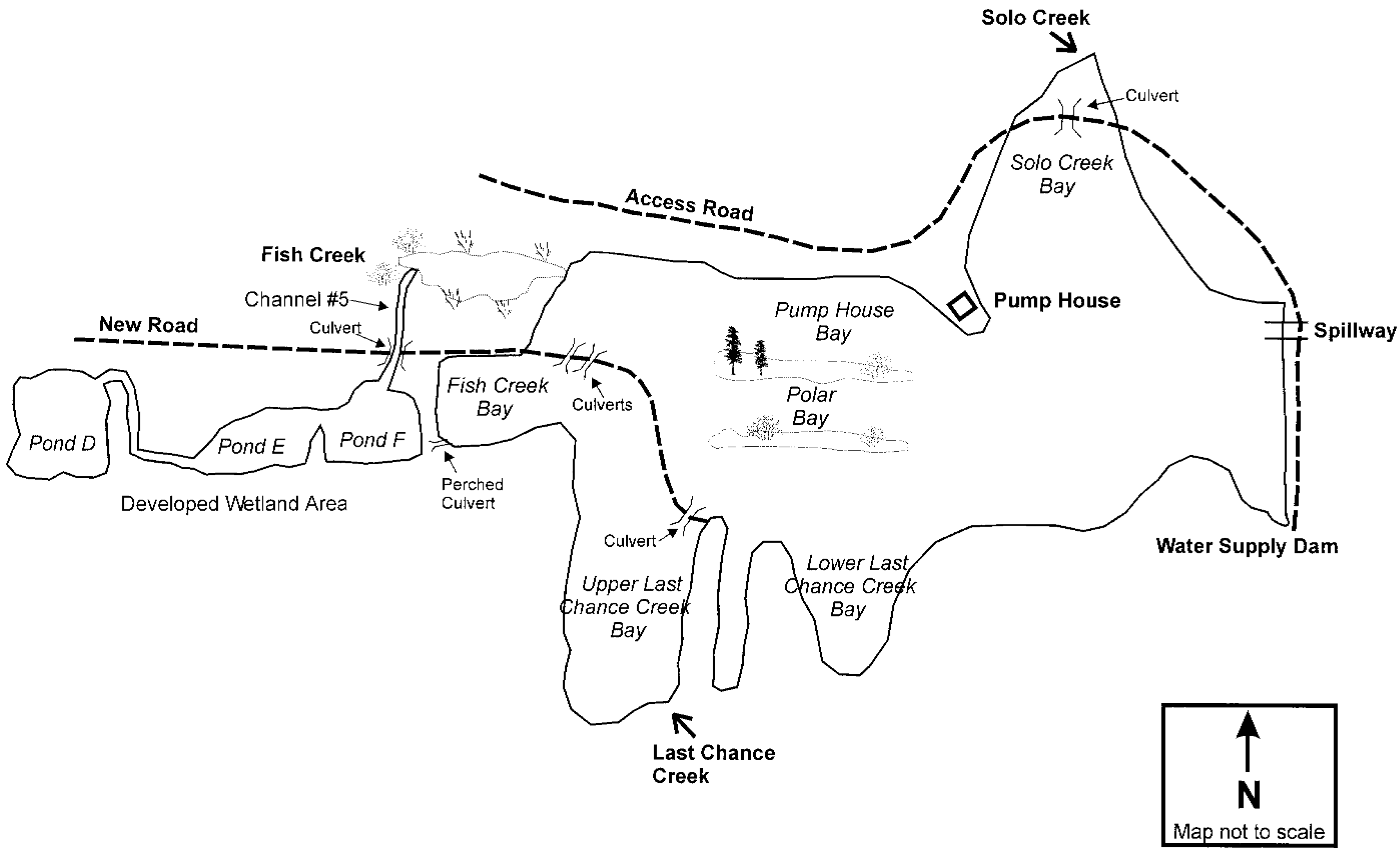



Figure 3. Sample areas in the Fort Knox water supply reservoir and developed wetlands.

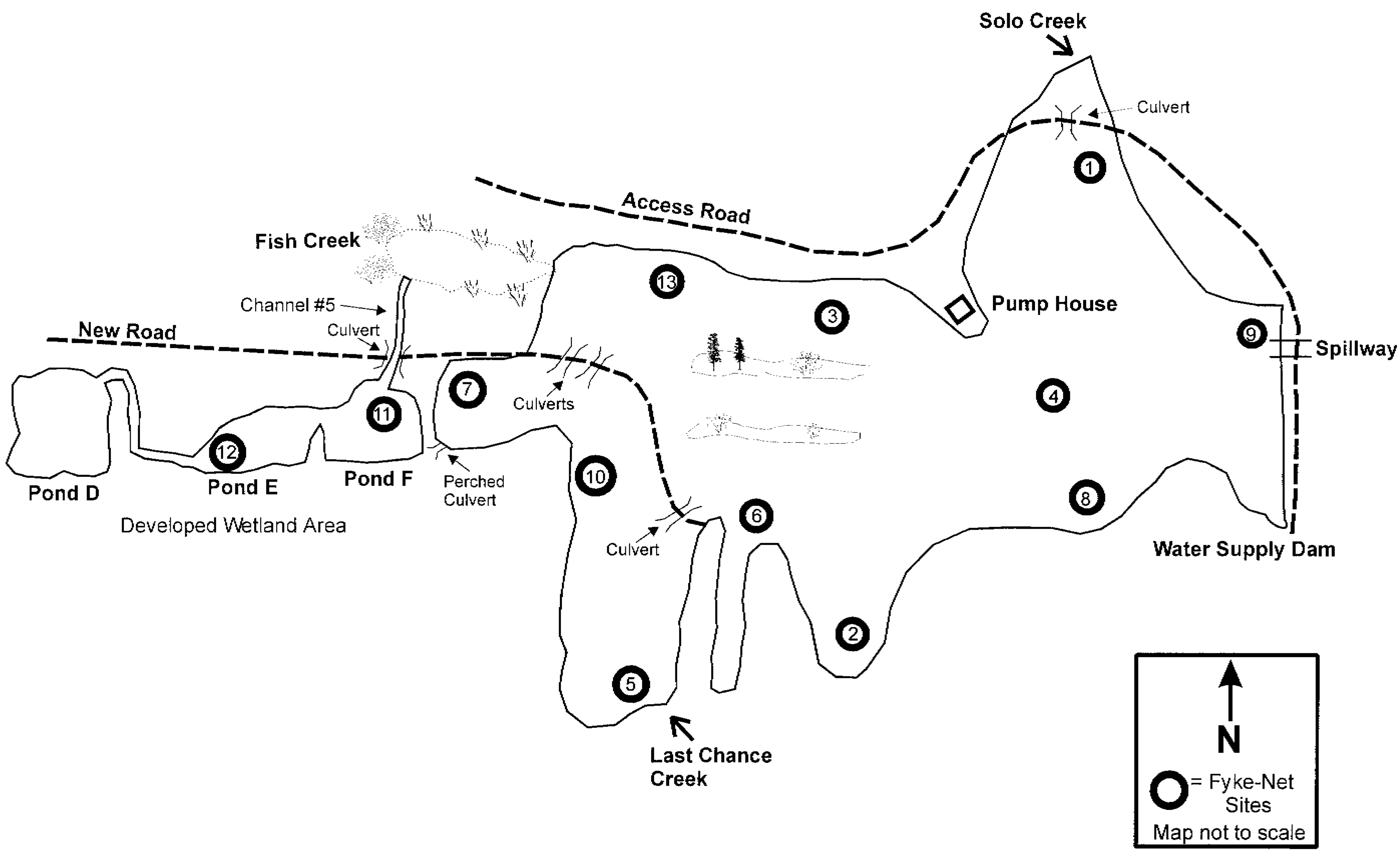



Figure 4. Fyke-net sample sites in the Fort Knox water supply reservoir and developed wetlands (1996-2000).

surface, and zooplankton were removed by opening the clamp on the outlet hose. Zooplankton were washed into plastic containers, labeled, and preserved in 70% ethyl alcohol.

Chlorophyll samples were collected at each of the five water quality sample sites in the WSR using methods described for Red Dog Mine samples (Alaska Department of Fish and Game 1998). Water was obtained at depth using a 2.2 l VanDorn vertical water sampler. The sampler features a full cylinder opening with unobstructed water flow through the sampler with flexible, plunger-like end seals pulled closed by an elastic (rubber) tube. The VanDorn sampler was lowered to the depth prescribed, then a metal messenger was dropped down the line to trip the closing mechanism. Water from the VanDorn sampler (1,000 ml) was filtered through a 0.45 um A/E glass fiber filter, attached to a hand vacuum pump. After extracting as much water as possible, about 1 ml of saturated $MgCO_3$ was added to the filter (to prevent acidification and the conversion of chlorophyll to phaeophytin), each sample was labeled, placed in a sealable plastic bag, and packed over silicon-gel desiccant to absorb additional moisture. Filters were frozen in a light-proof container with desiccant.

Filters were cut into small pieces and placed in a centrifuge tube with 10 ml of 90% buffered acetone. Extraction tubes were placed in a metal rack, covered with aluminum foil and held in a dark refrigerator for 24 hrs. After extraction, samples were read on a Shimadzu UV-1601 Spectrophotometer (1995) and a Turner Model 10 Fluorometer (1996). Trichromatic equations (according to Standard Methods, APHA 1992) were used to convert spectrophotometric optical densities to total chlorophyll-a. The Turner Fluorometer was calibrated with successive chlorophyll-a dilutions read on both the spectrophotometer and fluorometer. Primary and secondary standards were used to confirm the calibration curve, according to Standard Methods (APHA 1992).

## Fish

Field sampling methods and gear included visual observations, fyke-nets, and hoop traps (Figure 5). Burbot and Arctic grayling captured during May and June were measured and marked with a numbered Floy internal anchor tag. Two burbot,

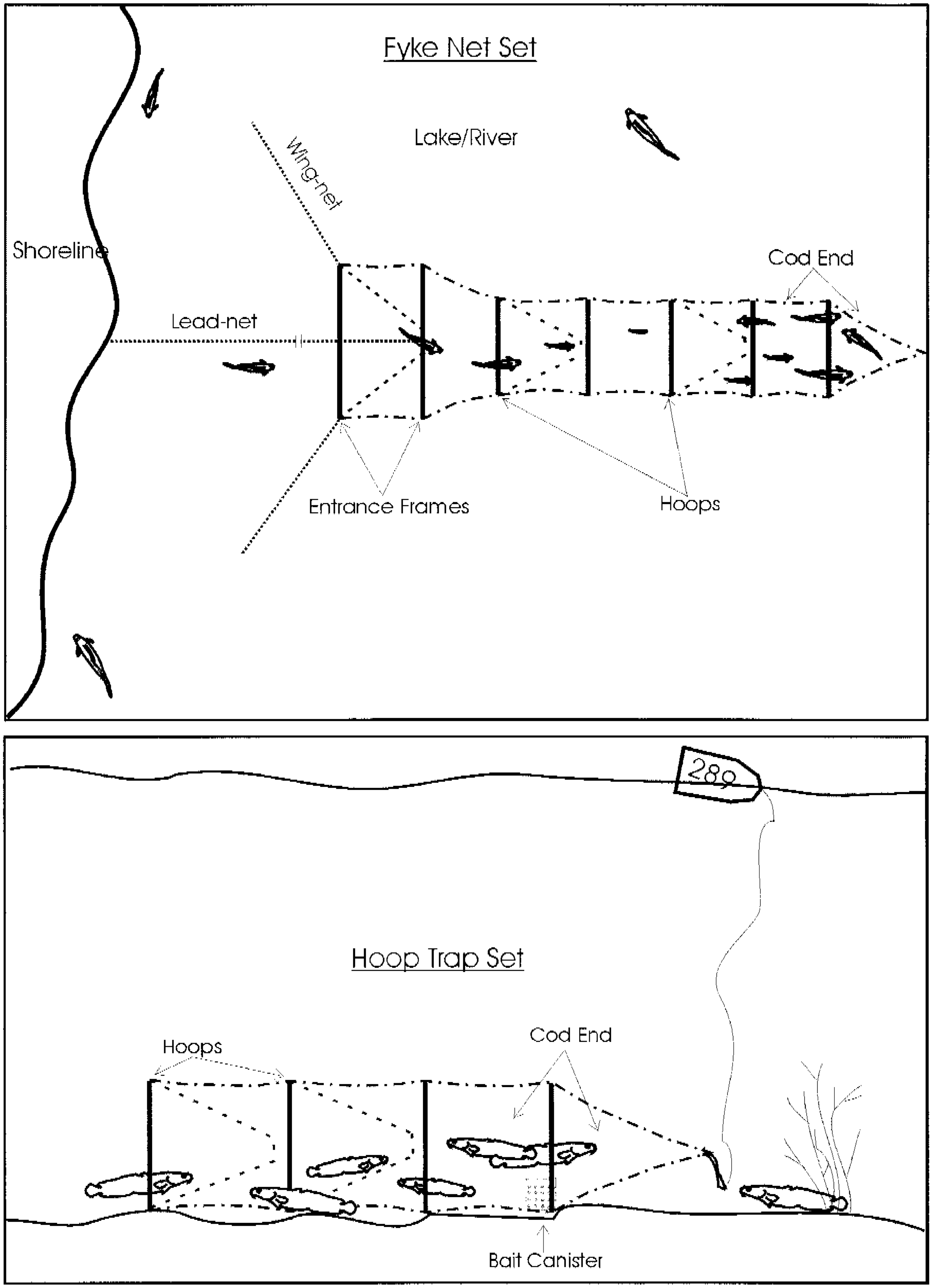



**Figure 5. Fyke-net and hoop trap sets (diagram).**

recaptured in 2000, which had been marked and injected with oxytetracycline in 1995, were retained for age validation studies.

Three sizes of fyke-nets were used. Entrance frames were either 0.9 $m^2$ or 1.2 $m^2$ or 0.69 m by 0.99 m (mini-fyke). The large fyke-nets were 3.7 m long, had five hoops, a 1.8 m cod end, and two 0.9 m by 7.6 m wing nets attached to the entrance frame. The mini-fyke nets were 3.7 m long, had four hoops, a 1.8 m cod end, and two 0.91 m by 4.6 m wing nets. All netting was 10 mm square mesh. Center leads varied from 7.6 m to 30.4 m and were deployed to the maximum extent possible without submerging the top of the entrance frame. Nets were set with the center lead either perpendicular to or at an angle to the shore. Unbaited fyke-nets were fished 24 hrs and either reset or removed.

