University of Minnesota
St. Anthony Falls Hydraulic Laboratory

Project Report No. 317

Field Testing of a Winter Lake Aeration System

by

Christopher R. Ellis

and

Heinz G. Stefan

Prepared for

LEGISLATIVE COMMISSION ON MINNESOTA RESOURCES
St. Paul, Minnesota

June 1991
Minneapolis, Minnesota

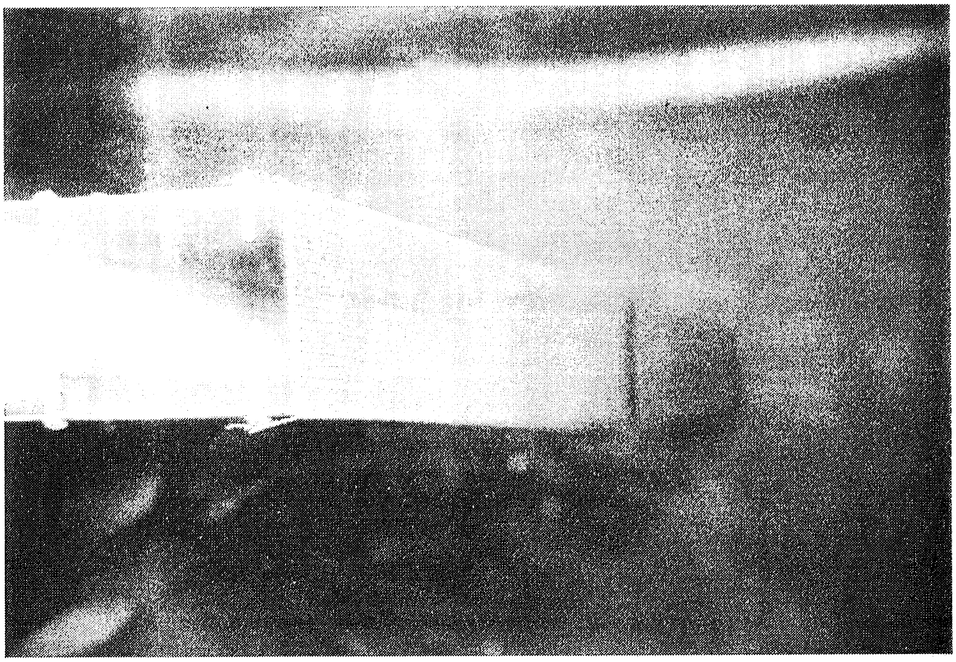


Photo 1. 1:4 scale model of manifold/diffuser used for hydraulic testing and design (Jan 1989)

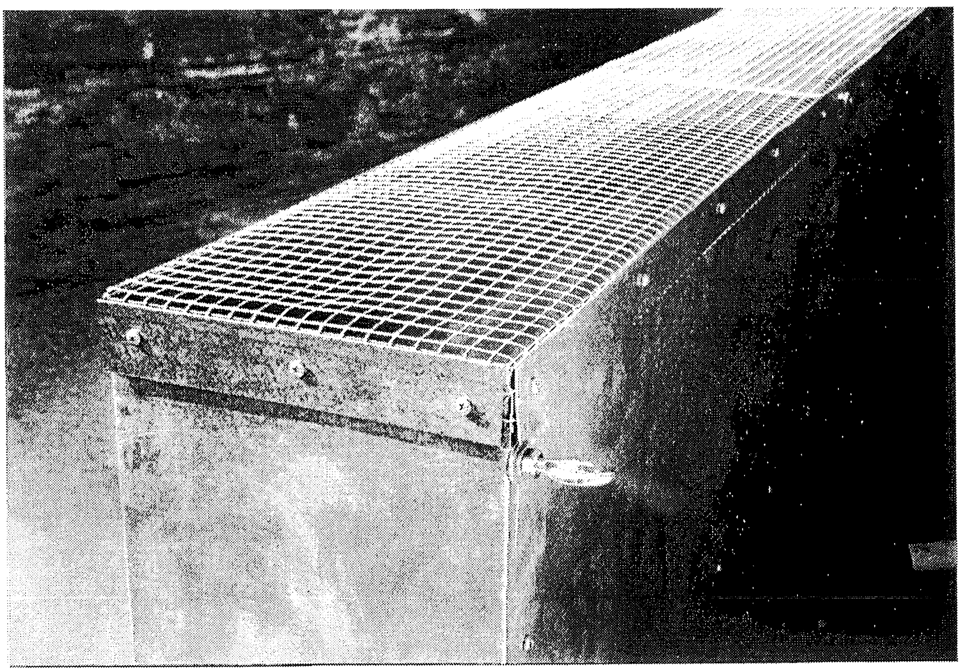


Photo 2. Manifold/diffuser section showing diffuser screen (Aug 1989).

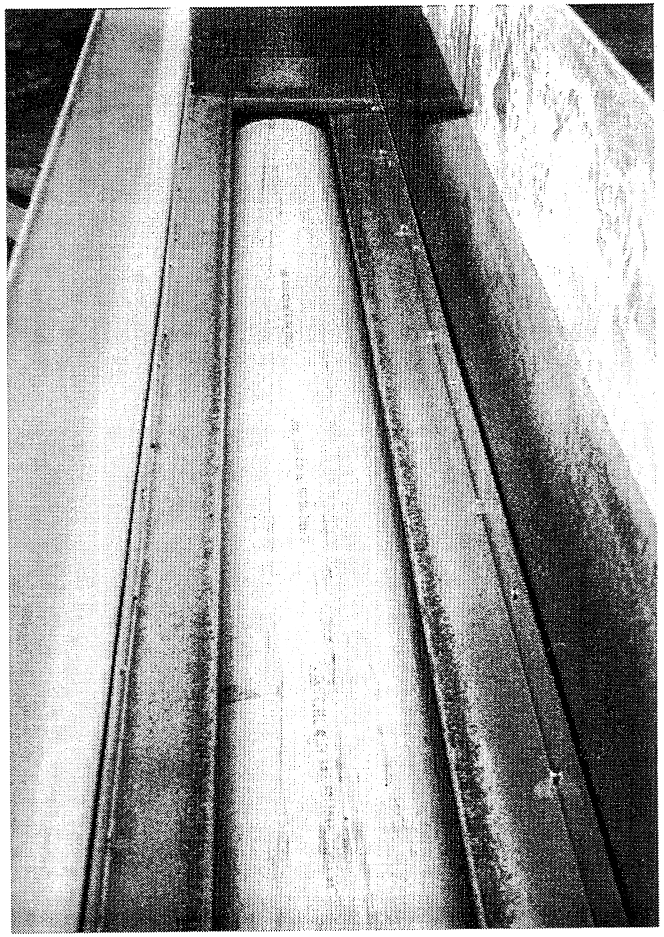


Photo 3. Manifold/diffuser section showing manifold and impact sills (Aug 1989).

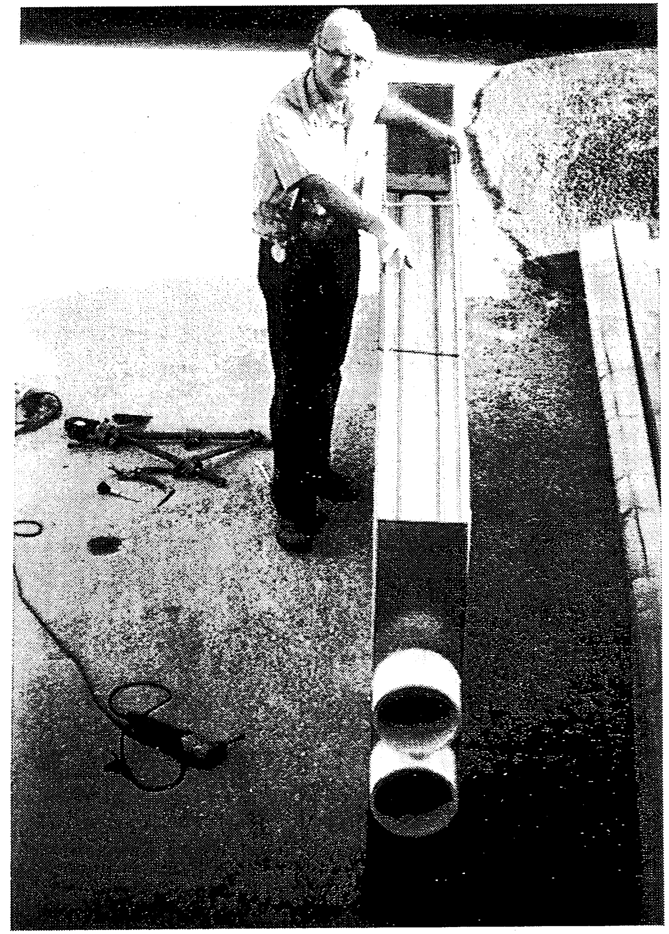


Photo 4. Manifold/diffuser section without diffuser screen (Aug 1989).

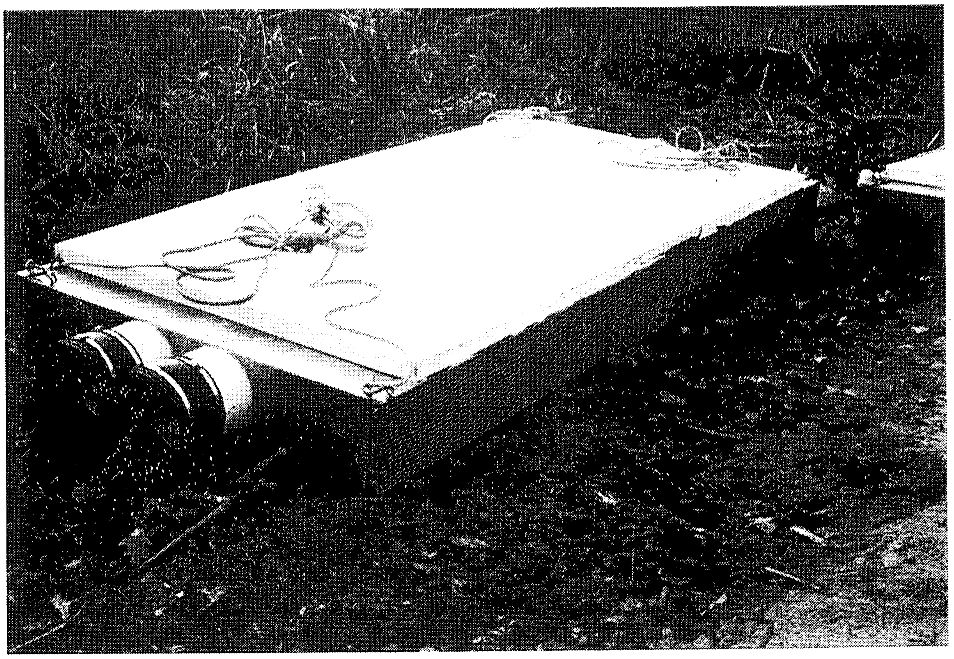


Photo 5. Manifold/Diffuser section ready for installation. Note: Bottom of section is facing up (Nov 1989).

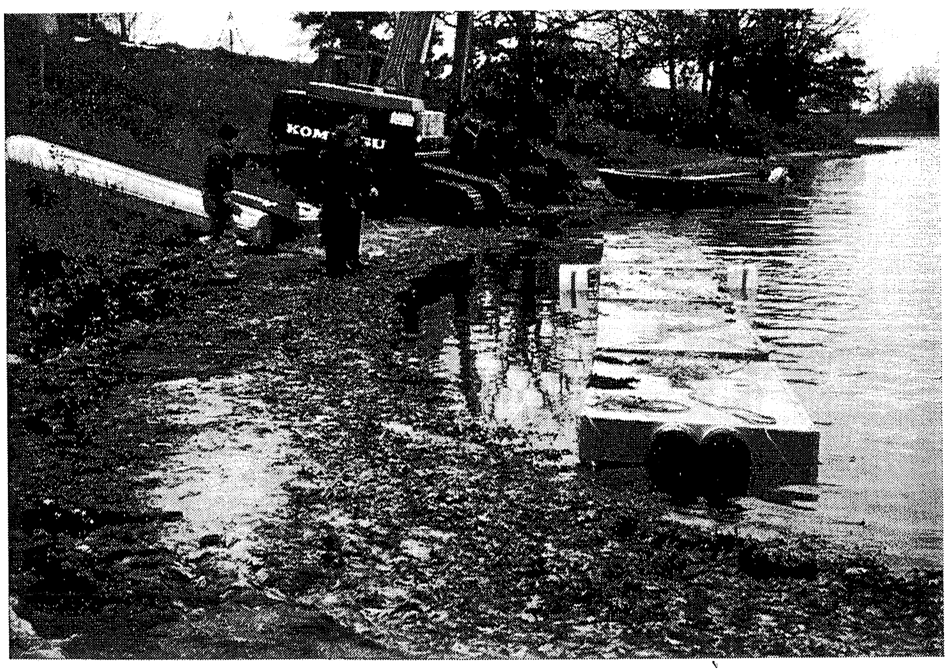


Photo 6. Manifold/diffuser (5 sections) connected and ready for installation (Nov 1989).

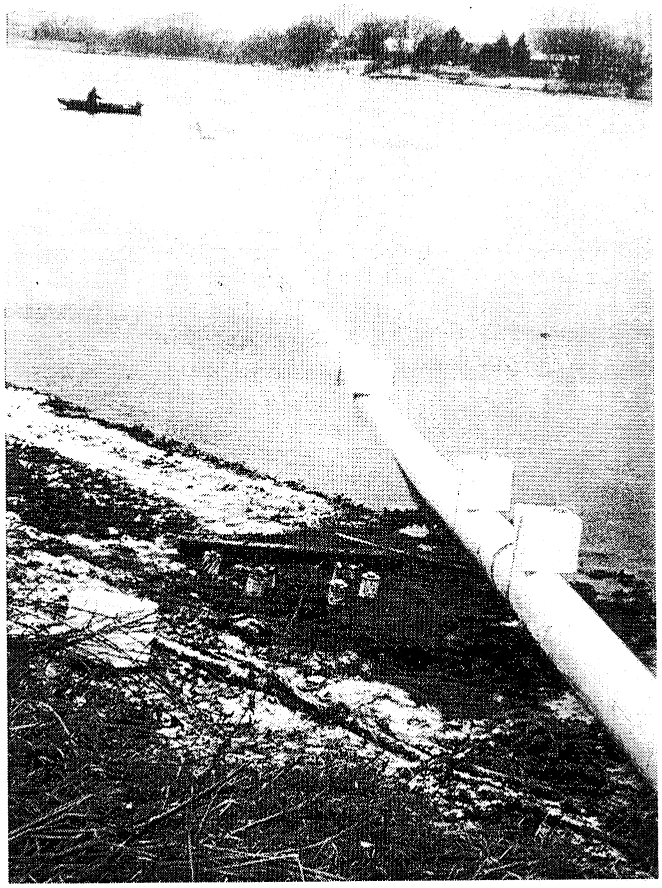


Photo 7. Discharge pipe connected to manifold/diffuser (Nov 1989).

Photo 8. Attachment of anchors to and submergence of manifold/diffuser (Sept 1990).

Photo 9. Illustration of open water area produced by shoreline discharge (Dec 1989).

Photo 10. Datalogger platform used to monitor water temperature profiles (Feb 1990).

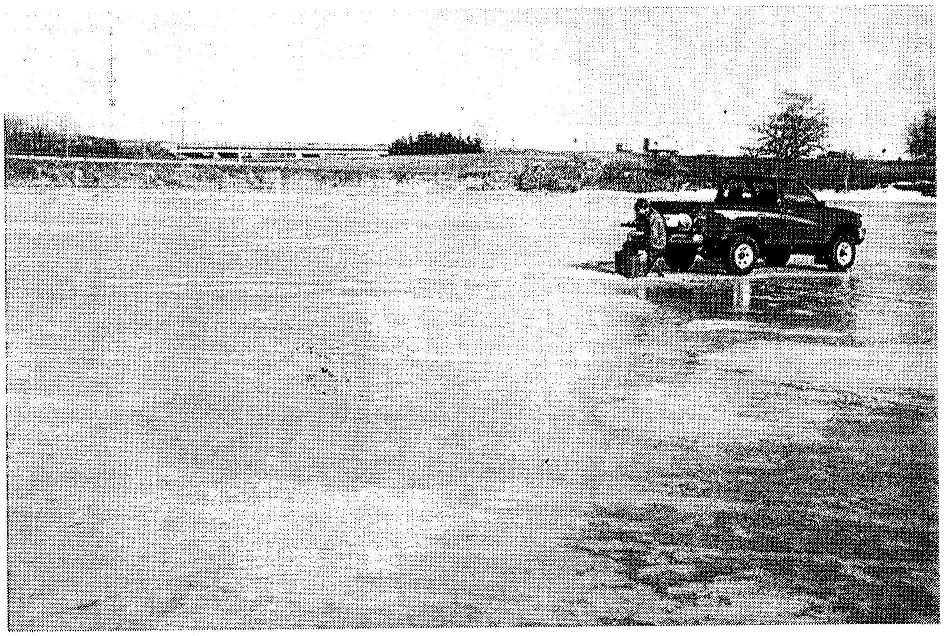


Photo 11. Area of ice above operating manifold/diffuser. Note: Absence of open water (March 15, 1991).

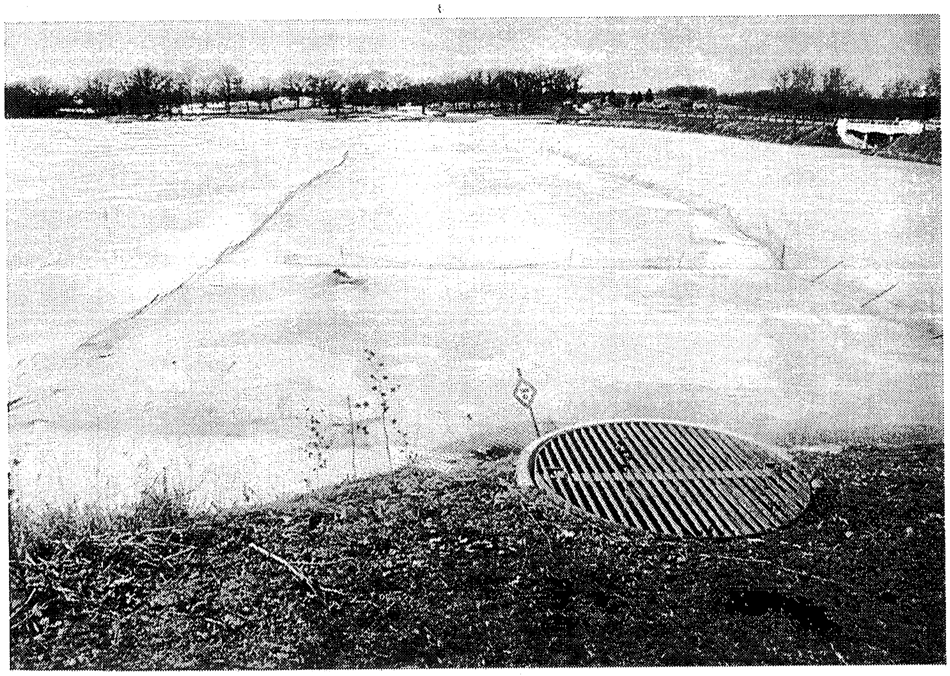


Photo 12. Area of ice above operating manifold/diffuser. Note: Absence of open water (March 15, 1991).

Table of Contents

		PAGE NO.
List of Figures		ii
Abstract		1
Introduction		2
Objectives of Field Study		5
Site and System Description		6
Procedures		10
Results		14
	Temperature Measurements	14
	Dye Study	20
	Ice Thickness	24
	Dissolved Oxygen Measurements	28
Conclusions		36
References		38
Appendix A	Schematic of Manifold/Diffuser Section	43
Appendix B	Dissolved Oxygen and Temperature Profiles 1989–90	45
Appendix C	Dissolved Oxygen and Temperature Profiles, 1990–91	59
Appendix D	Depth Averaged Dissolved Oxygen Concentrations: 1989–1990, 1990–1991	77
Appendix E	Time Series Plots of Temperatures Recorded by CSI Dataloggers	81
Appendix F	Surface and Underwater Photosynthetically Active Radiation (PAR) Measurements: 1989–1990, 1990–1991	95
Appendix G	Cascade Aerator Performance, 1991	103

List of Figures

Fig. 1. Schematic of proposed aeration system as originally designed (from Ellis and Stefan, 1990).

Fig. 2. Island Lake bathymetry and principal measuring stations.

Fig. 3. Schematic of Island Lake Aerator and Discharge Diffusers.

Fig. 4. Aeration chute detail.

Fig. 5. Measurement grid for dye study.

Fig. 6 (a & c) Air temperature and (b & d) snowfall and snow cover, Minneapolis/St. Paul, 1989–90 and 1990–91.

Fig. 7. Typical temperature and dissolved oxygen profiles.

Fig. 8. Temperature profiles, January 6 through 14, 1990.

Fig. 9. (a) Actual and (b) modeled temperature profiles near point of exhaust following initiation of aeration.

Fig. 10. Temperature profiles at points remote from aerator exhaust following initiation of aeration.

Fig. 11. Temperature and dissolved oxygen profiles four days after onset of aeration, 1991.

Fig. 12. Typical temperature profiles during dye study.

Fig. 13. Map showing front of dye plume at various times after initiation of dye injection. Injection started March 5, 1990.

Fig. 14. Dye profiles (a) one day after initiation of dye injection, 50 m from manifold/diffuser and (b) seven days after initiation of dye injection, 240 m from manifold/diffuser.

Fig. 15. Ice thickness and snow depth.

Fig. 16. Ice thickness measurements in area of diffuser.

Fig. 17. Open water due to aeration, February 1991.

Fig. 18. Mean lake dissolved oxygen concentrations.

Fig. 19. Depth averaged dissolved oxygen concentrations (mg/l).

Fig. 20. Photosynthetically active radiation (PAR) beneath ice under various conditions of ice and snow cover.

Fig. 21. Comparison of net rise of north end dissolved oxygen with aerator input, 1991.

Fig. 22. Cascade aerator performance, 1991.

Field Testing of a Winter Lake Aeration System

by Christopher R. Ellis and Heinz G. Stefan

ABSTRACT

Conventional aeration of winterkill lakes results in mixing of the water column and open water in the ice cover. A non–mixing winter lake aeration system has been designed and field tested that can maintain water temperature stratification in the lake and not create open water. The performance of a cascade aerator was evaluated for which the design discharge and dissolved oxygen input rate were 85 l/s and 70 kg/d, respectively. Unusually high levels of dissolved oxygen due to photosynthetic productivity under the ice–cover were also observed and are reported.

Introduction

The death of fish due to winterkill is a significant fisheries management problem for shallow lakes both in the United States and Canada. For example, hundreds of lakes are annually threatened by winterkill in Minnesota alone where nearly 300 aeration permits were issued for the winter of 1988–1989 (Enger 1989).

Aeration used in the prevention of winterkill typically results in one or more areas of open water within the ice cover posing a hazard to winter lake users. This is due to mixing of the water column by the aeration system which transports warm (3–4 °C) water from the lower depths to the surface where the heat melts the ice cover. In most cases, the effectiveness of supplying air (oxygen) to the under–ice water depends on the creation of a free water surface through which oxygen can be transferred from the atmosphere. The most commonly used technique, bubble diffuser aeration, supplies only a small amount of oxygen from the bubbles to the water compared with that supplied through the open water surface created by the bubble plume (Johnson 1970; Patriarche 1961; Skrypek and Shodeen 1977; Toetz *et al.* 1972).

Unlike aeration methods that depend on water column mixing and ice melting to operate effectively, others produce open water as a consequence, rather than a requirement, of their design. For example, pump and baffle (cascading) type aerators can be designed to amply provide for a lake's winter oxygen demand in the absence of open water but will usually cause ice melting where water is withdrawn from and discharged back into the lake.

In addition to melting the ice cover, mixing of the water column also increases oxygen consumption under the ice. Since the aeration system must provide for this added demand, its oxygen supply rate (and cost) must be increased accordingly.

For all of the above reasons, non–mixing aeration is an attractive alternative to conventional techniques. Design of a non–mixing winter lake aeration system was initiated at the St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota in 1988. The basic design concept employs a paired manifold/diffuser to selectively withdraw a layer of water from within the under–ice thermocline (typically 1 m below the ice), convey it to shore for aeration, and return it to the lake at the same depth and temperature from which it came without destratifying the water column (Fig. 1). Aeration can be accomplished using any of the existing technologies (*e.g.* cascades) as long as the water is (a) enriched with oxygen, (b) unchanged in temperature, and (c) devoid of air bubbles when returned to the lake. The key to the success of the strategy lies in the design of the manifold/diffuser. A suitable design was developed in a series of model experiments described elsewhere (Ellis and Stefan 1990).

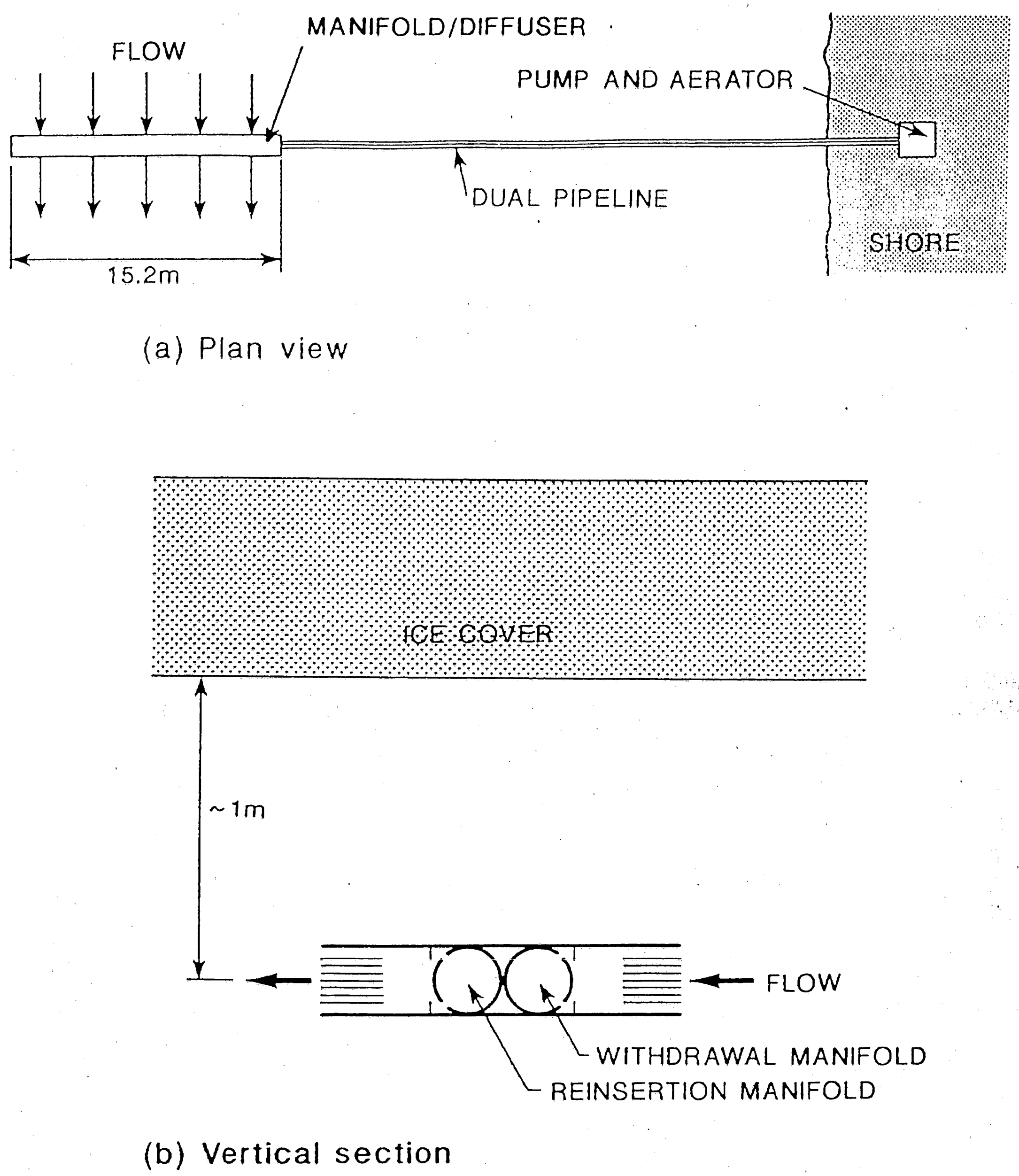


Fig. 1. Schematic of proposed aeration system as originally designed (from Ellis and Stefan, 1990).

In the summer of 1989, a county agency, already well along in the planning of an aeration system for Island Lake in Ramsey County, Minnesota, agreed to incorporate a prototype manifold/diffuser in its project. With some modification of the original design concept, an aeration system including the experimental manifold/diffuser was installed the following fall. This report describes the results of two winters of operation.

Objectives of Field Study

The primary goal of the experimental system is to distribute aerated water in a winter lake without degrading the ice cover. Laboratory model testing of the manifold/diffuser design indicated that this goal could be met. The operation of a prototype system in Island Lake would provide field verification of the laboratory results. In particular, water temperature profiles and the ice thickness growth rate in the vicinity of the discharge could be measured in the field and compared with those predicted by the model. The formation of a distinct oxygenated layer, shown in the model to occur at the level of the manifold/diffuser discharge, could be verified in the lake.

The laboratory scale model was designed as a sectional model to determine the local effect of the aerator discharge on water column stratification and the ice thickness growth rate in a laboratory setting. It could not predict the system's impact on whole–lake oxygen dynamics or circulation patterns. Only through a prototype experiment could the lateral extent of the aerated "refuge" and the tendency toward "short–circuiting" between the discharge and the intake be assessed. Dilution caused by entrainment of ambient water into the aerated plume as it spreads could also be measured only in the field.

Another objective of the field study was to estimate the winter oxygen demand in the lake with and without aeration. Previous studies have indicated that the two demand rates can be substantially different due to aerator induced water motion adjacent to the sediment (Belanger 1981; Boynton *et al.* 1981; Hall *et al.* 1989). From frequent measurements of oxygen profiles and knowing the rate of oxygen supplied by the aerator, the oxygen demand rates can be determined.

Site and System Description

Island Lake is located just north of St. Paul, Minnesota. It has a surface area of 17.1 hectares, a mean depth of 1.45 meters, and a maximum depth of 2.8 meters. Its bathymetry is illustrated in Fig. 2 which also includes the layout of the aeration system and the location of the measurement stations. Because of its shallowness and eutrophic condition, Island Lake usually experiences winterkill unless remedial action by aeration is taken. Due to changing hydrologic conditions, actual water depths were approximately 25 cm (0.8 ft) less during the 1989–90 winter and 25 cm (0.8 ft) more during the 1990–91 winter than those indicated on the map.

According to the original design, water was to be withdrawn through a 69 cm diameter grate flush with the lake bottom, pumped to a buried aeration chute, and discharged either directly at the adjacent shoreline or through a 30 cm opening, again flush with the lake bottom, located 12 m off shore. That ice melting would occur at either of the discharge points was taken for granted.

The fact that the intake and exhaust locations were to be widely separated precluded the use of a manifold/diffuser as originally designed with back to back intake and exhaust (Fig. 1). In order to incorporate the manifold/diffuser into the existing design, it was decided to have it serve exclusively as a discharge device. Thus, the water was withdrawn from the lake through a separate bottom intake and aerated as described above, piped 67 m out into the lake, and discharged through both sides of a 14 m long experimental manifold/diffuser submerged 140 cm below the surface (Fig. 3). (See also Appendix A.) Given a maximum expected ice thickness of 60 cm, this left a minimum of 80 cm between the underside ice surface and the discharge point putting it in the middle of the typical winter thermocline.

The aerator consisted of a baffled chute set at a 45^o angle through which the water flowed and entrained air (Fig. 4). This chute was buried in a hillside near the lake's edge. At the bottom of the chute, the aerated water collected in a well to which the discharge pipes were attached.

The system design discharge was 85 l/s which corresponded (coincidentally) to twice the design discharge of the manifold/diffuser as originally conceptualized, *ie.*, one manifold used as intake, one as exhaust. Using both sides of the manifold/diffuser as exhausts, the anticipated discharge velocity of the diffuser was 1.5 cm/sec. The system could be throttled to any smaller flow rate. The actual system discharge was limited by the head available in the well (diversion box) at the bottom of the aeration chute which provided the needed pressure to drive the flow out the double manifold. This head could not exceed 1.0 m.