We used hoop traps baited with salmon roe and fish to collect burbot. Traps generally fished 24 hrs and were rebaited if reset. Hoop traps were 1.6 m long with four hoops 54 cm in diameter. Netting was 8.5 mm bar mesh. All traps were kept stretched and open with spreader bars. Each trap had one throat and a cod end that was tied shut.

Abundance of Arctic grayling and burbot populations 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)

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

95% CI for the population estimate was calculated as

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

# Results and Discussion

## Water Supply Reservoir and Developed Wetlands, Water Quality

Five water quality sample sites were established and sampled in the WSR beginning in fall 1997 (Ott and Weber Scannell 1998) (Figure 6). Data collected at these five sites during all sample events are presented in Appendix 1.

In 2000, dissolved oxygen concentrations were lowest in May, and increased in June and August within 2 m of the surface at Site #2 (Figure 7). Concentrations of dissolved oxygen decreased with depth from the thermocline (the region of the water column with the highest rate of change in temperature with depth – about 2 m deep at Site 2). Oxygen concentrations were low in the lower layer (hypolimnion) of the reservoir during the summer.

Dissolved oxygen concentrations measured in spring 1999 and 2000 were highest in the epilimnion (upper water layer), then decreased sharply at the thermocline (about 5 m) (Figure 8). Concentrations throughout the water column were lower in spring 2000 than in spring 1999.

In fall 2000, dissolved oxygen concentrations at Sites #3 (Solo Creek Bay) and #11 (Polar Bay) decreased to a depth of 5 and 3 m (Figures 9 and 10). At Site #3, dissolved oxygen reversed the downward trend and increased at the 6 m depth. In Polar Bay, dissolved oxygen increased at the 4 and 5 m depth. These increased dissolved oxygen concentrations probably reflect freshwater input from Solo and Last Chance creeks. Dissolved oxygen concentrations in the epilimnion were similar in fall 1998 and 2000. Measurements recorded in fall 1998 may have coincided with the fall turnover of the water column that mixed waters creating a more uniform concentration of dissolved oxygen.

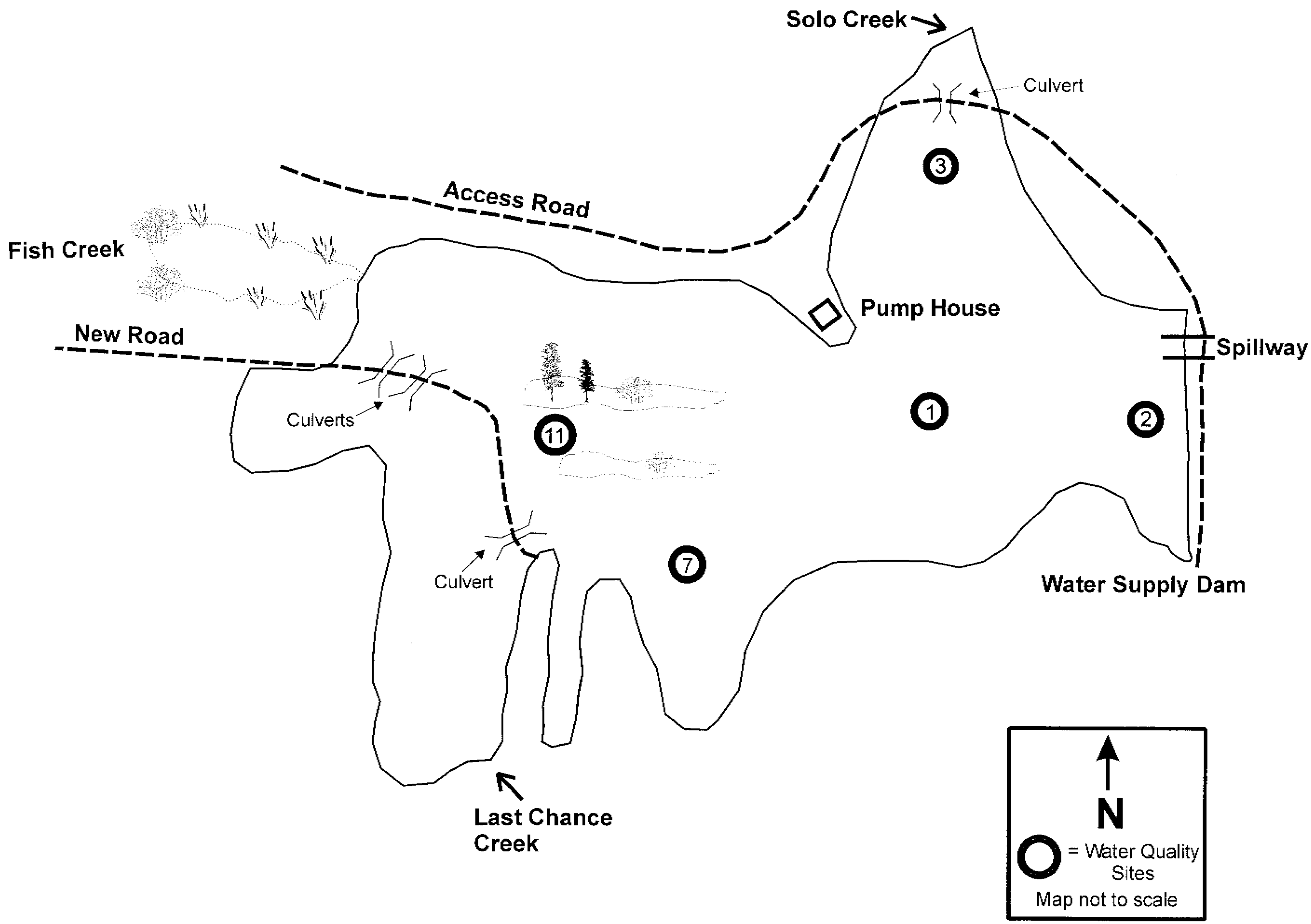
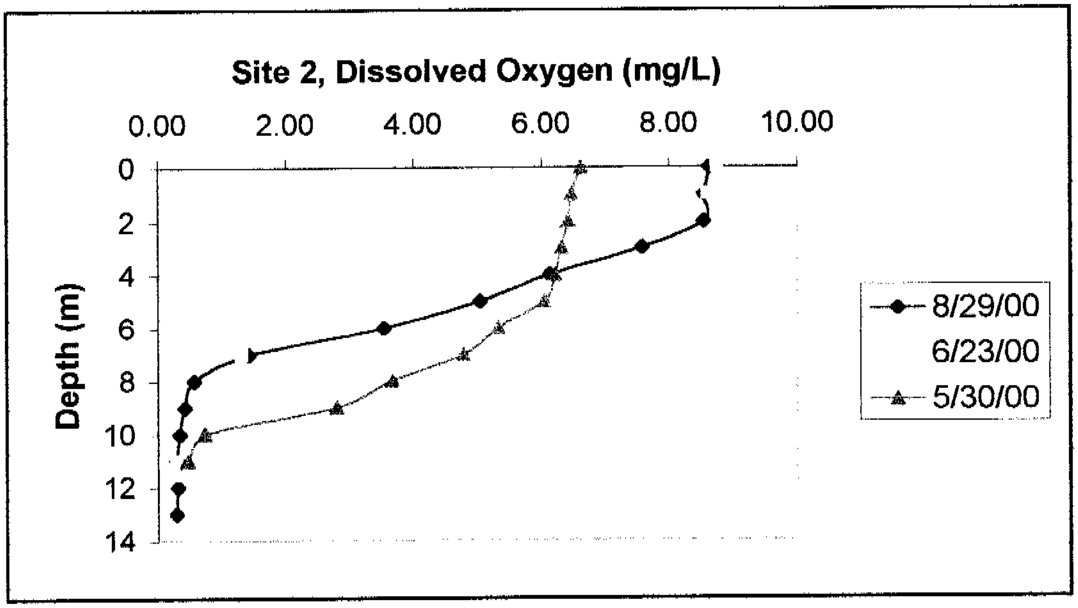



Figure 6.  Water quality sample sites in the Fort Knox water supply reservoir.



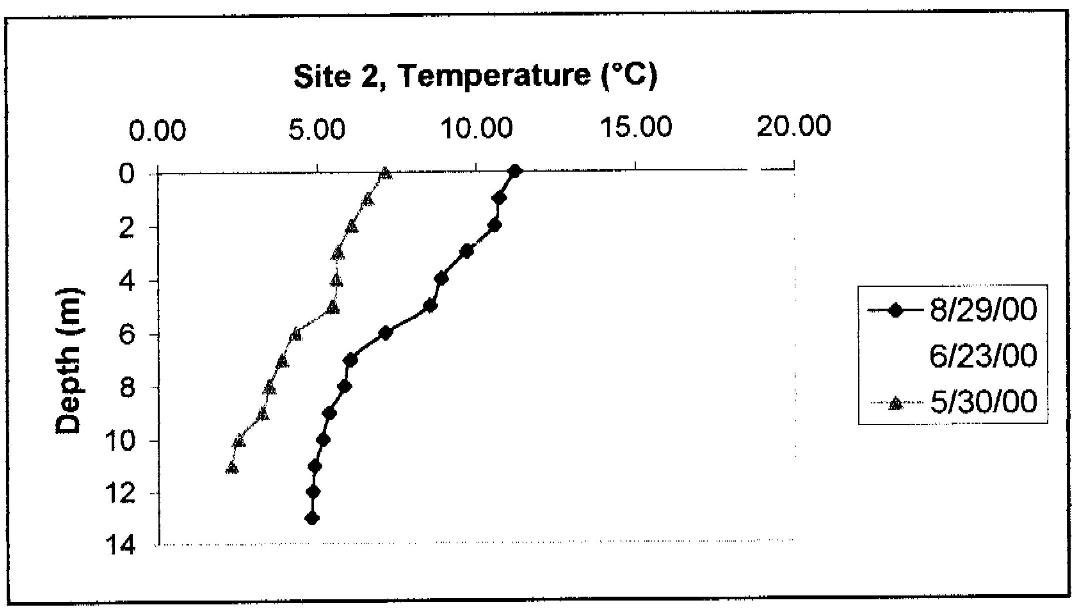
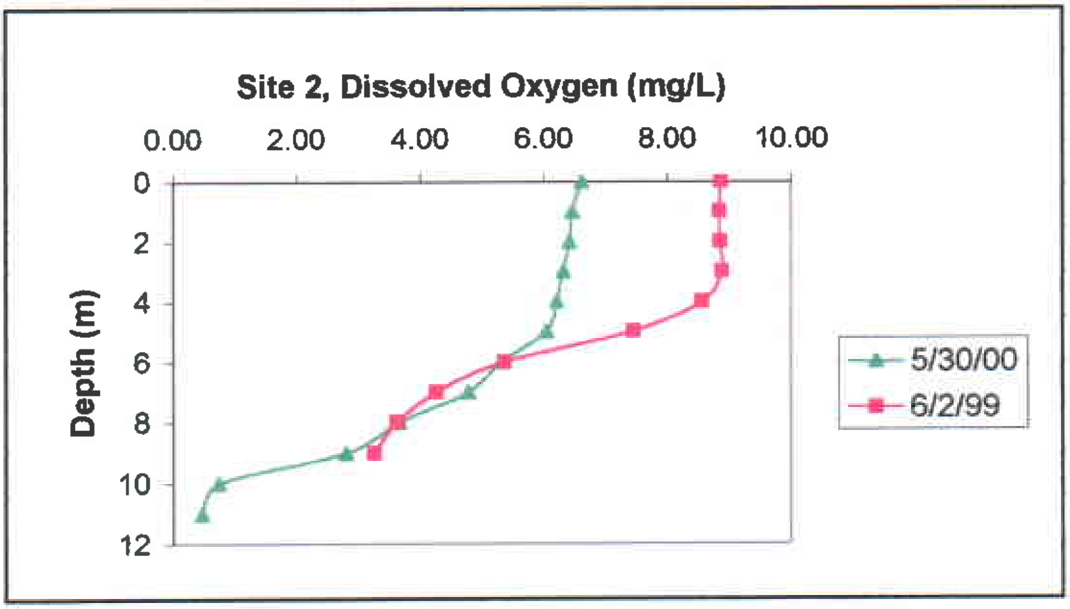




Figure 7. Dissolved oxygen concentration and temperature at Site #2 (Spillway) by depth in the water supply reservoir during the open water period, 2000.



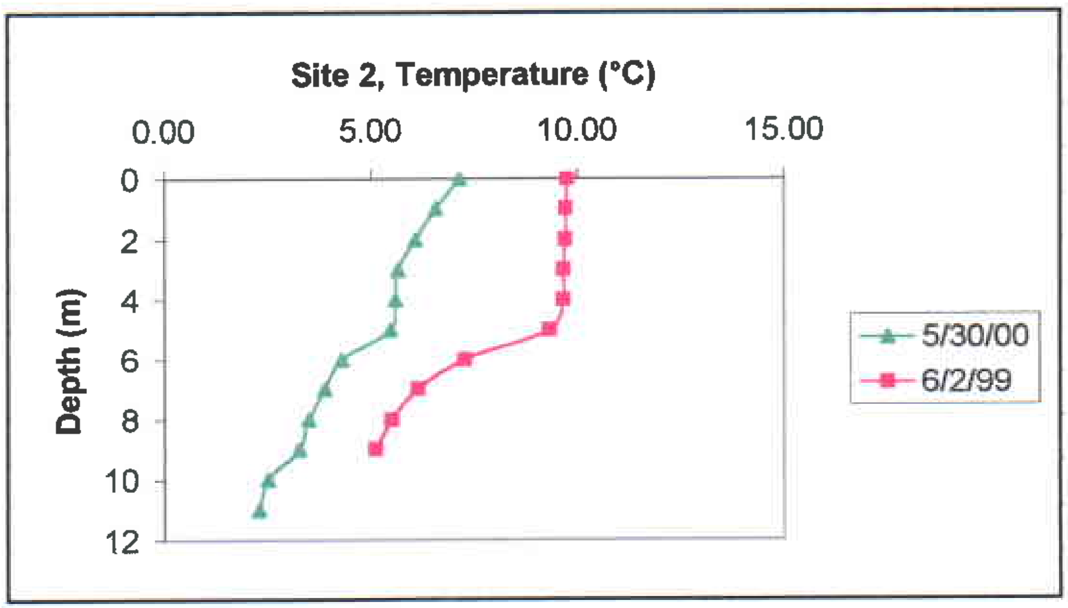
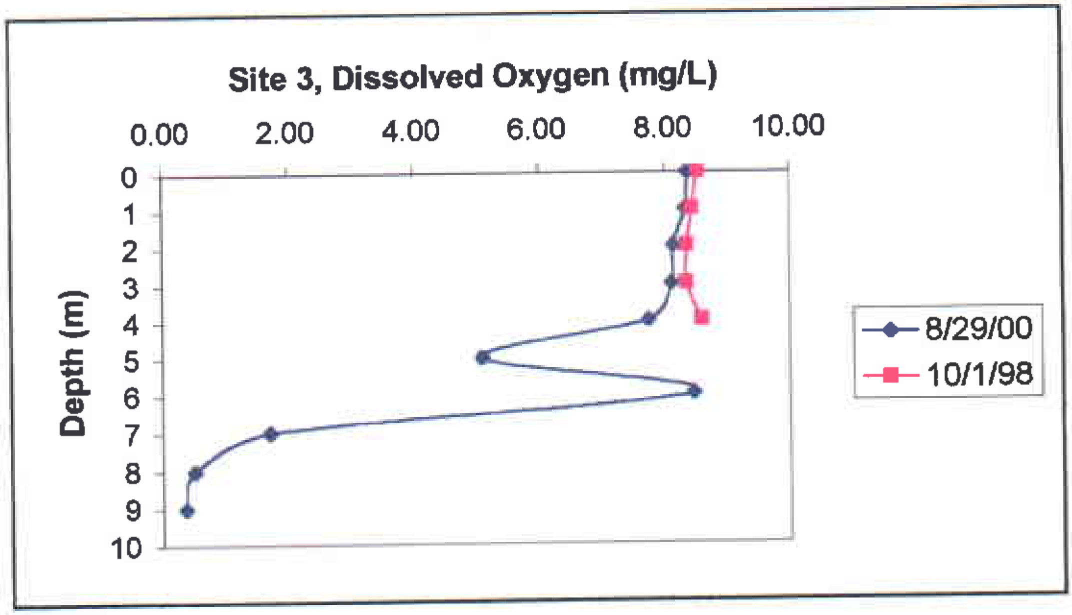




Figure 8. Dissolved oxygen concentration and temperature at Site #2 (Spillway) by depth in the water supply reservoir in early spring 1999 and 2000.



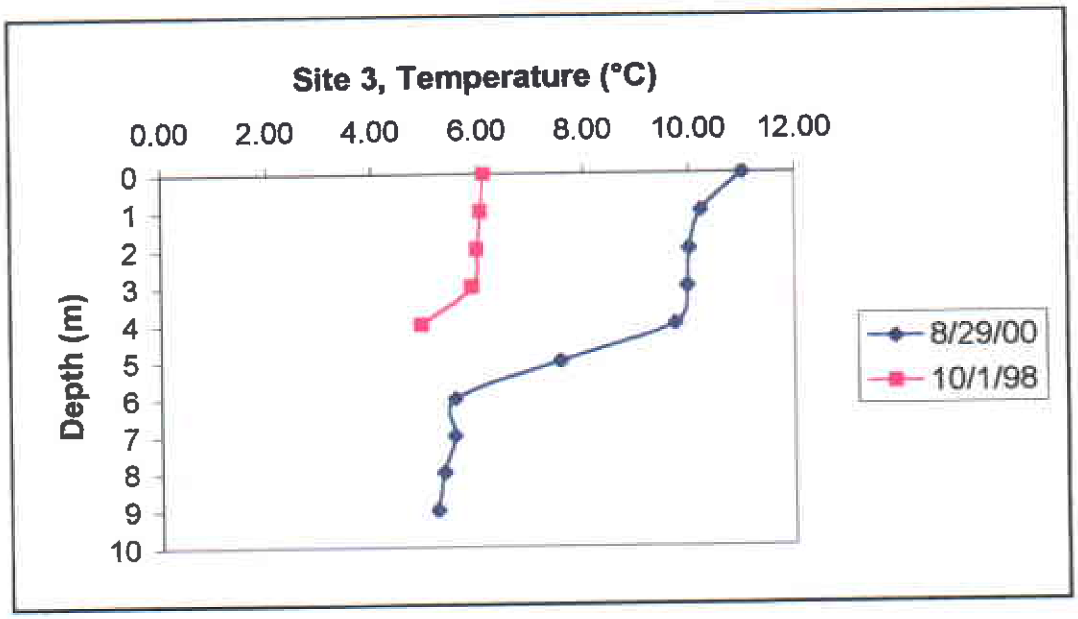
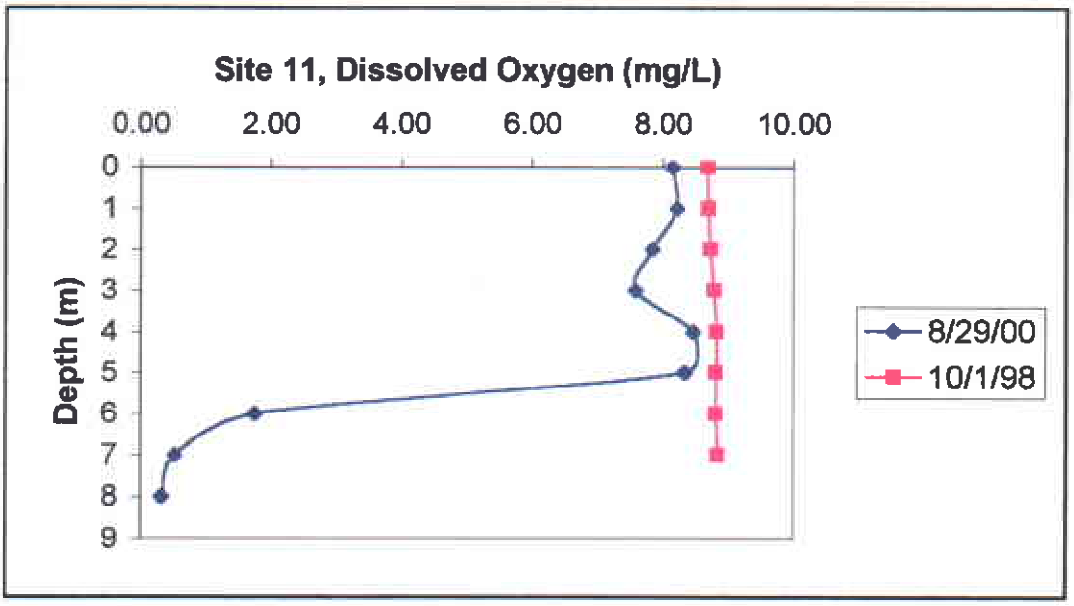




**Figure 9. Dissolved oxygen concentration and temperature at Site #3 (Solo Creek Bay) by depth in the water supply reservoir in fall 1998 and 2000.**



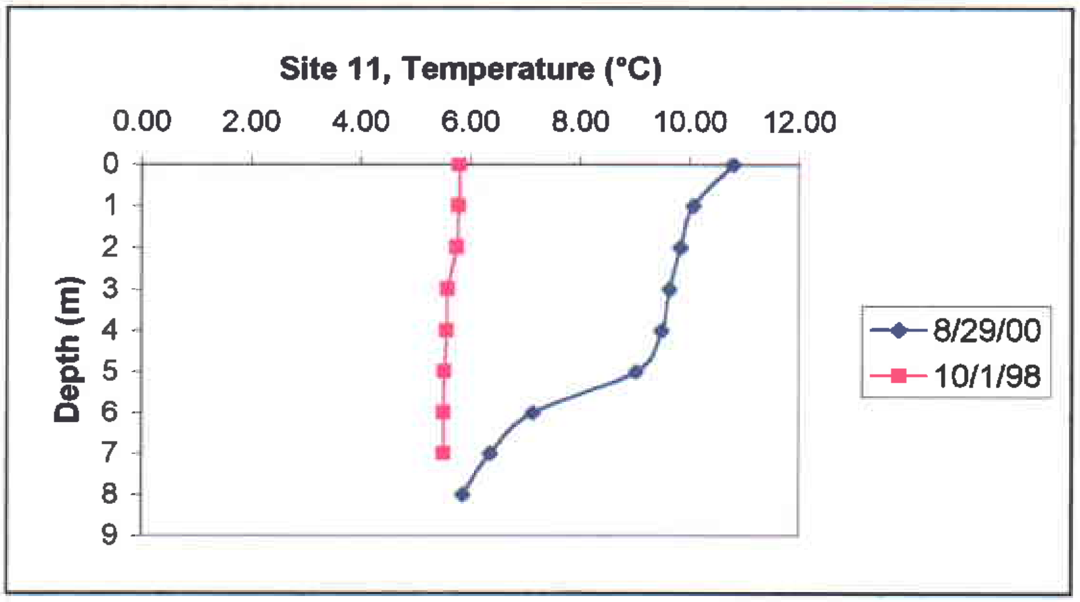




**Figure 10. Dissolved oxygen concentration and temperature at Site #11 (Polar Bay) by depth in the water supply reservoir in fall 1998 and 2000.**

By late September 1998, the WSR had filled with water and an estimated 2 to 3 cfs was flowing out of the reservoir through the low-flow channel of the spillway. The outflow of surface water from the WSR was the first reported since the dam was constructed. Water level in the WSR dropped during winter 1998/1999, but the reservoir was nearly full following spring breakup. Outflow of water through the spillway began again in June 1999 and was intermittent until fall with flow still present in the spillway flow channel in November 1999. During summer 2000, outflow of water occurred throughout the open-water period and continued through January 2001 at the time of report compilation.

The Fort Knox WSR inundated an area containing vast amounts of organic material creating the potential for high biological and chemical oxygen demand. Water quality monitoring in the WSR will continue to document changes in water quality over time.

Water quality data have been collected in the developed wetlands, the inlet to Pond A, and the outlet of Pond F (Figure 4) (Appendix 2). Spring 2000 sampling focused on the inlet to Pond A and outlet from Pond F. Sampling the outlet from Pond F provided water temperature data directly related to the movement and spawning of Arctic grayling. Water temperatures in Pond F outlet rose from 0.28°C on May 1 to 3.6°C on May 16. Specific conductivity in Pond F outlet was 137.6 u S/cm on May 1 but decreased as flows increased. Dissolved oxygen concentrations ranged from 11.23 to 12.3 mg/L. Adult Arctic grayling were captured in the fyke-net fished in Pond E on May 17. Adults probably began the spawning migration on May 16 at a water temperature of 3.6°C.

## Zooplankton and Phytoplankton

Zooplankton were collected at the five water quality sample sites in late August 2000. About 85% of the zooplankton were Daphnia and 15% were Copepoda. One Collembola and one phantom midge (Diptera: Chaoboridae) were recorded. Numerous free Daphnia eggs were observed and some of the Daphnia were still carrying oil sacs and egg cases. The estimated number of zooplankton ranged from 6.1 to 22.25 zooplankton per l (average 14.98, SD = 6.6). The highest concentration of zooplankton was found in lower Last Chance Bay; the lowest was in Polar Bay.

The phytoplankton standing crop in the WSR was estimated from chlorophyll-a concentrations extracted from filtered samples. Samples were collected from the surface and from one to two m intervals until the thermocline was reached. The estimates for phytoplankton do not reflect productivity of the system; phytoplankton standing crop likely is considerably lower than productivity because of high zooplankton grazing rates.

The average chlorophyll-a concentration was 2.9 $mg/m^3$. This estimate of phytoplankton standing crop is in the range defined by Wetzel (1975) for mesotrophic systems. The phytoplankton standing crop in the WSR is similar to that measured in mesotrophic Chena Lakes in fall 2000 (average 3.4 $mg/m^3$ chlorophyll-a) and considerably higher than that measured in oligotrophic Summit Lake in summer 1999 (average 0.13 $mg/m^3$ chlorophyll-a) (Weber Scannell, unpublished data).

The phytoplankton standing crop measured in the WSR was similar at the surface at all sites, then sharply declined near the thermocline in all locations except Lower Last Chance Bay (Site #7, Figure 11). Lower Last Chance Bay is a shallow area of the WSR where mixing likely occurs to greater depths. The upper, or photic, layer in the WSR appears to mix almost evenly to the thermocline. The nearly even distribution of phytoplankton reflects this mixing.