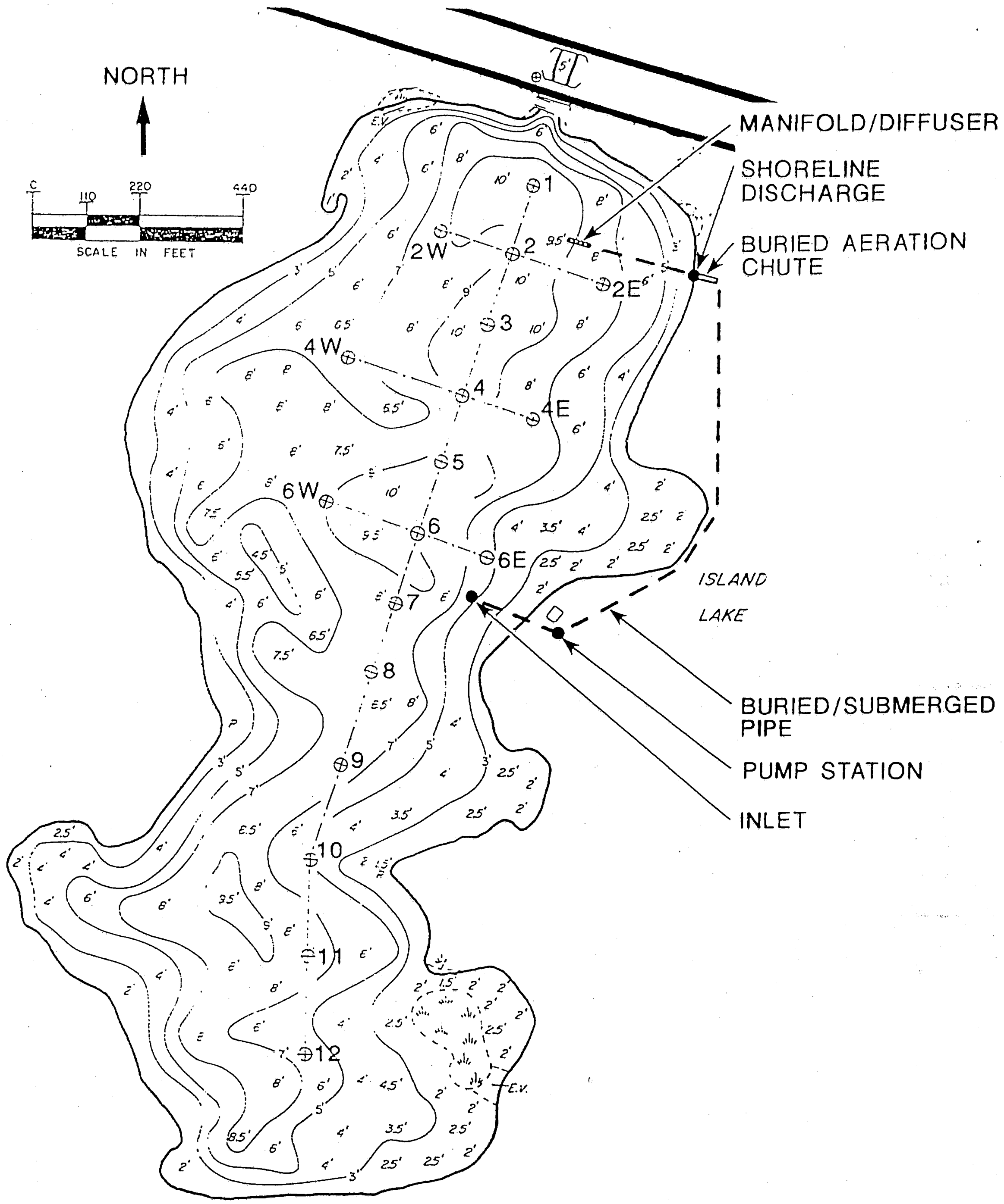


Fig. 2. Island Lake bathymetry and principal measuring stations.

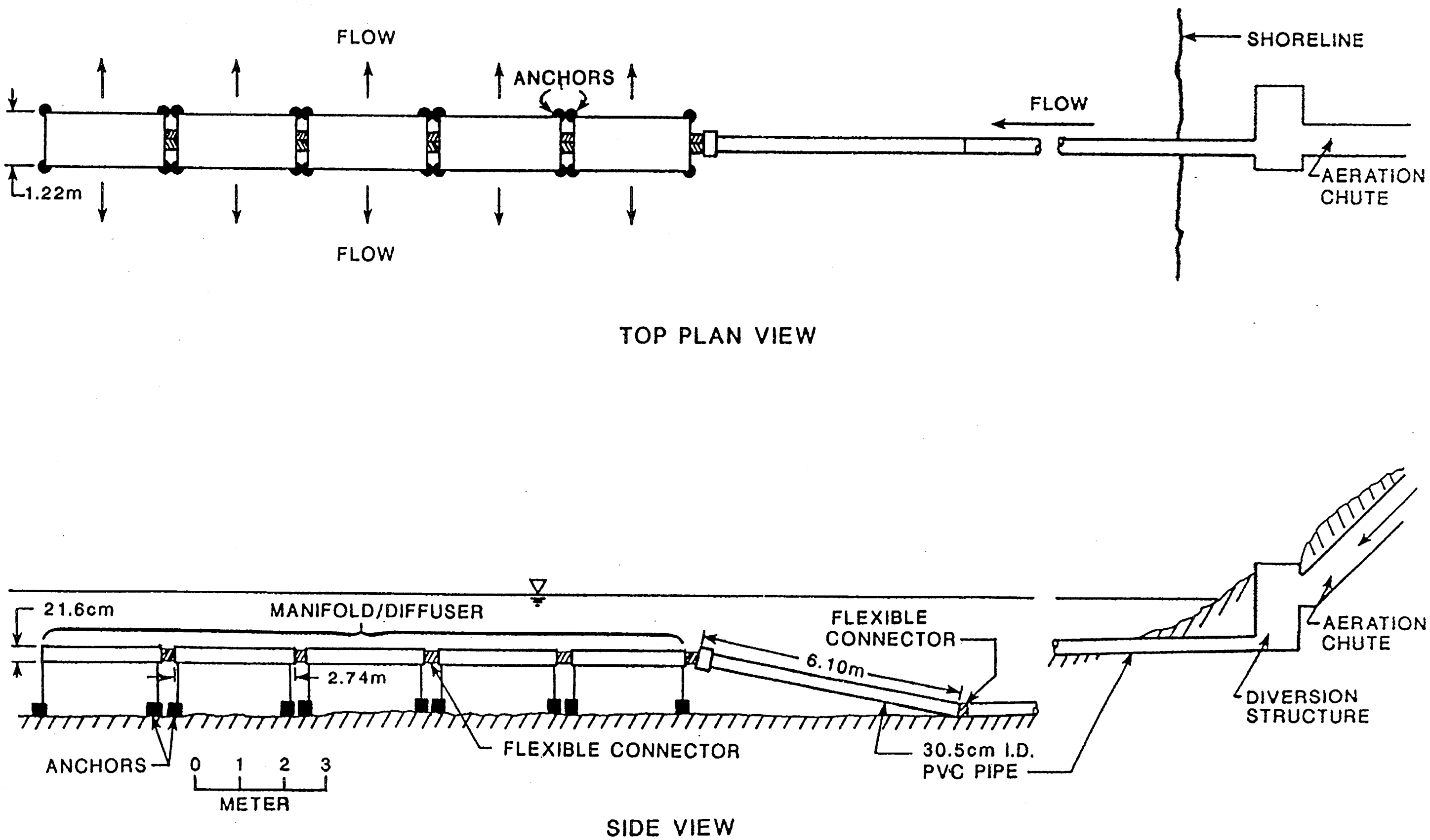


Fig. 3. Schematic of Island Lake Aerator and Discharge Diffusers.

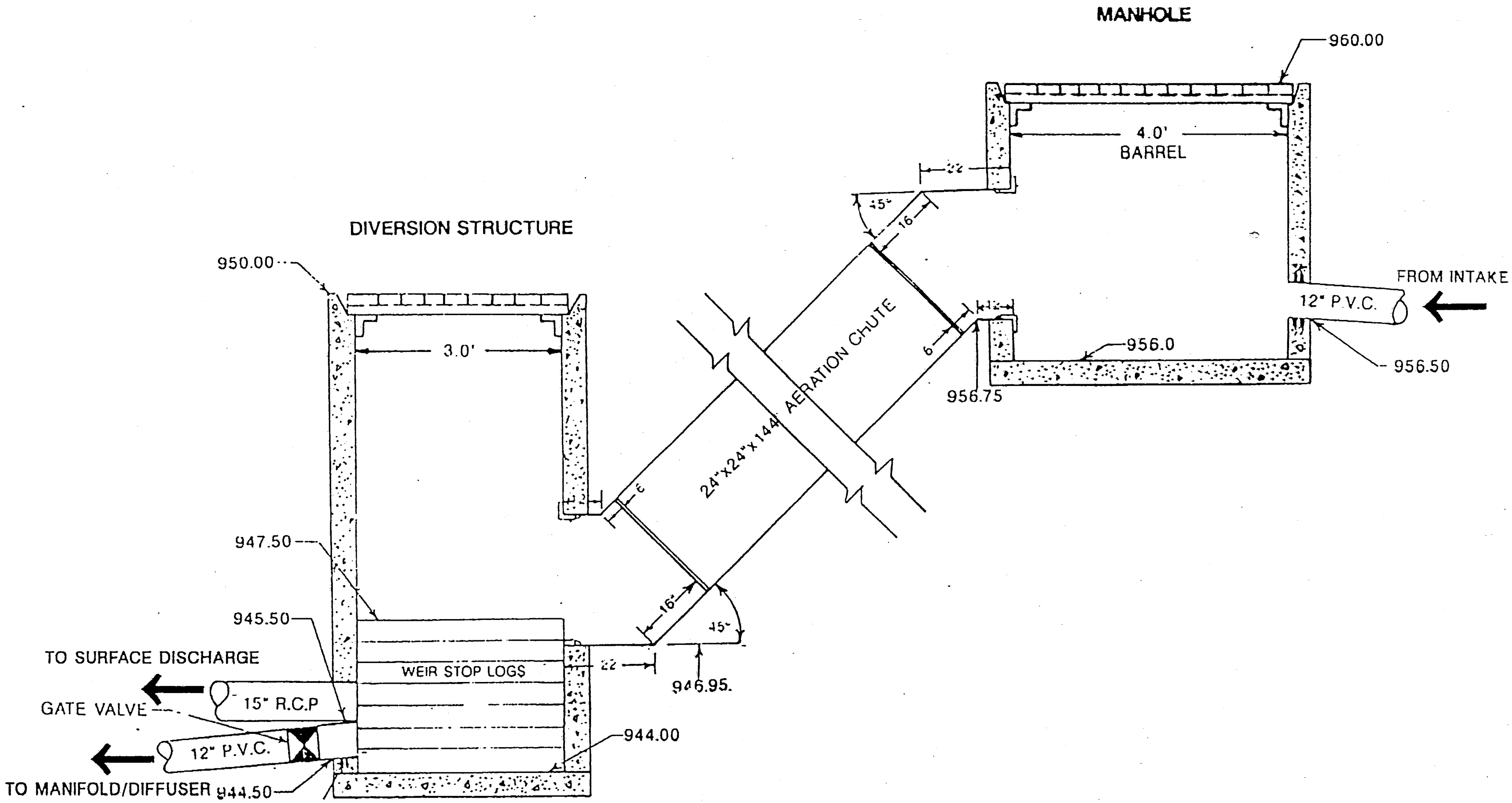


Fig. 4. Aeration chute detail.

Procedures

Testing of the aeration system performance included monitoring of oxygen and temperature profiles throughout the lake both before and during aeration. These profiles were measured at 18 locations from December 22, 1989 to March 13, 1990 and at 11 locations from January 3, 1991 to March 18, 1991 (Fig. 2). Stations 1, 3, 5, 7, 9, 10, and 12 were not used during the 1990–91 winter and station 11 was moved 30.5 m south of its previous position. From December 23, 1989 to March 31, 1990, temperature profiles were measured every 2 minutes by three thermistor chains connected to automated data loggers and placed at stations 2, 4, and 6 in Fig. 2. Absolute accuracy of the calibrated probes was ±0.05 °C while relative accuracy (the difference between successive measurements by the same probe at the same temperature) was ±0.01 °C. At 20 minute intervals, the preceding 10 measurements were averaged and stored for later retrieval. Thermistors were placed at 25 cm intervals from the ice surface to the 2.5 m depth. These profiles provided virtually continuous temperature records of the area between the intake and exhaust for the duration of ice–over during the winter of 1989–90. Ice and snow thicknesses were also recorded at all measurement stations.

A dye study was conducted from March 5–12, 1990 to track the spread and distribution of the aerated water and to measure dilution rates of the aerated plume. The fluorescent dye Rodamine WT was used as a tracer. A 10% dye solution (by weight) was added to the aerator flow at the pump station at a rate that varied from 5.6–10.8 mg/sec, the mean rate being 8.4 mg/sec, beginning at noon on March 5. Holes were cut through the ice in a 30 m by 30 m grid (Fig. 5) through which dye profiles were measured on a daily basis. This procedure was used to track the front of the dye plume and to characterize the dye profile near the front as it changed over time. Measurement of vertical dye concentration profiles were made to estimate dilution rates and vertical distributions of the aerated water over time and distance from the discharge point.

The flow rate of the aeration system was determined in two ways. Velocity profiles at a pump sump inlet pipe were measured with an electromagnetic current meter and integrated to yield the pipe discharge. Additionally, a dye dilution technique was used in which fluorescent dye was injected into the flow upstream of the cascade at a known concentration and rate and its concentration was measured downstream of the cascade where it was well mixed with the flow. The system flow rate was then determined from

$$Q_s = Q_d \frac{C_d}{C_s}$$

where Q is flow rate, C is concentration, and the subscripts s and d refer to system and dye, respectively.

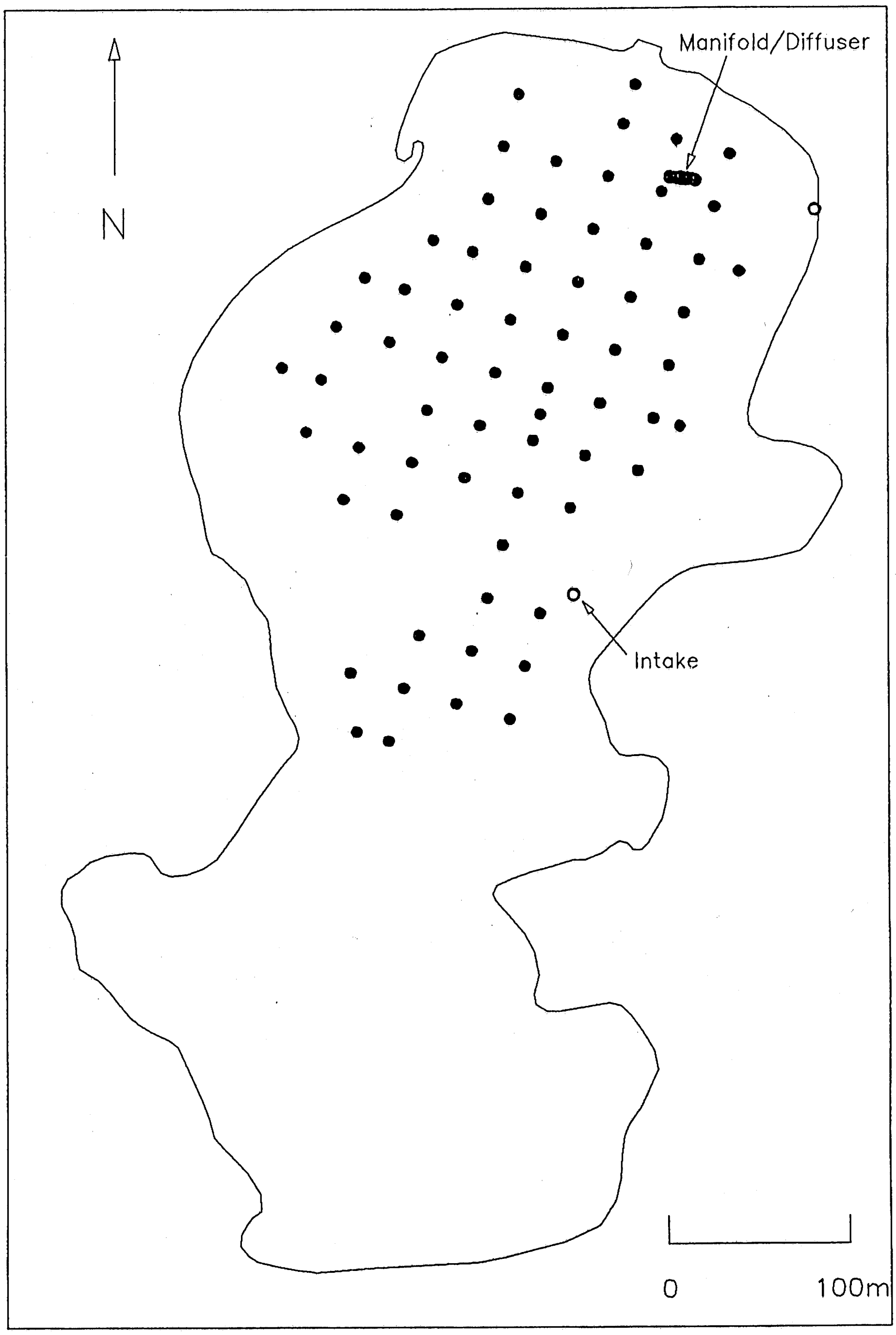


Fig. 5. Measurement grid for dye study.

Measurement of system flow rate, although attempted, proved unsuccessful in 1990. In 1991, it was assumed that the first flow measured was the same as that set in 1990. The rationale for this assumption was that since all system settings (*eg.* valves) had remained unchanged between the two winters and total operating head through the system was essentially the same, the flow rate also would be the same.

The aeration system was installed in November, 1989, and at the end of December, pump performance was tested using the surface shoreline discharge only. (A valve had been installed in the line leading to the manifold/diffuser which remained closed during this time.) As expected, an area of open water, approximately 20 m long and 10 m wide developed extending out into the lake from the shoreline. Since dissolved oxygen levels in the lake were high (~10 mg/l) at this time, the system was shut off. Aeration was to begin again when DO had declined to 2–4 mg/l.

Operation of the aeration system was initiated on February 22, 1990 and the flow adjusted to 64.3 l/s. Aeration continued until ice–out (March 30) using the manifold/diffuser exclusively as the means of discharge, though aeration of the lake for winterkill prevention proved unnecessary (see "*Oxygen Measurements*", below). In 1991, the aeration system was operated from February 1 to February 15 at flows of 64.3 l/s and 69.4 l/s and from March 4 to March 26 at a flow rate of 49.1 l/s. Dissolved oxygen levels and temperatures were periodically monitored upstream and downstream of the aeration chute. Ice thickness was measured in the area of the diffusers and at the intake location to assess the impact of system operation on the ice cover. Any ice melting that occurred was noted.

The weather during the 1989–90 winter proved very atypical. Air temperatures were below normal for most of December and above normal for the rest of the season, the latter often hovering around the freezing point (Fig. 6a). Snowfall for the winter was well below normal. Figure 6b shows daily snowfall and depth of snow on the ground in the Minneapolis/St. Paul area for the winter of 1989–90. Included in the figure are weekly snow cover measurements at Island Lake with the range of depths measured at the 18 stations indicated. The combination of frequent thaws and infrequent snowfall left the ice cover snow–free (or nearly so) and highly transparent for most of the months of January through March.

The winter of 1990–91 was again warmer with less snowfall than average (Figs. 6c and 6d). A small but significant amount of snow cover effectively blanketed the lake through January. During the first week of February, particularly warm weather caused the complete disappearance of snow cover, a condition which lasted for 10 days. After a 3.5 week period in late February and early March during which time a number of moderate snowfalls occurred, snow cover disappeared for good on about March 9.

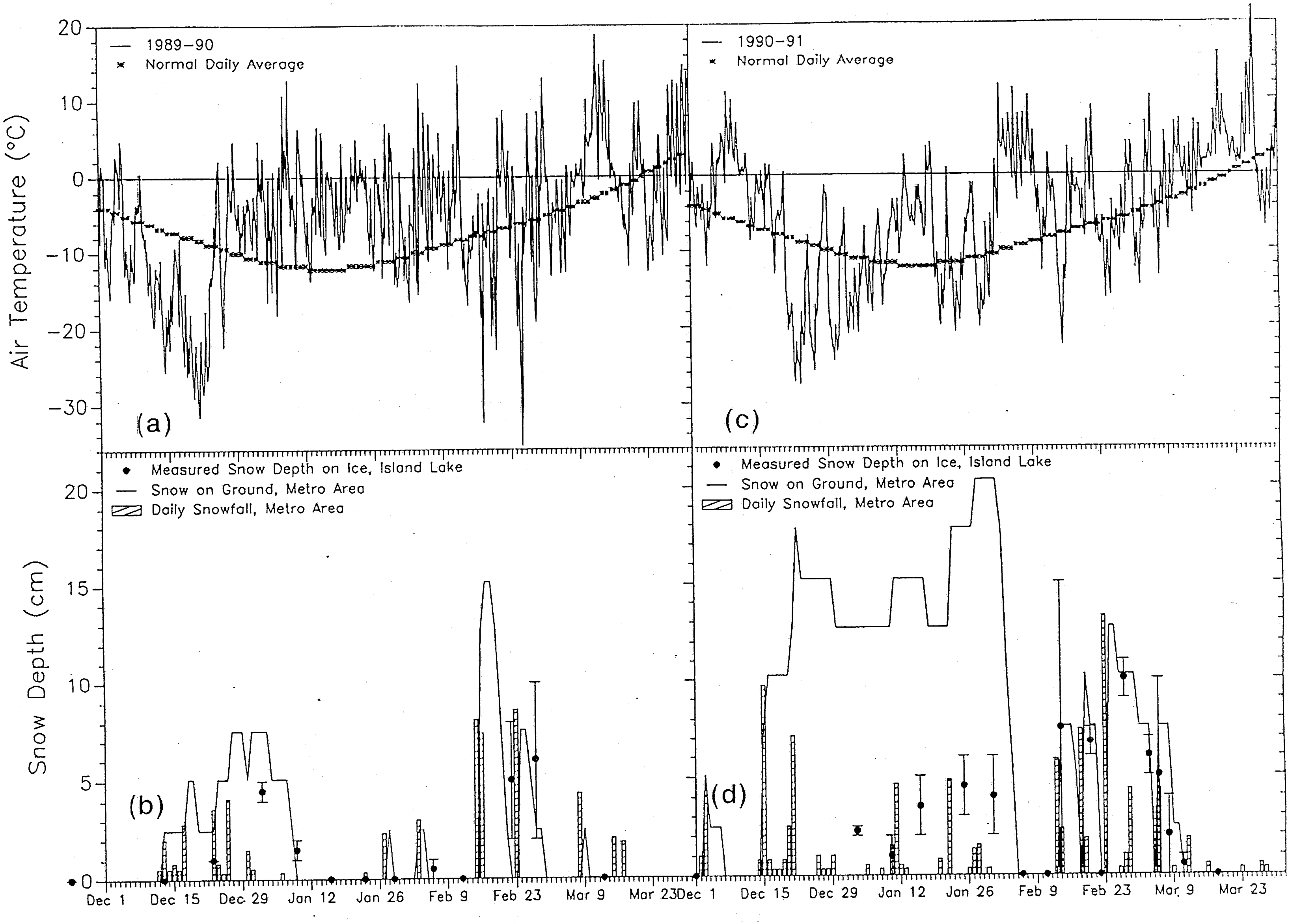


Fig. 6. (a & c) Air temperature and (b & d) snowfall and snow cover, Minneapolis/St. Paul, 1989–90 and 1990–91.

Results

Temperature Measurements

Figure 7 shows the seasonal evolution of water temperatures in a series of temperature and synoptic oxygen profiles taken over the course of the two winters. Early in the season, a typical winter thermocline developed which reached down to a depth of about 1.6 m. By the second week of January in 1990 and the second week of February in 1991, this was replaced by a much more isothermal profile with a thinner thermocline (Fig. 8) which persisted for most of the rest of the winters, the near–bottom temperatures often extending to within 25 cm of the ice cover. Rather than being positioned in the center of the thermocline, the manifold/diffuser was instead well within the isothermal region during both winters. Since it was intended that the manifold/diffuser would insert a layer of water within the thermocline (as would have been the case in a more typical winter), it was not tested as designed.

It was found that the water discharged from the aerator was usually about 0.5 ^{o}C cooler than the isothermal near–bottom water. This was probably due to the vertical withdrawal of water at the point of intake where less than a meter separated the ice cover from the lake bottom causing some of the water to be taken from the underside of the ice. Some local ice degradation was measured directly over the intake, lending support to this explanation.

With the initiation of aeration in 1990, the water immediately above and below the manifold/diffuser depth and near the discharge location quickly cooled by about 0.5 ^{o}C and assumed a fairly persistent temperature profile (Fig. 9a). The shape of this profile compares quite favorably with that measured in the laboratory during the modeling of the manifold/diffuser design (Fig. 9b, Ellis and Stefan 1990) even though the initial temperature profiles were considerably different. Elsewhere in the lake, the water column also cooled somewhat but was otherwise unaffected (Fig. 10). It should be noted that water column cooling during this period was due at least in part to the presence of snow cover and a period of cold weather that lasted from February 24–28, 1990. (The air temperature dropped below –30 ^{o}C early on February 25.) The temperature profiles shown in Fig. 9 suggest that the discharge effect was confined mainly to a layer about 1.5 m thick which extended from the 0.75 m depth to the 2.25 m depth.

Temperature and oxygen profiles measured during aeration in March, 1991 indicate the presence of a mixed, aerated layer between the depths of 0.9 m and 1.9 m below the ice cover (Fig. 11). The layer can be identified by slightly depressed temperatures and markedly elevated dissolved oxygen concentrations measured 4 days after the onset of aeration at the stations

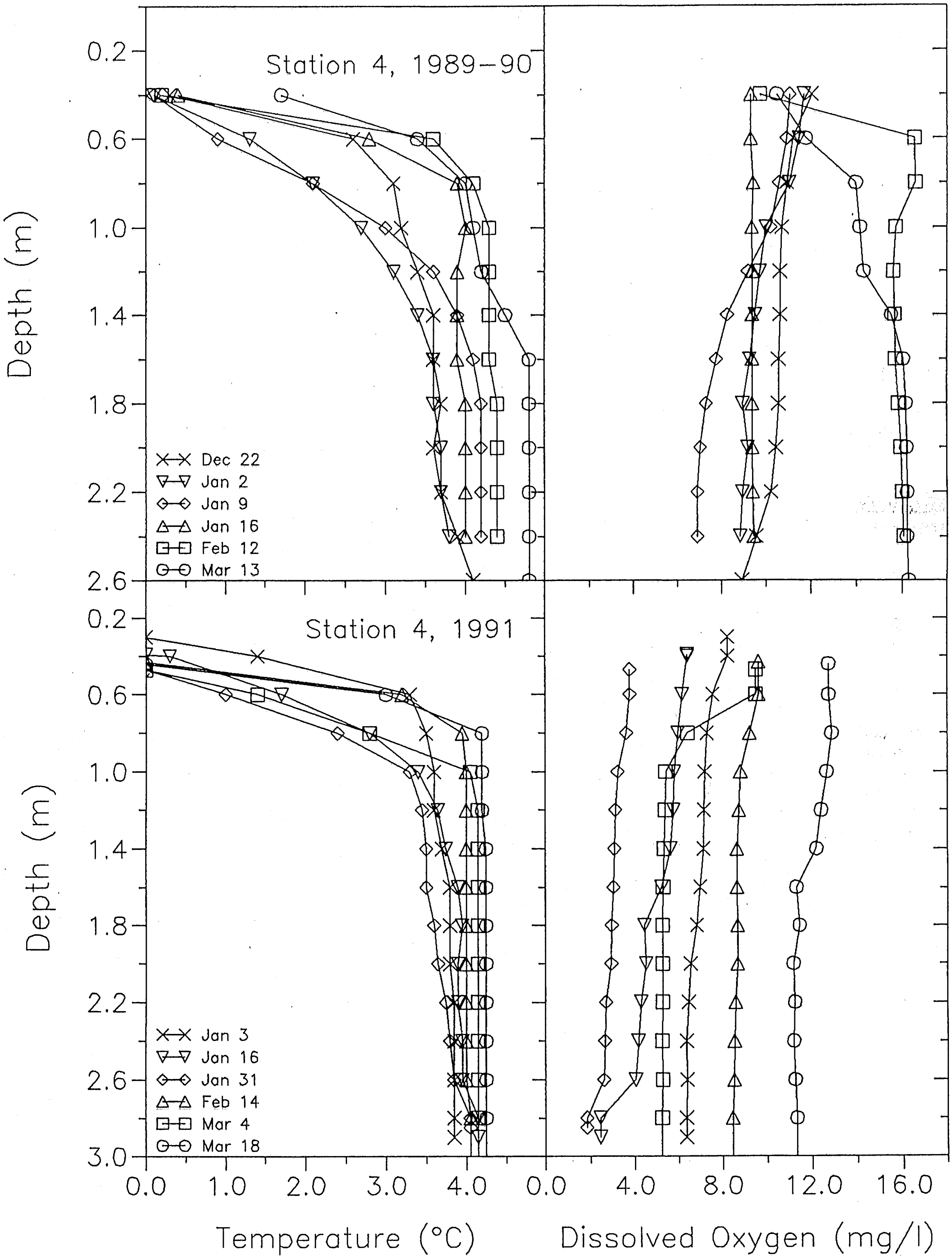


Fig. 7. Typical temperature and dissolved oxygen profiles.

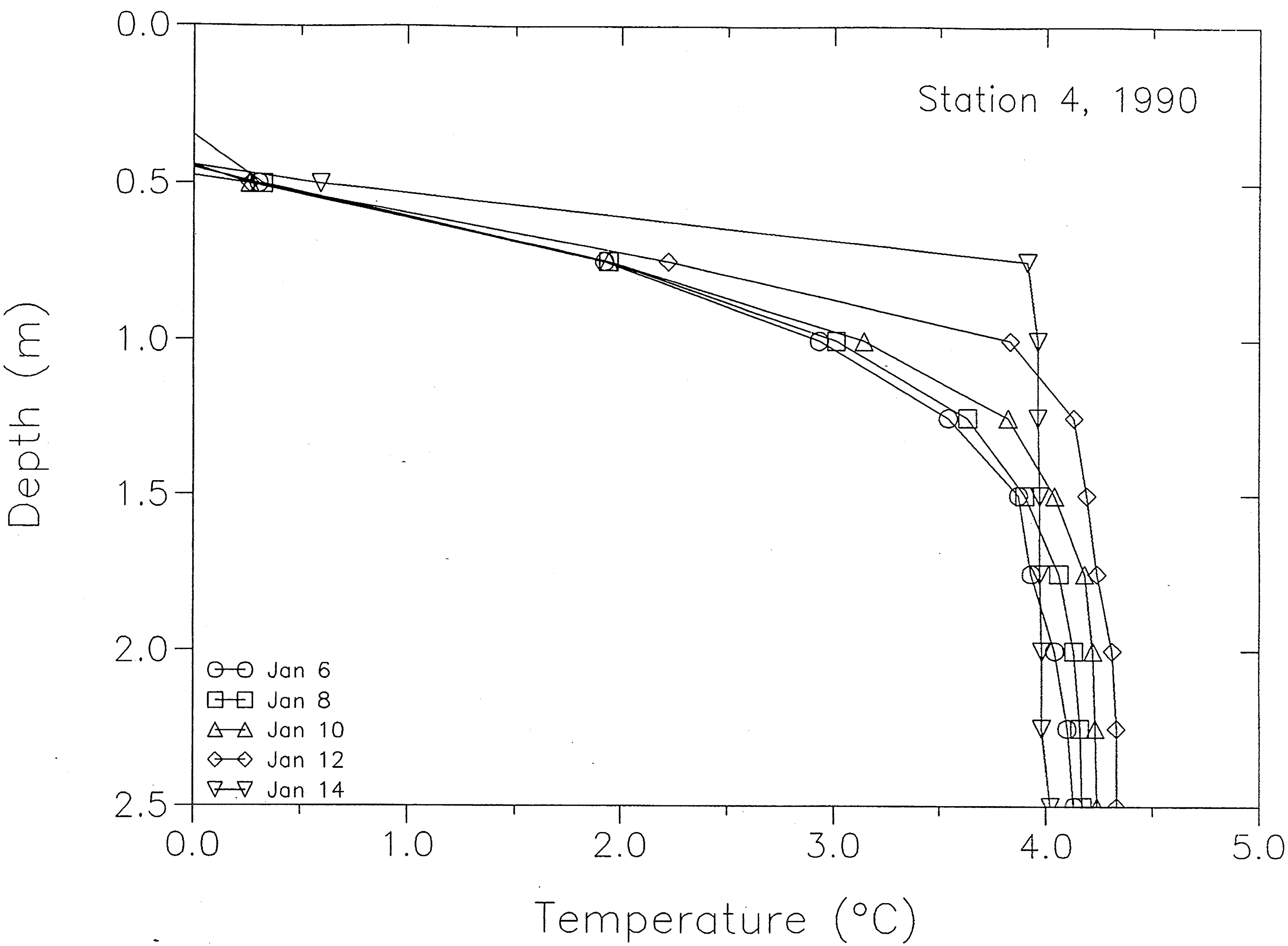


Fig. 8. Temperature profiles, January 6 through 14.