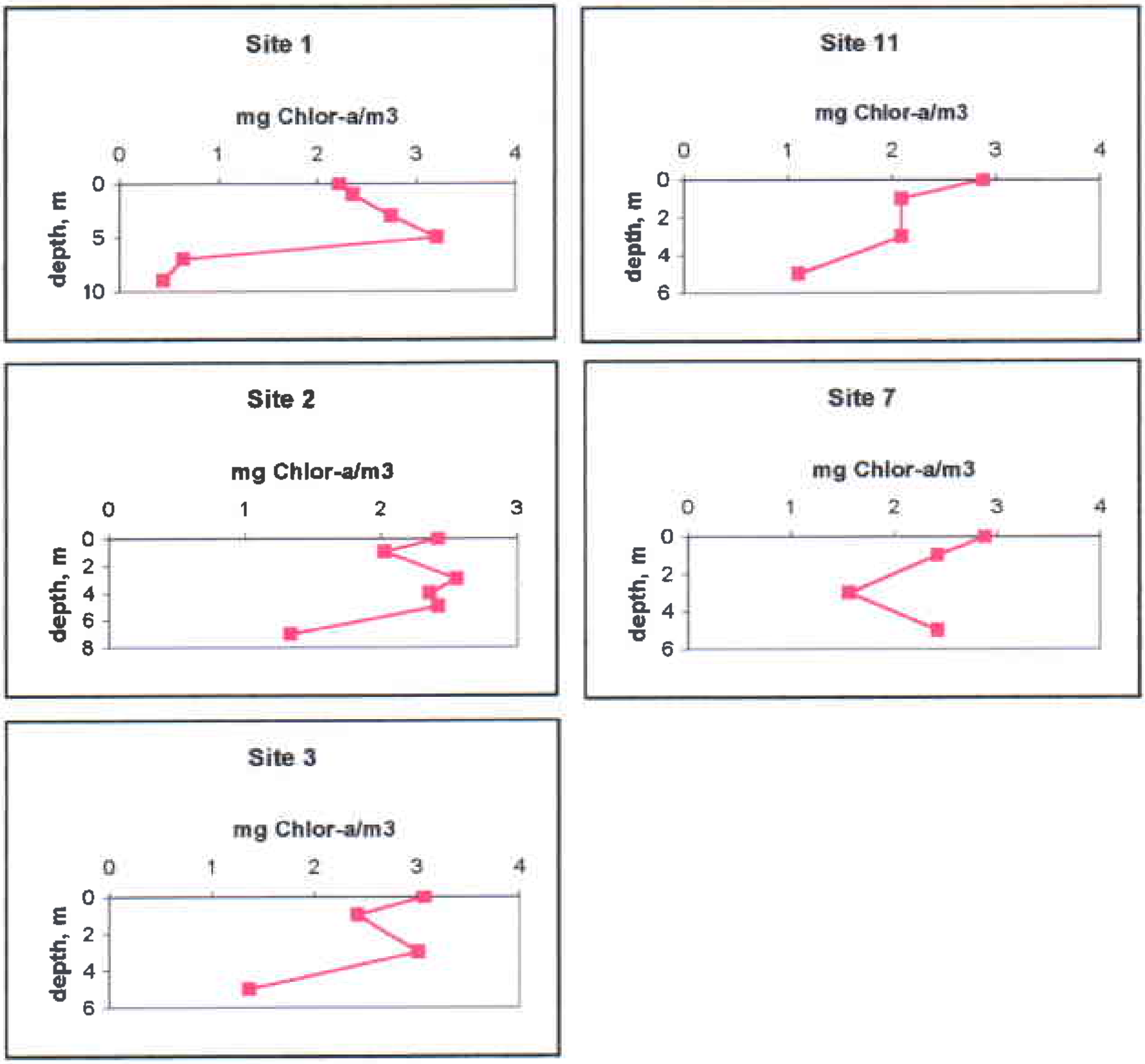



**Figure 11. Chlorophyll-a in the Fort Knox Water Supply Reservoir, late August 2000.**

## Water Supply Reservoir and Developed Wetlands, Arctic Grayling

Monitoring of Arctic grayling in the WSR has been conducted annually since 1996. Substantial recruitment of age-0 Arctic grayling to the population was not seen in 1996, 1997, or 1998. Poor recruitment was believed to be due to a lack of spawning habitat and predation by burbot (Ott and Morris 2000). In spring 1999, Channel #5 was built to connect a portion of the developed wetlands to the WSR to provide Arctic grayling access to the lower end of the developed wetlands for spawning (Figure 12).

Channel #5 was constructed in early May 1999. The channel is about 75 m long with a grade of about 0.5%. Water from Channel #5 enters a sedge-grass meadow and flows about 330 m to the WSR (Figures 12 and 13). Arctic grayling used Channel #5 in spring 1999 to access the developed wetlands. Active spawning was observed in Channel #5 and in the channel connecting Ponds D and E. Age-0 Arctic grayling were caught in a fyke-net in Pond E (Figure 14) and observed in Ponds D, E, and F in fall 1999 (Ott and Morris 2000).

In May 2000, we made a number of site visits to monitor Arctic grayling use of the developed wetlands. Water temperatures reached 2.7°C on May 15. Adult and juvenile Arctic grayling were caught in a fyke-net set in Pond E (Table 1). We caught four burbot, two adult Arctic grayling, and 93 juvenile Arctic grayling (80 to 143 mm) on May 16 and 17 (Table 1). Seventy-four of the juvenile Arctic grayling were <110 mm. Five juvenile Arctic grayling (91 to 102 mm) were retained and aged using otoliths – these fish were age-1+ and are progeny from the successful spawning in spring 1999.

On May 28, 2000 active spawning by Arctic grayling was seen throughout the fluvial reaches in the developed wetlands from the upper end of Pond C to the lower end of Channel #5. Age-0 Arctic grayling were observed throughout these areas on June 23, 2000. Hundreds of fry were seen in the ponds and in the channels connecting the

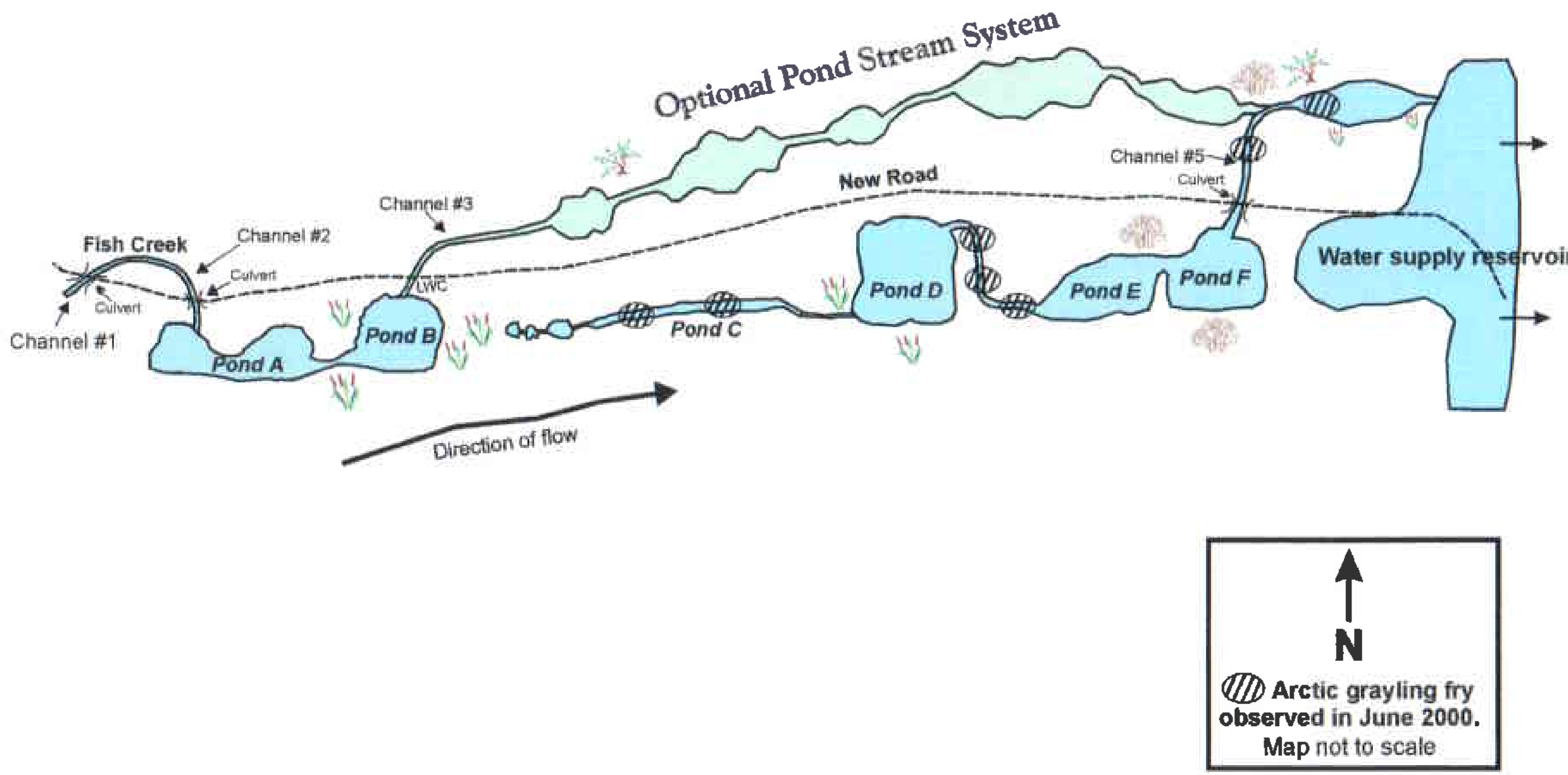



Figure 12. Fort Knox developed wetlands and optional wetlands.

Figure 13. Channel #5 was constructed in May 1999 and was used by Arctic grayling as spawning and rearing habitat in spring 1999 and 2000.

Figure 14. Pond E in Fort Knox developed wetlands. Fyke-net site #12.

**Table 1. Arctic grayling and burbot catches in fyke nets fished for about 24 hr in Fort Knox developed wetlands, 1999 and 2000.**

| Sample Date | Sample Location | Number of Grayling (<150 mm) | Number of Grayling (>150 mm) | Number of Burbot |
|---|---|---|---|---|
| 5/17/99 | Pond F | 0 | 10 | 0 |
| 5/18/99 | Pond F | 2 | 107 | 0 |
| 5/19/99 | Pond F | 3 | 25 | 0 |
| 5/20/99 | Pond E | 0 | 226 | 0 |
| 9/1/99 | Pond E | 36 | 1 | 19 |
| 5/16/00 | Pond E | 67 | 0 | 2 |
| 5/17/00 | Pond E | 26 | 2 | 2 |
| 8/29/00 | Pond E | 25 | 1 | 50 |

ponds. In early August 2000, we saw substantial numbers of small Arctic grayling actively feeding in the wetland complex and in shallow water areas of the WSR. In late August, we fished a fyke-net in Pond E and caught 26 juvenile Arctic grayling and 50 burbot (Table 1). Most of the Arctic grayling, except two juveniles (138, 150 mm) and one adult (310 mm) were judged to be age-0 fish. Age-0 Arctic grayling ranged in size from 53 to 86 mm (n = 23, average length = 65, SD = 8.2). The age-0 fish caught in fall 1999 were larger and averaged 91 mm (Ott and Morris 2000). All burbot had full stomachs and 48 of the 50 handled had Arctic grayling tail fins protruding from the mouth.

Based on visual observations made during summer 1999 and 2000 and the capture of some age-0 and juvenile Arctic grayling, we believe that substantial numbers are now present in the WSR and the developed wetlands. As our sampling program continues, we should see recruitment of Arctic grayling into the adult population.

A fyke-net was set on May 16 at Site #13 (Figure 4) in the WSR. Our objectives were to recapture marked fish and to mark about 300 Arctic grayling ≥200 mm long. The fyke-net fished for about 36 hrs, and 1,261 Arctic grayling were captured. Juvenile Arctic grayling were not caught – the smallest fish measured was 235 mm. Three hundred Arctic grayling were marked with individually numbered green Floy internal anchor tags.

Fish previously marked from 1993 through 1999 were recaptured. We recaptured 107 of the 591 Arctic grayling tagged in summer 1996 (Table 2). Most of the Arctic grayling handled were still rigid, with only a few females running eggs. Virtually all fish were in excellent condition.

Our highest catches of Arctic grayling from 1997 through 2000 have occurred in late May with fyke-nets fished along the shoreline of the main reservoir. These high catches all occurred during early spring as adult Arctic grayling actively moved along the shoreline to find suitable spawning habitat. The number of juvenile Arctic grayling <150 mm in our catches remains extremely small in relationship to the larger fish (Table 3).

**Table 2.** **Number of Arctic grayling marked by year and the number of recaptures seen during May 1998, 1999, and 2000 sample events. Arctic grayling >200 mm handled in May 1998, May 1999, and May 2000 were 1,140; 1,275; and 1,261; respectively.**

| Year (Tag Color) | Number of Fish Tagged | Number of Recaptures May 1998 | Number of Recaptures May 1999 | Number of Recaptures May 2000 |
|---|---|---|---|---|
| 93 (yellow) | 413 | 4 | 4 | 2 |
| 94 (white) | 798 | 5 | 8 | 4 |
| 95 (orange) | 1315 | 39 | 36 | 24 |
| 96 (blue) | 591 | 124 | 102 | 107 |
| 98 (orange) | 181 | | 34 | 22 |
| 99 (yellow) | 497 | | | 140 |
| 00 (green) | 300 | | | |

**Table 3. Arctic grayling catches in fyke nets fished in the Fort Knox water supply reservoir and developed wetlands, 1996 to 2000.**

| Sample Date | Number of Nets | Number of Grayling (<150 mm) | Number of Grayling (>150 mm) | CPUE (AG/trap/day) |
|---|---|---|---|---|
| 6/26/96 | 2 | 6 | 57 | 31.5 |
| 6/27/96 | 2 | 6 | 85 | 45.5 |
| 6/28/96 | 2 | 9 | 104 | 56.5 |
| 8/6/96 | 4 | 17 | 201 | 54.5 |
| 8/7/96 | 5 | 17 | 123 | 28.0 |
| 8/8/96 | 5 | 6 | 140 | 29.2 |
| 8/27/96 | 5 | 16 | 150 | 33.2 |
| 8/28/96 | 5 | 18 | 109 | 25.4 |
| 8/29/96 | 5 | 11 | 145 | 31.2 |
| 8/30/96 | 5 | 9 | 110 | 23.8 |
| 5/21/97[1] | 2 | | | 320.0 |
| 8/26/97 | 5 | 6 | 19 | 5.0 |
| 8/27/97 | 5 | 7 | 49 | 11.2 |
| 9/7/97 | 5 | 8 | 37 | 9.0 |
| 5/19/98 | 2 | 0 | 29 | 14.5 |
| 5/20/98 | 3 | 1 | 1002 | 334.0 |
| 5/27/98 | 2 | 0 | 3 | 1.5 |
| 5/28/98 | 3 | 0 | 30 | 15.0 |
| 5/29/98 | 3 | 2 | 72 | 24.7 |
| 5/20/99 | 1 | 0 | 953 | 953.0 |
| 5/18/00 | 1 | 0 | 1,261 | 840.7 |

[1]Arctic grayling were counted and released - measurements were not made due to the large number of fish. We did estimate that less than 10 of the 640 were small (i.e., <150 mm).

Length frequency distributions for Arctic grayling collected during spring 1995, 1996, 1998, 1999, and 2000 are presented in Figure 15. Data from 1999 and 2000 include Arctic grayling caught in fyke-nets fished in the developed wetlands. Juvenile Arctic grayling from successful spawning in the developed wetlands in spring 1999 were captured in spring 2000.

We recaptured 140 tagged Arctic grayling in spring 2000 that were handled during spring 1999. Average growth for these fish was 17 mm (Figure 16). Annual growth of Arctic grayling in the WSR since 1996, even though the average size of fish is increasing and few small fish have been observed, remained fairly constant for the first three years. Prior to construction of the freshwater dam, average annual growth for Arctic grayling collected in the Last Chance Creek pond complex was 9 mm. Average growth for fish in summer 1996 was 41 mm and from 1996 through 1998 the average growth was 39 mm. Average annual growth decreased to 16 and 17 mm for spring 1998 to 1999 and spring 1999 to 2000 periods. Decreased growth rates are to be expected as the population grows older, and most individuals reach sexual maturity and spend most of their energy reserves on reproduction rather than growth.

We estimated the abundance of the Arctic grayling population in the WSR using spring 1999 as the mark event ($n_1$ = 682) and spring 2000 as the recapture event. In spring 2000, we caught 1,261 Arctic grayling ($n_2$ = 1,261) with 208 recaptures ($m_2$ = 208). Our spring 1999 estimated Arctic grayling population size for fish >200 mm was 4,123 (95% CI 3,698 to 4,548). This is a decrease from our spring 1998 estimated population size of Arctic grayling that was 5,800 (95% CI 4,705 to 6,895).

We plan to continue our spring sampling in the WSR and developed wetlands with emphasis on assessing spawning success of Arctic grayling, growth of juvenile fish, and recruitment over time into the adult population. Our work with FGMI to improve the aquatic productivity of the WSR and developed wetlands also will continue. In summer 2000, additional opportunities for improving the aquatic productivity of the developed wetlands were identified.

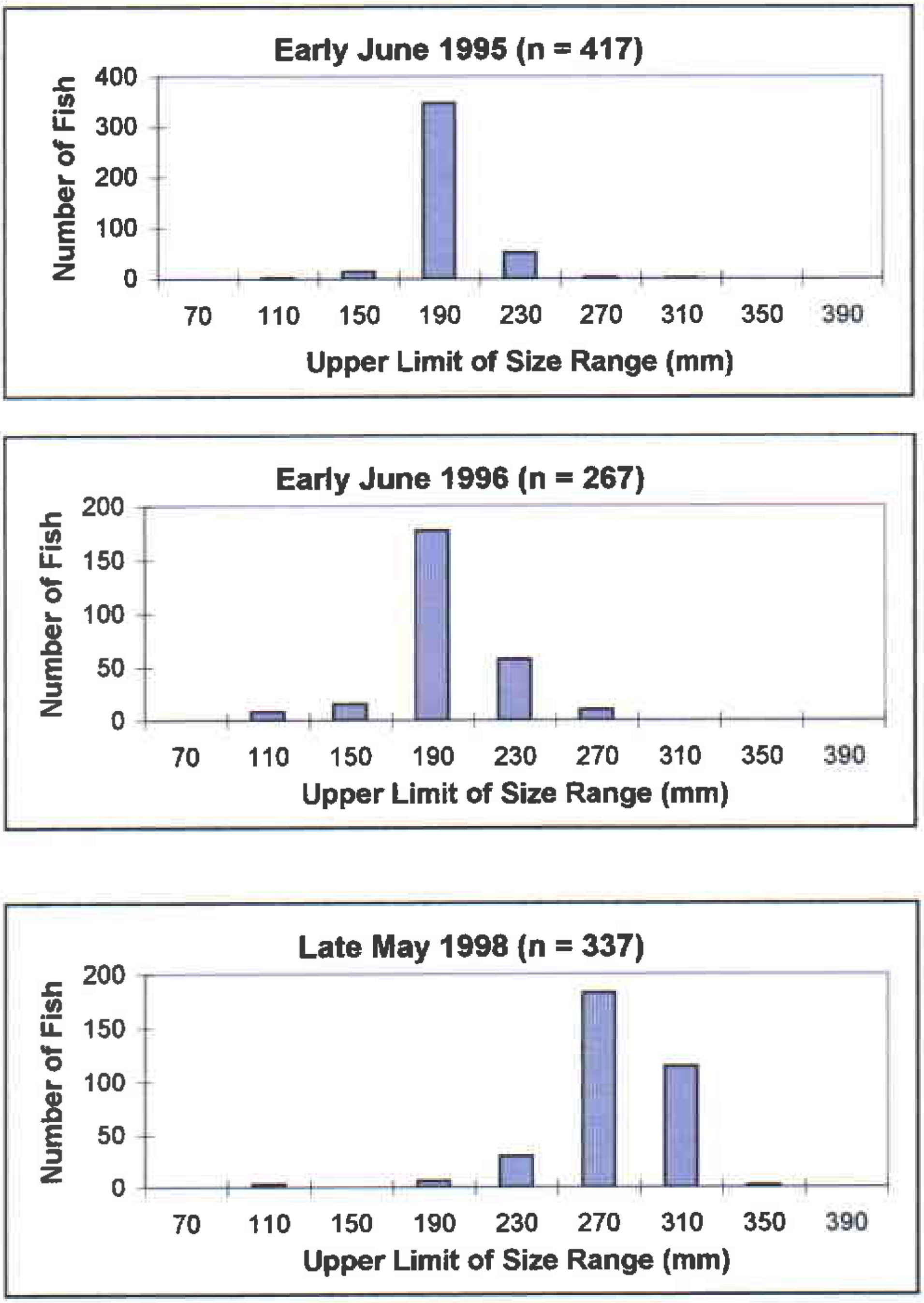



Figure 15. Length-frequency distributions of Arctic grayling caught in the water supply reservoir and developed wetlands (1995, 1996, 1998, 1999, and 2000).

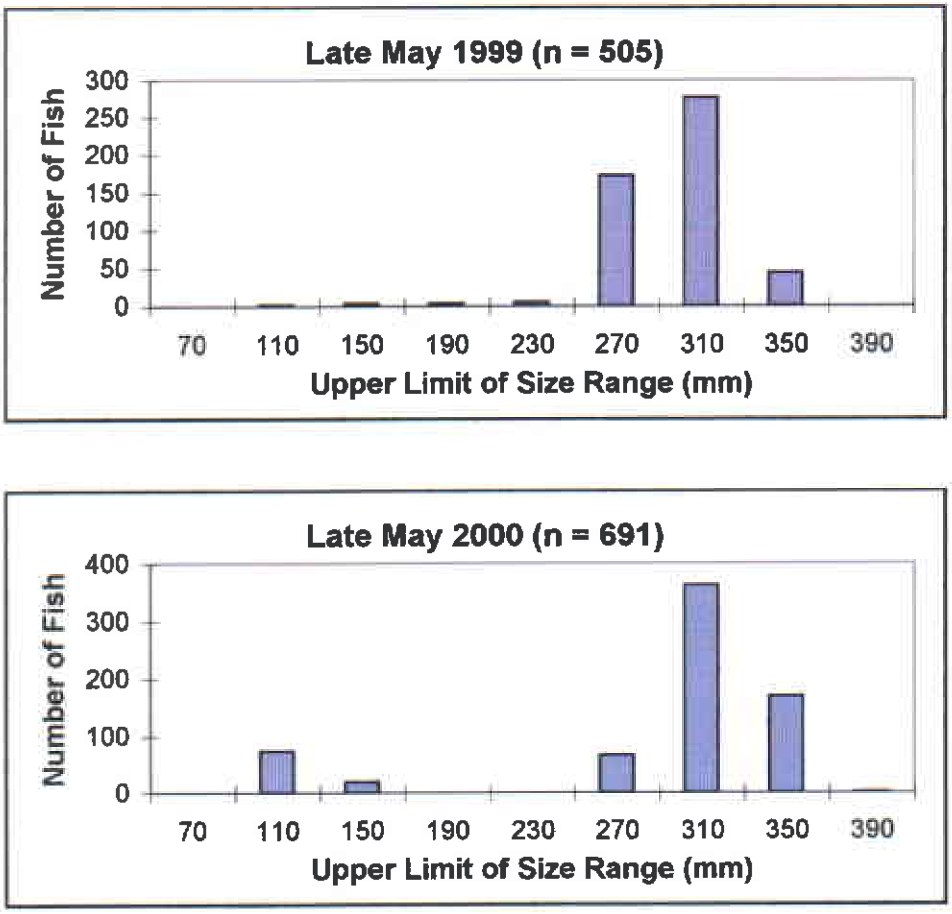



Figure 15. (concluded).

| Year | Average | Maximum | Minimum | Number of Fish |
|---|---|---|---|---|
| 94-95 | 9 | 57 | 0 | 208 |
| 95-96 | 21 | 38 | 2 | 30 |
| 96 | 41 | 60 | 9 | 42 |
| 96-97 | 38 | 68 | 16 | 7 |
| 96-98 | 39 | 65 | 16 | 121 |
| 98-99 | 16 | 59 | 0 | 73 |
| 99-00 | 17 | 63 | 0 | 140 |

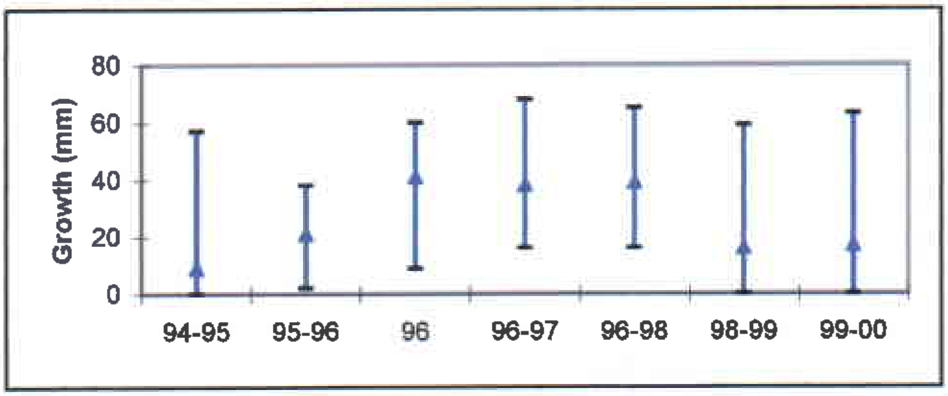



**Figure 16. The minimum, maximum, and average annual growth of Arctic grayling in upper Fish Creek and the Fort Knox water supply reservoir from 1994 to 2000.**

During the operational phase of the Fort Knox Mine, there is minimal surface flow into the upper portion of the developed wetlands because Fish Creek is blocked by the tailing dam and groundwater in the Fish Creek valley is collected immediately below the tailing dam with interceptor wells and pumped back into the tailing impoundment. Ponds A and B are fed by surface flow during breakup and by groundwater during summer, but there is no surface flow connection to the upper end of Pond C. In addition, there is a substantial gradient change between Fish Creek and the head of Pond C. The potential exists to keep Fish Creek on the north side of the valley and to develop additional wetlands and ponds along that route (Figure 12). Ponds C, D, E, and F currently are fed by groundwater and surface runoff with a fairly constant summer flow of about 2 cfs. On January 22, 2001 there was flow under ice-cover from Pond F. These ponds (C, D, E, and F) could be maintained as a separate system that already is providing conditions suitable for Arctic grayling spawning and rearing and maybe overwintering. We plan to continue to work with Fairbanks Gold Mining Inc. to evaluate the option of creating a second series of ponds along the north side of the Fish Creek valley.

## Fort Knox Water Supply Reservoir, Burbot

Burbot were found in the Lower Last Chance Creek pond and in Polar Ponds #1 and #2 prior to construction of the freshwater dam (Ott and Weber Scannell 1996). In May 1995, we conducted a mark/recapture effort and estimated abundance of burbot (150 to 331 mm) to be 825 fish (Ott and Weber Scannell 1996). Flooding of the WSR began in November 1995, isolating burbot upstream of the dam.

Burbot population estimates in the WSR for 1995, 1997, and 1998 were 825, 622, and 703 fish, respectively. The 1995 estimate included burbot >150 mm, the 1997 and 1998 estimates were for burbot ≥250 and ≥300 mm. Assuming the population sampled is the same group of fish, survival of these fish has been extremely high.

On May 29, 2000 the WSR was ice-free. Twenty-four hoop traps were set and checked on May 30, May 31, and June 1. Traps were set along the edges of the WSR in water generally less than 3 m deep to avoid placement of traps in deeper water where dissolved oxygen concentrations were depressed. We estimated the burbot population in the WSR using spring 1999 as a mark event ($n_1$ = 568) and spring 2000 as the recapture event. In spring 2000, we caught 428 ($n_2$) burbot with 58 recaptures ($m_2$). Our spring 1999 estimate of abundance for burbot >200 mm was 4,136 (95% CI 3,215 to 5,057). Using the same approach, we had estimated the abundance of burbot (fish >200 mm) in spring 1998 at 3,609 (95% CI 2,731 to 4,485) (Ott and Morris 2000). The increase in burbot numbers is due to recruitment of burbot less than 300 mm into the population. Several burbot have been extremely successful in the WSR (Figure 17) and have reached lengths over 500 mm (Figure 18).

We marked 250 burbot in spring 2000 with individually numbered green Floy internal anchor tags. CPUE for hoop traps fished has been calculated since 1996 (Table 4). Catch rates have been similar the last three years. Calculated length frequency distributions for burbot captured from May 1995 to May 2000 are shown in Figure 19. The population is dominated by burbot from 275 to 325 mm long.


Figure 17. Water supply reservoir looking northeast across Solo Creek Bay.

Figure 18. A 700 mm burbot caught in the Fort Knox water supply reservoir.