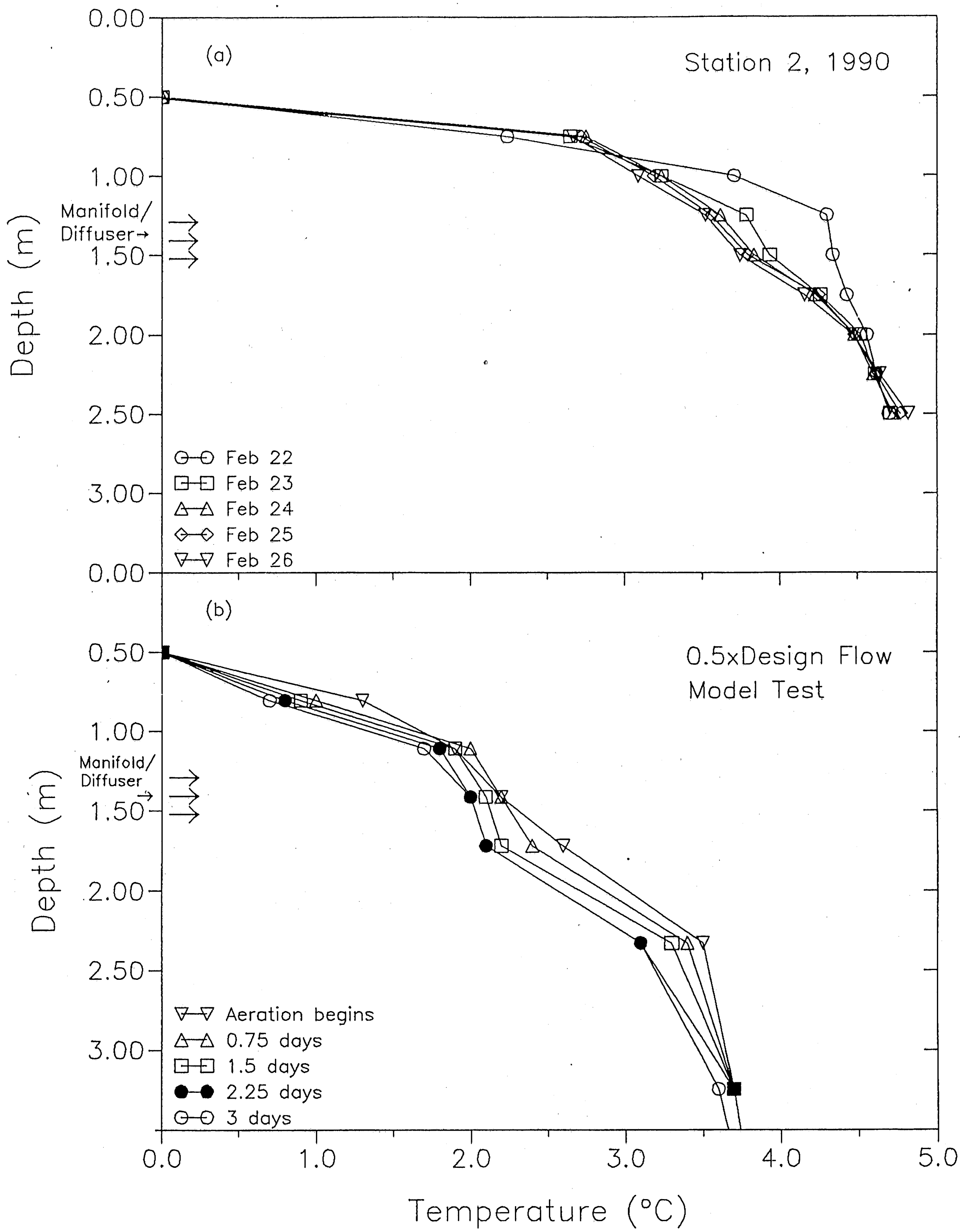


Fig. 9. (a) Actual and (b) modeled temperature profiles near point of exhaust following initiation of aeration.

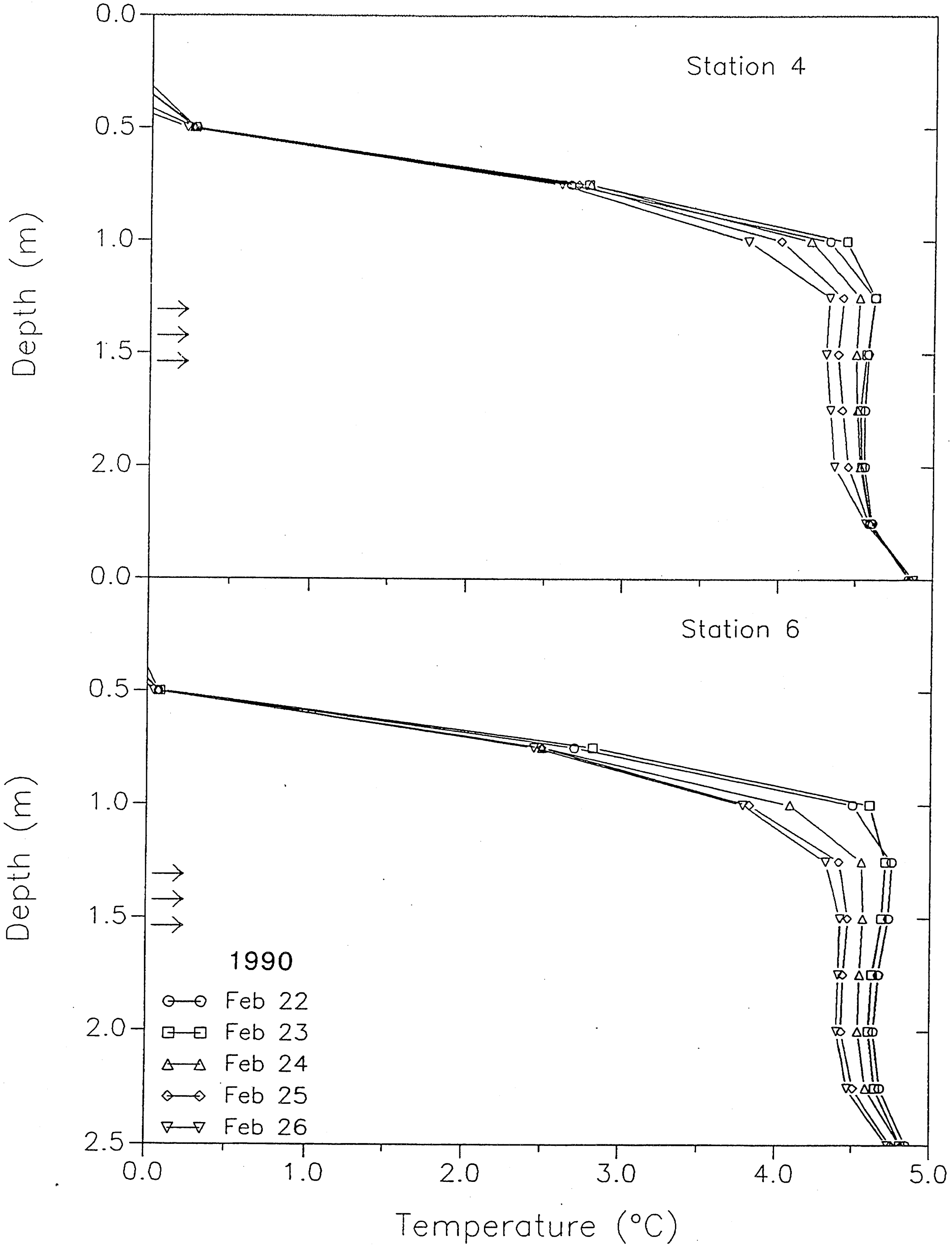


Fig. 10. Temperature profiles at points remote from aerator exhaust following initiation of aeration.

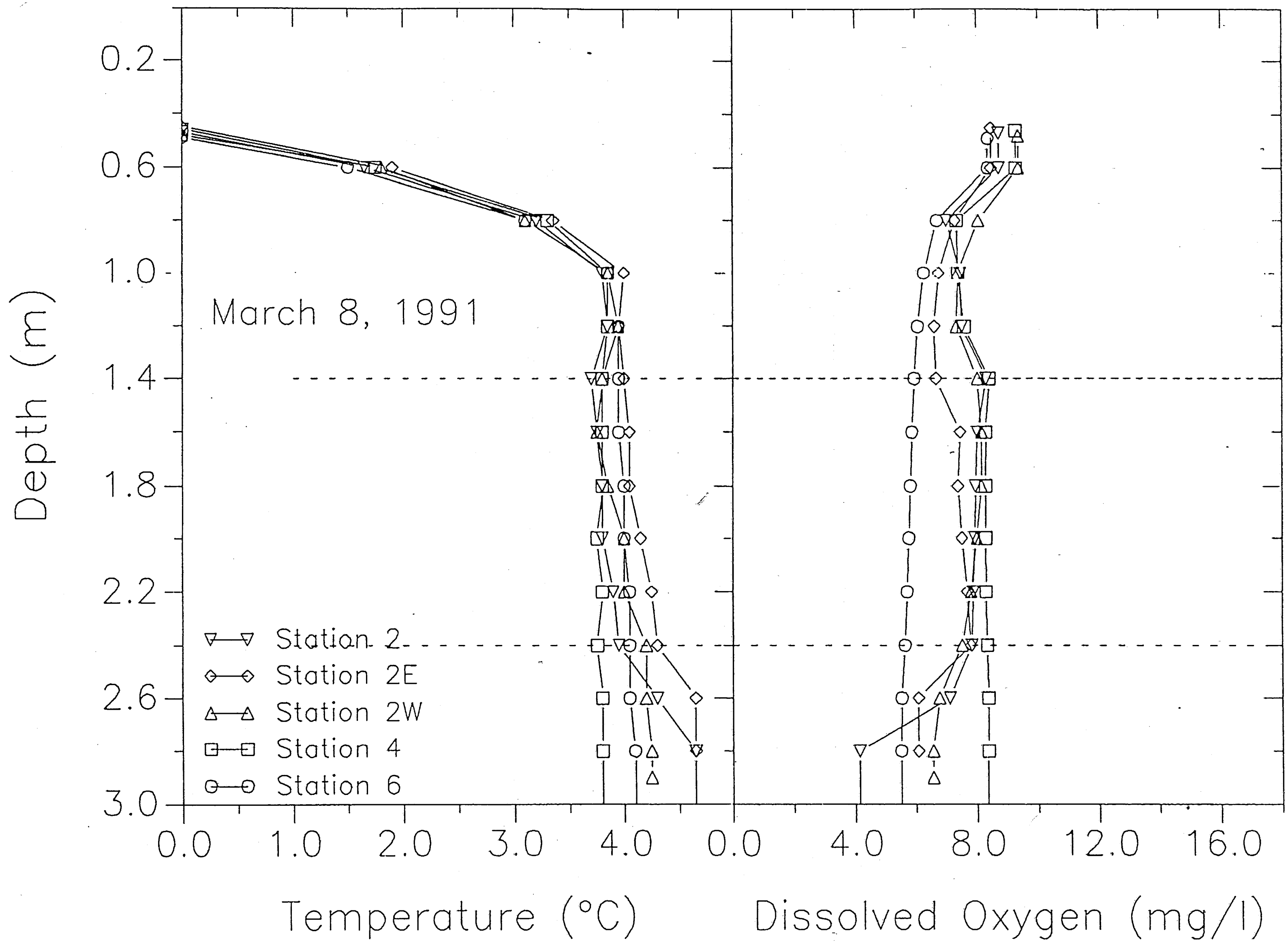


Fig. 11. Temperature and dissolved oxygen profiles four days after onset of aeration, 1991.

close to the diffusers (stations 2, 2E, 2W, and 4). Station 6, being remote from the aerator exhaust, showed no such characteristics. An increase in photosynthetic productivity at this time made further examination of the aerated region impossible.

Dye Study

The dye study was conducted from March 5–12, 1990, two weeks after the aeration system had been turned on. A steady state flow therefore existed during the dye study. Dye injection began at 12 noon on March 5. Air temperatures averaged –6 °C at the start of the study and rose throughout the week reaching a high of 19 °C on the afternoon of March 12. As a result of the warm weather and/or radiation transmitted through the ice, water column temperatures were high (nearly 5°C) and almost uniform from the bottom to 25 cm below the ice cover, especially in the early part of the week (Fig. 12). Since the water column at the depth of the aeration exhaust and below was isothermal, the development of a stratified flow (which the manifold/diffusers were designed to produce) did not seem likely to occur with the onset of aeration.

The progress of the front of the dye plume is illustrated in Fig. 13. The movement of the aerated water in plan view was essentially as would be expected from a potential flow analysis of the flow field. The travel time from the point of discharge to the intake was 6 days. The length of this time and the broad extent of the front shows that "short circuiting" of the aerated water is not a problem for this system. There was significant penetration of aerated water into the portion of the lake beyond (south of) the intake point.

Stratification was evident in most of the dye profiles. Figure 14 gives two such profiles. Concentrations are shown as normalized values relative to the concentration at the point of exhaust. Typically, the center of the plume (the depth of maximum dye concentration) was found 25 cm to 75 cm below the ice. This was above the level of the manifold/diffuser (90 cm below the ice) because the discharge was colder and more buoyant than the ambient water causing it to rise. Often, very little dye was found near the lake bottom. Unreliable fluorometer calibration during the dye study made errors in absolute concentrations (and thus normalized concentrations and dilution rates) large.

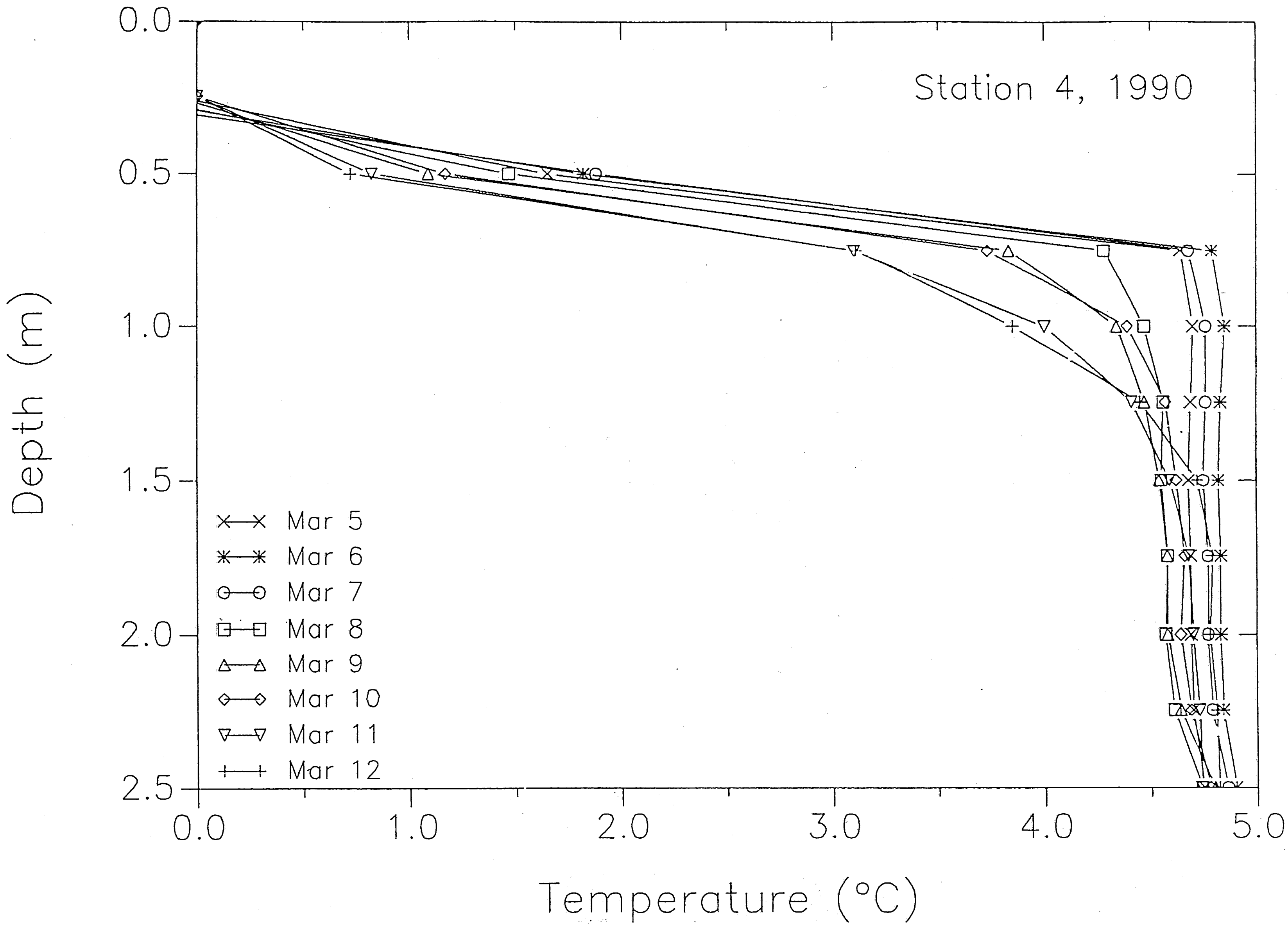


Fig. 12. Typical temperature profiles during dye study.

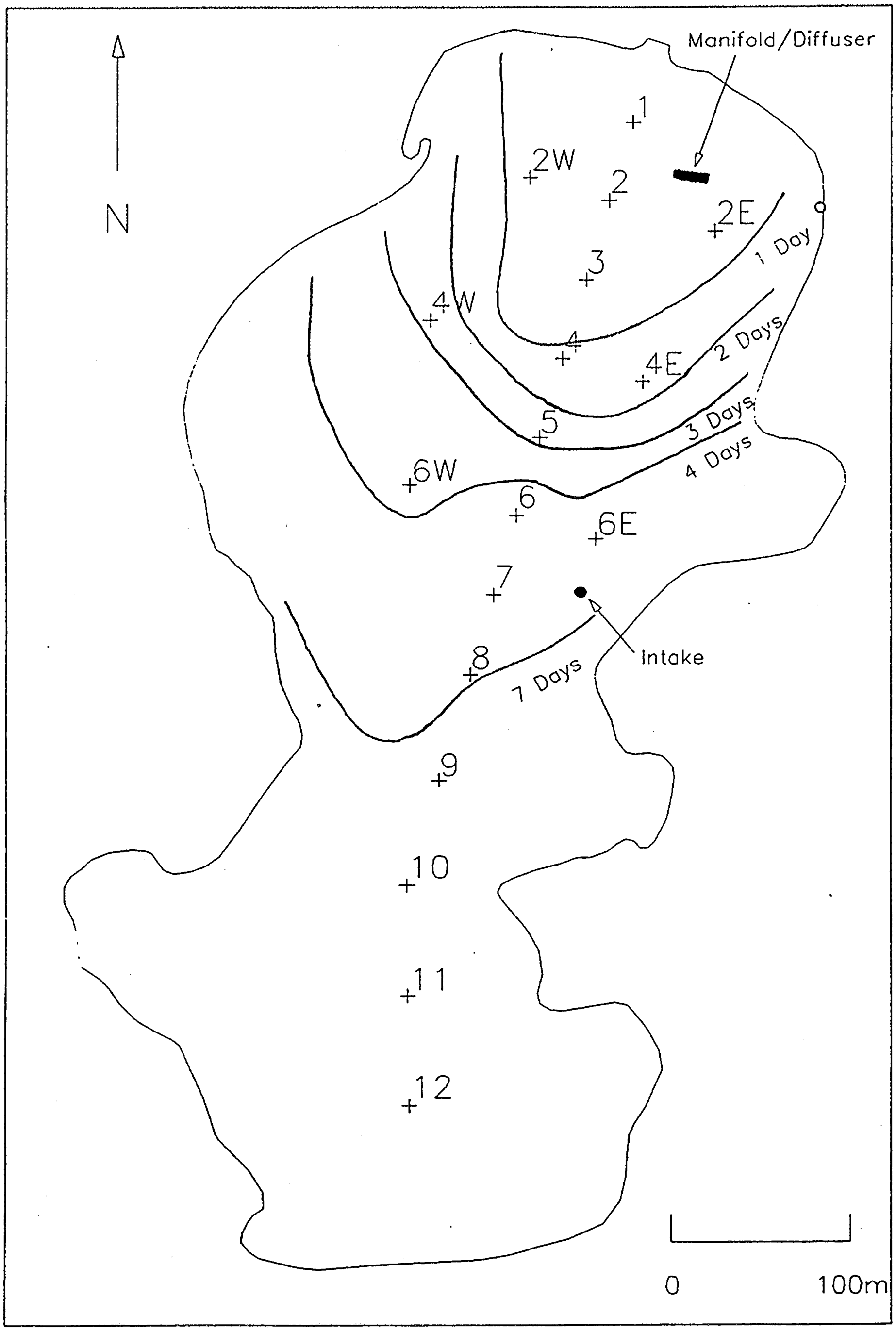


Fig. 13. Map showing front of dye plume at various times after initiation of dye injection. Injection started March 5, 1990.

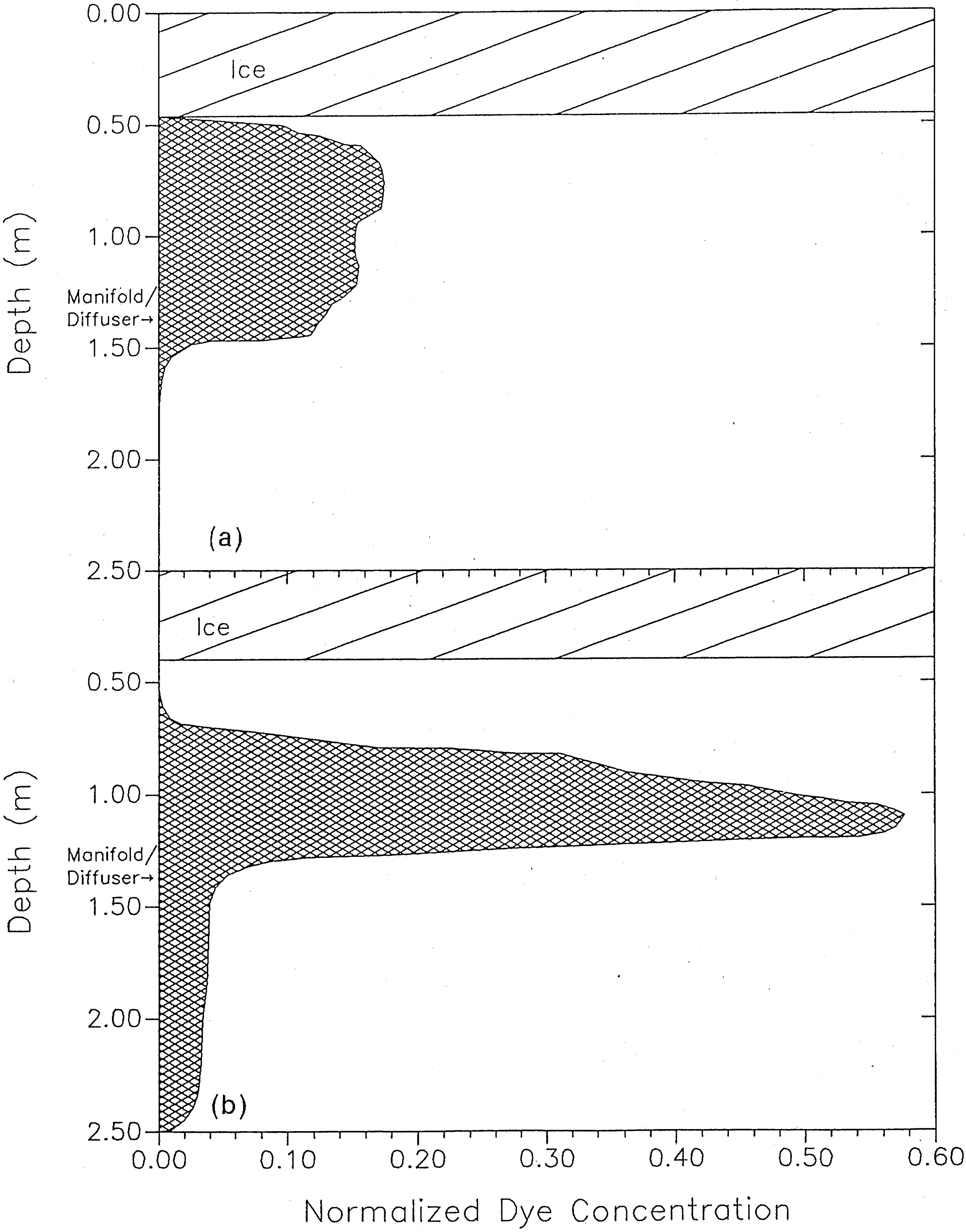


Fig. 14. Dye profiles (a) one day after initiation of dye injection, 50 m from manifold/diffuser and (b) seven days after initiation of dye injection, 240 m from manifold/diffuser.

Ice Thickness

Ice thickness was measured at least once a week at the measurement stations shown in Fig. 2 and proved very uniform over the entire lake, never varying by more than a few centimeters at any time (Fig. 15). Operation of the aerator had little or no effect on ice thickness at these locations.

Figure 16(a) shows the results of ice thickness measurements made in the vicinity of the manifold/diffuser and the intake one week after inception of aeration in 1990. The system flow rate during that period was 64.3 l/s. Measurements made at the 18 stations 2 days earlier yielded values between 49 cm and 53 cm. A 0.6 m by 1.2 m hole had been eroded through the ice at the location indicated in the figure by a nearly constant stream of bubbles emerging with the aerator discharge. A small but significant quantity of air remaining from the cascade aeration was making its way to the manifold/diffuser and released with the discharged water. Thus, in the winter of 1989–90, the system failed to meet the design requirement that the aerated water be free of bubbles before being exhausted. The effect was local and directly associated with the vented bubbles, whereas the area over the path of the diffuser discharge displayed little signs of ice thickness degradation after one week of operation.

Measurements made at this time (early March, 1990) in the area of the intake indicated ice thicknesses generally consistent with those found over the rest of the lake except for the ice directly over the intake which was substantially (25 cm) thinner. Since that portion of the ice had been removed some weeks earlier to install a grate on the mouth of the intake, it is possible that it had not yet frozen to full thickness. On the other hand, it would not be surprising if flow into the intake had caused some local melting of the ice cover.

Bubbles in the discharged water were nearly eliminated in the winter of 1990–91. This was accomplished by a modification of the diversion structure at the foot of the cascade which caused the water discharged from the cascade to follow a longer free surface path before entering the pipe which conveyed it to the diffusers. Aeration was initiated on February 1, 1991 at which time the mean lake dissolved oxygen concentration had fallen to 2.8 mg/l. After 6 days of operation at 64.3 l/s and 5 days at 69.4 l/s, three small areas of open water appeared in the ice cover (Fig. 17). Some residual bubbles (foam) from the cascade aeration were in evidence in the holes. After 3 more days of operation at 69.4 l/s, a single large area of open water developed (Fig. 17). The aerator was turned off at this time (February 15). The average air temperature during this period of aerator operation was –0.8 °C.

Aeration began again on March 4, 1991 using a reduced flow rate of 49.5 l/s. After 11 days of operation, no open was present and ice thicknesses in the vicinity of the diffuser were measured (Fig. 16b). A very small quantity of foam (bubbles) originating from the aerator was still escaping from the diffuser (seen in three of the holes drilled over the center of the diffuser for the purpose of ice thickness measurement). Clearly, some ice degradation had occurred though it is likely that the ice cover had not achieved full thickness during the 2.5 weeks that the system was not in

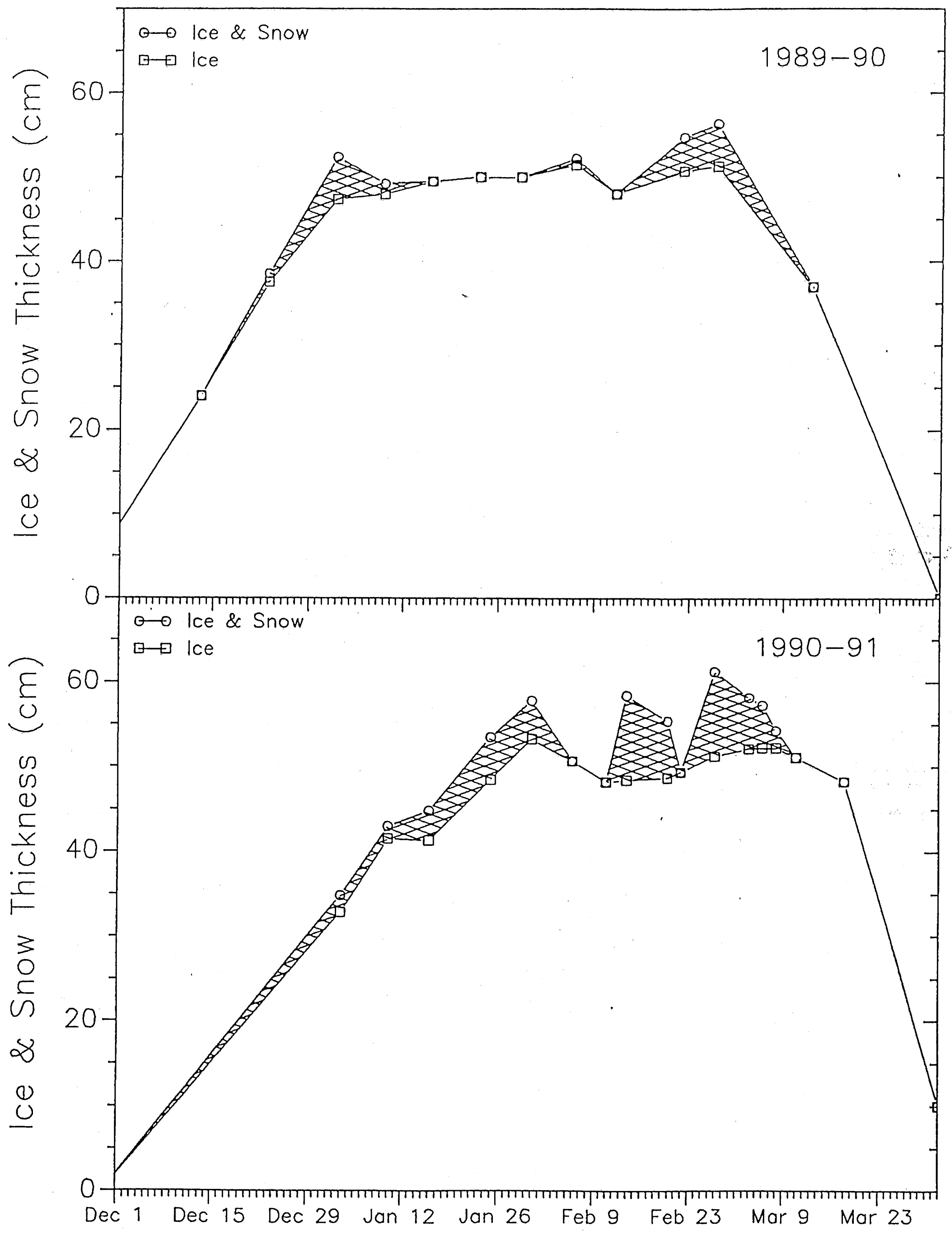


Fig. 15. Ice thickness and snow depth.