**Table 4. Burbot catches in the water supply reservoir (1996 to 2000) using hoop traps.**

| Sample Date | Gear Type | Number of Traps | Catch (Total) | Mean CPUE[1] (BB/trap/day) |
|---|---|---|---|---|
| May 22, 96 | small hoop | 11 | 36 | 3.3 |
| May 22, 96 | large hoop | 4 | 6 | 1.5 |
| May 23, 96 | small hoop | 11 | 19 | 1.7 |
| May 23, 96 | large hoop | 4 | 2 | 0.5 |
| May 20, 97 | small hoop | 11 | 58 | 5.3 |
| May 20, 97 | large hoop | 13 | 24 | 1.8 |
| May 21, 97 | small hoop | 11 | 61 | 5.5 |
| May 21, 97 | large hoop | 17 | 56 | 3.3 |
| May 28, 97 | small hoop | 11 | 45 | 4.1 |
| May 28, 97 | large hoop | 19 | 42 | 2.2 |
| May 29, 97 | small hoop | 11 | 32 | 2.9 |
| May 29, 97 | large hoop | 20 | 39 | 2.0 |
| May 20, 98 | small hoop | 7 | 87 | 12.4 |
| May 21, 98 | small hoop | 9 | 61 | 6.8 |
| May 21, 98 | large hoop | 3 | 20 | 6.7 |
| May 22, 98 | small hoop | 9 | 57 | 6.3 |
| May 27, 98 | small hoop | 9 | 61 | 6.8 |
| May 28, 98 | small hoop | 9 | 67 | 7.4 |
| May 29, 98 | small hoop | 9 | 44 | 4.9 |
| June 3, 99 | small hoop | 17 | 135 | 7.9 |
| June 4, 99 | small hoop | 17 | 124 | 7.3 |
| June 5, 99 | small hoop | 17 | 136 | 8.0 |
| June 7, 99 | small hoop | 17 | 142 | 4.2 |
| June 8, 99 | small hoop | 17 | 89 | 5.2 |
| May 30, 00 | small hoop | 24 | 191 | 7.9 |
| May 31, 00 | small hoop | 24 | 105 | 4.4 |
| June 1, 00 | small hoop | 24 | 122 | 5.1 |

[1]CPUE = catch per unit of effort

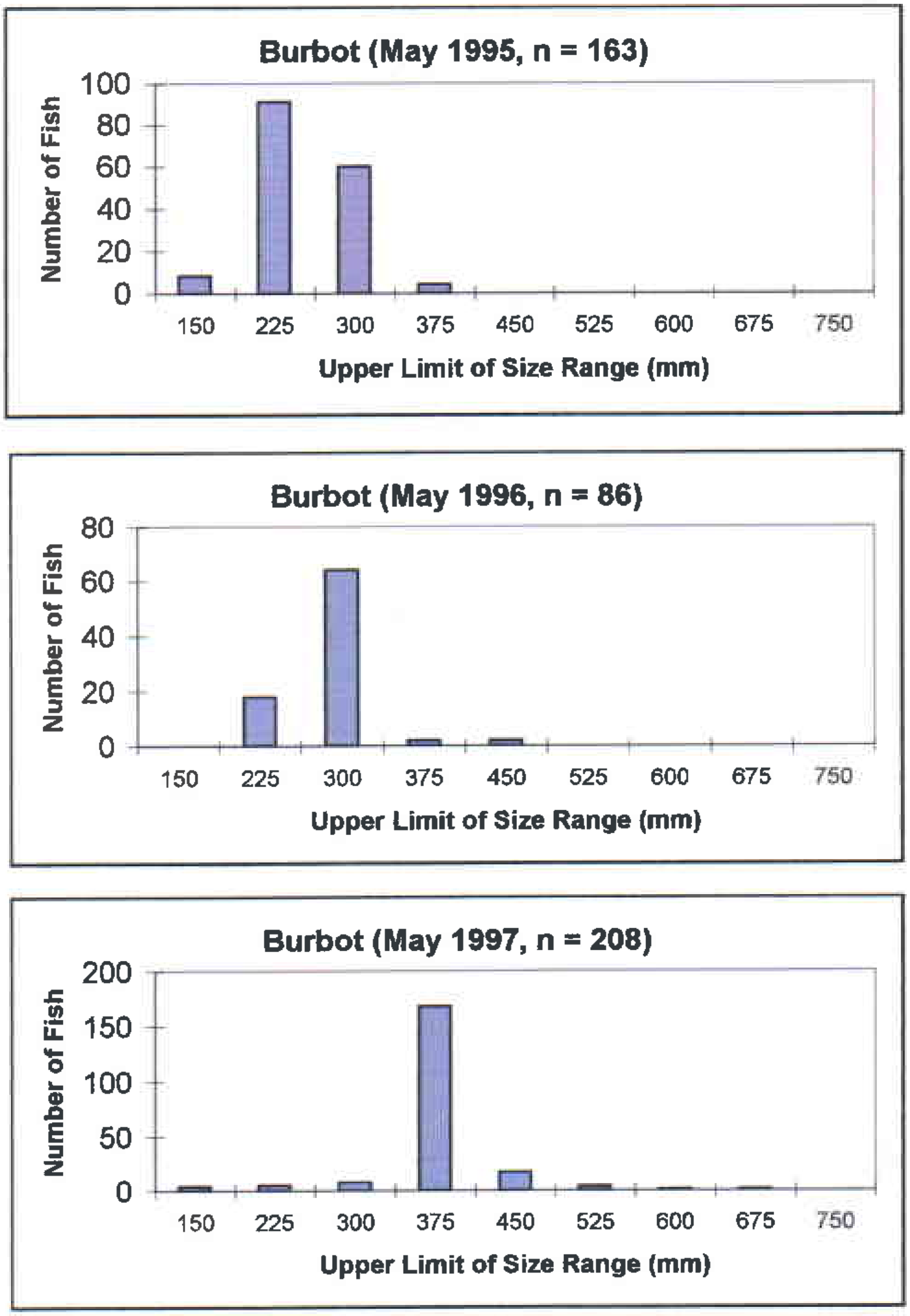



Figure 19. Length-frequency distributions of burbot caught in the water supply reservoir, 1995 to 2000. (Note: The y-axis is a different scale in every chart).

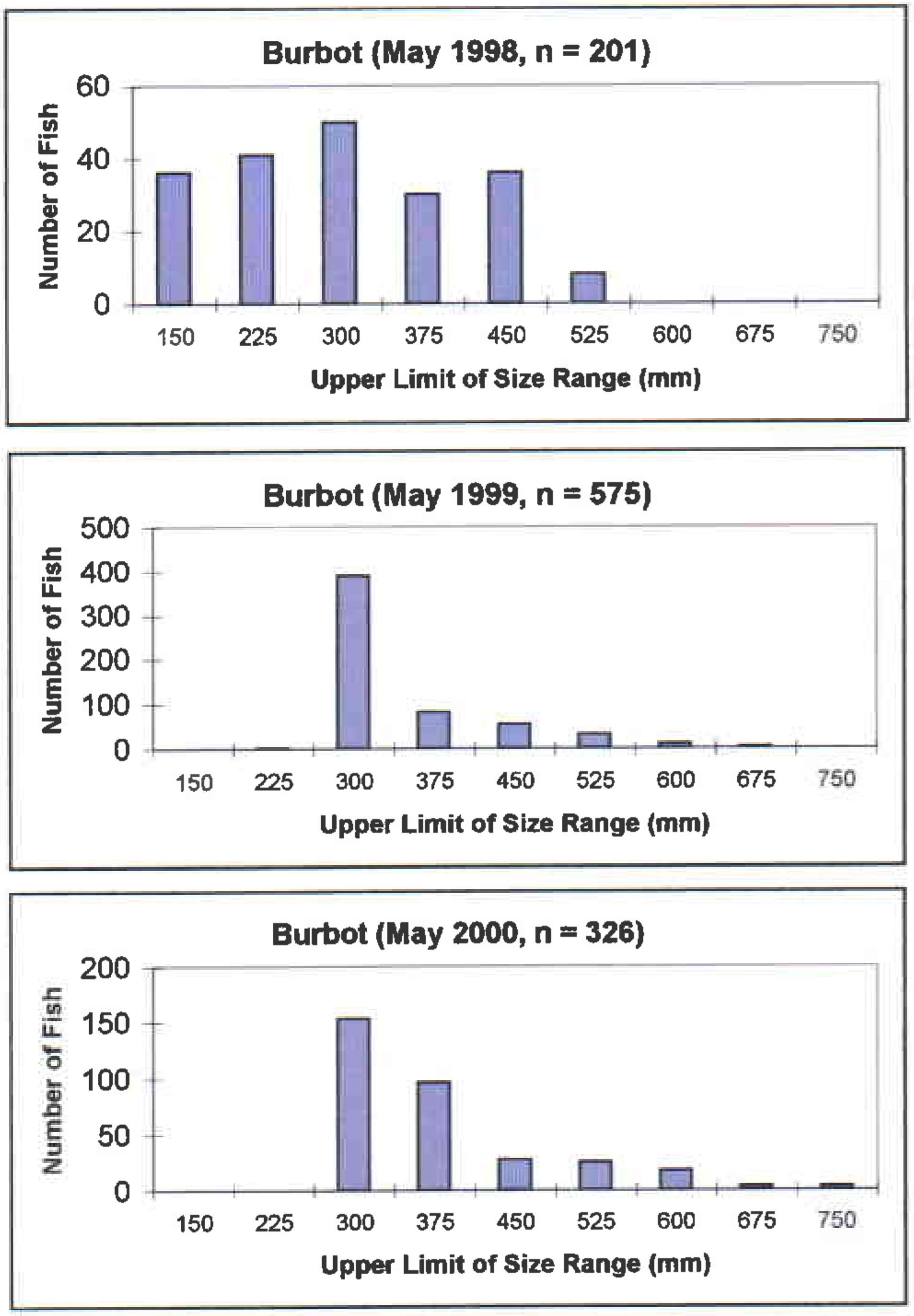



Figure 19. (concluded).

Growth of tagged burbot from 1998 to 1999 and from 1999 to 2000 is shown in Table 5. Burbot ranging in length from 275 to 400 mm when tagged exhibited slow growth compared with burbot >400 mm. The higher growth rates for the larger burbot have been seen the last three years. General observations made during spring 1998 through spring 2000 indicate that small burbot (<275 mm) and larger burbot (>400 mm) were in better condition than intermediate sized burbot. However, in spring 2000 even the burbot from 275 to 400 mm long appeared to be in better condition than in spring 1998 and 1999.

**Table 5. Growth of burbot tagged in May 1998 and June 1999 and recaptured in June 1999 and June 2000 using hoop traps.**

| Length at Tagging (mm) | Sample Size | Average Growth (mm) | Standard Deviation |
|---|---|---|---|
| 225-249 | 3 | 33 | 7.8 |
| 250-274 | 5 | 19 | 15.9 |
| 275-299 | 14 | 10 | 5.8 |
| 300-324 | 7 | 16 | 6.0 |
| 325-349 | 5 | 8 | 1.5 |
| 350-374 | 7 | 15 | 10.6 |
| 375-399 | 12 | 10 | 9.6 |
| 400-424 | 9 | 21 | 14.6 |
| 425-449 | 9 | 31 | 20.0 |
| 450-474 | 7 | 34 | 22.4 |
| 475-499 | 6 | 36 | 12.8 |
| 500-524 | 6 | 33 | 18.9 |
| 525-549 | 2 | 44 | - |
| 550-574 | 4 | 31 | 20.7 |
| 575-599 | 2 | 25 | - |

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# Appendix 1 - Water Quality: Water Supply Reservoir

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity (u S/cm) | pH |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 2 | 8/29/00 | 0 | 11.22 | 80.7 | 8.63 | 107.5 | 7.24 |
| | | 1 | 10.72 | 79.2 | 8.55 | 107.7 | 7.19 |
| | | 2 | 10.59 | 78.8 | 8.54 | 108.1 | 7.18 |
| | | 3 | 9.70 | 68.5 | 7.58 | 107.9 | 7.07 |
| | | 4 | 8.89 | 54.0 | 6.13 | 106.8 | 6.87 |
| | | 5 | 8.56 | 44.3 | 5.04 | 106.7 | 6.78 |
| | | 6 | 7.15 | 29.9 | 3.54 | 102.9 | 6.64 |
| | | 7 | 6.04 | 11.5 | 1.42 | 114.2 | 6.50 |
| | | 8 | 5.86 | 4.7 | 0.57 | 126.2 | 6.40 |
| | | 9 | 5.38 | 3.5 | 0.42 | 138.2 | 6.34 |
| | | 10 | 5.17 | 2.7 | 0.34 | 139.9 | 6.37 |
| | | 11 | 4.90 | 2.4 | 0.29 | 142.2 | 6.41 |
| | | 12 | 4.84 | 2.5 | 0.31 | 142.7 | 6.42 |
| | | 13 (bottom) | 4.81 | 2.3 | 0.29 | 143.2 | 6.44 |
| | | | | | | | |
| 2 | 6/23/00 | 0 | 18.76 | 95.5 | 8.75 | 103.1 | 7.57 |
| | | 1 | 18.43 | 93.3 | 8.61 | 103.0 | 7.61 |
| | | 2 | 14.73 | 72.2 | 7.21 | 103.7 | 7.15 |
| | | 3 | 8.20 | 23.7 | 2.75 | 108.0 | 6.65 |
| | | 4 | 6.37 | 22.7 | 2.75 | 108.9 | 6.62 |
| | | 5 | 5.69 | 16.7 | 2.07 | 112.1 | 6.58 |
| | | 6 | 4.89 | 14.0 | 1.76 | 115.8 | 6.55 |
| | | 7 | 4.61 | 10.3 | 1.31 | 119.2 | 6.52 |
| | | 8 | 4.26 | 9.5 | 1.21 | 121.8 | 6.50 |
| | | 9 | 4.07 | 7.4 | 0.96 | 123.9 | 6.51 |
| | | 10 | 3.89 | 4.6 | 0.59 | 128.4 | 6.50 |
| | | 11 | 3.57 | 2.3 | 0.30 | 134.2 | 6.46 |
| | | 11.5 (bottom) | 3.41 | 2.0 | 0.26 | 139.8 | 6.43 |
| | | | | | | | |
| 2 | 5/30/00 | 0 | 7.14 | 55.3 | 6.61 | 109.3 | 6.73 |
| | | 1 | 6.57 | 53.2 | 6.46 | 108.0 | 6.72 |
| | | 2 | 6.07 | 52.2 | 6.41 | 106.9 | 6.71 |
| | | 3 | 5.65 | 51.0 | 6.31 | 105.7 | 6.71 |
| | | 4 | 5.59 | 50.0 | 6.21 | 105.5 | 6.70 |
| | | 5 | 5.47 | 48.5 | 6.04 | 106.5 | 6.69 |
| | | 6 | 4.30 | 41.5 | 5.32 | 109.1 | 6.66 |
| | | 7 | 3.89 | 36.8 | 4.78 | 114.7 | 6.64 |
| | | 8 | 3.48 | 28.0 | 3.67 | 126.0 | 6.61 |
| | | 9 | 3.26 | 21.9 | 2.80 | 133.0 | 6.59 |
| | | 10 | 2.51 | 5.5 | 0.74 | 164.6 | 6.52 |
| | | 11 (bottom) | 2.29 | 3.4 | 0.47 | 179.7 | 6.50 |
| | | | | | | | |