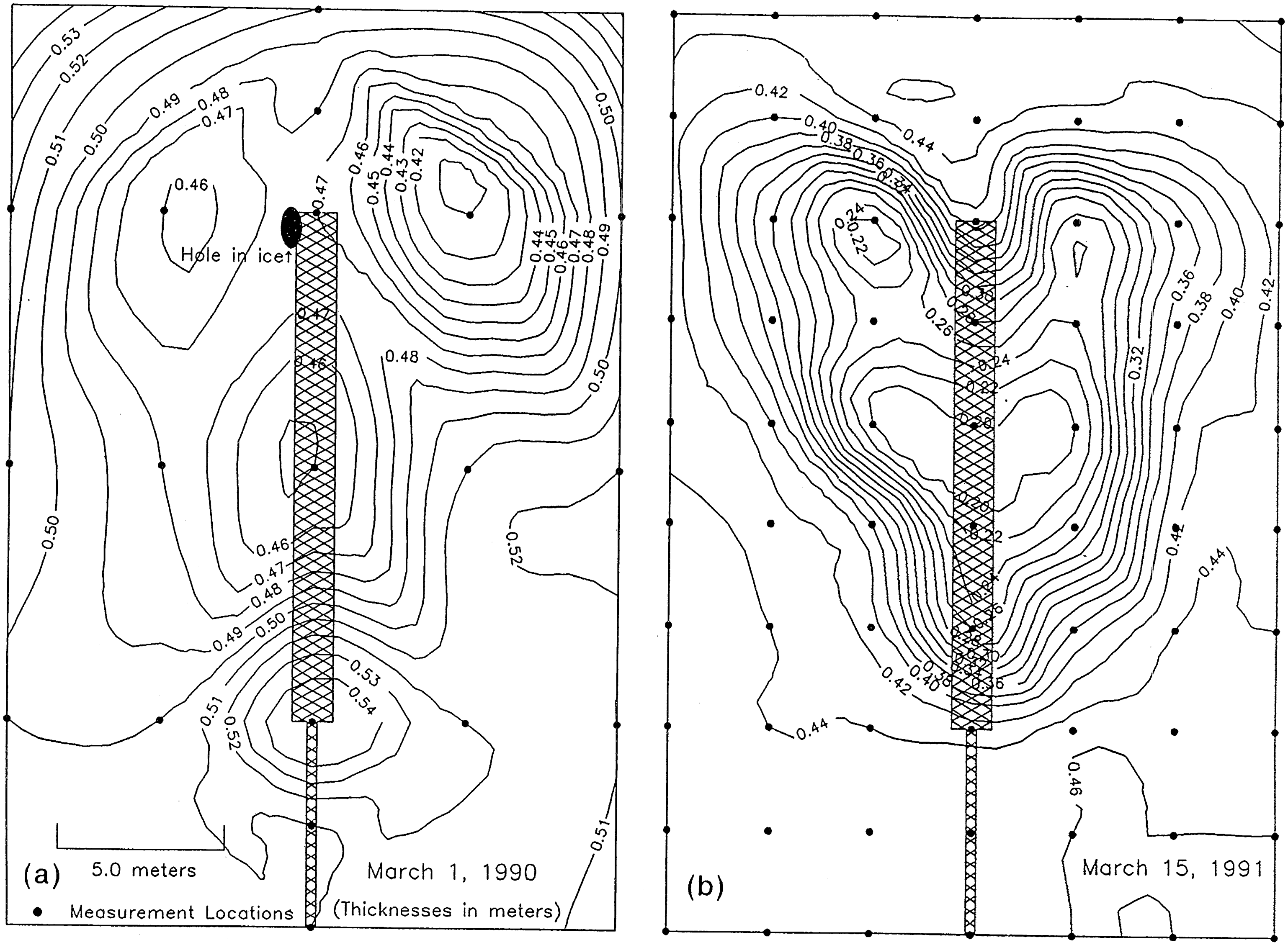


Fig. 16. Ice thickness measurements in area of diffuser.

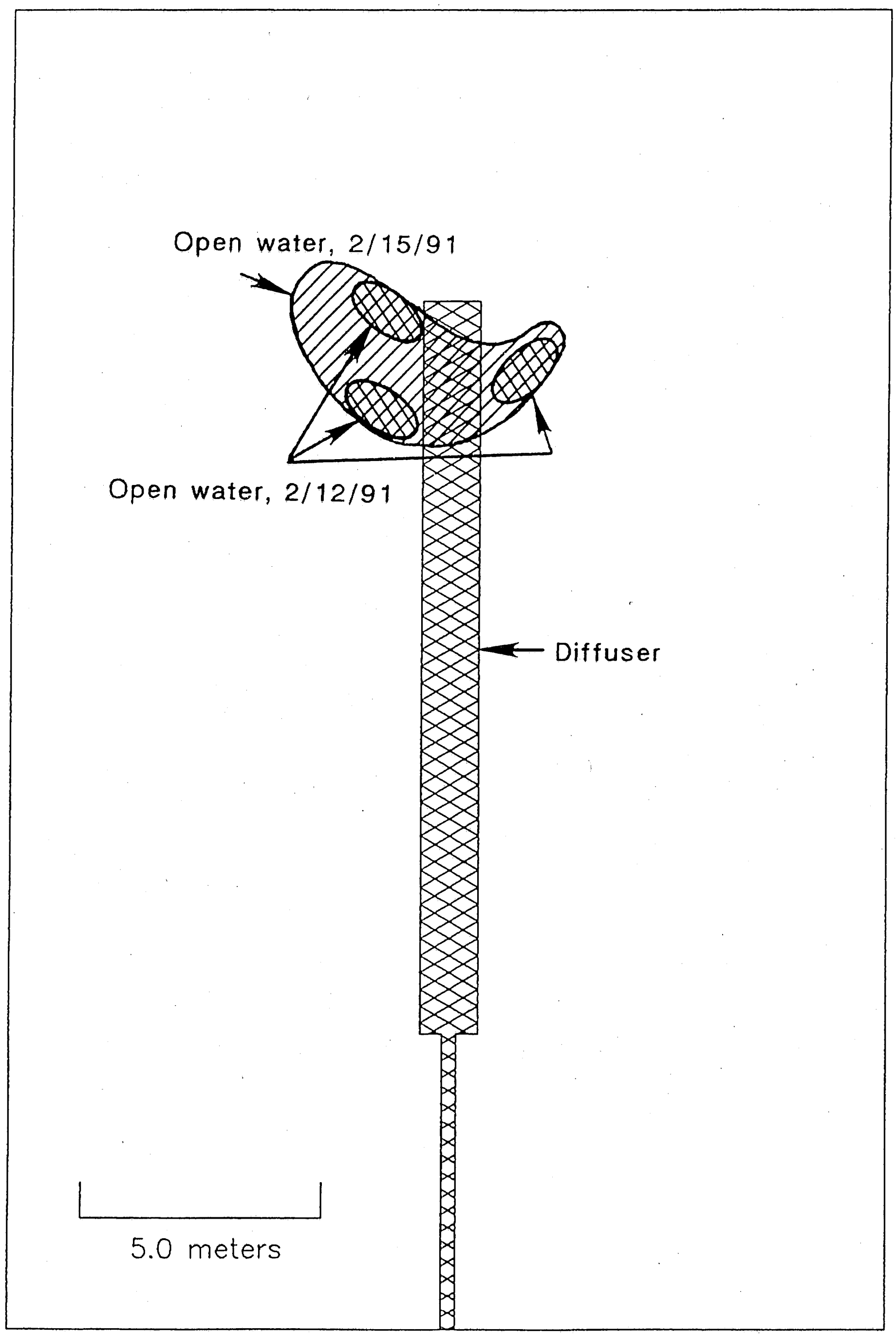


Fig. 17. Open water due to aeration, February 1991.

operation since the average air temperature during that time was –5.4 °C. As of March 26 (after 22 days of operation at the reduced flow rate during which time the average air temperature was 2.6 °C and when 1–3 m of open water existed around the shoreline indicating general ice cover deterioration), still no open water was in evidence in the area of the diffuser.

Dissolved Oxygen Measurements

Dissolved oxygen concentrations were measured with a YSI Model 58 DO meter which was calibrated against samples taken at the beginning and end of the day that measurements were performed. Sample concentrations were found by Winkler Titration. Accuracy of measured DO concentrations is estimated to be ±0.05 mg/l.

Mean lake DO concentrations were determined by computing the depth averaged concentration for each available measured profile and calculating mean lake concentration as a weighted average of these values based on the volumes of each lake sub–basin associated with the measurement location (Fig. 2). Sub–basin volumes were determined by planimetering the isopleths of the portion of the bathymetric map associated with the sub–basin.

Figure 18 shows mean lake dissolved oxygen concentrations estimated from data collected by Ramsey County employees during five previous winters and those measured during this study (1989–91). Whereas oxygen levels fell in a manner typical of winterkill lakes during all winters preceding 1989–90, they fell only until January 9 in 1990 and rose and remained high thereafter. In 1991, dissolved oxygen levels declined until January 31 after which time they rose markedly, in part due to the initiation of aeration but primarily due to photosynthetic production (see below). Lines fit to the previously measured data, that measured until January 9, 1990, and that measured until January 31 in 1991 yield a mean winter oxygen depletion rate (WODR) of 0.135 $mgO_2/l/day$ (0.196 $gO_2/m^2/day$). This compares favorably to 0.166 $mgO_2/l/day$ (0.241 $gO_2/m^2/day$), the value predicted by previous studies (Ellis and Stefan 1989; Mathias and Barica 1980).

During periods of oxygen depletion in both winters of the study, vertical distributions of dissolved oxygen were typical of a shallow ice covered lake showing a general DO decline and the development of a vertical dissolved oxygen gradient (Fig. 7). Since most of the winter oxygen demand occurs at the sediment surface (Brewer et al. 1977; Greenbank 1945; Hargrave 1969; Hargrave 1972; Mathias and Barica 1980) and vertical mixing under ice is minimal, DO concentrations in the deeper waters fall faster than those closer to the ice cover creating the vertical gradient. During periods of rising DO levels, vertical dissolved oxygen gradients either disappeared or reversed direction. This phenomenon can only be explained by the presence of an oxygen source at the mid and lower depths.

During the 1989–90 winter, from January 16 until ice–out on March 30, at least some of the lake was supersaturated with dissolved oxygen, reaching 22 mg/l at times. (Clean water oxygen saturation is 13.1 mg/l at

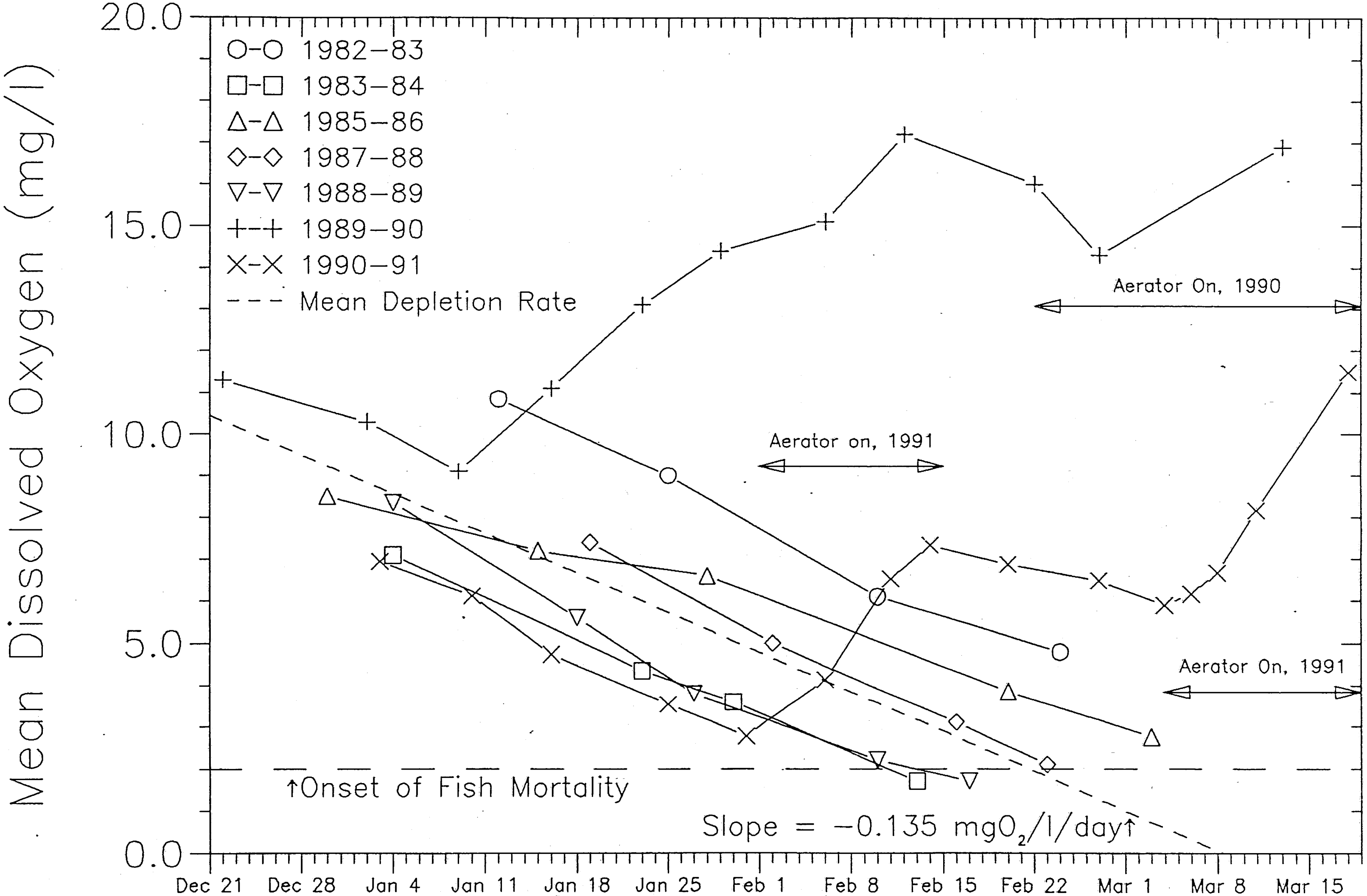


Fig. 18. Mean lake dissolved oxygen concentrations.

4 °C.) The observed rise in DO concentrations in the absence of aeration and the presence of DO supersaturation was the result of photosynthetic activity of a dense bed of macrophytes that covered nearly the entire bottom of the lake. These plants were easily visible through holes made in the ice.

Figure 19 illustrates the horizontal distribution of dissolved oxygen in the lake during mid–winter, 1989–90. Although local lateral differences in concentration were small, a variation of up to about 5 mg/l DO usually existed from one end of the lake to the other. The higher oxygen concentrations found in the shallower south end of the lake were likely due to less attenuation of light reaching the macrophyte bed and a smaller volume of water to which the oxygen was added.

Measurement of photosynthetically active radiation (PAR) under the ice verified significant penetration of light through the ice cover under conditions of no or minimal snow cover (Fig. 20). Underwater measurements of PAR were made by cutting a 5 cm by 40 cm slot through the ice through which light probes were lowered. The presence of the slot changed the optical characteristics of the ice and snow cover and thus affected the measurements, the bulk of the affect being confined to a region of the water column close to the ice. The lines through the data are best fit regressions assuming an exponential decay of light with depth. Whereas 52% of the incident PAR reached the water column through uncovered 49 cm thick ice in the 1989–90 winter, only 28% reached the water through uncovered ice of nearly the same thickness the following winter illustrating the variability of ice opacity. As little as 4 cm of snow is sufficient to nearly extinguish light penetration to the underlying water.

Supersaturated conditions during 1990 created some obvious problems for the study. The lake was clearly not in need of aeration. Indeed, operation of the aeration system would decrease DO levels in supersaturated water since exposure to atmospheric oxygen tends to drive concentrations down to the saturation level. Also, DO could not be used as a tracer to track the distribution of aerated water due to the fact that the discharged and ambient waters had nearly the same concentrations. The dye study conducted in March did much to characterize the discharge distribution. However, it could not reproduce the source/sink nature of the lake bottom and macrophytes regarding oxygen. The impact of the aeration system on the lake's winter oxygen demand could not be assessed because the DO balance upon which the analysis depends was seriously altered by the unquantifiable photosynthetic oxygen source.

In 1991, dissolved oxygen levels fell at the 0.135 mg/l/day rate observed in previous years until the thaw that occurred during the first week of February. At that same time (February 1), aeration was initiated. By February 15 when aeration was discontinued, 405 kg of dissolved oxygen had been added by the aerator which on a whole lake volumetric basis (neglecting the volume of the ice cover) amounts to 1.6 mg/l. The measured whole lake average oxygen concentration rose by 4.6 mg/l during this period. Assuming that sediment oxygen demand was a steady 0.135 mg O_2/l/day (1.9 mg/l over two weeks), photosynthetic productivity accounted for a dissolved oxygen input of 4.9 mg/l, over 3 times that due to aeration during this period.

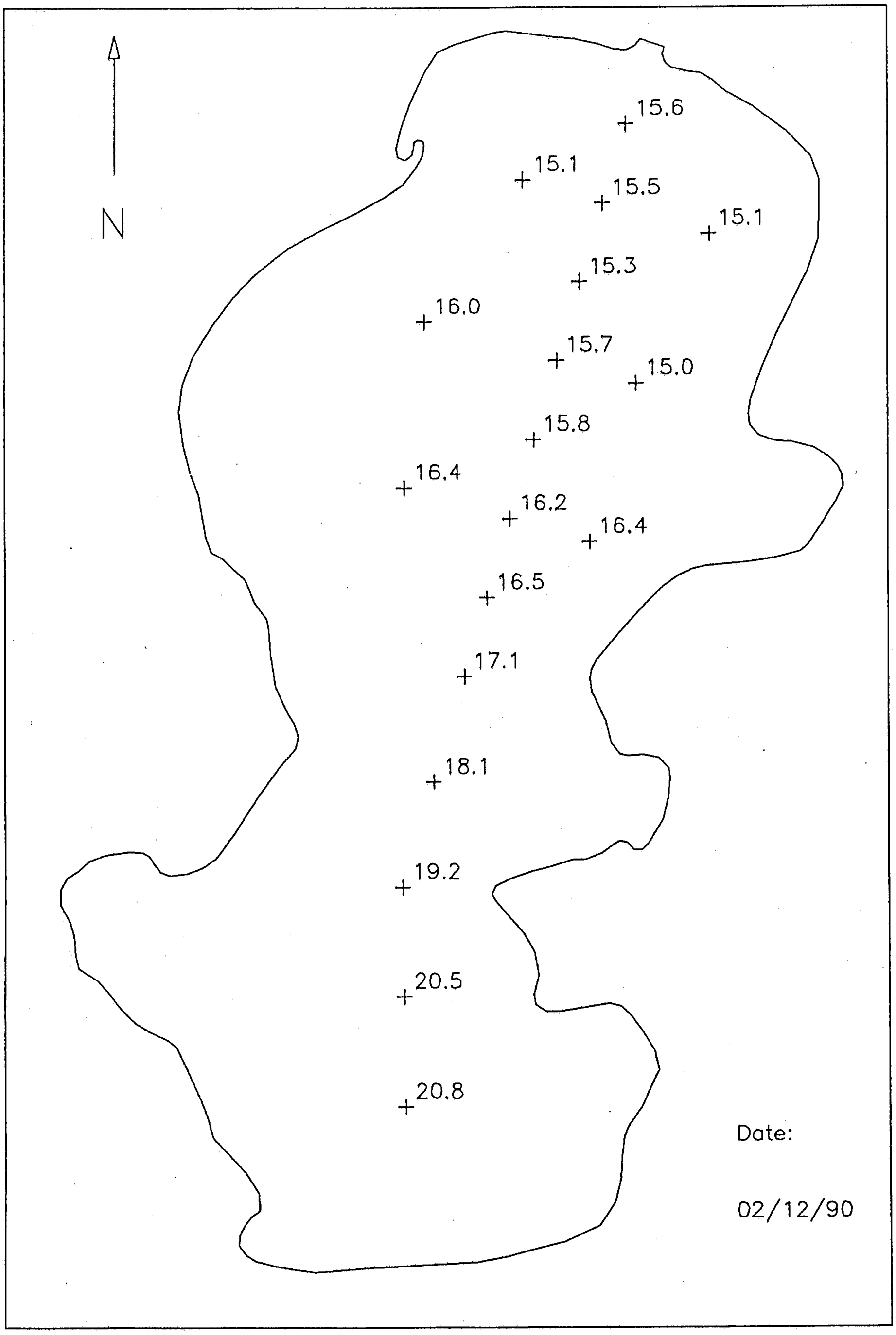


Fig. 19. Depth averaged dissolved oxygen concentrations (mg/l).

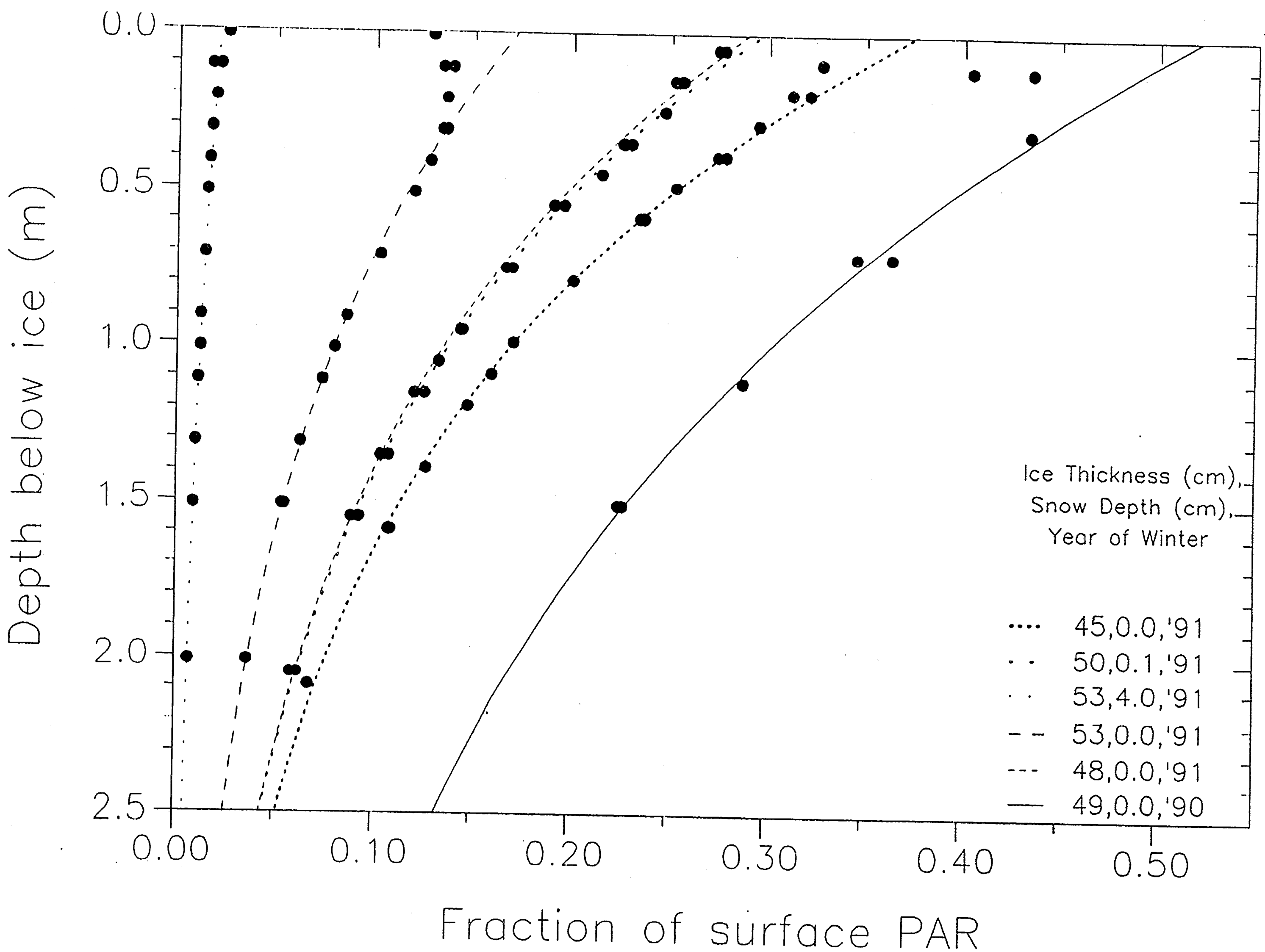


Fig. 20. Photosynthetically active radiation (PAR) beneath ice under various conditions of ice and snow cover.

During the period March 4–8, 1991, the aerator was operating and light penetration to the water column was diminished (but not prevented) by snow cover. Over these days, oxygen input from the aerator was 79.8 kg or 0.3 mg/l while measured average oxygen levels rose by 0.8 mg/l implying a photosynthetic input of 1.0 mg/l, again over 3 times the input attributable to aeration. As in the previous winter, photosynthetic productivity was obscuring the effect and extent of aeration.

In an effort to separate internal sources/sinks of oxygen from aeration, an analysis was performed which split the lake into two parts and considered rates of change of dissolved oxygen on an areal basis. The southern basin (that area south of Station 10, Fig. 2) is somewhat separated morphometrically from the rest of the lake and is unlikely to be affected by the operation of the aeration system. The analysis used that area as a control to which oxygen dynamics of the northern, aerated lake area were compared. Since sediment oxygen demand (the internal sink) and photosynthetic productivity (the internal source) are proportional to area rather than volume, the comparisons were made on an areal basis. If internal oxygen sources/sinks are the same (on an areal basis) in the northern and southern parts of the lake, oxygen input due to the aerator should appear as a net increase in dissolved oxygen in the northern basin as computed relative to the southern basin.

Although a rough correspondence between aerator input and net rise in north–end oxygen content existed, it was far from exact (Fig. 21). Apparently, south–end oxygen productivity/consumption (as derived from a single profile location) is only a crude predictor of productivity/consumption in the rest of the lake. In any case, an assessment of the impact of aeration system operation on sediment oxygen consumption for a second time proved impossible.

Aerator performance and the dissolved oxygen input rate were evaluated from measurements of system flow rate and DO concentrations upstream and downstream of the cascade (Fig. 22). Oxygen input is simply the product of system flow rate and the DO concentration rise through the aerator. Aerator efficiency is defined as

$$\eta = \frac{C_{out} - C_{in}}{C_{sat} - C_{in}}$$

where η is the aerator efficiency, C_{out} is the outlet DO concentration, C_{in} is the inlet DO concentration, and C_{sat} is the oxygen saturation concentration at the temperature of the water in the aerator. Actually, rather than using the pure water saturation value at 4 °C of 13.1 mg/l, a value of 12.1 mg/l was used in the above equation. This was done due to unrealistically low efficiency values that resulted from calculations made when inlet concentrations were high, *ie.* $C_{out} - C_{in}$ was small. It is quite possible that chemical constituents in the water (as evidenced by the abundant amount of foam found in the cascade discharge) caused a reduction of the saturation concentration as compared to what would be expected in pure water.

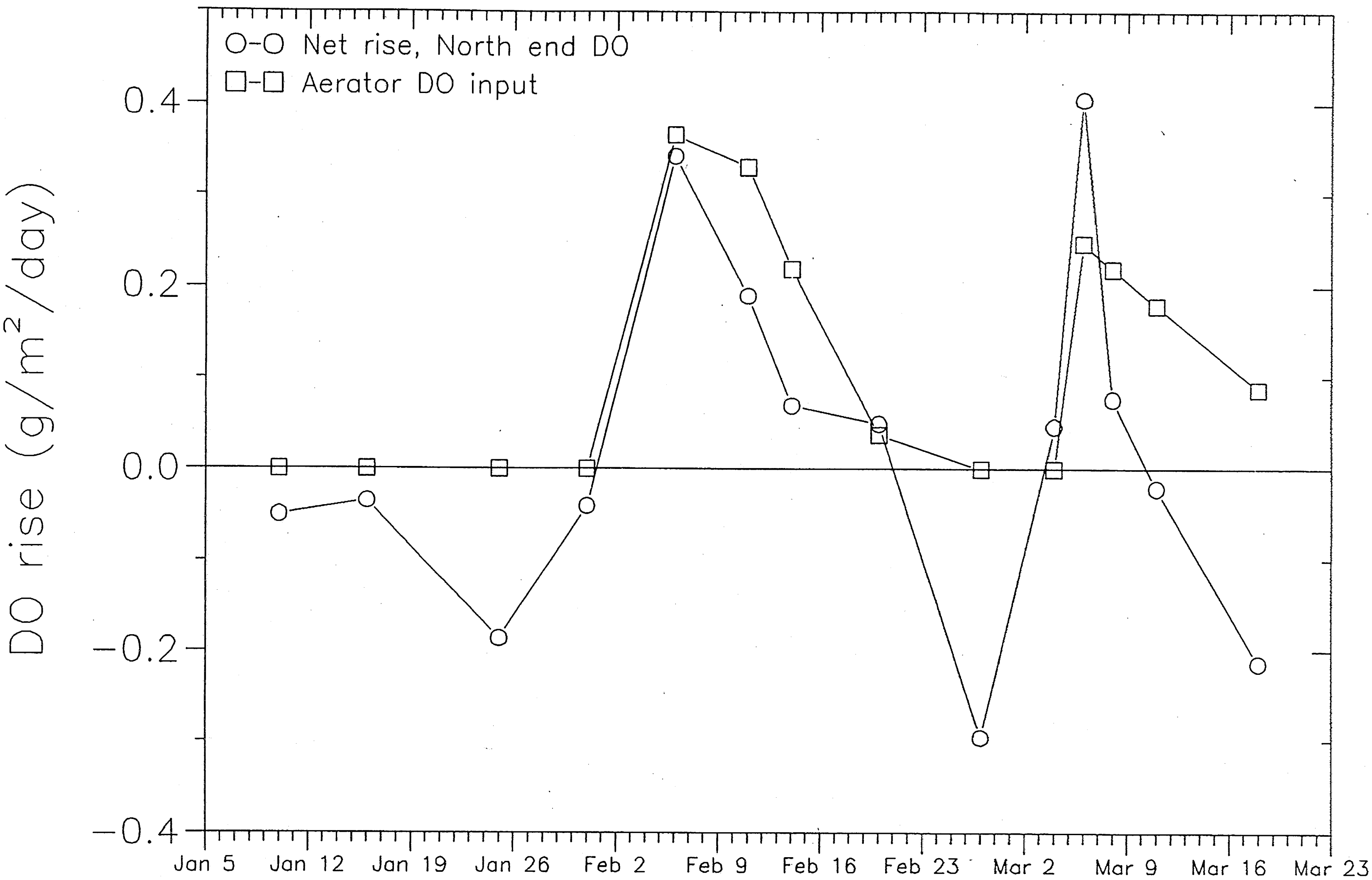


Fig. 21. Comparison of net rise of north end D.O. with aerator input, 1991.

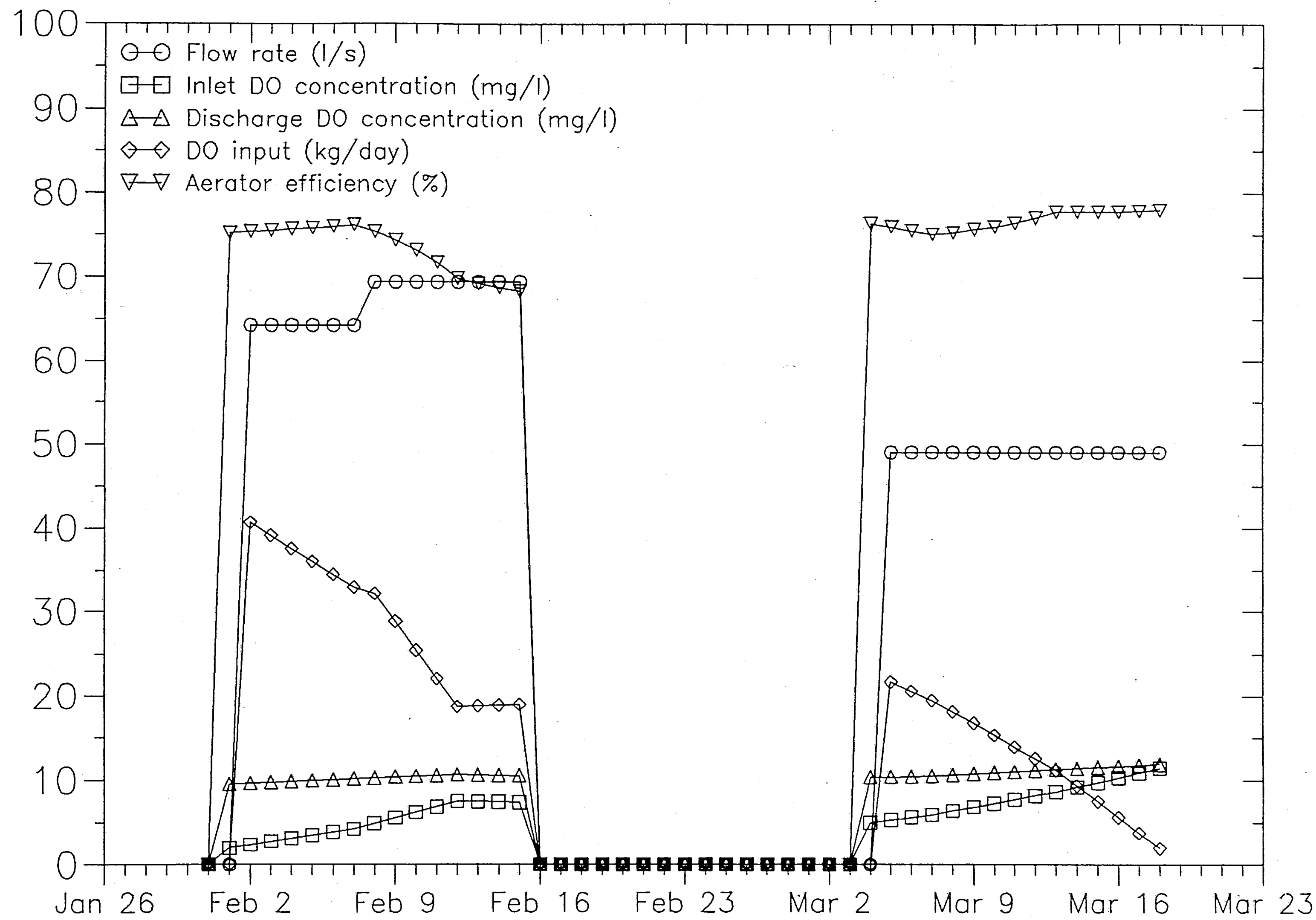


Fig. 22. Cascade aerator performance, 1991.

Conclusions

Island lake, a very shallow and eutrophic urban lake, habitually winterkills without human intervention. The fact that for both winters of the study it not only avoided anoxia on its own but achieved dissolved oxygen levels nearly twice saturation values during one of the winters was highly unusual and prevented the direct measurement of the impact of the experimental aeration system on oxygen dynamics. Likewise, temperature profiles which are uniform and close to 5 ^{o}C below 25 cm under the ice cover are normally observed only when ice–out is imminent. Under normal winter conditions, under–ice water is weakly stratified to a depth of about 2 m below the ice cover. During most of this study, temperature stratification was confined to a thin water layer under the ice. In relatively warm, nearly isothermal water and at near–freezing air temperatures, virtually any under–ice disturbance will cause ice degradation (Ellis and Stefan 1990).

Despite the exceptional conditions, several observations were made which point to the effectiveness of the manifold/diffuser design in providing non–mixing winter aeration. Aerator operation created a more stratified water temperature profile (Fig. 9a). Temperatures near the bottom were unaffected by by the onset of aeration while those near the ice rose only slightly. A narrow, nearly–mixed layer was created at the depth of the manifold/diffuser. These characteristics are nearly identical to those observed in the laboratory scale model tests conducted during the design phase (Fig. 9b).

The maintenance of stratified conditions was also clearly shown in the 1990 dye study and the March 8, 1991 oxygen profiles. Even under nearly isothermal conditions, much of the dye plume remained high in the water column even after one week and over 300 meters of travel.

The manifold/diffuser functioned well as a non–mixing water distribution device. The ice melting that occurred above the diffuser during the first winter's operation was clearly related to mixing associated with escaping air bubbles. Ice melting caused by the aeration system during the second winter may have been due in part to air bubbles in the discharge but was likely due primarily to near–freezing (–0.8 ^{o}C on average) air temperatures during the first 2 weeks of operation and unforeseen flow patterns generated by the dual discharge configuration of the diffuser for which it was never tested. (The device was originally designed and tested as a paired manifold/diffuser operating as an intake on one side and a discharge on the other.) The evidence shows (both from the temperature profiles and the dye study) that the aerated water remained as a distinct inter–layer in the water column, isolated from the sediment surface. Only for the higher flow (69.4 l/s) did local melting of the ice cover occur. At the somewhat lower flow rate (49.1 l/s), ice cover integrity was maintained for the three weeks of operation even under conditions of above freezing average air temperatures (2.6 ^{o}C). Further testing needs to be done to ascertain flow characteristics in the dual discharge configuration as compared to flow patterns produced by the diffuser as it was originally designed (paired intake/discharge). Non–degradation of the ice cover and separation of the oxygenated layer from the lake bottom (to minimize oxygen consumption) were the main goals of the manifold/diffuser design.

The two winters of the study, although climatically unusual, made clear the potential influence of internal photosynthetic productivity on dissolved oxygen levels and winterkill prevention. Nearly the entire bottom of Island Lake is covered with a dense bed of macrophytes. This is made possible by its shallowness which allows sunlight to penetrate to the bed everywhere in the lake and the fertile (eutrophic) nature of the sediments. Most lakes that can sustain substantial fish populations have only the beds of their littoral (near–shore) regions sunlit. Consequently, only those regions are capable of macrophyte growth. Additionally, shallowness does not guarantee in general the presence of macrophytes.

One possible winterkill prevention technique that could be applied to Island Lake (or any relatively shallow lake with a significant portion of its bed supporting macrophytes) would be to maintain snow–free conditions for a portion of the winter. Typically, Island Lake, in the absence of aeration, reaches winterkill conditions in mid–February and ice–out occurs usually in early April. DO levels measured in 1990 indicate that under snow–free conditions, photosynthetic productivity can provide 0.421 mg O_2/l/day or a net rise of 0.286 mg/l/day when the sediment depletion rate (0.135 mg/l/day) is subtracted (Fig. 18). Dissolved oxygen sufficient to provide for 2 months of sediment oxygen demand must be added to the under–ice water to prevent fish mortality before ice–out. This amounts to 8.1 mg/l which can be photosynthetically produced in 20 days of snow–free conditions. Thus, if snow–free conditions exist (either naturally or due to human intervention) for a total of 3 weeks between ice–over and ice–out, winterkill conditions will be averted. An added benefit of this winterkill prevention strategy is that since oxygen is added without water motion, naturally occurring (stratified, quiescent) conditions will be maintained and no artificially induced ice melting will occur. Although successful winterkill prevention could not be assured in other lakes using this concept, it may be worth investigating before more costly and less safe alternatives are implemented.

References

Barica, J., Gibson, J., and Howard, W. (1983). Feasibility of snow clearing to improve dissolved oxygen conditions in a winterkill lake. *Can. J. Fish. Aquat. Sci.* 40:1526–1531.

Belanger, T. V. (1981). Benthic oxygen demand in Lake Apopka, Florida. *Water Research.* 15:267–274.

Boynton, W. R., Kemp, W. M., Osborne, C. G., Kaymeyer, K. R., and M. C. Jenkins, M. C. (1981). Influence of water circulation rate on *in situ* measurements of benthic community respiration. *Marine Biol.* 65:185–190.

Brewer, W. S., Abernathy, A. R., and Poynter, M.J.B. (1977). Oxygen consumption by freshwater sediments. *Water Research.* 11:471–473.

Ellis, C. R. and Stefan, H. G. (1989) Oxygen demand in ice covered lakes as it pertains to winter aeration. AWRA, *Water Resources Bulletin.* 25(6):1169–1176.

Ellis, C. R. and Stefan, H. G. (1990). Hydraulic design of a winter lake aeration system. ASCE, *Jour. Environmental. Eng.* 116(2):376–393.

Enger, S. (1989). Aeration permit program annual report, 1988–1989. Staff Rep. No. 6. Mn. Dept. Nat. Resources, Div. Fish Wild., Ecol. Serv. Sec. 54 pp.

Greenbank, J. (1945). Limnological conditions in ice–covered lakes, especially as related to winterkill of fish. *Ecol. Monogr.* 15:343–392.

Hall, P. O. J., Anderson, L. G., Rutgers van der Loeff, M. M. Sundby, B. and Westerlund, S.F.G. (1989). Oxygen uptake kinetics in the benthic boundary layer. *Limnology and Oceanogr.*, 34(4):734–746.

Hargrave, B. T. (1969). Similarity of oxygen uptake by benthic communities. *Limnology and Oceanog.* 14:801–805.

Hargrave, B. T. (1972). A comparison of sediment oxygen uptake, hypolimnetic oxygen deficit and primary production in Lake Esrom, Denmark. *Verh. Internat. Verein. Limnol.* 18:134–139.

Johnson, L. (1970). The management of winterkill lakes. pp. 73–75 in E. Schneberger, ed. A symposium on the management of midwestern winterkill lakes. North Cent. Div. Am. Fish. Soc. Sp. Publ.

Mathias, J. A. and Barica, J. (1980). Factors controlling oxygen depletion in ice–covered lakes. *Canadian Jour. Fish. Aq. Sci.* 37:185–194.

Patriarche, M. H. (1961). Air–induced winter circulation of two shallow Michigan Lakes. *Jour. Wildlife Management.* 25(3):282–289.

Paulin, L. (1960). Snow removal heads off winterkill. *Wis. Conserv. Bull.* 25:24–25.

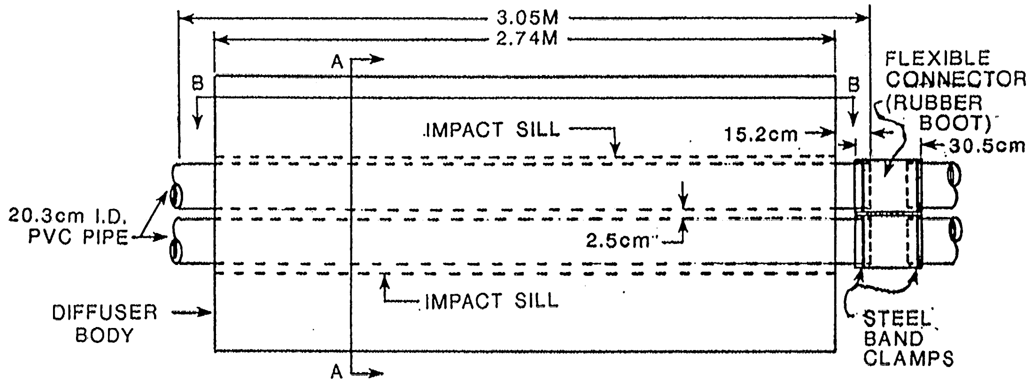
Skrypek, J. L. and Shodeen, D. M. (1977). Preliminary guidelines for installation and operation of aeration systems for winterkill prevention. Minn. Dept. Nat. Res., St. Paul, MN. Unpublished Memo, 5pp.

Toetz, D., Wilhm, J. and Summerfelt, R. (1972). Biological effects of artificial destratification and aeration in lakes and reservoirs – analysis and bibliography. Bur. of Recl. Publ. REC–ERC–72–33. U.S. Dept. Int. 177pp.

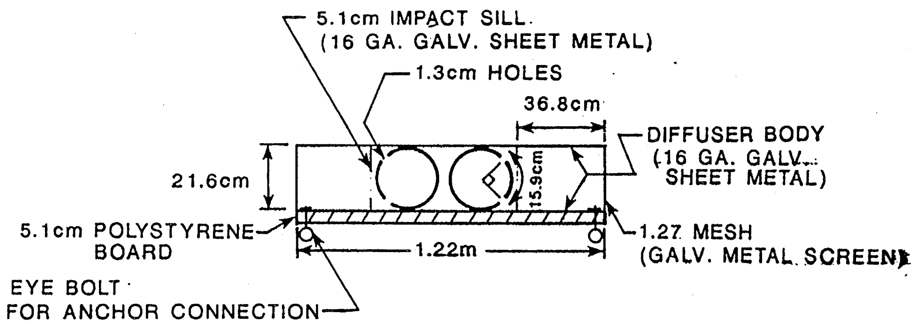
APPENDICES

APPENDIX A

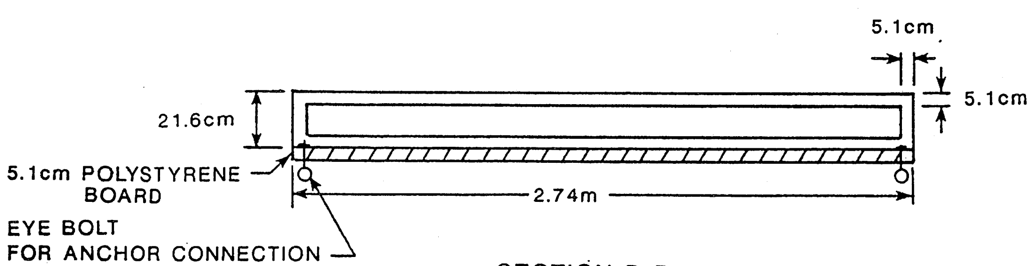
Schematic of Manifold/Diffuser Section



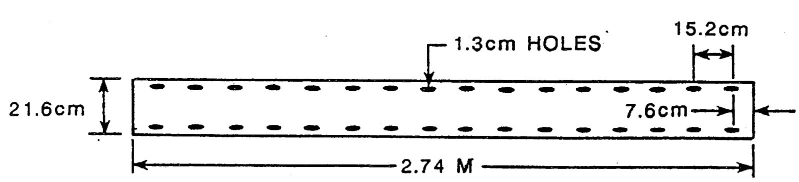
TOP PLAN VIEW OF MANIFOLD/DIFFUSER SECTION
SHOWING INTER-SECTION CONNECTION



SECTION A-A



SECTION B-B
(SHOWING IMPACT SILLS)



HOLE PLACEMENT IN 20.3cm (I.D.) MANIFOLD
(SCHEDULE 40 PVC PIPE)

APPENDIX B

Dissolved oxygen and temperature profiles, 1989–90

Date: 122289

	Station 1		Station 2		Station 2E		Station 2W		Station 3		Station 4		Station 4E		Station 4W		Station 5	
Ice Thick [m]				0.38								0.37						
Ice Bottom [m]				0.35								0.34						
LakeBottom [m]				2.70								2.70						
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.40			1.20	13.11							0.30	12.04						
0.60			2.70	12.46							2.60	11.20						
0.80			3.10	12.21							3.10	10.91						
1.00			3.30	11.99							3.20	10.70						
1.20			3.30	11.99							3.40	10.62						
1.40			3.40	11.76							3.60	10.62						
1.60			3.40	11.68							3.60	10.55						
1.80			3.40	11.64							3.70	10.55						
2.00			3.40	11.50							3.60	10.43						
2.20			3.40	11.16							3.70	10.22						
2.40			3.50	11.11							3.90	9.56						
2.60			3.50	11.02							4.10	8.92						

	Station 6		Station 6E		Station 6W		Station 7		Station 8		Station 9		Station 10		Station 11		Station 12	
Ice Thick [m]		0.39																0.36
Ice Bottom [m]		0.36																0.33
LakeBottom [m]		2.70																2.00
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.40	0.50	11.00															0.00	13.46
0.60	1.80	10.43															0.80	14.13
0.80	3.10	10.05															1.60	13.09
1.00	3.30	9.97															2.80	12.97
1.20	3.50	9.92															3.00	12.89
1.40	3.50	9.87															3.20	12.82
1.60	3.70	9.83															3.30	12.41
1.80	3.70	9.90															3.40	10.62
2.00	3.70	10.43																
2.20	3.80	10.86																
2.40	3.80	10.97																
2.60	4.00	10.90																

Date: 010290

	Station 1		Station 2		Station 2E		Station 2W		Station 3		Station 4		Station 4E		Station 4W		Station 5	
Ice Thick [m]	0.47		0.48						0.48		0.49						0.46	
Ice Bottom [m]	0.42		0.43						0.43		0.44						0.41	
LakeBottom [m]	2.50		2.60						2.65		2.60						2.65	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.15	11.12	2.80	9.42					1.40	11.35	1.30	11.46					1.60	11.45
0.80	2.00	10.72	3.80	9.26					2.20	10.89	2.10	11.03					2.10	11.10
1.00	2.60	10.45	3.80	9.19					2.80	10.33	2.70	10.01					2.80	10.58
1.20	3.20	9.57	3.90	8.80					3.10	10.01	3.10	9.72					3.20	9.79
1.40	3.80	8.49	4.00	8.65					3.40	9.69	3.40	9.50					3.50	8.89
1.60	4.05	7.72	4.00	8.51					3.60	9.54	3.60	9.28					3.70	8.67
1.80	4.20	6.55	4.00	8.43					3.70	9.39	3.60	8.95					3.70	8.69
2.00	4.30	5.92	3.90	8.32					3.80	9.18	3.70	9.17					3.60	9.42
2.20	4.40	5.81	3.90	8.11					3.80	8.69	3.70	8.94					3.60	9.63
2.40	4.55	5.50	4.00	8.06					3.80	8.66	3.80	8.84					3.70	9.76
2.60									3.95	8.63							4.00	9.79

	Station 6		Station 6E		Station 6W		Station 7		Station 8		Station 9		Station 10		Station 11		Station 12	
Ice Thick [m]	0.47						0.48		0.47				0.47				0.47	
Ice Bottom [m]	0.43						0.44		0.43				0.43				0.43	
LakeBottom [m]	2.60						2.50		2.40				2.00				2.00	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.30	11.52					1.30	11.81	1.30	11.56			1.20	11.75			1.00	12.87
0.80	2.30	11.12					2.30	11.46	2.20	11.28			2.20	11.26			1.80	12.42
1.00	2.80	10.83					2.70	10.94	2.70	10.76			2.60	11.03			2.30	12.12
1.20	3.30	9.53					3.40	10.12	3.20	10.38			3.00	10.71			2.70	11.89
1.40	3.60	8.92					3.50	8.84	3.20	10.21			3.20	10.84			2.90	11.83
1.60	3.80	8.70					3.50	9.08	3.40	10.70			3.40	10.74			3.10	11.79
1.80	3.80	8.58					3.50	9.77	3.50	9.94			4.20	8.45			3.80	9.24
2.00	3.70	8.76					3.60	10.01	3.60	9.23								
2.20	3.60	9.56					3.60	10.07	3.70	8.62								
2.40	3.60	9.64					4.00	10.05										

Date: 010990

	Station 1		Station 2		Station 2E		Station 2W		Station 3		Station 4		Station 4E		Station 4W		Station 5	
Ice Thick [m]		0.47		0.47		0.48		0.49		0.49		0.50		0.50		0.49		0.48
Ice Bottom [m]		0.42		0.42		0.43		0.44		0.44		0.45		0.45		0.45		0.44
LakeBottom [m]		2.50		2.65		2.40		2.45		2.60		2.60		2.40		2.25		2.60
Depth	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	1.00	10.65	1.00	11.30	0.90	11.37	1.00	11.25	1.00	10.96	0.90	10.94	1.10	10.90	1.10	11.14	1.00	11.25
0.80	1.90	10.01	2.00	11.08	1.90	11.05	1.90	10.96	2.00	10.56	2.10	10.59	1.90	10.48	2.00	10.70	2.00	10.83
1.00	3.00	9.22	2.80	10.51	2.80	10.46	2.80	10.55	2.60	9.96	3.00	10.20	2.90	10.10	2.90	9.78	2.80	10.11
1.20	3.50	8.16	3.50	9.73	3.60	7.29	3.40	9.25	3.40	8.42	3.60	9.19	3.40	9.44	3.40	8.55	3.40	9.18
1.40	3.70	7.11	3.80	8.34	3.90	5.90	3.60	7.39	3.70	7.19	3.90	8.26	3.50	7.75	3.70	7.36	3.70	8.16
1.60	3.80	6.92	4.00	7.56	4.00	5.73	3.70	7.33	3.90	6.90	4.10	7.76	3.70	6.55	3.90	6.64	3.80	7.84
1.80	4.00	6.51	4.10	7.17	4.10	5.65	4.00	7.28	4.10	6.75	4.20	7.30	3.90	6.14	4.00	5.87	3.80	7.71
2.00	4.00	6.18	4.20	6.97	4.20	5.51	4.00	7.25	4.10	6.74	4.20	7.04	4.00	5.07	4.00	5.63	3.90	7.41
2.20	4.20	5.78	4.20	6.85	4.30	5.50	4.10	7.29	4.20	6.55	4.20	6.91	4.40	3.86			4.00	7.30
2.40	4.60	4.08	4.20	6.67					4.20	6.56	4.20	6.91					4.10	7.28

	Station 6		Station 6E		Station 6W		Station 7		Station 8		Station 9		Station 10		Station 11		Station 12	
Ice Thick [m]		0.49		0.49		0.49		0.48		0.47		0.49		0.48		0.48		0.48
Ice Bottom [m]		0.45		0.45		0.45		0.44		0.42		0.44		0.43		0.44		0.44
LakeBottom [m]		2.60		2.00		2.40		2.50		2.40		2.20		2.00		2.20		2.00
Depth	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	0.70	10.96	0.90	11.15	0.90	10.79	0.90	10.77	0.90	10.54	0.80	10.87	0.80	11.09	0.80	12.49	0.90	13.05
0.80	2.00	10.78	2.00	10.76	2.00	10.38	1.90	10.48	2.00	10.37	1.90	10.41	2.00	10.81	1.90	12.08	1.90	13.15
1.00	2.90	10.09	3.00	9.95	2.80	9.71	2.90	9.86	2.90	9.83	2.80	9.84	2.80	10.49	2.70	11.46	2.50	12.87
1.20	3.50	8.82	3.40	8.86	3.30	8.51	3.50	8.64	3.30	8.99	3.30	8.98	3.30	11.24	2.80	11.47	2.80	11.80
1.40	3.80	8.24	3.60	7.33	3.50	8.03	3.70	8.06	3.60	8.01	3.50	8.55	3.60	11.30	3.20	10.23	3.10	11.24
1.60	3.90	7.83	3.70	6.57	3.70	7.02	3.80	7.56	3.80	7.73	3.80	8.27	4.10	10.80	3.40	10.21	3.30	11.38
1.80	4.00	7.69	4.00	3.04	4.00	6.71	3.90	7.39	3.90	7.49	4.00	7.47	4.40	6.04	3.70	9.63	4.00	9.60
2.00	4.00	7.34			4.00	6.66	4.00	7.47	4.00	6.84	4.30	6.90			3.90	9.14		
2.20	4.10	7.29			4.00	6.64	4.00	7.95	4.10	6.55								
2.40	4.00	10.32					4.00	11.05										

Date: 011690

	Station 1		Station 2		Station 2E		Station 2W		Station 3		Station 4		Station 4E		Station 4W		Station 5	
Ice Thick [m]	0.47		0.47		0.47		0.49		0.50		0.50		0.51		0.49		0.50	
Ice Bottom [m]	0.43		0.43		0.43		0.44		0.45		0.45		0.47		0.45		0.46	
LakeBottom [m]	2.40		2.60		2.40		2.50		2.60		2.60		2.40		2.20		2.60	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	2.40	9.06	2.80	9.42	2.80	9.05	2.60	10.49	2.30	9.27	2.80	9.33	2.80	10.46	2.60	9.99	2.40	10.41
0.80	3.80	9.70	3.80	9.26	3.70	8.98	3.90	9.57	3.90	9.07	3.90	9.42	3.70	9.25	3.60	10.05	3.60	10.24
1.00	3.80	8.72	3.80	9.19	3.90	8.93	3.90	9.57	4.00	9.25	4.00	9.36	3.80	9.15	3.70	10.10	3.80	10.17
1.20	3.90	8.63	3.90	8.80	3.90	8.90	4.00	9.26	4.00	9.22	3.90	9.38	3.90	9.14	3.70	10.04	3.80	10.16
1.40	4.00	8.49	4.00	8.65	4.00	8.77	4.00	8.86	4.00	9.19	3.90	9.38	3.90	9.15	3.80	10.03	3.90	10.15
1.60	4.00	8.34	4.00	8.51	4.00	8.62	4.00	8.47	4.00	9.16	3.90	9.38	3.90	9.05	3.80	9.98	4.00	10.13
1.80	4.00	8.35	4.00	8.43	4.00	8.51	4.00	8.19	4.00	9.19	4.00	9.38	4.00	9.08	3.80	9.96	4.00	10.14
2.00	4.00	8.43	3.90	8.32	4.00	8.02	4.00	8.13	4.00	9.17	4.00	9.39	4.00	9.19	3.90	9.98	4.00	10.17
2.20	4.00	8.41	3.90	8.11	4.10	7.34	4.10	8.07	4.00	9.17	4.00	9.41	4.20	9.27			4.00	10.16
2.40			4.00	8.06			4.20	8.02	4.00	9.27	4.00	9.44					4.00	10.14

	Station 6		Station 6E		Station 6W		Station 7		Station 8		Station 9		Station 10		Station 11		Station 12	
Ice Thick [m]	0.51		0.51		0.51		0.50		0.50		0.51		0.51		0.51		0.51	
Ice Bottom [m]	0.47		0.47		0.46		0.45		0.45		0.46		0.46		0.47		0.47	
LakeBottom [m]	2.60		2.00		2.40		2.50		2.40		2.20		2.00		2.20		2.00	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	2.30	9.79	2.40	12.87	2.40	9.95	2.20	11.15	2.50	12.24	2.50	11.28	2.80	14.11	2.80	13.94	2.30	14.65
0.80	3.70	9.63	3.80	11.03	3.80	10.09	3.80	11.42	3.80	12.09	3.80	11.65	3.90	13.61	3.20	14.49	3.70	14.48
1.00	3.80	10.31	4.00	10.61	4.00	9.94	4.00	11.28	3.90	12.07	3.90	11.61	4.00	13.66	3.70	14.82	3.80	14.49
1.20	3.90	10.38	4.00	10.53	4.00	9.92	4.00	11.23	4.00	11.89	3.90	11.58	4.00	13.62	3.80	15.19	3.80	14.49
1.40	4.00	10.41	4.00	10.44	4.00	9.89	4.00	11.20	4.00	11.72	3.90	11.57	4.00	13.58	3.80	15.55	3.80	14.47
1.60	4.00	10.38	4.00	10.44	4.00	9.88	4.00	11.07	4.00	11.65	4.00	11.55	4.00	13.57	3.80	16.03	3.80	14.47
1.80	4.00	10.38	4.00	10.38	4.00	9.88	4.00	11.06	4.00	11.60	4.00	11.11	4.30	13.21	3.80	16.51	3.90	14.46
2.00	4.00	10.31			4.00	9.91	4.00	11.05	4.00	11.59	4.00	11.56			3.80	16.52		
2.20	4.00	10.30			4.10	9.97	4.00	11.05	4.10	11.57								
2.40	4.00	10.32					4.00	11.05										

Date: 012390

	Station 1		Station 2		Station 2E		Station 2W		Station 3		Station 4		Station 4E		Station 4W		Station 5	
Ice Thick [m]		0.50		0.50		0.49		0.50		0.50		0.50		0.50		0.50		0.50
Ice Bottom [m]		0.46		0.46		0.46		0.44		0.46		0.45		0.46		0.45		0.45
LakeBottom [m]		2.40		2.60		2.40		2.40		2.60		2.60		2.40		2.20		2.60
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	2.40	11.41	2.60	10.78	2.80	12.73	2.40	12.11	2.80	11.55	2.60	12.98	3.20	13.39	3.20	10.96	3.00	13.36
0.80	4.10	11.33	4.00	10.59	4.10	11.88	4.10	10.94	4.10	11.01	4.00	12.54	4.00	12.41	4.00	11.58	3.90	13.35
1.00	4.20	11.26	4.10	10.54	4.10	11.67	4.20	10.78	4.20	10.84	4.00	11.82	4.30	11.76	4.00	11.45	4.00	12.98
1.20	4.20	11.29	4.20	10.53	4.20	11.64	4.20	10.76	4.20	10.79	4.00	11.44	4.30	11.27	4.10	11.74	4.10	12.85
1.40	4.10	11.29	4.20	10.56	4.20	11.24	4.20	10.57	4.20	10.69	4.10	11.30	4.30	11.24	4.10	11.82	4.10	12.75
1.60	4.10	11.30	4.20	10.60	4.20	11.16	4.20	10.38	4.20	10.60	4.20	11.00	4.30	10.82	4.10	11.78	4.10	12.65
1.80	4.10	11.31	4.20	10.64	4.30	11.04	4.20	10.29	4.20	10.52	4.20	10.94	4.30	10.60	4.10	11.79	4.10	11.94
2.00	4.10	11.32	4.20	10.62	4.40	10.67	4.20	10.26	4.20	10.26	4.20	10.87	4.40	10.52	4.30	11.87	4.20	11.85
2.20	4.30	11.25	4.20	10.58	4.40	10.19	4.20	10.30	4.30	10.22	4.20	10.79	4.40	10.48			4.20	11.87
2.40			4.30	10.58					4.30	10.19	4.30	10.77					4.30	11.78

	Station 6		Station 6E		Station 6W		Station 7		Station 8		Station 9		Station 10		Station 11		Station 12	
Ice Thick [m]		0.50		0.50		0.50		0.49		0.49		0.50		0.50		0.50		0.50
Ice Bottom [m]		0.45		0.45		0.46		0.45		0.45		0.45		0.44		0.45		0.45
LakeBottom [m]		2.60		2.00		2.40		2.50		2.40		2.20		2.00		2.20		2.00
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	3.20	13.81	3.60	12.66	2.90	12.29	3.20	13.77	3.20	14.61	3.80	15.54	3.60	17.39	3.30	15.33	2.90	17.37
0.80	4.00	13.29	4.20	12.46	3.90	12.46	4.00	13.32	4.00	14.48	4.10	14.11	4.10	16.81	3.70	15.95	3.80	16.95
1.00	4.10	12.83	4.30	12.39	4.00	12.57	4.10	13.05	4.10	13.82	4.20	13.84	4.20	16.67	3.90	16.13	3.90	16.28
1.20	4.20	12.66	4.30	12.35	4.10	12.44	4.20	12.81	4.20	13.47	4.20	13.82	4.20	16.68	3.90	15.98	3.90	16.30
1.40	4.12	12.36	4.30	12.33	4.10	12.29	4.20	12.48	4.20	13.20	4.20	13.78	4.20	16.68	3.90	16.02	3.90	16.12
1.60	4.20	12.24	4.30	12.31	4.10	12.20	4.20	12.28	4.20	13.17	4.20	13.76	4.20	16.67	3.90	16.04	3.90	16.08
1.80	4.20	12.16	4.30	12.36	4.10	12.12	4.20	12.15	4.20	13.07	4.20	13.77	5.00	13.46	4.00	16.04	4.10	16.04
2.00	4.20	12.11			4.10	12.10	4.20	12.15	4.20	13.03	4.40	13.70			4.00	16.06		
2.20	4.20	12.07			4.10	12.10	4.20	12.18	4.20	13.03								
2.40	4.30	12.06					4.20	11.98										

Date: 012990

	Station 1	Station 2	Station 2E	Station 2W	Station 3	Station 4	Station 4E	Station 4W	Station 5
Ice Thick [m]	0.50	0.50	0.50	0.51	0.50	0.50	0.48	0.50	0.50
Ice Bottom [m]	0.46	0.46	0.45	0.45	0.45	0.45	0.45	0.46	0.46
LakeBottom [m]	2.40	2.60	2.30	2.40	2.55	2.60	2.20	2.20	2.60