Appendix 1 (continued).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity (u S/cm) | pH |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 2 | 6/2/99 | 0 | 9.74 | 81.0 | 8.86 | 134.2 | 7.47 |
| | | 1 | 9.72 | 80.5 | 8.84 | 134.4 | 7.44 |
| | | 2 | 9.70 | 80.6 | 8.85 | 134.9 | 7.44 |
| | | 3 | 9.66 | 80.9 | 8.88 | 134.8 | 7.43 |
| | | 4 | 9.66 | 77.9 | 8.56 | 135.1 | 7.40 |
| | | 5 | 9.31 | 67.7 | 7.45 | 133.9 | 7.16 |
| | | 6 | 7.26 | 46.0 | 5.36 | 133.7 | 7.04 |
| | | 7 | 6.13 | 36.0 | 4.26 | 135.0 | 6.97 |
| | | 8 | 5.50 | 29.9 | 3.62 | 136.0 | 6.90 |
| | | 9 | 5.11 | 26.5 | 3.25 | 137.1 | 6.84 |
| | | 9.5 (bottom) | 4.98 | 25.4 | 3.14 | 137.6 | 6.81 |
| | | | | | | | |
| 2 | 4/15/99 | 2 | 1.41 | 25.4 | 3.50 | 161.4 | 6.13 |
| | | 3 | 1.70 | 24.5 | 3.34 | 160.8 | 6.30 |
| | | 4 | 1.95 | 24.7 | 3.34 | 159.8 | 6.22 |
| | | 5 | 2.12 | 23.3 | 3.13 | 159.8 | 6.23 |
| | | 6 | 2.26 | 20.3 | 2.72 | 160.1 | 6.19 |
| | | 7 | 2.44 | 17.1 | 2.28 | 160.8 | 6.16 |
| | | 8 | 2.43 | 3.9 | 0.52 | 166.1 | 6.16 |
| | | 9 | 2.42 | 1.7 | 0.21 | 180.6 | 6.17 |
| | | 10 | 2.41 | 1.0 | 0.13 | 244.9 | 6.24 |
| | | | | | | | |
| 2 | 10/1/98 | surface | 6.35 | 60.6 | 7.21 | 144.3 | 7.62 |
| | | 1 | 6.25 | 60.1 | 7.18 | 144.8 | 7.58 |
| | | 2 | 6.24 | 59.7 | 7.11 | 144.3 | 7.57 |
| | | 3 | 6.22 | 59.0 | 7.06 | 144.5 | 7.56 |
| | | 4 | 6.22 | 58.4 | 6.99 | 144.7 | 7.56 |
| | | 5 | 6.20 | 58.0 | 6.94 | 144.4 | 7.56 |
| | | 6 | 6.20 | 58.0 | 6.95 | 144.4 | 7.57 |
| | | 7 | 6.18 | 58.0 | 6.97 | 144.4 | 7.56 |
| | | 8 | 6.12 | 59.0 | 7.08 | 144.6 | 7.58 |
| | | 9 (bottom) | 6.13 | 58.7 | 7.00 | 144.7 | 7.60 |
| | | | | | | | |
| 2 | 7/28/98 | surface | 17.52 | 87.1 | 8.11 | 161.6 | 7.41 |
| | | 1 | 17.25 | 85.1 | 7.98 | 162.1 | 7.44 |
| | | 2 | 16.86 | 83.3 | 7.92 | 161.2 | 7.46 |
| | | 3 | 14.17 | 48.0 | 4.80 | 156.9 | 6.98 |
| | | 4 | 11.63 | 28.7 | 3.04 | 142.3 | 6.78 |
| | | 5 | 10.31 | 22.8 | 2.46 | 138.4 | 6.70 |
| | | 6 | 8.26 | 7.3 | 0.82 | 155.2 | 6.65 |
| | | 7 | 7.62 | 4.4 | 0.52 | 159.8 | 6.64 |
| | | 8 (bottom) | 6.78 | 3.7 | 0.44 | 169.1 | 6.63 |

Appendix 1 (continued).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity ($u$ S/cm) | pH |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 2 | 3/18/98 | 1 | 0.49 | N/T | 1.26 | 176.0 | 7.01 |
| | | 2 | 0.79 | N/T | 1.70 | 175.0 | 6.93 |
| | | 3 | 0.94 | N/T | 1.58 | 176.0 | 6.85 |
| | | 4 | 0.97 | N/T | 1.08 | 178.0 | 6.81 |
| | | 5 | 0.99 | N/T | 0.77 | 182.0 | 6.77 |
| | | 6 | 1.08 | N/T | 0.39 | 184.0 | 6.75 |
| | | 7 | 0.85 | N/T | 0.08 | 214.0 | 6.60 |
| | | 7.8 (bottom) | 0.06 | N/T | 0.06 | 281.0 | 6.53 |
| | | | | | | | |
| 2 | 9/25/97 | surface | 9.34 | N/T | 6.10 | 143.0 | 7.23 |
| | | 1 | 9.23 | N/T | 5.76 | 145.0 | 7.10 |
| | | 3 | 9.18 | N/T | 5.67 | 147.0 | 7.05 |
| | | 5 | 9.01 | N/T | 4.58 | 147.0 | 6.95 |
| | | 7.5 (bottom) | 8.49 | N/T | 2.65 | 145.0 | 6.92 |

N/T = Not Tested

Appendix 1 (continued).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity (*u* S/cm) | pH |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 1 | 8/29/00 | 0 | 11.17 | 79.2 | 8.46 | 108.8 | 7.11 |
| | | 1 | 10.50 | 77.6 | 8.44 | 108.8 | 7.13 |
| | | 2 | 10.29 | 77.1 | 8.42 | 108.8 | 7.13 |
| | | 3 | 9.92 | 72.6 | 8.01 | 108.8 | 7.09 |
| | | 4 | 8.85 | 54.1 | 6.14 | 106.8 | 6.90 |
| | | 5 | 8.19 | 41.2 | 4.72 | 106.3 | 6.77 |
| | | 6 | 6.98 | 41.7 | 4.93 | 97.7 | 6.66 |
| | | 7 | 6.05 | 18.6 | 2.24 | 109.6 | 6.50 |
| | | 8 | 5.53 | 5.3 | 0.65 | 136.8 | 6.39 |
| | | 9 | 5.23 | 3.4 | 0.45 | 140.0 | 6.45 |
| | | 10 (bottom) | 5.04 | 2.6 | 0.33 | 142.5 | 6.47 |
| | | | | | | | |
| 1 | 6/23/00 | 0 | 18.23 | 95.2 | 8.81 | 103.8 | 7.56 |
| | | 1 | 17.35 | 93.0 | 8.75 | 102.6 | 7.57 |
| | | 2 | 12.95 | 52.6 | 5.50 | 105.1 | 6.91 |
| | | 3 | 7.67 | 24.9 | 2.92 | 108.8 | 6.69 |
| | | 4 | 5.71 | 17.4 | 2.15 | 114.0 | 6.57 |
| | | 5 | 5.08 | 13.9 | 1.76 | 117.2 | 6.54 |
| | | 6 | 4.60 | 9.9 | 1.25 | 119.4 | 6.52 |
| | | 7 | 4.39 | 8.4 | 1.08 | 121.9 | 6.51 |
| | | 8 | 4.30 | 6.5 | 0.83 | 122.5 | 6.50 |
| | | 9 (bottom) | 4.10 | 2.6 | 0.34 | 125.9 | 6.49 |
| | | | | | | | |
| 1 | 5/30/00 | 0 | 7.31 | 56.3 | 6.72 | 108.4 | 6.77 |
| | | 1 | 6.24 | 53.1 | 6.51 | 108.2 | 6.73 |
| | | 2 | 5.79 | 51.9 | 6.40 | 106.8 | 6.71 |
| | | 3 | 5.56 | 50.3 | 6.25 | 107.9 | 6.71 |
| | | 4 | 5.45 | 49.9 | 6.21 | 107.1 | 6.70 |
| | | 5 | 5.42 | 49.6 | 6.18 | 107.5 | 6.70 |
| | | 6 | 4.81 | 45.1 | 5.73 | 109.3 | 6.68 |
| | | 7 (bottom) | 3.95 | 33.3 | 4.33 | 120.5 | 6.64 |
| | | | | | | | |
| 1 | 6/2/99 | 0 | 9.49 | 82.9 | 9.13 | 134.7 | 7.29 |
| | | 1 | 9.50 | 81.4 | 8.99 | 134.9 | 7.27 |
| | | 2 | 9.52 | 81.1 | 8.95 | 134.5 | 7.29 |
| | | 3 | 9.48 | 80.7 | 8.92 | 134.7 | 7.30 |
| | | 4 | 9.29 | 77.1 | 8.54 | 135.5 | 7.24 |
| | | 5 | 7.47 | 54.5 | 6.26 | 133.4 | 7.07 |
| | | 6 | 6.36 | 42.3 | 5.05 | 134.9 | 6.99 |
| | | 7 | 5.81 | 36.3 | 4.39 | 135.6 | 6.93 |
| | | 8 | 5.14 | 29.8 | 3.67 | 137.3 | 6.91 |
| | | 9 | 4.98 | 28.2 | 3.48 | 137.5 | 6.90 |

Appendix 1 (continued).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity (*u* S/cm) | pH |
|---|---|---|---|---|---|---|---|
| 1 | | 10 | 4.86 | 26.5 | 3.24 | 137.8 | 6.89 |
| | | 11 | 4.79 | 25.5 | 3.16 | 138.4 | 6.88 |
| | | 12 (bottom) | 4.75 | 24.9 | 3.09 | 138.3 | 6.86 |
| | | | | | | | |
| 1 | 10/1/98 | surface | 6.27 | 62.7 | 7.49 | 145.1 | 7.60 |
| | | 1 | 6.24 | 62.6 | 7.49 | 145.0 | 7.57 |
| | | 2 | 6.21 | 62.4 | 7.47 | 144.6 | 7.58 |
| | | 3 | 6.20 | 62.3 | 7.45 | 144.5 | 7.58 |
| | | 4 | 6.14 | 62.9 | 7.54 | 144.8 | 7.60 |
| | | 5 | 6.03 | 64.1 | 7.70 | 144.8 | 7.62 |
| | | 6 | 5.87 | 64.3 | 7.75 | 144.3 | 7.61 |
| | | 7 | 5.84 | 64.3 | 7.74 | 144.4 | 7.61 |
| | | 8 (bottom) | 5.82 | 64.5 | 7.79 | 144.0 | 7.59 |
| | | | | | | | |
| 1 | 7/28/98 | surface | 17.33 | 84.2 | 7.85 | 161.9 | 7.56 |
| | | 1 | 16.83 | 81.2 | 7.67 | 162.0 | 7.54 |
| | | 2 | 16.66 | 80.5 | 7.65 | 162.2 | 7.55 |
| | | 3 | 14.30 | 45.7 | 4.55 | 157.5 | 7.08 |
| | | 4 | 11.78 | 25.7 | 2.72 | 141.4 | 6.84 |
| | | 5 | 9.93 | 50.7 | 5.51 | 118.6 | 6.97 |
| | | 6 (bottom) | 9.25 | 33.3 | 3.71 | 127.6 | 6.90 |
| | | | | | | | |
| 1 | 7/28/98 | surface | 17.21 | 83.6 | 7.84 | 159.6 | 7.64 |
| | | 1 | 17.14 | 82.9 | 7.80 | 159.8 | 7.63 |
| | | 2 | 16.81 | 82.3 | 7.78 | 160.3 | 7.63 |
| | | 3 | 14.49 | 46.9 | 4.64 | 157.6 | 7.13 |
| | | 4 | 7.92 | 27.1 | 3.51 | 165.0 | 6.87 |
| | | 5 | 6.68 | 64.7 | 7.63 | 115.2 | 7.03 |
| | | 6 | 3.48 | 9.6 | 1.14 | 170.0 | 6.75 |
| | | 7 (bottom) | 5.23 | 1.0 | 0.12 | 173.0 | 6.81 |
| | | | | | | | |
| 1 | 3/18/98 | 1 | 0.50 | N/T | 1.27 | 176.0 | 6.96 |
| | | 2 | 0.79 | N/T | 1.89 | 178.0 | 6.89 |
| | | 3 | 0.89 | N/T | 1.71 | 179.0 | 6.87 |
| | | 4 | 0.96 | N/T | 2.10 | 182.0 | 6.84 |
| | | 5 (bottom) | 0.96 | N/T | 0.47 | 186.0 | 6.75 |