Depth [m]	Station 1 Temp [C]	Station 1 D.O. [mg/l]	Station 2 Temp [C]	Station 2 D.O. [mg/l]	Station 2E Temp [C]	Station 2E D.O. [mg/l]	Station 2W Temp [C]	Station 2W D.O. [mg/l]	Station 3 Temp [C]	Station 3 D.O. [mg/l]
0.60	3.60	12.77	3.20	13.24	3.20	13.32	3.00	13.07	3.60	13.72
0.80	4.30	12.70	4.20	12.93	4.30	12.20	4.20	12.49	4.30	12.78
1.00	4.30	12.69	4.10	12.55	4.30	12.04	4.20	12.41	4.30	12.75
1.20	4.30	12.71	4.20	12.44	4.30	12.03	4.20	12.35	4.30	12.69
1.40	4.30	12.67	4.20	12.41	4.30	12.03	4.20	12.37	4.30	12.69
1.60	4.30	12.73	4.20	12.42	4.30	12.05	4.20	12.27	4.30	12.69
1.80	4.30	12.78	4.20	12.41	4.30	12.03	4.20	12.23	4.30	12.64
2.00	4.30	12.86	4.20	12.40	4.30	11.94	4.20	12.20	4.30	12.64
2.20	4.60	12.63	4.20	12.35	4.50	11.02	4.20	12.19	4.30	12.63
2.40			4.20	12.26					4.30	12.68

Depth [m]	Station 4 Temp [C]	Station 4 D.O. [mg/l]	Station 4E Temp [C]	Station 4E D.O. [mg/l]	Station 4W Temp [C]	Station 4W D.O. [mg/l]	Station 5 Temp [C]	Station 5 D.O. [mg/l]
0.60	3.80	13.91	4.20	12.62	2.60	13.33	3.50	13.55
0.80	4.30	12.77	4.30	12.70	4.00	13.00	4.20	13.20
1.00	4.30	12.57	4.30	12.67	4.10	12.93	4.30	13.11
1.20	4.30	12.60	4.30	12.63	4.10	12.84	4.20	13.04
1.40	4.30	12.61	4.30	12.62	4.10	12.74	4.20	13.00
1.60	4.20	12.61	4.30	12.59	4.10	12.74	4.20	13.17
1.80	4.20	12.59	4.30	12.59	4.10	12.68	4.20	13.27
2.00	4.20	12.52	4.30	12.60	4.20	12.68	4.20	13.33
2.20	4.20	12.52					4.20	13.41
2.40	4.20	12.50					4.30	13.50

	Station 6	Station 6E	Station 6W	Station 7	Station 8	Station 9	Station 10	Station 11	Station 12
Ice Thick [m]	0.50	0.49	0.50	0.50	0.49	0.50	0.50	0.50	0.50
Ice Bottom [m]	0.45	0.45	0.46	0.45	0.46	0.46	0.45	0.45	0.46
LakeBottom [m]	2.60	2.00	2.45	2.45	2.30	2.00	1.80	2.10	1.80

Depth [m]	Station 6 Temp [C]	Station 6 D.O. [mg/l]	Station 6E Temp [C]	Station 6E D.O. [mg/l]	Station 6W Temp [C]	Station 6W D.O. [mg/l]	Station 7 Temp [C]	Station 7 D.O. [mg/l]	Station 8 Temp [C]	Station 8 D.O. [mg/l]
0.60	3.00	13.88	3.30	13.69	3.60	14.53	3.70	14.66	3.20	15.59
0.80	4.00	13.64	4.20	13.37	3.80	14.11	4.20	13.61	4.10	14.52
1.00	4.20	13.54	4.20	13.26	4.00	13.96	4.20	13.70	4.20	14.18
1.20	4.20	13.50	4.20	13.19	4.00	13.92	4.20	13.67	4.20	14.06
1.40	4.20	13.51	4.20	13.11	4.00	13.86	4.20	13.62	4.20	14.00
1.60	4.20	13.54	4.20	13.03	4.00	13.82	4.20	13.72	4.20	13.99
1.80	4.20	13.59	4.50	12.11	4.10	13.82	4.20	13.74	4.20	13.95
2.00	4.20	13.62			4.10	13.82	4.20	13.75	4.20	13.92
2.20	4.20	13.63			4.10	13.82	4.20	13.78	4.20	13.86
2.40	4.20	13.74			4.10	13.67	4.20	13.32		

Depth [m]	Station 9 Temp [C]	Station 9 D.O. [mg/l]	Station 10 Temp [C]	Station 10 D.O. [mg/l]	Station 11 Temp [C]	Station 11 D.O. [mg/l]	Station 12 Temp [C]	Station 12 D.O. [mg/l]
0.60	3.40	15.56	3.40	18.00	3.60	17.99	3.80	18.86
0.80	4.20	14.83	4.00	17.57	3.80	17.93	4.00	18.12
1.00	4.20	14.74	4.00	17.37	3.90	17.90	4.00	18.08
1.20	4.20	14.72	4.00	17.32	3.90	17.87	4.00	17.97
1.40	4.20	14.72	4.00	17.30	3.90	17.80	4.00	17.78
1.60	4.20	14.69	4.10	17.20	3.90	17.78	4.00	17.69
1.80	4.20	14.69			3.90	17.76		
2.00					4.00	17.76		

Date: 020690

	Station 1		Station 2		Station 2E		Station 2W		Station 3		Station 4		Station 4E		Station 4W		Station 5	
Ice Thick [m]		0.50		0.52		0.51		0.51		0.52		0.52		0.50		0.51		0.51
Ice Bottom [m]		0.46		0.46		0.47		0.45		0.47		0.47		0.46		0.45		0.47
LakeBottom [m]		2.35		2.55		2.30		2.35		2.55		2.55		2.20		2.20		2.60
Depth	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	1.20	14.46	1.40	15.24	1.60	14.66	1.40	14.60	1.60	15.49	1.90	15.50	1.80	14.63	1.40	15.68	1.80	15.54
0.80	2.70	14.42	3.10	15.06	2.80	14.21	2.80	14.90	2.80	15.40	2.90	15.18	3.40	14.30	2.70	15.27	3.60	15.16
1.00	3.40	14.27	3.80	14.44	4.00	13.38	3.30	15.26	3.50	15.25	3.70	14.96	4.00	13.43	3.80	14.37	3.90	14.25
1.20	3.80	13.92	3.90	13.68	4.10	13.03	3.60	14.88	3.70	15.06	3.80	14.91	4.10	12.91	4.00	13.48	4.10	14.27
1.40	3.80	13.18	3.90	13.95	4.20	12.30	3.80	14.25	3.80	14.52	3.80	14.55	4.20	12.46	4.00	13.90	4.10	13.53
1.60	3.80	13.15	3.90	13.55	4.20	11.82	3.80	14.11	3.80	14.16	3.80	14.30	4.20	12.11	4.10	12.92	4.10	12.92
1.80	3.80	12.99	4.00	13.10	4.20	11.18	3.80	13.87	3.80	13.67	3.90	13.85	4.20	12.07	4.10	12.85	4.10	12.74
2.00	4.00	12.67	4.00	12.62	4.40	9.52	3.80	13.64	3.80	13.19	3.90	13.22	4.20	12.02	4.10	12.84	4.10	12.67
2.20	4.40	8.96	4.00	12.35	4.50	9.48	3.90	13.58	3.70	13.31	3.90	13.08					4.10	12.69
2.40			4.00	12.32					3.90	13.30	4.00	12.93					4.30	12.68

	Station 6		Station 6E		Station 6W		Station 7		Station 8		Station 9		Station 10		Station 11		Station 12	
Ice Thick [m]		0.53		0.50		0.52		0.51		0.51		0.51		0.51		0.52		0.53
Ice Bottom [m]		0.47		0.45		0.47		0.46		0.47		0.47		0.46		0.46		0.48
LakeBottom [m]		2.60		2.00		2.35		2.35		2.25		2.00		1.80		2.10		1.80
Depth	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	1.80	15.75	1.70	15.07	1.60	15.98	1.60	15.56	1.60	16.52	1.80	18.20	2.20	18.79	2.30	19.20	2.40	19.09
0.80	3.80	14.73	3.40	13.37	3.30	15.84	3.80	15.13	3.50	15.80	3.90	15.48	3.80	17.91	3.80	18.53	3.60	18.62
1.00	4.00	13.66	4.00	13.06	3.80	14.74	4.00	14.20	4.00	14.73	4.00	15.30	3.90	17.91	3.90	18.20	3.70	18.57
1.20	4.10	13.43	4.00	12.99	4.00	14.62	4.10	13.75	4.10	14.38	4.00	15.18	3.90	17.57	3.90	19.16	3.80	18.53
1.40	4.10	13.29	4.10	13.00	4.00	14.24	4.10	13.51	4.10	14.09	4.10	15.26	4.00	17.62	3.90	18.12	3.90	18.48
1.60	4.10	12.97	4.10	12.68	4.00	14.11	4.10	13.40	4.10	13.87	4.10	15.24	4.00	17.65	4.00	18.09	3.90	18.44
1.80	4.10	12.93	4.30	7.23	4.00	14.03	4.10	13.37	4.10	13.77	4.20	15.18			4.00	18.09		
2.00	4.10	12.85			4.00	13.98	4.10	13.40	4.10	13.79					4.10	18.14		
2.20	4.10	12.85			4.20	13.93	4.20	13.33	4.30	13.82								
2.40	4.20	13.07																

Date: 021290

	Station 1	Station 2	Station 2E	Station 2W	Station 3	Station 4	Station 4E	Station 4W	Station 5
Ice Thick [m]	0.50	0.48	0.47	0.50	0.48	0.48	0.46	0.50	0.47
Ice Bottom [m]	0.45	0.43	0.44	0.45	0.44	0.44	0.44	0.46	0.43
LakeBottom [m]	2.35	2.55	2.30	2.35	2.55	2.55	2.25	2.20	2.60

	Station 1		Station 2		Station 2E		Station 2W		Station 3		Station 4		Station 4E		Station 4W		Station 5	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	2.80	16.39	3.40	15.80	4.00	15.50	3.10	15.66	3.80	16.35	3.60	16.55	4.30	15.27	3.50	15.53	3.60	17.03
0.80	4.10	16.02	4.10	16.04	4.20	15.73	4.30	15.34	4.30	15.85	4.10	16.59	4.50	15.10	4.20	16.36	4.20	16.79
1.00	4.30	15.90	4.10	16.10	4.40	15.51	4.30	15.29	4.30	15.78	4.30	15.72	4.60	15.12	4.20	16.19	4.40	16.30
1.20	4.30	15.84	4.30	15.95	4.30	15.38	4.30	15.26	4.30	15.56	4.30	15.60	4.60	15.08	4.30	16.26	4.40	16.01
1.40	4.30	15.81	4.30	15.76	4.30	15.26	4.30	15.34	4.30	15.38	4.30	15.67	4.70	15.09	4.30	16.30	4.40	15.97
1.60	4.30	15.81	4.30	15.59	4.30	15.20	4.30	15.36	4.40	15.25	4.30	15.70	4.70	15.15	4.30	16.37	4.40	16.01
1.80	4.30	15.69	4.30	15.61	4.30	15.07	4.30	15.37	4.40	15.20	4.40	15.84	4.70	15.31	4.30	16.39	4.40	16.02
2.00	4.30	15.77	4.30	15.58	4.30	15.18	4.30	15.46	4.40	15.22	4.40	15.94	4.70	15.42	4.30	16.43	4.50	16.02
2.20	4.40	14.69	4.30	15.43	4.50	15.18	4.40	15.58	4.40	15.29	4.40	15.99	4.70	15.46			4.50	16.08
2.40			4.30	15.40					4.40	15.26	4.40	16.05					4.70	16.10

	Station 6	Station 6E	Station 6W	Station 7	Station 8	Station 9	Station 10	Station 11	Station 12
Ice Thick [m]	0.49	0.47	0.49	0.49	0.49	0.48	0.46	0.50	0.49
Ice Bottom [m]	0.45	0.42	0.45	0.45	0.46	0.44	0.42	0.46	0.46
LakeBottom [m]	2.60	2.00	2.35	2.35	2.25	2.00	1.80	2.10	1.85

	Station 6		Station 6E		Station 6W		Station 7		Station 8		Station 9		Station 10		Station 11		Station 12	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	4.00	17.21	4.50	16.64	3.70	17.09	4.00	17.25	4.00	17.51	4.20	18.41	3.80	19.81	3.60	20.91	3.60	21.24
0.80	4.30	16.82	4.60	16.60	4.40	16.64	4.40	16.62	4.40	17.58	4.30	18.42	4.30	19.81	4.20	21.00	4.10	21.37
1.00	4.50	16.70	4.60	16.55	4.40	16.50	4.50	16.59	4.50	17.47	4.40	18.46	4.30	19.81	4.20	21.77	4.20	21.35
1.20	4.50	16.37	4.60	16.60	4.50	16.49	4.60	16.60	4.60	17.38	4.50	18.55	4.30	19.79	4.20	20.76	4.20	21.39
1.40	4.60	16.20	4.60	16.63	4.50	16.45	4.60	16.62	4.60	17.28	4.60	18.53	4.50	19.86	4.20	20.72	4.20	21.42
1.60	4.60	16.14	4.60	16.69	4.50	16.45	4.60	16.63	4.60	17.32	4.60	18.56	4.50	19.85	4.20	20.76	4.20	21.40
1.80	4.60	16.06	4.60	16.64	4.50	16.49	4.60	16.64	4.60	17.38	4.60	18.59			4.20	20.79	4.40	21.40
2.00	4.60	16.17			4.50	16.51	4.60	16.66	4.60	17.39					4.20	20.81		
2.20	4.60	16.23			4.50	16.54	4.70	16.70	4.60	17.42								
2.40	4.60	16.33																

Date: 022290

	Station 1		Station 2		Station 2E		Station 2W		Station 3		Station 4		Station 4E		Station 4W		Station 5	
Ice Thick [m]		0.50		0.51		0.50		0.54		0.52		0.52		0.49		0.51		0.50
Ice Bottom [m]		0.46		0.47		0.47		0.49		0.48		0.48		0.46		0.48		0.47
LakeBottom [m]		2.40		2.60		2.30		2.40		2.60		2.50		2.25		2.20		2.60
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.40	18.19	1.40	18.33	1.40	19.26	1.40	18.32	1.20	19.79	1.30	20.11	1.30	20.20	1.20	17.36	1.60	21.58
0.80	2.90	18.92	3.20	19.14	3.00	18.54	3.00	18.29	3.20	18.69	3.00	19.12	3.50	17.62	2.60	16.88	3.20	19.51
1.00	3.90	17.29	4.00	17.60	4.00	15.77	3.80	17.23	4.00	16.58	4.00	16.48	4.40	14.86	3.80	15.98	4.00	15.13
1.20	4.10	15.77	4.10	16.22	4.10	15.38	4.00	16.27	4.20	14.96	4.20	14.81	4.40	13.87	3.80	15.60	4.20	14.52
1.40	4.20	15.18	4.20	15.61	4.20	14.55	4.10	15.44	4.20	14.92	4.20	14.83	4.50	13.44	4.00	15.21	4.40	14.28
1.60	4.20	15.14	4.20	15.27	4.20	14.50	4.10	15.12	4.20	14.94	4.20	14.46	4.50	13.41	4.20	14.62	4.40	14.19
1.80	4.30	14.91	4.30	14.91	4.30	14.31	4.20	15.02	4.20	14.86	4.30	14.36	4.60	13.18	4.20	14.66	4.40	14.16
2.00	4.40	13.75	4.40	14.37	4.40	9.06	4.20	14.45	4.20	14.72	4.30	14.40	4.70	12.26	4.40	12.37	4.40	14.14
2.20	4.60	8.10	4.40	13.61	4.60	8.10	4.40	11.19	4.20	14.41	4.40	14.22					4.40	14.11
			4.50	13.34					4.40	13.76	4.60	11.91					4.60	13.61

55

	Station 6		Station 6E		Station 6W		Station 7		Station 8		Station 9		Station 10		Station 11		Station 12	
Ice Thick [m]		0.50		0.51		0.50		0.51		0.52		0.50		0.49		0.51		0.50
Ice Bottom [m]		0.47		0.46		0.47		0.46		0.50		0.47		0.46		0.47		0.47
LakeBottom [m]		2.60		2.00		2.30		2.40		2.30		2.05		1.90		2.20		1.90
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.60	22.02	1.60	22.09	1.60	20.21	1.40	21.62	1.40	21.59	1.40	21.72	1.70	21.38	1.50	21.25	1.90	20.72
0.80	3.10	19.35	3.40	15.72	3.30	17.48	3.40	19.80	3.40	19.75	3.30	19.46	3.90	19.50	4.00	19.68	3.80	18.51
1.00	4.00	16.19	4.20	14.05	3.80	15.47	4.30	14.76	4.10	14.74	4.20	15.17	4.50	15.87	4.40	19.02	4.20	17.48
1.20	4.20	15.51	4.30	13.84	4.10	15.00	4.40	14.15	4.20	14.50	4.40	14.86	4.60	15.51	4.50	17.74	4.40	17.34
1.40	4.20	14.62	4.40	13.75	4.20	14.74	4.40	14.24	4.40	14.40	4.40	14.76	4.60	14.56	4.50	16.45	4.40	17.30
1.60	4.30	14.48	4.40	13.66	4.20	14.73	4.40	14.24	4.40	14.42	4.50	14.68	4.60	12.63	4.50	15.95	4.50	17.23
1.80	4.40	14.42	4.80	7.68	4.20	14.71	4.40	14.26	4.40	14.31	4.60	14.38	5.00	8.17	4.60	15.81	4.90	11.73
2.00	4.40	14.32			4.20	14.42	4.40	14.26	4.40	14.22					4.70	11.43		
2.20	4.40	14.28			4.40	11.55	4.60	12.06	4.50	14.21								
2.40	4.60	13.28																

Date: 022790

	Station 1		Station 2		Station 2E		Station 2W		Station 3		Station 4		Station 4E		Station 4W		Station 5	
Ice Thick [m]	0.52		0.53		0.50		0.54		0.52		0.52		0.49		0.53		0.52	
Ice Bottom [m]	0.48		0.49		0.47		0.49		0.48		0.48		0.48		0.48		0.50	
LakeBottom [m]	2.40		2.60		2.30		2.40		2.60		2.50		2.10		2.20		2.60	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.70	15.68	1.50	14.35	1.50	13.52	1.40	13.92	1.40	14.45	1.10	14.79	1.50	15.54	1.60	15.31	1.40	14.75
0.80	2.80	14.45	2.70	14.03	3.20	13.82	2.70	14.25	2.60	13.86	2.50	14.59	2.90	15.61	2.80	14.37	2.80	14.82
1.00	3.10	14.26	3.10	13.82	4.00	13.76	3.20	14.81	3.10	13.77	3.50	14.88	3.60	15.63	3.00	13.98	3.80	14.58
1.20	3.30	14.37	3.50	13.84	4.20	14.01	3.20	13.84	3.60	14.03	4.00	14.46	4.20	15.22	3.20	14.02	3.90	14.51
1.40	3.30	13.70	3.90	13.88	4.20	13.76	3.30	13.70	4.00	14.26	4.10	14.21	4.20	14.17	3.40	14.17	4.00	14.42
1.60	3.40	13.58	4.00	14.06	4.20	13.55	3.60	13.50	4.10	14.25	4.10	14.20	4.40	14.48	3.80	14.15	4.00	14.40
1.80	3.70	13.51	4.20	14.10	4.40	13.44	4.00	13.64	4.10	14.17	4.10	14.17	4.60	14.36	4.20	14.04	4.00	14.36
2.00	4.10	12.49	4.30	13.22	4.50	13.10	4.30	13.49	4.20	14.13	4.10	14.11	4.90	9.89	4.60	6.34	4.00	14.48
2.20	4.30	7.31	4.40	11.85	4.80	8.80	4.80	6.24	4.30	13.92	4.20	14.06					4.00	14.48
2.40			4.50	9.47					4.70	11.38	4.40	8.96					4.40	13.86

	Station 6		Station 6E		Station 6W		Station 7		Station 8		Station 9		Station 10		Station 11		Station 12	
Ice Thick [m]	0.49		0.49		0.49		0.51		0.51		0.50		0.53		0.53		0.52	
Ice Bottom [m]	0.45		0.46		0.46		0.47		0.47		0.48		0.48		0.49		0.48	
LakeBottom [m]	2.60		2.00		2.30		2.40		2.30		2.05		1.90		2.20		1.90	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.40	14.91	1.60	15.84	1.60	14.99	1.50	16.18	1.70	17.24	1.50	20.28	1.60	20.38	1.70	20.53	1.70	20.73
0.80	2.70	14.59	3.00	16.25	2.70	14.25	2.60	14.94	3.60	17.06	3.50	18.79	4.00	15.77	4.20	18.19	4.10	17.89
1.00	3.80	14.49	3.50	15.26	3.20	14.40	4.00	15.27	4.20	16.82	4.30	15.16	4.30	15.74	4.30	15.64	4.20	16.66
1.20	4.00	14.42	3.80	14.98	3.50	14.25	4.00	15.18	4.40	15.22	4.30	14.96	4.30	15.78	4.30	15.56	4.20	16.58
1.40	4.10	14.41	3.90	14.96	3.80	13.44	4.10	15.20	4.40	14.23	4.40	14.93	4.40	15.61	4.40	15.58	4.30	16.53
1.60	4.10	14.33	4.00	14.79	3.90	13.29	4.10	15.15	4.40	14.12	4.40	14.41	4.90	9.81	4.40	15.53	4.60	15.41
1.80	4.20	14.34	4.50	10.22	4.00	13.22	4.20	15.14	4.40	14.12	4.90	9.13			4.60	15.18	5.10	8.57
2.00	4.20	14.32			4.10	13.19	4.20	15.13	4.50	9.68					5.00	7.32		
2.20	4.20	14.32			4.60	8.97	4.20	15.10	4.70	9.29								
2.40	4.60	13.28																

Date: 031390

	Station 1	Station 2	Station 2E	Station 2W	Station 3	Station 4	Station 4E	Station 4W	Station 5
Ice Thick [m]	0.35	0.37	0.38	0.40	0.38	0.40	0.35	0.38	0.36
Ice Bottom [m]	0.34	0.34	0.36	0.36	0.35	0.38	0.33	0.36	0.34
LakeBottom [m]	2.60	2.70	2.60	2.60	2.70	2.70	2.50	2.40	2.70

Depth [m]	Station 1 Temp [C]	Station 1 D.O. [mg/l]	Station 2 Temp [C]	Station 2 D.O. [mg/l]	Station 2E Temp [C]	Station 2E D.O. [mg/l]	Station 2W Temp [C]	Station 2W D.O. [mg/l]	Station 3 Temp [C]	Station 3 D.O. [mg/l]	Station 4 Temp [C]	Station 4 D.O. [mg/l]	Station 4E Temp [C]	Station 4E D.O. [mg/l]	Station 4W Temp [C]	Station 4W D.O. [mg/l]	Station 5 Temp [C]	Station 5 D.O. [mg/l]
0.40	2.00	11.05	1.60	11.51	1.60	11.35	1.80	11.31	1.70	10.22	1.70	10.48	2.00	11.24	1.90	11.52	1.60	11.13
0.60	3.20	11.92	3.10	12.11	3.00	12.76	3.00	12.34	3.60	11.54	3.40	11.77	3.70	12.18	3.60	12.45	3.50	11.51
0.80	3.50	13.13	3.60	13.61	3.70	14.16	3.70	13.56	3.90	13.81	4.00	13.96	4.00	14.27	3.90	13.56	3.80	14.08
1.00	3.80	13.97	3.90	14.02	4.20	14.74	3.90	14.21	3.90	13.99	4.10	14.13	4.30	14.51	4.10	14.27	4.20	14.43
1.20	3.90	14.14	4.00	14.25	4.20	14.71	3.90	14.36	4.10	14.18	4.20	14.30	4.60	14.96	4.20	14.42	4.70	15.71
1.40	4.30	14.93	4.40	16.22	4.30	14.61	3.90	14.38	4.40	14.60	4.50	15.52	4.70	16.65	4.60	16.79	4.80	17.68
1.60	4.30	15.01	4.60	15.97	4.50	16.04	4.00	14.78	4.60	15.90	4.80	16.05	4.70	16.91	4.60	16.88	4.80	17.87
1.80	4.20	14.96	4.50	15.72	4.60	16.09	4.10	15.39	4.70	15.96	4.80	16.16	4.70	17.13	4.70	17.01	4.80	17.96
2.00	4.10	15.03	4.40	15.56	4.60	16.21	4.20	15.38	4.70	16.00	4.80	16.18	4.70	17.12	4.70	17.06	4.80	18.01
2.20	3.90	15.19	4.20	15.26	4.70	16.15	4.30	14.83	4.60	15.93	4.80	16.21	4.80	15.32	4.80	17.00	4.80	18.02
2.40	3.70	13.75	4.20	14.81	5.00	8.33	4.80	8.23	4.60	15.75	4.80	16.21					4.80	18.11
2.60			4.70	9.19					5.00	11.38	4.80	16.29					4.80	18.13

	Station 6	Station 6E	Station 6W	Station 7	Station 8	Station 9	Station 10	Station 11	Station 12
Ice Thick [m]	0.38	0.35	0.39	0.38	0.39	0.37	0.35	0.37	0.37
Ice Bottom [m]	0.35	0.32	0.35	0.35	0.36	0.35	0.32	0.34	0.34
LakeBottom [m]	2.70	2.20	2.60	2.60	2.50	2.20	2.10	2.40	2.00

Depth [m]	Station 6 Temp [C]	Station 6 D.O. [mg/l]	Station 6E Temp [C]	Station 6E D.O. [mg/l]	Station 6W Temp [C]	Station 6W D.O. [mg/l]	Station 7 Temp [C]	Station 7 D.O. [mg/l]	Station 8 Temp [C]	Station 8 D.O. [mg/l]	Station 9 Temp [C]	Station 9 D.O. [mg/l]	Station 10 Temp [C]	Station 10 D.O. [mg/l]	Station 11 Temp [C]	Station 11 D.O. [mg/l]	Station 12 Temp [C]	Station 12 D.O. [mg/l]
0.40	1.80	11.47	2.20	11.81	1.60	11.27	1.50	11.19	1.70	11.75	1.80	12.15	1.50	12.63	1.50	11.19	2.10	11.16
0.60	4.20	11.59	3.80	11.68	4.00	11.54	3.20	12.87	3.20	14.83	4.10	15.02	3.60	16.37	3.40	13.60	4.50	14.52
0.80	4.20	13.77	4.00	13.48	4.10	13.60	3.70	13.88	3.60	15.53	5.10	20.56	4.90	21.81	3.80	19.66	4.50	21.34
1.00	4.30	14.19	4.20	15.16	4.10	13.92	4.00	14.78	4.10	19.19	5.20	20.57	5.00	21.85	4.20	21.76	4.40	21.72
1.20	4.40	14.53	4.40	17.57	4.20	15.91	4.40	17.17	4.80	19.67	5.20	20.66	5.00	21.76	4.20	21.40	4.40	21.77
1.40	4.70	17.17	4.60	17.93	4.40	16.59	4.60	18.33	4.80	19.35	5.20	20.71	5.00	21.78	4.20	22.18	4.40	21.73
1.60	4.70	17.80	4.60	18.07	4.50	17.09	4.70	18.58	4.80	19.17	5.20	20.77	4.90	21.94	4.20	21.14	4.20	21.71
1.80	4.70	17.99	4.70	18.17	4.60	17.12	4.70	18.64	4.80	19.04	5.20	20.74	4.90	21.45	4.20	21.11	4.20	18.34
2.00	4.70	18.07	4.80	16.49	4.70	17.16	4.70	18.69	4.80	18.87	5.20	19.37	5.00	12.74	4.20	21.10		
2.20	4.70	18.11			4.70	17.29	4.70	18.70	4.80	18.71					4.70	13.23		
2.40	4.70	18.11			4.70	16.98	4.80	18.22	4.80	18.63								
2.60	4.80	18.16																

APPENDIX C

Dissolved oxygen and temperature profiles, 1990–91

Date: 010391

	Station 2		Station 2E		Station 2W		Station 4		Station 4E		Station 4W		Station 6		Station 6E		Station 6W	
Ice Thick [m]		0.33						0.33						0.34				
Ice Bottom [m]		0.30						0.30						0.31				
LakeBottom [m]		2.90						2.90						3.05				
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.40	1.20	8.67					1.40	8.25					0.50	8.18				
0.60	3.10	8.14					3.30	7.57					3.40	7.72				
0.80	3.40	7.71					3.50	7.31					3.65	7.23				
1.00	3.50	7.64					3.60	7.21					3.70	6.99				
1.20	3.60	7.51					3.60	7.17					3.75	6.89				
1.40	3.60	7.24					3.70	7.14					3.75	6.84				
1.60	3.60	7.29					3.80	6.99					3.75	6.88				
1.80	3.70	7.22					3.80	6.82					3.75	6.85				
2.00	3.65	7.22					3.80	6.55					3.75	6.82				
2.20	3.65	7.30					3.85	6.45					3.80	6.74				
2.40	3.65	7.25					3.85	6.36					3.80	6.70				
2.60	3.70	7.19					3.85	6.37					3.80	6.67				
2.80	3.75	7.16					3.85	6.34					3.80	6.62				

	Station 8		Station 11		Station 12	
Ice Thick [m]				0.31		
Ice Bottom [m]				0.29		
LakeBottom [m]				2.50		
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.40			1.10	11.26		
0.60			2.70	9.30		
0.80			3.50	8.68		
1.00			3.80	8.25		
1.20			4.10	7.13		
1.40			4.40	6.12		
1.60			4.45	4.07		
1.80			4.45	4.24		
2.00			4.45	3.93		
2.20			4.50	3.68		
2.40			4.50	3.33		

Date: 011091

	Station 2 Temp [C]	Station 2 D.O. [mg/l]	Station 2E Temp [C]	Station 2E D.O. [mg/l]	Station 2W Temp [C]	Station 2W D.O. [mg/l]	Station 4 Temp [C]	Station 4 D.O. [mg/l]	Station 4E Temp [C]	Station 4E D.O. [mg/l]	Station 4W Temp [C]	Station 4W D.O. [mg/l]	Station 6 Temp [C]	Station 6 D.O. [mg/l]	Station 6E Temp [C]	Station 6E D.O. [mg/l]	Station 6W Temp [C]	Station 6W D.O. [mg/l]
Ice Thick [m]	0.42						0.41						0.42					
Ice Bottom [m]	0.39						0.38						0.38					
LakeBottom [m]	2.95						2.90						3.00					
Depth [m]																		
0.40	0.80	7.38					0.20	7.22					0.40	7.46				
0.60	2.80	6.92					2.40	6.67					2.35	6.71				
0.80	3.40	6.72					3.30	6.43					3.20	6.46				
1.00	3.60	6.65					3.50	6.35					3.55	6.43				
1.20	3.60	6.65					3.55	6.35					3.60	6.39				
1.40	3.60	6.55					3.55	6.44					3.60	6.36				
1.60	3.60	6.52					3.50	6.46					3.60	6.30				
1.80	3.65	6.42					3.60	6.44					3.60	6.25				
2.00	3.75	6.36					3.60	6.37					3.60	6.11				
2.20	3.80	5.93					3.65	6.30					3.65	6.01				
2.40	3.80	5.53					3.75	5.99					3.65	6.02				
2.60	3.80	5.36					3.90	5.44					3.65	6.03				
2.80	3.90	5.23					4.00	5.07					3.70	6.00				

	Station 8 Temp [C]	Station 8 D.O. [mg/l]	Station 11 Temp [C]	Station 11 D.O. [mg/l]	Station 12 Temp [C]	Station 12 D.O. [mg/l]
Ice Thick [m]			0.41			
Ice Bottom [m]			0.37			
LakeBottom [m]			2.50			
Depth [m]						
0.40			0.20	6.75		
0.60			2.00	6.28		
0.80			3.20	6.01		
1.00			3.45	5.89		
1.20			3.65	5.56		
1.40			3.60	5.54		
1.60			3.70	5.45		
1.80			3.75	5.18		
2.00			3.75	5.14		
2.20			3.75	4.95		
2.40			3.80	4.60		

Date: 011691

	Station 2		Station 2E		Station 2W		Station 4		Station 4E		Station 4W		Station 6		Station 6E		Station 6W	
Ice Thick [m]	0.41						0.41						0.42					
Ice Bottom [m]	0.39						0.39						0.39					
LakeBottom [m]	2.95						2.90						3.00					
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.40	0.20	6.41					0.30	6.40					0.10	6.77				
0.60	1.75	6.18					1.70	6.17					1.20	6.36				
0.80	2.70	6.03					2.80	5.96					2.80	6.07				
1.00	3.40	6.01					3.40	5.81					3.45	6.02				
1.20	3.55	5.79					3.65	5.76					3.70	5.74				
1.40	3.80	5.62					3.75	5.63					3.80	5.42				
1.60	4.05	4.80					3.90	5.22					3.85	4.76				
1.80	4.10	4.65					3.95	4.45					3.80	5.35				
2.00	4.10	3.57					3.90	4.52					3.85	5.03				
2.20	4.10	3.12					3.90	4.29					3.90	4.37				
2.40	4.15	3.00					3.95	4.17					3.90	4.30				
2.60	4.15	2.94					3.95	4.05					3.90	4.22				
2.80	4.15	2.63					4.15	2.47					3.90	4.21				

	Station 8		Station 11		Station 12	
Ice Thick [m]				0.41		
Ice Bottom [m]				0.37		
LakeBottom [m]				2.50		
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.40			0.10	6.16		
0.60			1.25	5.86		
0.80			2.20	5.63		
1.00			3.20	5.27		
1.20			3.75	3.40		
1.40			3.80	3.14		
1.60			3.80	3.06		
1.80			3.80	3.04		
2.00			3.80	2.99		
2.20			3.80	2.91		
2.40			3.90	2.47		

Date: 012591

	Station 2	Station 2E	Station 2W	Station 4	Station 4E	Station 4W	Station 6	Station 6E	Station 6W
Ice Thick [m]	0.49			0.48			0.49		
Ice Bottom [m]	0.46			0.45			0.45		
LakeBottom [m]	2.95			2.85			3.00		

Depth [m]	Station 2 Temp [C]	Station 2 D.O. [mg/l]	Station 2E Temp [C]	Station 2E D.O. [mg/l]	Station 2W Temp [C]	Station 2W D.O. [mg/l]	Station 4 Temp [C]	Station 4 D.O. [mg/l]	Station 4E Temp [C]	Station 4E D.O. [mg/l]	Station 4W Temp [C]	Station 4W D.O. [mg/l]	Station 6 Temp [C]	Station 6 D.O. [mg/l]	Station 6E Temp [C]	Station 6E D.O. [mg/l]	Station 6W Temp [C]	Station 6W D.O. [mg/l]
0.60	1.95	4.32					1.70	4.19					1.75	3.78				
0.80	3.45	4.09					3.20	3.84					3.25	3.57				
1.00	3.50	3.96					3.55	3.75					3.55	3.37				
1.20	3.50	3.93					3.55	3.71					3.55	3.32				
1.40	3.50	3.89					3.55	3.70					3.55	3.32				
1.60	3.55	3.89					3.55	3.68					3.55	3.31				
1.80	3.55	3.88					3.55	3.67					3.55	3.30				
2.00	3.60	3.85					3.55	3.69					3.55	3.28				
2.20	3.60	3.85					3.60	3.59					3.60	3.27				
2.40	3.60	3.84					3.65	3.34					3.60	3.27				
2.60	3.60	3.85					3.80	3.08					3.60	3.26				
2.80	3.60	3.85					4.15	2.42					3.60	3.23				

	Station 8	Station 11	Station 12
Ice Thick [m]		0.48	
Ice Bottom [m]		0.43	
LakeBottom [m]		2.45	

Depth [m]	Station 8 Temp [C]	Station 8 D.O. [mg/l]	Station 11 Temp [C]	Station 11 D.O. [mg/l]	Station 12 Temp [C]	Station 12 D.O. [mg/l]
0.60			1.20	4.50		
0.80			2.45	4.14		
1.00			3.45	3.48		
1.20			3.60	3.48		
1.40			3.65	3.38		
1.60			3.70	3.27		
1.80			3.70	3.18		
2.00			3.75	3.13		
2.20			3.80	2.82		
2.40						
2.60						

Date: 013191

	Station 2		Station 2E		Station 2W		Station 4		Station 4E		Station 4W		Station 6		Station 6E		Station 6W	
Ice Thick [m]	0.53							0.53						0.54				
Ice Bottom [m]	0.48							0.47						0.48				
LakeBottom [m]	2.95							2.85						3.00				
Depth	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	1.20	3.52					1.00	3.81					1.10	3.70				
0.80	2.45	3.09					2.40	3.65					2.50	3.40				
1.00	3.40	2.96					3.30	3.25					3.30	3.13				
1.20	3.70	2.79					3.45	3.15					3.55	2.99				
1.40	3.85	2.68					3.50	3.09					3.60	2.91				
1.60	3.80	2.62					3.50	3.05					3.65	2.81				
1.80	3.80	2.46					3.60	2.97					3.65	2.74				
2.00	3.85	2.50					3.65	2.95					3.65	2.67				
2.20	3.90	2.44					3.75	2.72					3.75	2.43				
2.40	3.90	2.41					3.80	2.66					3.80	2.25				
2.60	3.90	2.31					3.85	2.61					3.80	2.24				
2.80	3.90	2.28					4.05	1.85					3.80	2.19				

	Station 8		Station 11		Station 12	
Ice Thick [m]				0.53		
Ice Bottom [m]				0.43		
LakeBottom [m]				2.45		
Depth	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60			0.80	3.91		
0.80			1.90	3.67		
1.00			2.60	2.89		
1.20			3.50	2.81		
1.40			3.50	2.64		
1.60			3.60	2.60		
1.80			3.60	2.31		
2.00			3.65	2.08		
2.20			3.80	1.74		
2.40			4.00	0.58		
2.60						

Date: 020691

	Station 2		Station 2E		Station 2W		Station 4		Station 4E	
Ice Thick [m]	0.53		0.47		0.51		0.52		0.50	
Ice Bottom [m]	0.50		0.44		0.48		0.47		0.47	
LakeBottom [m]	2.95		2.70		2.75		2.85		2.65	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	2.40	4.75	2.05	3.85	2.00	5.00	2.05	5.27	1.70	4.27
0.80	3.40	6.29	3.30	4.69	3.25	4.84	3.55	4.59	3.40	3.57
1.00	3.45	6.41	3.60	4.12	3.50	5.01	3.85	4.39	3.85	3.36
1.20	3.45	6.46	3.75	3.66	3.50	5.25	3.85	4.33	3.85	3.30
1.40	3.50	6.37	3.85	3.40	3.50	5.25	3.85	4.25	3.85	3.27
1.60	3.50	6.31	3.85	3.18	3.55	5.28	3.90	3.99	3.80	3.24
1.80	3.55	6.33	3.85	3.24	3.65	5.25	3.95	3.97	3.80	3.21
2.00	3.55	6.13	3.85	3.19	3.65	5.20	3.95	3.88	3.80	3.23
2.20	3.60	6.01	3.85	3.22	3.70	5.25	3.95	3.68	3.70	3.24
2.40	3.70	5.88	3.85	3.23	3.70	5.24	4.00	3.66	3.60	3.54
2.60	3.75	5.76	3.85	3.27	3.75	5.32	4.10	3.48	3.75	4.17
2.80	3.80	5.67					4.30	3.45		

	Station 4W		Station 6		Station 6E		Station 6W	
Ice Thick [m]	0.50		0.54		0.50		0.49	
Ice Bottom [m]	0.46		0.48		0.45		0.45	
LakeBottom [m]	2.65		3.05		2.50		2.65	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.90	4.83	1.75	4.63	1.70	4.60	2.00	4.79
0.80	3.25	6.41	3.20	4.13	3.50	3.44	3.70	4.66
1.00	3.70	5.50	3.75	3.89	3.85	3.36	3.95	4.53
1.20	3.70	5.39	3.85	3.81	3.90	3.33	3.95	4.46
1.40	3.70	5.34	3.85	3.78	3.90	3.33	3.95	4.44
1.60	3.70	5.28	3.90	3.75	3.90	3.33	3.95	4.39
1.80	3.70	5.25	3.90	3.68	3.90	3.38	3.95	4.42
2.00	3.70	5.25	4.00	3.66	4.00	4.31	3.95	4.43
2.20	3.70	5.31	4.05	3.69	4.15	4.79	3.95	4.45
2.40	3.75	5.34	4.05	3.72	4.25	4.55	3.95	4.46
2.60	3.80	5.42	4.05	3.71				
2.80			4.05	3.87				

	Station 8		Station 11		Station 12	
Ice Thick [m]	0.53		0.49			
Ice Bottom [m]	0.50		0.43			
LakeBottom [m]	2.70		2.40			
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.75	4.68	1.90	3.00		
0.80	3.05	4.23	2.55	2.87		
1.00	3.40	3.93	3.10	2.88		
1.20	3.80	3.93	3.35	2.89		
1.40	3.90	3.93	3.50	2.90		
1.60	4.00	3.98	3.55	2.95		
1.80	4.00	4.06	3.65	3.14		
2.00	4.00	4.38	3.85	3.40		
2.20	4.00	4.43	3.95	3.66		
2.40	4.00	4.48				
2.60	4.00	4.54				

Date: 021191

	Station 2	Station 2E	Station 2W	Station 4	Station 4E	Station 4W	Station 6	Station 6E	Station 6W
Ice Thick [m]	0.50	0.43	0.50	0.49	0.48	0.47	0.50	0.50	0.48
Ice Bottom [m]	0.46	0.40	0.46	0.45	0.45	0.43	0.44	0.46	0.44
LakeBottom [m]	3.05	2.75	2.85	3.05	2.70	2.70	3.05	2.50	2.70

Depth [m]	Station 2 Temp [C]	Station 2 D.O. [mg/l]	Station 2E Temp [C]	Station 2E D.O. [mg/l]	Station 2W Temp [C]	Station 2W D.O. [mg/l]	Station 4 Temp [C]	Station 4 D.O. [mg/l]	Station 4E Temp [C]	Station 4E D.O. [mg/l]	Station 4W Temp [C]	Station 4W D.O. [mg/l]	Station 6 Temp [C]	Station 6 D.O. [mg/l]	Station 6E Temp [C]	Station 6E D.O. [mg/l]	Station 6W Temp [C]	Station 6W D.O. [mg/l]
0.60	4.20	8.01	4.30	5.72	4.20	7.90	4.00	7.06	4.05	7.29	4.10	6.09	4.00	7.12	3.90	7.05	3.90	6.60
0.80	4.20	7.70	4.30	5.05	4.20	7.86	4.10	7.08	4.05	7.12	4.20	6.08	4.20	7.02	4.15	7.01	4.20	6.50
1.00	4.10	7.70	4.25	5.50	4.25	7.95	4.15	7.29	4.20	7.06	4.20	6.06	4.20	6.98	4.10	7.00	4.15	6.43
1.20	4.10	7.71	4.20	5.75	4.30	7.95	4.20	7.39	4.20	7.06	4.20	6.01	4.20	6.98	4.10	6.98	4.20	6.39
1.40	4.10	7.70	4.20	5.71	4.30	7.89	4.15	7.42	4.20	7.06	4.15	5.96	4.20	6.96	4.15	6.99	4.20	6.35
1.60	4.10	7.71	4.20	5.82	4.25	7.82	4.15	7.46	4.25	7.08	4.15	5.97	4.20	6.94	4.20	7.02	4.20	6.48
1.80	4.10	7.71	4.20	5.81	4.30	7.82	4.20	7.46	4.25	7.11	4.15	5.96	4.20	7.12	4.20	7.04	4.20	6.58
2.00	4.10	7.71	4.20	5.83	4.30	7.78	4.20	7.43	4.30	7.15	4.15	6.03	4.20	7.16	4.20	7.09	4.20	6.70
2.20	4.10	7.68	4.20	5.87	4.30	7.84	4.20	7.40	4.30	7.19	4.10	6.06	4.20	7.19	4.20	7.11	4.20	6.80
2.40	4.20	7.66	4.20	5.94	4.30	7.88	4.20	7.37	4.30	7.21	4.10	6.05	4.15	7.24	4.20	7.24	4.20	6.82
2.60	4.30	7.66	4.20	6.08	4.30	7.86	4.20	7.38	4.30	7.22	4.20	6.22	4.15	7.26			4.20	6.91
2.80	4.75	6.83			4.40	7.90	4.20	7.35					4.15	7.27				

	Station 8	Station 11	Station 12
Ice Thick [m]	0.49	0.46	0.48
Ice Bottom [m]	0.46	0.42	0.45
LakeBottom [m]	2.80	2.60	2.75

Depth [m]	Station 8 Temp [C]	Station 8 D.O. [mg/l]	Station 11 Temp [C]	Station 11 D.O. [mg/l]	Station 12 Temp [C]	Station 12 D.O. [mg/l]
0.60	4.15	6.29	4.15	6.52	4.15	5.25
0.80	4.40	6.29	4.20	6.53	4.20	5.20
1.00	4.40	6.31	4.25	5.56	4.40	5.19
1.20	4.40	6.23	4.25	5.29	4.50	5.25
1.40	4.30	6.23	4.30	4.78	4.45	5.29
1.60	4.25	6.24	4.30	4.44	4.40	5.21
1.80	4.25	6.35	4.20	4.67	4.40	5.18
2.00	4.25	6.41	4.20	5.22	4.45	5.01
2.20	4.25	6.44	4.20	5.82	4.60	5.12
2.40	4.25	6.44	4.40	5.77	4.60	5.22
2.60	4.25	6.44			4.60	5.22

Date: 021491

	Station 2	Station 2E	Station 2W	Station 4	Station 4E	Station 4W	Station 6	Station 6E	Station 6W
Ice Thick [m]	0.50	0.46	0.47	0.50	0.49	0.48	0.50	0.49	0.48
Ice Bottom [m]	0.45	0.41	0.45	0.43	0.44	0.42	0.44	0.44	0.44
LakeBottom [m]	3.05	2.80	2.85	3.05	2.70	2.70	3.05	2.50	2.70

Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	3.80	9.85	3.70	8.22	3.85	9.73	3.20	9.62	3.75	8.23	3.60	7.46	3.30	8.61	3.60	7.64	3.50	8.17
0.80	3.95	8.98	3.80	8.58	4.00	9.12	3.95	9.22	4.00	8.20	3.90	7.27	4.00	8.03	4.05	7.56	4.00	7.54
1.00	4.00	8.89	3.95	8.21	4.00	8.53	4.00	8.82	4.05	8.18	3.95	7.25	4.00	7.75	4.05	7.56	4.00	7.39
1.20	4.00	8.80	4.00	7.73	4.00	8.38	4.00	8.75	4.05	8.12	3.95	7.21	4.00	7.73	4.05	7.53	4.00	7.39
1.40	3.95	8.73	4.00	7.43	4.00	8.33	4.00	8.66	4.05	8.03	3.95	7.23	4.00	7.70	4.05	7.52	4.05	7.34
1.60	4.00	8.73	4.00	7.34	4.00	8.26	4.00	8.66	4.05	8.00	3.95	7.22	4.00	7.67	4.05	7.51	4.05	7.31
1.80	4.00	8.73	4.05	7.28	4.00	8.28	4.00	8.68	4.05	7.80	3.95	7.21	4.00	7.64	4.05	7.50	4.05	7.31
2.00	4.00	8.71	4.05	7.24	4.00	8.27	4.00	8.68	4.05	7.82	3.95	7.13	4.00	7.64	4.05	7.50	4.05	7.30
2.20	4.00	8.69	4.05	7.22	4.00	8.26	4.00	8.59	4.05	7.79	3.95	7.11	4.00	7.61	4.05	7.35	4.05	7.31
2.40	4.00	8.67	4.05	7.18	4.00	8.30	4.00	8.54	4.05	7.79	3.95	7.06	4.00	7.60	4.15	6.93	4.05	7.30
2.60	4.15	8.64	4.10	7.17	4.00	8.30	4.00	8.53	4.05	7.79	4.10	6.75	4.00	7.58			4.05	7.27
2.80	4.70	7.84			4.15	8.13	4.05	8.45					4.05	7.58				

	Station 8	Station 11	Station 12
Ice Thick [m]	0.50	0.48	0.49
Ice Bottom [m]	0.45	0.43	0.44
LakeBottom [m]	2.80	2.60	2.75

Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	3.25	7.52	2.40	9.11	2.65	6.44
0.80	4.00	7.46	3.80	6.29	3.90	6.90
1.00	4.10	6.97	4.10	6.19	4.15	7.01
1.20	4.15	6.50	4.15	6.05	4.25	6.63
1.40	4.20	6.24	4.20	5.87	4.30	6.35
1.60	4.20	6.16	4.20	5.90	4.35	6.05
1.80	4.20	6.09	4.20	6.04	4.35	5.86
2.00	4.15	6.07	4.20	6.04	4.40	5.79
2.20	4.15	6.01	4.30	5.93	4.50	5.59
2.40	4.15	6.00	4.50	5.93	4.60	5.36
2.60	4.15	5.95			4.60	4.91

Date: 022091

	Station 2		Station 2E		Station 2W		Station 4		Station 4E		Station 4W		Station 6		Station 6E		Station 6W	
Ice Thick [m]		0.50		0.46		0.47		0.50		0.49		0.48		0.50		0.49		0.48
Ice Bottom [m]		0.46		0.41		0.44		0.46		0.46		0.45		0.45		0.46		0.45
LakeBottom [m]		3.05		2.80		2.90		3.05		2.75		2.70		3.05		2.50		2.65
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.80	9.13	1.85	9.59	1.75	7.50	1.80	9.18	1.80	9.04	1.85	8.34	1.75	9.16	1.65	9.11	1.70	8.15
0.80	3.20	7.33	3.20	8.29	3.40	6.97	3.40	8.52	3.40	8.59	3.70	8.03	3.35	8.68	3.60	7.94	3.30	8.00
1.00	3.80	7.25	3.75	8.02	3.90	6.71	3.80	8.35	3.85	8.52	3.95	7.94	3.80	7.83	4.00	6.11	3.50	7.87
1.20	3.90	7.65	3.90	8.34	4.00	6.88	3.90	8.17	3.95	8.44	3.95	7.87	3.85	7.76	4.15	5.97	3.85	7.79
1.40	3.85	8.72	3.90	8.47	4.00	7.61	3.95	7.25	3.95	8.36	3.95	7.80	4.05	7.31	4.20	5.57	3.95	7.21
1.60	3.80	8.95	4.00	8.34	4.00	7.90	4.10	7.00	4.00	8.04	4.00	7.61	4.10	6.68	4.20	5.33	4.05	7.06
1.80	3.80	8.96	3.95	8.28	4.00	7.99	4.10	6.85	4.00	7.69	4.00	7.53	4.15	6.30	4.20	5.21	4.20	6.55
2.00	3.85	8.83	4.05	8.14	4.10	7.90	4.10	6.73	4.00	7.37	4.00	7.54	4.20	6.01	4.20	4.89	4.20	5.86
2.20	4.00	8.79	4.10	8.08	4.20	7.53	4.10	6.69	4.00	7.06	4.00	7.21	4.25	5.33	4.20	4.66	4.20	5.57
2.40	4.10	8.62	4.20	7.69	4.25	7.42	4.10	6.65	4.00	7.04	4.00	7.20	4.30	5.17	4.35	4.51	4.20	5.22
2.60	4.40	8.01	4.40	6.13	4.25	7.39	4.10	6.63	4.15	6.67	4.20	6.89	4.35	5.07			4.35	4.88
2.80	4.60	5.87			4.35	7.17	4.10	6.60					4.35	5.00				

	Station 8		Station 11		Station 12	
Ice Thick [m]		0.50		0.48		0.49
Ice Bottom [m]		0.45		0.44		0.44
LakeBottom [m]		2.75		2.60		2.70
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.70	7.90	1.60	9.20	1.40	8.23
0.80	3.20	7.63	2.75	7.69	2.60	7.79
1.00	3.80	7.39	3.85	7.20	3.75	7.18
1.20	4.00	7.11	4.25	5.19	4.20	6.04
1.40	4.05	6.99	4.30	4.62	4.40	5.24
1.60	4.15	6.64	4.30	4.62	4.45	4.81
1.80	4.20	6.38	4.30	4.45	4.45	4.51
2.00	4.25	5.89	4.30	4.41	4.45	4.35
2.20	4.30	5.71	4.30	4.38	4.45	4.28
2.40	4.30	5.59	4.30	4.32	4.45	4.27
2.60	4.30	5.50			4.45	4.12

Date: 022791

	Station 2		Station 2E		Station 2W		Station 4		Station 4E		Station 4W		Station 6		Station 6E		Station 6W	
Ice Thick [m]	0.51		0.48		0.51		0.51		0.51		0.50		0.51		0.51		0.52	
Ice Bottom [m]	0.46		0.43		0.47		0.46		0.46		0.46		0.46		0.48		0.45	
LakeBottom [m]	3.05		2.80		2.90		2.90		2.75		2.70		3.05		2.50		2.65	
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.75	8.70	1.65	8.70	1.70	8.20	1.60	8.77	1.85	8.49	1.60	8.48	1.45	8.46	1.45	8.68	1.60	8.65
0.80	3.25	7.59	3.25	7.79	3.65	6.64	3.05	7.64	3.30	7.78	3.35	6.82	3.20	8.06	3.15	7.33	3.20	7.69
1.00	3.85	7.40	3.60	8.10	4.10	6.87	3.85	7.50	3.85	7.56	4.05	6.42	3.80	7.71	3.80	6.44	3.95	7.20
1.20	3.90	7.39	3.80	8.09	4.15	6.83	3.90	7.35	3.95	7.32	4.15	6.12	3.90	7.44	4.00	6.04	4.10	6.88
1.40	3.95	7.44	3.85	7.99	4.15	6.81	4.05	6.75	3.95	6.95	4.20	5.92	4.15	6.75	4.00	5.80	4.30	5.76
1.60	4.00	7.77	3.85	8.04	4.15	6.81	4.05	6.73	4.00	6.69	4.20	5.88	4.20	6.42	4.00	5.74	4.30	5.40
1.80	4.05	8.04	3.95	8.03	4.15	6.81	4.10	6.28	4.05	6.35	4.20	5.82	4.20	6.05	4.00	5.70	4.30	5.35
2.00	4.10	8.02	3.95	7.99	4.15	6.82	4.15	6.20	4.10	6.22	4.20	5.78	4.20	5.81	4.00	5.66	4.35	5.24
2.20	4.15	7.96	4.05	7.80	4.15	6.81	4.15	5.84	4.10	6.17	4.20	5.78	4.20	5.85	4.00	5.64	4.35	5.23
2.40	4.30	7.70	4.30	7.09	4.20	6.81	4.15	5.77	4.15	6.01	4.20	5.78	4.20	5.81	4.20	5.22	4.35	5.18
2.60	4.45	5.82	4.60	2.54	4.20	6.59	4.15	5.79	4.25	4.60	4.20	5.59	4.20	5.77			4.35	5.13
2.80	4.65	2.70			4.40	5.75	4.15	5.75					4.20	5.74				

	Station 8		Station 11		Station 12	
Ice Thick [m]	0.55		0.53			
Ice Bottom [m]	0.48		0.47			
LakeBottom [m]	2.75		2.60			
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.60	8.14	1.05	9.39		
0.80	3.20	7.30	2.80	9.15		
1.00	4.00	6.98	3.45	6.98		
1.20	4.20	5.98	3.80	6.36		
1.40	4.20	5.88	3.80	6.08		
1.60	4.30	5.64	3.90	5.49		
1.80	4.30	5.45	3.95	5.42		
2.00	4.30	5.43	3.95	5.35		
2.20	4.30	5.23	3.95	5.21		
2.40	4.30	5.30	3.95	5.16		
2.60	4.30	5.23				

Date: 030491

	Station 2		Station 2E		Station 2W		Station 4		Station 4E		Station 4W		Station 6		Station 6E		Station 6W	
Ice Thick [m]		0.52		0.50		0.55		0.53		0.51		0.51		0.53		0.52		0.51
Ice Bottom [m]		0.46		0.45		0.49		0.47		0.46		0.48		0.48		0.47		0.46
LakeBottom [m]		3.05		2.80		2.90		3.05		2.75		2.70		3.05		2.50		2.65
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.40	9.42	1.40	9.77	1.30	9.50	1.40	9.49	1.40	8.80	1.40	9.42	1.20	9.07	1.45	8.25	1.25	9.36
0.80	3.00	7.75	2.75	8.27	2.75	7.85	2.80	6.40	3.05	7.87	3.25	6.18	3.00	7.57	3.10	4.86	3.20	7.00
1.00	3.70	7.30	3.65	7.98	3.95	6.49	4.05	5.42	4.05	6.34	4.05	5.62	3.80	6.89	3.95	4.81	4.00	5.12
1.20	3.90	7.15	3.75	7.86	4.00	6.31	4.15	5.39	4.05	5.97	4.15	5.34	4.15	6.34	4.00	4.68	4.10	5.06
1.40	3.95	7.07	3.80	7.82	4.05	6.24	4.15	5.33	4.05	5.80	4.15	5.31	4.20	5.49	4.00	4.61	4.10	5.01
1.60	3.95	7.06	3.80	7.79	4.05	6.17	4.15	5.29	4.05	5.70	4.15	5.28	4.25	5.22	4.00	4.55	4.10	4.99
1.80	3.95	7.07	3.90	7.73	4.05	6.21	4.15	5.27	4.05	5.65	4.15	5.25	4.25	5.19	4.00	4.51	4.15	4.93
2.00	4.00	7.05	4.00	7.26	4.10	6.18	4.15	5.26	4.05	5.60	4.15	5.22	4.25	5.06	4.00	4.48	4.15	4.89
2.20	4.05	7.05	4.20	7.29	4.15	6.09	4.15	5.26	4.05	5.58	4.15	5.23	4.25	4.93	4.00	4.46	4.15	4.87
2.40	4.20	6.91	4.40	5.71	4.20	6.05	4.15	5.25	4.05	5.57	4.20	5.32	4.25	4.82	4.40	4.42	4.15	4.89
2.60	4.35	6.68	4.65	3.20	4.20	6.15	4.15	5.26	4.05	5.59	4.20	5.34	4.25	4.78			4.15	4.91
2.80	4.55	3.76			4.25	6.03	4.15	5.24					4.25	4.77				

	Station 8		Station 11		Station 12	
Ice Thick [m]		0.54		0.52		
Ice Bottom [m]		0.49		0.47		
LakeBottom [m]		2.75		2.60		
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.20	8.96	1.20	8.59		
0.80	3.15	7.82	2.40	7.95		
1.00	4.15	5.34	3.35	6.69		
1.20	4.30	5.12	3.80	5.47		
1.40	4.30	4.99	3.90	5.15		
1.60	4.30	4.97	3.90	4.83		
1.80	4.30	4.90	3.90	4.68		
2.00	4.30	4.88	3.90	4.60		
2.20	4.30	4.86	4.00	4.39		
2.40	4.30	4.85	4.10	3.79		
2.60	4.30	4.83				

Date: 030691

	Station 2	Station 2E	Station 2W	Station 4	Station 4E	Station 4W	Station 6	Station 6E	Station 6W
Ice Thick [m]	0.52	0.50	0.54	0.52	0.52	0.51	0.53	0.52	0.52
Ice Bottom [m]	0.48	0.45	0.50	0.47	0.48	0.48	0.49	0.48	0.48
LakeBottom [m]	3.05	2.80	2.90	3.05	2.75	2.70	3.05	2.50	2.65

Depth	Station 2		Station 2E		Station 2W		Station 4		Station 4E	
	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	1.65	9.00	1.90	8.70	1.70	9.15	1.45	9.54	1.55	9.41
0.80	3.45	7.63	3.40	7.90	3.50	8.25	3.50	7.75	3.60	6.60
1.00	3.90	7.23	3.90	7.49	3.85	7.47	3.85	7.34	4.00	6.05
1.20	4.10	6.75	4.00	7.17	3.90	7.15	3.90	7.18	4.00	5.87
1.40	4.15	6.26	4.00	7.20	3.95	7.06	3.90	7.09	4.00	5.82
1.60	4.15	6.36	4.00	7.04	4.00	7.01	3.90	7.19	4.00	5.79
1.80	4.05	6.45	4.00	7.14	4.10	7.00	3.90	7.28	4.00	5.76
2.00	4.10	6.63	4.05	7.14	4.20	6.20	3.90	7.26	4.00	5.83
2.20	4.15	6.79	4.15	6.86	4.20	5.90	3.90	7.39	4.00	5.84
2.40	4.30	6.38	4.40	6.83	4.15	5.81	3.85	7.39	4.00	5.86
2.60	4.40	5.81	4.65	4.59	4.15	5.83	3.85	7.37	4.00	5.88
2.80	4.55	4.35			4.20	5.75	3.90	7.37		

Depth	Station 4W		Station 6		Station 6E		Station 6W	
	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	1.55	9.71	1.30	8.77	1.30	10.70	1.35	9.42
0.80	3.20	7.29	3.00	7.18	3.65	5.32	3.40	5.40
1.00	3.70	6.77	3.95	5.60	4.05	5.19	4.00	5.20
1.20	3.90	6.54	3.95	5.63	4.10	5.14	4.00	5.17
1.40	3.85	6.43	3.95	5.57	4.10	5.06	4.00	5.10
1.60	3.90	6.39	3.95	5.54	4.10	4.91	4.05	5.07
1.80	3.90	6.40	3.95	5.50	4.10	4.91	4.05	5.04
2.00	3.90	6.37	3.95	5.47	4.15	4.87	4.05	5.00
2.20	3.90	6.33	4.00	5.46	4.15	4.84	4.05	4.98
2.40	3.90	6.34	4.00	5.46	4.15	4.81	4.05	4.98
2.60	3.95	6.32	4.00	5.47			4.10	4.97
2.80			4.00	5.46				

	Station 8	Station 11	Station 12
Ice Thick [m]	0.54	0.53	
Ice Bottom [m]	0.50	0.48	
LakeBottom [m]	2.75	2.60	

Depth	Station 8		Station 11		Station 12	
	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	1.20	9.11	1.00	7.63		
0.80	3.15	6.70	2.10	7.40		
1.00	4.00	5.83	3.40	6.47		
1.20	4.10	5.78	3.80	5.67		
1.40	4.10	5.76	3.95	5.17		
1.60	4.10	5.64	4.00	4.79		
1.80	4.10	5.55	4.00	4.43		
2.00	4.10	5.52	4.15	4.37		
2.20	4.10	5.52	4.10	4.21		
2.40	4.10	5.53	4.15	4.12		
2.60	4.10	5.55				

Date: 030891

	Station 2		Station 2E		Station 2W		Station 4		Station 4E		Station 4W		Station 6		Station 6E		Station 6W	
Ice Thick [m]		0.52		0.50		0.53		0.52		0.52		0.52		0.53		0.52		0.52
Ice Bottom [m]		0.47		0.45		0.48		0.46		0.47		0.48		0.49		0.48		0.48
LakeBottom [m]		3.05		2.80		2.90		3.05		2.75		2.70		3.05		2.55		2.70
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.65	8.73	1.90	8.47	1.80	9.36	1.75	9.28	1.60	9.87	1.85	9.40	1.50	8.36	1.60	9.29	1.65	10.02
0.80	3.20	7.00	3.35	7.28	3.10	8.04	3.30	7.34	3.25	7.36	3.70	6.90	3.10	6.69	3.55	6.00	3.65	6.27
1.00	3.80	7.46	4.00	6.75	3.85	7.37	3.85	7.38	3.95	6.53	3.95	6.77	3.85	6.26	4.05	5.68	3.95	5.86
1.20	3.85	7.50	3.95	6.60	3.95	7.33	3.85	7.58	4.00	6.38	3.95	6.71	3.95	6.06	4.05	5.65	3.95	5.84
1.40	3.70	8.29	4.00	6.65	3.80	8.01	3.80	8.40	4.00	6.28	4.00	6.64	3.95	5.94	4.10	5.59	3.95	5.83
1.60	3.75	8.01	4.05	7.45	3.75	8.15	3.80	8.29	4.00	6.26	4.00	6.62	3.95	5.87	4.10	5.58	4.00	5.82
1.80	3.80	7.95	4.05	7.37	3.85	8.14	3.80	8.28	4.00	6.22	4.00	6.58	4.00	5.81	4.05	5.60	4.00	5.78
2.00	3.80	7.92	4.15	7.50	4.00	7.98	3.75	8.28	4.05	6.15	3.95	6.56	4.00	5.76	4.05	5.60	4.00	5.74
2.20	3.90	7.87	4.25	7.67	4.00	7.79	3.80	8.29	4.05	6.15	3.95	6.54	4.05	5.70	4.05	5.60	4.00	5.74
2.40	3.95	7.82	4.30	7.78	4.20	7.50	3.75	8.33	4.05	6.16	3.95	6.52	4.05	5.62	4.15	5.47	4.00	5.74
2.60	4.30	7.10	4.65	6.07	4.20	6.76	3.80	8.37	4.05	6.17	4.00	6.54	4.05	5.52			4.00	5.62
2.80	4.65	4.14			4.25	6.56	3.80	8.36					4.10	5.50				