Appendix 1 (continued).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity (u S/cm) | pH |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 3 | 8/29/00 | 0 | 11.02 | 78.1 | 8.37 | 108.9 | 7.13 |
| | | 1 | 10.23 | 76.2 | 8.34 | 108.5 | 7.11 |
| | | 2 | 10.00 | 74.2 | 8.15 | 108.4 | 7.09 |
| | | 3 | 9.96 | 73.8 | 8.12 | 108.5 | 7.08 |
| | | 4 | 9.74 | 70.2 | 7.75 | 108.8 | 7.02 |
| | | 5 | 7.55 | 43.6 | 5.09 | 100.3 | 6.80 |
| | | 6 | 5.56 | 69.1 | 8.46 | 82.1 | 6.76 |
| | | 7 | 5.54 | 14.1 | 1.71 | 112.0 | 6.46 |
| | | 8 | 5.34 | 4.2 | 0.51 | 132.3 | 6.40 |
| | | 9 (bottom) | 5.22 | 3.0 | 0.37 | 138.0 | 6.45 |
| | | | | | | | |
| 3 | 6/23/00 | 0 | 18.34 | 93.8 | 8.67 | 103.6 | 7.48 |
| | | 1 | 16.30 | 88.7 | 8.56 | 103.0 | 7.43 |
| | | 2 | 10.25 | 33.1 | 3.69 | 107.0 | 6.68 |
| | | 3 | 6.92 | 20.8 | 2.48 | 112.1 | 6.60 |
| | | 4 | 5.80 | 14.1 | 1.74 | 113.4 | 6.55 |
| | | 5 | 5.18 | 12.1 | 1.52 | 115.2 | 6.51 |
| | | 5.75 (bottom) | 4.79 | 7.6 | 0.98 | 118.1 | 6.50 |
| | | | | | | | |
| 3 | 5/30/00 | 0 | 5.80 | 49.0 | 6.06 | 108.8 | 6.70 |
| | | 1 | 5.82 | 48.0 | 5.95 | 108.9 | 6.69 |
| | | 2 | 5.80 | 47.9 | 5.91 | 108.9 | 6.69 |
| | | 3 | 4.72 | 43.0 | 5.50 | 110.9 | 6.67 |
| | | 3.5 (bottom) | 4.56 | 40.6 | 5.19 | 112.3 | 6.66 |
| | | | | | | | |
| 3 | 6/2/99 | 0 | 9.67 | 88.4 | 9.67 | 135.1 | 7.32 |
| | | 1 | 9.60 | 84.4 | 9.29 | 134.8 | 7.32 |
| | | 2 | 9.21 | 77.9 | 8.66 | 134.8 | 7.27 |
| | | 3 | 7.71 | 57.4 | 6.50 | 134.5 | 7.10 |
| | | 4 | 6.93 | 48.1 | 5.59 | 132.5 | 7.02 |
| | | 5 | 5.61 | 64.3 | 7.83 | 115.0 | 7.11 |
| | | 6 | 5.02 | 69.2 | 8.55 | 110.5 | 7.14 |
| | | 7 (bottom) | 4.92 | 70.7 | 8.75 | 110.5 | 7.11 |
| | | | | | | | |
| 3 | 10/1/98 | surface | 6.11 | 71.2 | 8.53 | 144.2 | 7.30 |
| | | 1 | 6.05 | 70.5 | 8.44 | 144.2 | 7.32 |
| | | 2 | 5.98 | 69.4 | 8.36 | 144.2 | 7.34 |
| | | 3 | 5.88 | 69.2 | 8.35 | 144.2 | 7.36 |
| | | 4 (bottom) | 4.93 | 69.5 | 8.59 | 139.4 | 7.36 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Appendix 1 (continued).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity ($u$ S/cm) | pH |
|---|---|---|---|---|---|---|---|
| 3 | 7/28/98 | surface | 17.24 | 86.9 | 8.15 | 161.3 | 7.57 |
| | | 1 | 16.71 | 80.0 | 7.58 | 161.8 | 7.52 |
| | | 2 | 16.33 | 66.9 | 6.38 | 161.2 | 7.33 |
| | | 3 (bottom) | 14.62 | 58.4 | 5.75 | 150.6 | 7.19 |
| | | | | | | | |
| 3 | 3/18/98 | 1 | 0.47 | N/T | 0.31 | 176.0 | 6.93 |
| | | 1.5 (bottom) | | | | | |
| | | | | | | | |
| 3 | 9/25/97 | surface | 9.36 | N/T | 5.90 | 156.0 | 7.94 |
| | | 1 | 9.25 | N/T | 5.62 | 156.0 | 7.68 |
| | | 3 | 9.10 | N/T | 5.42 | 155.0 | 7.38 |
| | | 4.5 (bottom) | 8.96 | N/T | 4.30 | 155.0 | 7.13 |

Appendix 1 (continued).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity (*u* S/cm) | pH |
|---|---|---|---|---|---|---|---|
| 11 | 8/29/00 | 0 | 10.80 | 75.1 | 8.15 | 108.4 | 7.09 |
| | | 1 | 10.07 | 74.8 | 8.22 | 108.2 | 7.09 |
| | | 2 | 9.84 | 70.9 | 7.84 | 108.2 | 7.07 |
| | | 3 | 9.64 | 68.5 | 7.59 | 108.5 | 7.00 |
| | | 4 | 9.50 | 76.0 | 8.47 | 105.7 | 7.01 |
| | | 5 | 9.03 | 74.2 | 8.34 | 104.5 | 7.00 |
| | | 6 | 7.15 | 14.9 | 1.75 | 112.2 | 6.68 |
| | | 7 | 6.37 | 4.4 | 0.53 | 121.1 | 6.45 |
| | | 8 (bottom) | 5.87 | 2.6 | 0.32 | 139.8 | 6.45 |
| | | | | | | | |
| 11 | 6/23/00 | 0 | 18.15 | 93.8 | 8.71 | 103.7 | 7.53 |
| | | 1 | 15.99 | 86.0 | 8.35 | 103.3 | 7.42 |
| | | 2 | 13.45 | 57.6 | 5.88 | 105.3 | 6.95 |
| | | 3 | 7.29 | 23.0 | 2.73 | 110.5 | 6.63 |
| | | 4 | 6.07 | 16.6 | 2.02 | 113.6 | 6.56 |
| | | 5 | 5.39 | 11.8 | 1.48 | 118.0 | 6.52 |
| | | 6 | 4.94 | 9.0 | 1.14 | 120.6 | 6.49 |
| | | 7 | 4.73 | 6.5 | 0.82 | 123.0 | 6.48 |
| | | 8 | 4.62 | 4.7 | 0.60 | 125.0 | 6.48 |
| | | 8.5 (bottom) | 4.52 | 3.6 | 0.45 | 126.7 | 6.43 |
| | | | | | | | |
| 11 | 5/30/00 | 0 | 6.21 | 51.0 | 6.25 | 109.7 | 6.78 |
| | | 1 | 5.64 | 47.4 | 5.88 | 110.3 | 6.69 |
| | | 2 | 4.80 | 42.7 | 5.40 | 111.9 | 6.70 |
| | | 3 | 4.43 | 38.6 | 4.94 | 114.9 | 6.66 |
| | | 4 | 4.25 | 37.2 | 4.77 | 116.3 | 6.64 |
| | | 5 | 3.95 | 33.9 | 4.40 | 117.8 | 6.64 |
| | | 6 | 3.81 | 31.6 | 4.10 | 121.5 | 6.63 |
| | | 7 | 3.88 | 31.5 | 4.09 | 124.4 | 6.60 |
| | | 8 (bottom) | 3.30 | 7.4 | 1.05 | 231.6 | 6.35 |
| | | | | | | | |
| 11 | 6/2/99 | 0 | 8.37 | 66.7 | 7.60 | 134.0 | 7.15 |
| | | 1 | 8.00 | 61.3 | 7.01 | 133.7 | 7.12 |
| | | 2 | 7.44 | 54.7 | 6.34 | 133.9 | 7.13 |
| | | 3 | 6.52 | 44.2 | 5.26 | 134.0 | 7.06 |
| | | 4 | 6.17 | 40.1 | 4.80 | 135.1 | 7.03 |
| | | 5 | 5.86 | 36.4 | 4.42 | 135.9 | 7.01 |
| | | 6 | 6.58 | 44.5 | 5.26 | 135.1 | 7.03 |
| | | 7 (bottom) | 7.38 | 53.8 | 6.44 | 134.0 | 7.09 |

Appendix 1 (continued).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity (u S/cm) | pH |
|---|---|---|---|---|---|---|---|
| 11 | 10/1/98 | surface | 5.80 | 71.9 | 8.69 | 144.1 | 7.57 |
| | | 1 | 5.78 | 72.0 | 8.70 | 144.1 | 7.57 |
| | | 2 | 5.75 | 72.1 | 8.73 | 143.9 | 7.58 |
| | | 3 | 5.59 | 72.3 | 8.78 | 144.0 | 7.59 |
| | | 4 | 5.57 | 72.5 | 8.82 | 143.3 | 7.60 |
| | | 5 | 5.53 | 72.4 | 8.81 | 143.8 | 7.59 |
| | | 6 | 5.51 | 72.3 | 8.81 | 143.3 | 7.59 |
| | | 7 (bottom) | 5.51 | 72.6 | 8.84 | 143.5 | 7.57 |
| | | | | | | | |
| 11 | 7/28/98 | surface | 17.07 | 82.4 | 7.75 | 160.6 | 7.60 |
| | | 1 | 16.82 | 79.0 | 7.47 | 161.0 | 7.57 |
| | | 2 | 16.15 | 60.8 | 5.84 | 160.0 | 7.23 |
| | | 3 | 14.57 | 38.1 | 3.72 | 155.8 | 7.00 |
| | | 4 | 12.31 | 15.5 | 1.66 | 152.8 | 6.84 |
| | | 5 | 10.53 | 7.1 | 0.78 | 166.7 | 6.80 |
| | | 5.5 (bottom) | 9.78 | 5.0 | 0.56 | 175.8 | 6.83 |

Appendix 1 (continued).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity (u S/cm) | pH |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 7 | 8/29/00 | 0 | 10.54 | 75.7 | 8.22 | 108.3 | 7.06 |
| | | 1 | 10.11 | 72.5 | 7.95 | 108.9 | 7.04 |
| | | 2 | 9.94 | 71.5 | 7.84 | 108.4 | 7.02 |
| | | 3 | 9.71 | 68.3 | 7.60 | 108.8 | 7.00 |
| | | 4 | 9.30 | 67.1 | 7.50 | 105.9 | 6.95 |
| | | 5 (bottom) | 8.38 | 68.5 | 7.81 | 103.0 | 6.93 |
| | | | | | | | |
| 7 | 6/23/00 | 0 | 18.23 | 90.7 | 8.40 | 103.9 | 7.40 |
| | | 1 | 16.22 | 82.5 | 7.92 | 103.4 | 7.23 |
| | | 2 | 12.30 | 47.3 | 4.98 | 105.4 | 6.79 |
| | | 3 | 8.07 | 16.9 | 1.96 | 111.1 | 6.64 |
| | | 4 | 6.00 | 6.7 | 0.82 | 116.0 | 6.51 |
| | | 5 | 5.36 | 4.2 | 0.52 | 119.0 | 6.46 |
| | | | | | | | |
| 7 | 5/30/00 | 0 | 6.80 | 52.3 | 6.30 | 110.7 | 6.75 |
| | | 1 | 6.39 | 49.4 | 5.99 | 110.5 | 6.72 |
| | | 2 | 4.93 | 41.1 | 5.19 | 110.7 | 6.70 |
| | | 3 | 4.19 | 35.1 | 4.54 | 116.8 | 6.64 |
| | | 4 | 4.10 | 33.4 | 4.31 | 117.5 | 6.63 |
| | | 5 (bottom) | 3.99 | 29.6 | 3.84 | 119.0 | 6.61 |
| | | | | | | | |
| 7 | 6/2/99 | 0 | 8.84 | 72.0 | 8.06 | 133.5 | 7.21 |
| | | 1 | 8.82 | 70.3 | 7.90 | 133.8 | 7.20 |
| | | 2 | 8.65 | 68.2 | 7.67 | 133.6 | 7.21 |
| | | 3 | 6.21 | 42.5 | 5.09 | 134.9 | 7.01 |
| | | 4 | 6.17 | 38.8 | 4.64 | 135.0 | 7.01 |
| | | 4.5 (bottom) | 6.16 | 37.1 | 4.45 | 134.9 | 7.00 |
| | | | | | | | |
| 7 | 10/1/98 | surface | 5.63 | 67.6 | 8.22 | 143.6 | 7.59 |
| | | 1 | 5.52 | 68.0 | 8.29 | 143.9 | 7.57 |
| | | 2 | 5.37 | 68.4 | 8.36 | 143.4 | 7.58 |
| | | 3 | 5.00 | 68.9 | 8.51 | 143.4 | 7.59 |
| | | 4 | 4.92 | 69.0 | 8.53 | 143.0 | 7.59 |
| | | 5 (bottom) | 4.97 | 66.6 | 8.21 | 143.2 | 7.56 |
| | | | | | | | |
| 7 | 7/28/98 | surface | 17.22 | 82.5 | 7.71 | 160.5 | 7.59 |
| | | 1 | 16.82 | 79.7 | 7.54 | 161.2 | 7.57 |
| | | 2 | 13.82 | 58.9 | 6.70 | 155.5 | 7.31 |
| | | 3 (bottom) | 13.22 | 43.1 | 4.40 | 146.3 | 7.20 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Appendix 1 (concluded).

| Site Number | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity ($u$ S/cm) | pH |
|---|---|---|---|---|---|---|---|
| 7 | 9/25/97 | surface | 9.22 | N/T | 6.34 | 141.0 | 7.01 |
| | | 1 | 8.97 | N/T | 5.77 | 141.0 | 7.01 |
| | | 3 | 8.86 | N/T | 4.90 | 142.0 | 6.94 |
| | | 4 | 8.90 | N/T | 4.76 | 141.0 | 6.92 |
| | | 4.5 (bottom) | | | | | |

# Appendix 2 - Water Quality: Fort Knox Wetlands

| Pond | Date | Depth (m) | Temperature (C) | % Saturation Dissolved Oxygen | Dissolved Oxygen (mg/L) | Conductivity (u S/cm) | pH |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| A | 9/3/99 | 0.5 | 11.70 | 75.9 | 8.06 | 230.5 | 7.84 |
| | 5/16/00 | 0.5 | 5.22 | 74.0 | 9.19 | 112.8 | 7.05 |
| | | | | | | | |
| B | 9/3/99 | 0.5 | 10.11 | 73.2 | 8.06 | 187.5 | 7.10 |
| | | | | | | | |
| C | 9/3/99 | 0.3 | 12.11 | 87.1 | 9.16 | 236.1 | 8.28 |
| | | | | | | | |
| D | 9/3/99 | 0.5 | 12.13 | 78.8 | 8.31 | 222.6 | 7.69 |
| | | | | | | | |
| E | 9/3/99 | 0.3 | 8.78 | 49.5 | 5.61 | 226.1 | 7.16 |
| | | | | | | | |
| F | 9/3/99 | 0.5 | 11.85 | 71.2 | 7.53 | 190.6 | 7.68 |
| | | | | | | | |
| | | | | | | | |
| A Inlet | 5/1/00 | 0.5 | 0.30 | 89.7 | 13.31 | 139.1 | 7.07 |
| | 5/15/00 | 0.5 | 4.08 | 95.9 | 12.16 | 223.9 | 7.36 |
| | 5/16/00 | 0.5 | 4.55 | 91.6 | 11.50 | 231.4 | 7.48 |
| | | | | | | | |
| F Outlet | 5/1/00 | 0.5 | 0.28 | 76.6 | 11.39 | 137.6 | 6.62 |
| | 5/4/00 | 0.5 | 0.37 | 87.5 | 12.30 | 90.4 | 6.51 |
| | 5/9/00 | 0.5 | 1.42 | 85.8 | 11.69 | 74.0 | 6.57 |
| | 5/15/00 | 0.5 | 2.65 | 86.5 | 11.42 | 86.9 | 6.99 |
| | 5/16/00 | 0.5 | 3.60 | 87.3 | 11.23 | 94.0 | 6.78 |