	Station 8		Station 11		Station 12	
Ice Thick [m]		0.53		0.54		0.52
Ice Bottom [m]		0.48		0.50		0.48
LakeBottom [m]		2.80		2.60		2.75
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	1.35	8.66	1.10	8.09	1.05	9.63
0.80	3.20	7.35	2.00	7.43	2.35	8.00
1.00	3.95	6.48	3.50	6.61	3.60	5.35
1.20	4.00	6.29	3.80	5.64	4.00	4.60
1.40	4.00	6.13	3.85	5.57	4.10	4.29
1.60	4.00	6.09	3.95	5.31	4.10	4.29
1.80	4.00	6.05	4.10	5.31	4.10	4.19
2.00	4.00	6.02	4.10	5.29	4.10	4.16
2.20	4.00	5.97	4.20	5.28	4.10	4.13
2.40	4.00	5.94	4.20	5.21	4.10	4.14
2.60	4.00	5.94			4.15	4.03

Date: 031191

	Station 2		Station 2E		Station 2W		Station 4	
Ice Thick [m]		0.50		0.49		0.53		0.50
Ice Bottom [m]		0.45		0.44		0.48		0.45
LakeBottom [m]		3.05		2.80		2.90		3.05
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	2.15	9.49	2.25	7.85	2.25	9.79	2.25	9.20
0.80	4.00	9.49	3.50	7.31	4.00	9.44	3.40	9.43
1.00	4.00	9.42	4.05	7.26	4.10	9.31	3.75	9.29
1.20	3.95	9.33	4.05	7.26	4.05	9.30	4.10	9.12
1.40	3.90	9.29	4.20	7.58	4.00	9.37	4.10	8.89
1.60	3.90	9.29	4.20	7.80	4.00	9.30	4.10	8.76
1.80	3.90	9.54	4.25	7.85	4.00	9.29	4.10	8.74
2.00	4.00	9.54	4.30	8.29	4.00	9.24	4.10	8.71
2.20	4.00	9.22	4.25	8.11	4.00	9.29	4.10	8.59
2.40	4.15	8.56	4.40	8.20	4.00	9.22	4.05	8.64
2.60	4.45	8.32	4.95	8.34	4.05	9.38	4.05	8.64
2.80	4.80	5.13			4.15	9.27	4.05	8.63

	Station 4E		Station 4W		Station 6		Station 6E		Station 6W	
Ice Thick [m]		0.51		0.50		0.51		0.51		0.52
Ice Bottom [m]		0.46		0.47		0.47		0.47		0.48
LakeBottom [m]		2.75		2.70		3.05		2.55		2.70
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	2.20	9.13	2.40	8.40	2.25	9.43	2.40	7.73	2.60	8.35
0.80	4.20	9.05	4.00	9.15	3.90	7.63	4.05	8.25	4.15	7.59
1.00	4.20	8.87	4.05	9.13	4.00	7.38	4.05	8.13	4.15	7.51
1.20	4.20	8.78	4.05	9.08	4.00	7.28	4.10	8.08	4.15	7.44
1.40	4.20	8.67	4.05	8.94	4.00	7.27	4.05	8.01	4.10	7.38
1.60	4.20	8.71	4.05	8.89	4.00	7.27	4.05	7.99	4.10	7.36
1.80	4.20	8.71	4.05	8.71	4.00	7.21	4.05	7.97	4.10	7.35
2.00	4.20	8.64	4.05	8.70	4.00	7.17	4.05	7.97	4.10	7.34
2.20	4.20	8.57	4.05	8.82	4.00	7.18	4.05	8.01	4.10	7.35
2.40	4.20	8.54	4.05	8.83	4.00	7.16	4.05	8.04	4.10	7.41
2.60	4.20	8.65	4.05	8.79	4.00	7.16			4.10	7.54
2.80					4.00	7.24				

	Station 8		Station 11		Station 12	
Ice Thick [m]		0.53		0.53		0.53
Ice Bottom [m]		0.49		0.49		0.49
LakeBottom [m]		2.80		2.60		2.75
Depth [m]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]	Temp [C]	D.O. [mg/l]
0.60	2.25	8.11	1.65	7.75	2.10	9.63
0.80	3.65	7.59	3.30	8.01	3.25	9.69
1.00	4.05	7.57	4.05	7.88	4.05	8.42
1.20	4.05	7.57	4.15	7.92	4.25	8.04
1.40	4.10	7.70	4.15	7.86	4.25	7.73
1.60	4.10	7.73	4.15	7.88	4.25	7.74
1.80	4.05	7.71	4.10	7.87	4.25	7.59
2.00	4.05	7.73	4.10	7.89	4.25	7.49
2.20	4.05	7.76	4.15	7.90	4.25	7.44
2.40	4.05	7.75	4.15	7.89	4.25	7.44
2.60	4.05	7.75			4.25	7.40

Date: 031891

	Station 2	Station 2E	Station 2W	Station 4	Station 4E	Station 4W	Station 6	Station 6E	Station 6W
Ice Thick [m]	0.48	0.45	0.48	0.48	0.48	0.48	0.50	0.48	0.47
Ice Bottom [m]	0.43	0.41	0.43	0.44	0.44	0.44	0.45	0.44	0.42
LakeBottom [m]	3.05	2.80	2.90	3.05	2.75	2.70	3.05	2.55	2.70

	Station 2		Station 2E		Station 2W		Station 4		Station 4E		Station 4W		Station 6		Station 6E		Station 6W	
Depth	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	3.05	12.69	3.30	12.22	3.40	14.31	3.00	12.75	3.40	11.73	3.60	10.84	3.25	9.37	3.75	11.06	3.60	10.20
0.80	4.00	12.68	4.10	12.63	4.20	13.39	4.20	12.88	4.00	11.83	4.15	10.62	4.05	9.65	4.20	11.44	4.20	9.55
1.00	4.05	12.68	4.25	12.28	4.25	12.70	4.20	12.66	4.10	11.92	4.20	10.55	4.25	10.13	4.25	11.60	4.25	9.45
1.20	4.00	12.62	4.40	12.09	4.25	12.55	4.20	12.41	4.10	11.92	4.20	10.52	4.25	10.15	4.25	11.65	4.25	9.42
1.40	4.00	12.63	4.40	12.03	4.25	12.37	4.25	12.20	4.10	11.90	4.20	10.51	4.25	10.18	4.25	11.65	4.25	9.45
1.60	4.10	12.57	4.40	11.94	4.25	12.28	4.25	11.29	4.10	11.89	4.20	10.49	4.25	10.18	4.25	11.61	4.25	9.48
1.80	4.10	12.59	4.40	11.88	4.25	12.24	4.25	11.44	4.10	11.86	4.20	10.49	4.25	10.21	4.25	11.62	4.25	9.49
2.00	4.20	12.48	4.40	11.84	4.25	12.09	4.25	11.16	4.10	11.88	4.20	10.49	4.20	10.25	4.25	11.70	4.25	9.50
2.20	4.20	12.43	4.40	11.84	4.30	12.16	4.25	11.22	4.10	11.94	4.20	10.51	4.20	10.27	4.25	11.78	4.25	9.56
2.40	4.40	12.12	4.40	11.84	4.35	12.12	4.25	11.18	4.10	12.04	4.20	10.65	4.20	10.31	4.25	11.66	4.25	10.12
2.60	4.60	12.21	4.75	11.45	4.40	11.74	4.25	11.23	4.15	12.01	4.20	10.75	4.20	10.33			4.30	9.71
2.80	5.00	9.85			4.45	11.04	4.25	11.30					4.25	10.50				

	Station 8	Station 11	Station 12
Ice Thick [m]	0.50	0.50	0.49
Ice Bottom [m]	0.45	0.45	0.45
LakeBottom [m]	2.80	2.60	2.75

	Station 8		Station 11		Station 12	
Depth	Temp	D.O.	Temp	D.O.	Temp	D.O.
[m]	[C]	[mg/l]	[C]	[mg/l]	[C]	[mg/l]
0.60	2.95	10.77	2.30	13.55	2.85	14.80
0.80	4.00	10.53	3.40	13.75	3.70	14.03
1.00	4.10	10.41	3.85	13.51	4.20	13.55
1.20	4.10	10.35	4.00	13.26	4.20	13.30
1.40	4.10	10.33	4.05	13.07	4.30	12.98
1.60	4.05	10.28	4.05	13.00	4.35	12.97
1.80	4.05	10.27	4.05	12.96	4.35	12.96
2.00	4.05	10.27	4.05	12.95	4.35	12.96
2.20	4.05	10.28	4.05	12.90	4.35	12.99
2.40	4.05	10.36	4.45	11.99	4.35	13.04
2.60	4.05	10.34			4.35	12.27

APPENDIX D

Depth averaged dissolved oxygen concentrations: 1989–1990, 1990–1991

Depth averaged dissolved oxygen concentrations, 1989-90 [mg/l]

Sta	12/22	1/2	1/9	1/16	1/23	1/29	2/6	2/12	2/22	2/27	3/13
1		8.6	7.9	8.7	11.2	12.7	13.0	15.6	15.8	12.2	14.1
2	11.8	9.4	8.7	8.7	10.6	12.5	13.6	15.5	15.8	13.2	15.1
2E			7.8	8.7	11.4	12.1	12.3	15.1	14.6	13.1	14.9
2W			8.8	8.9	10.6	12.4	14.3	15.1	15.6	12.8	13.9
3		9.8	8.2	9.2	10.6	12.8	14.4	15.3	15.9	13.8	14.6
4	10.6	9.8	8.6	9.5	11.4	12.8	14.3	15.7	15.5	13.7	14.9
4E			8.2	9.3	11.4	12.6	13.0	15.0	14.9	14.1	15.2
4W			8.2	10.0	11.6	12.9	13.9	16.0	15.3	13.1	15.2
5		9.9	8.7	10.2	12.4	13.3	13.7	15.8	15.6	14.5	16.2
6	10.3	9.8	8.7	10.2	12.5	13.7	13.6	16.2	15.9	14.2	16.0
6E			8.1	10.9	12.3	13.1	12.3	16.4	14.2	14.4	15.9
6W			8.3	9.9	12.2	13.9	14.6	16.4	15.3	13.2	15.4
7		10.3	8.7	11.1	12.6	13.9	14.0	16.5	15.6	15.3	16.6
8		10.4	8.6	11.8	13.5	14.3	14.6	17.1	16.1	14.5	17.9
9			9.1	11.5	14.0	14.9	15.8	18.1	16.6	15.3	19.3
10		10.9	10.5	13.6	16.4	17.0	17.5	19.2	16.1	15.4	20.4
11			10.9	15.3	15.8	17.8	18.5	20.5	17.5	15.8	19.7
12	12.9	12.0	12.0	14.4	16.4	17.9	18.4	20.8	17.6	16.8	19.6
All	11.3	10.3	9.1	11.1	13.1	14.4	15.1	17.2	16.0	14.3	16.9

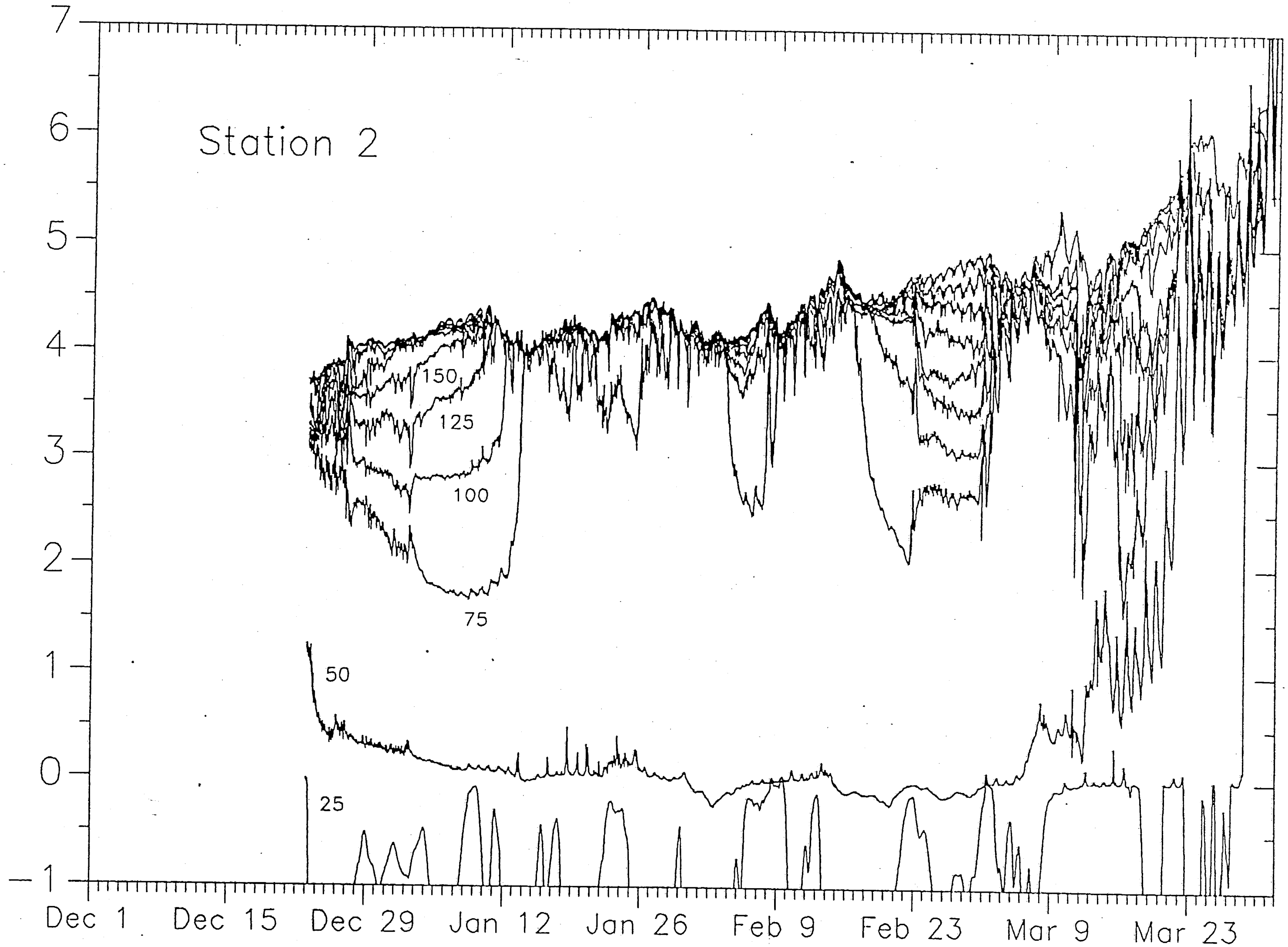
Depth averaged dissolved oxygen concentrations, 1991 [mg/l]

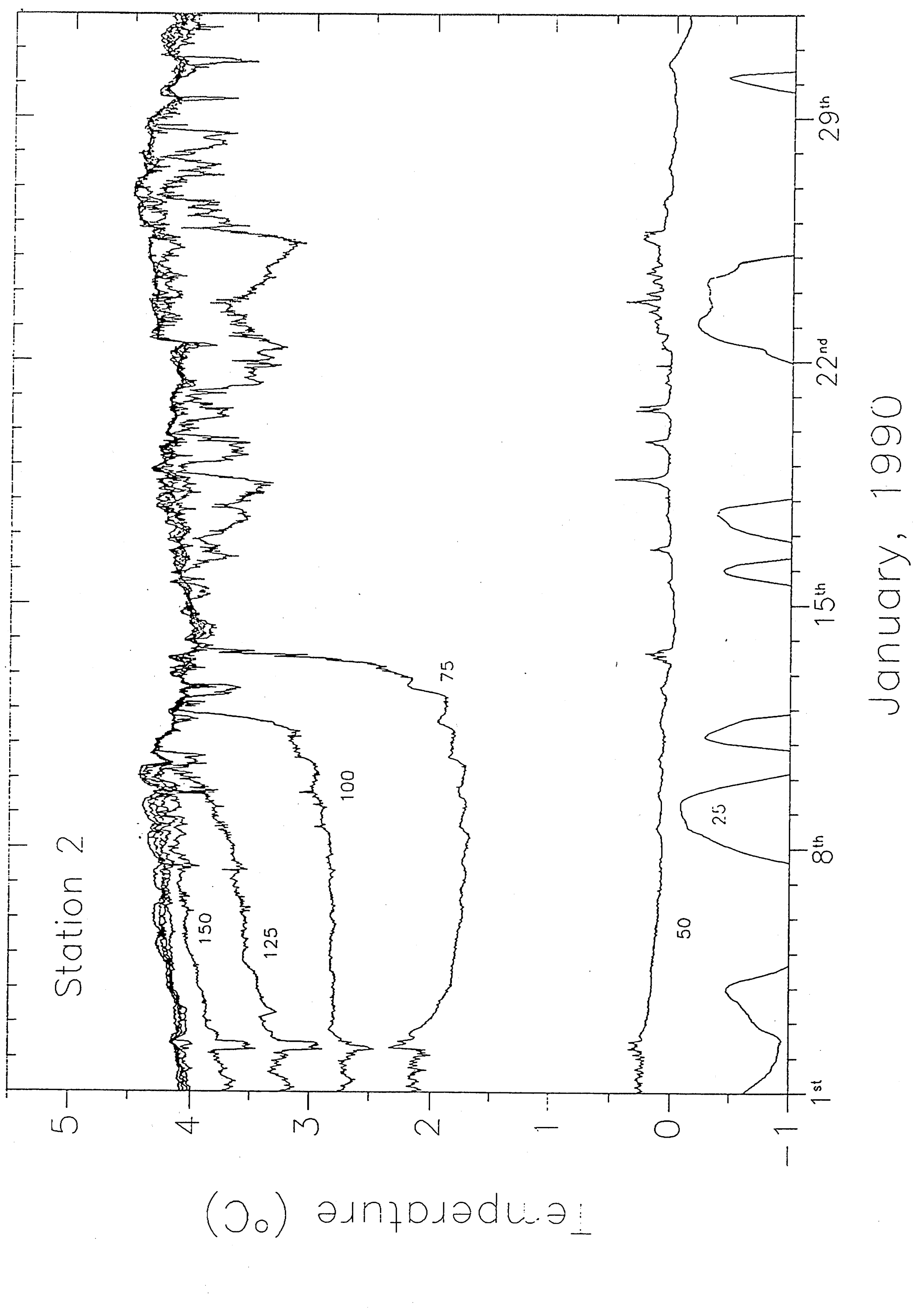
Sta	1/3	1/10	1/16	1/25	1/31	2/6	2/11	2/14	2/20	2/27	3/4	3/6	3/8	3/11	3/18
2	7.50	6.27	4.57	3.94	2.67	6.02	7.61	8.74	8.06	6.97	6.87	6.52	7.30	8.68	12.2
2e						3.56	5.74	7.61	8.10	7.30	7.21	7.02	7.21	7.83	12.0
2w						3.56	7.87	8.52	7.42	6.83	6.62	6.88	7.76	9.35	12.5
4	6.96	6.24	4.94	3.59	3.01	4.11	7.34	8.77	7.37	6.73	5.75	7.53	8.21	8.88	11.8
4e						3.49	7.14	7.98	7.89	6.72	6.26	6.27	6.72	8.76	11.9
4w						5.38	6.05	7.18	7.65	6.26	5.81	6.83	6.91	8.85	10.6
6	6.98	6.30	5.19	3.36	2.77	3.87	7.11	7.77	6.64	6.63	5.81	5.91	6.07	7.46	10.1
6e						3.86	7.05	7.47	5.99	6.25	5.01	5.63	6.02	8.01	11.6
6w						4.51	6.60	7.44	6.82	6.24	5.63	5.53	6.24	7.52	9.65
8						4.23	6.34	6.45	6.62	6.05	5.59	6.03	6.44	7.73	10.4
11	6.38	5.54	3.92	3.45	2.62	3.08	5.51	6.41	5.65	6.44	5.57	5.39	5.94	7.88	13.1
All	6.95	6.12	4.74	3.54	2.77	4.14	6.52	7.33	6.87	6.48	5.9	6.16	6.67	8.16	11.5

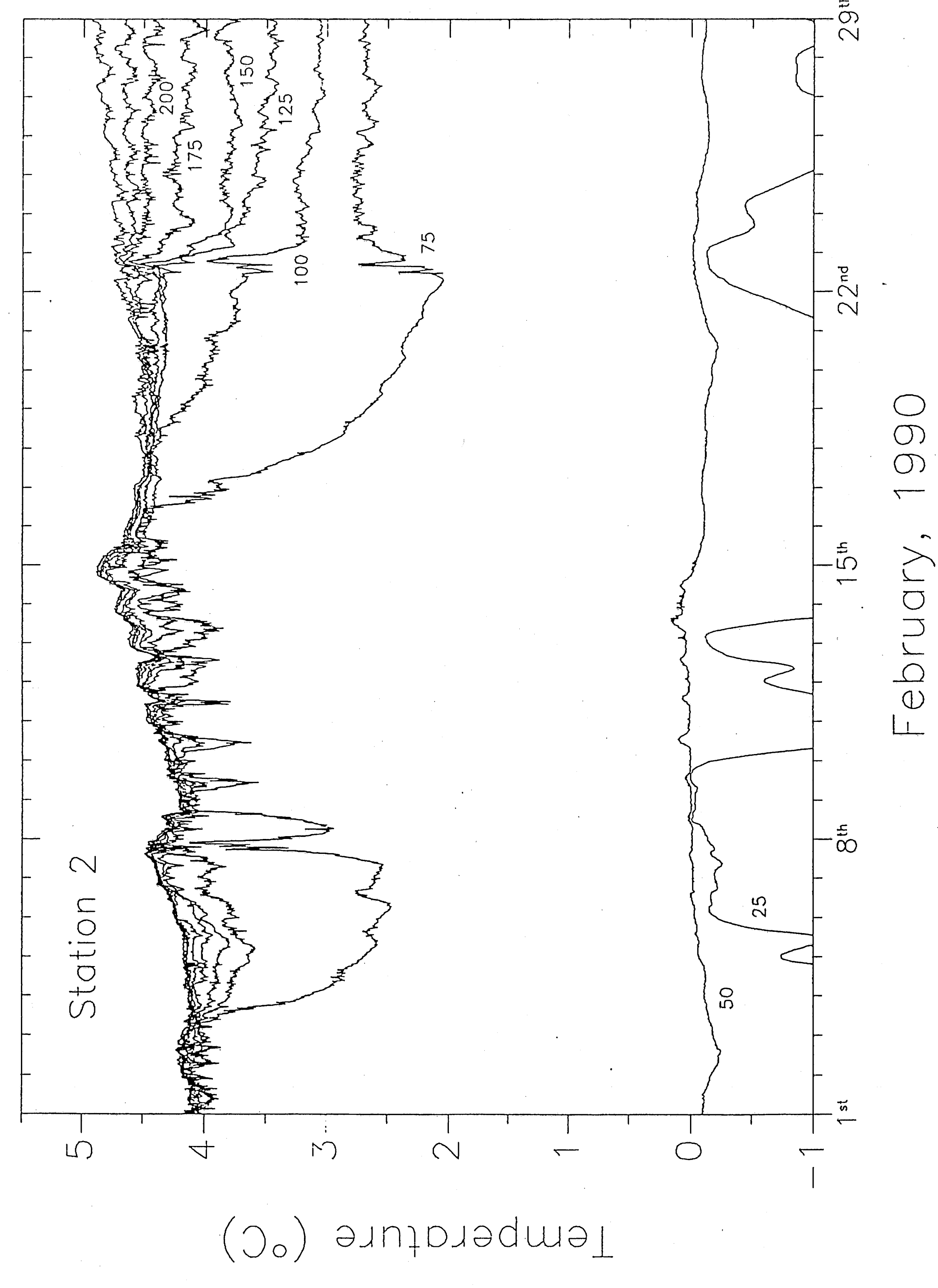
APPENDIX E

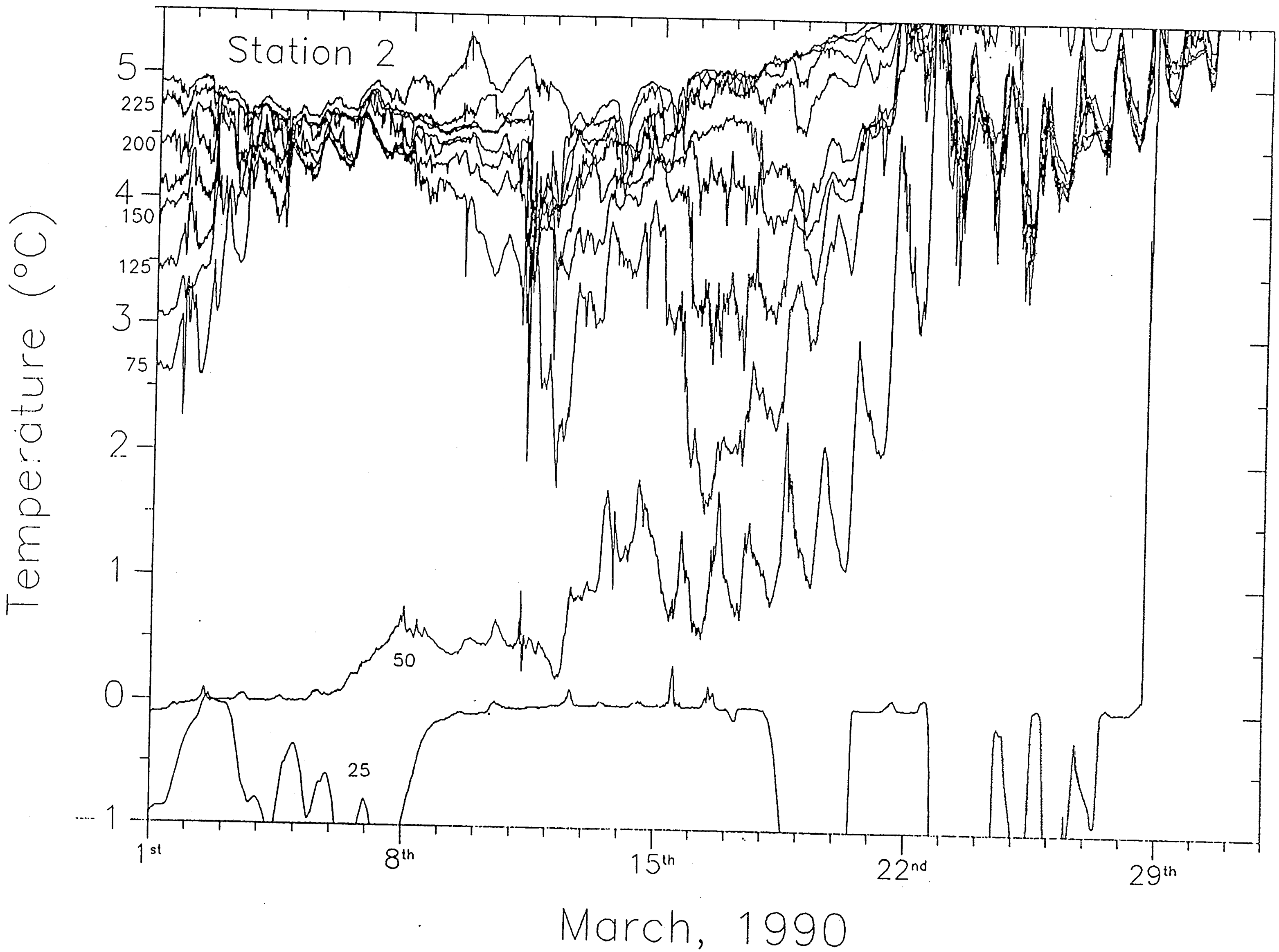
Time series plots of temperatures measured by CSI dataloggers

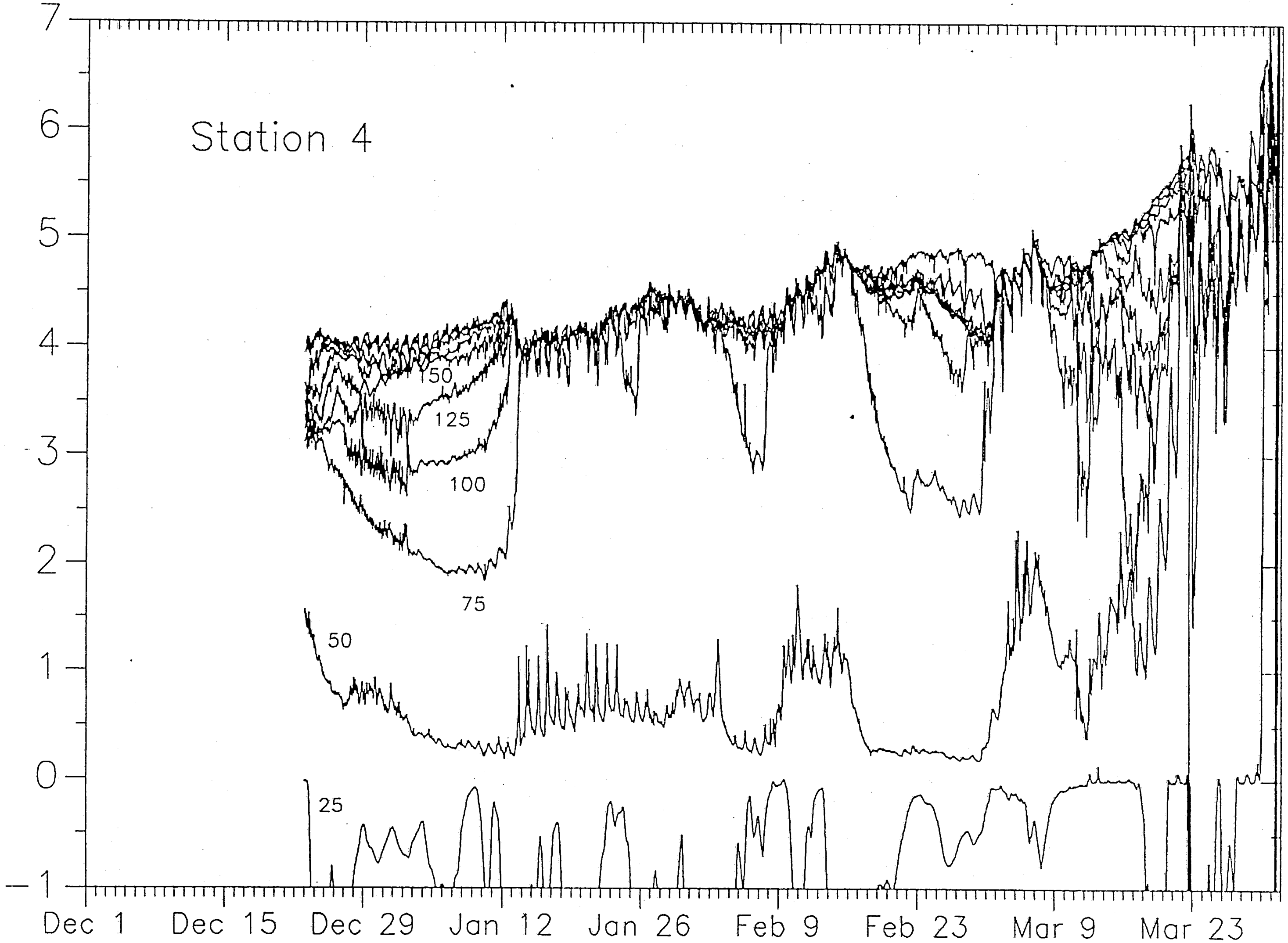
(Note: Plots include depths of measurements in cm.)

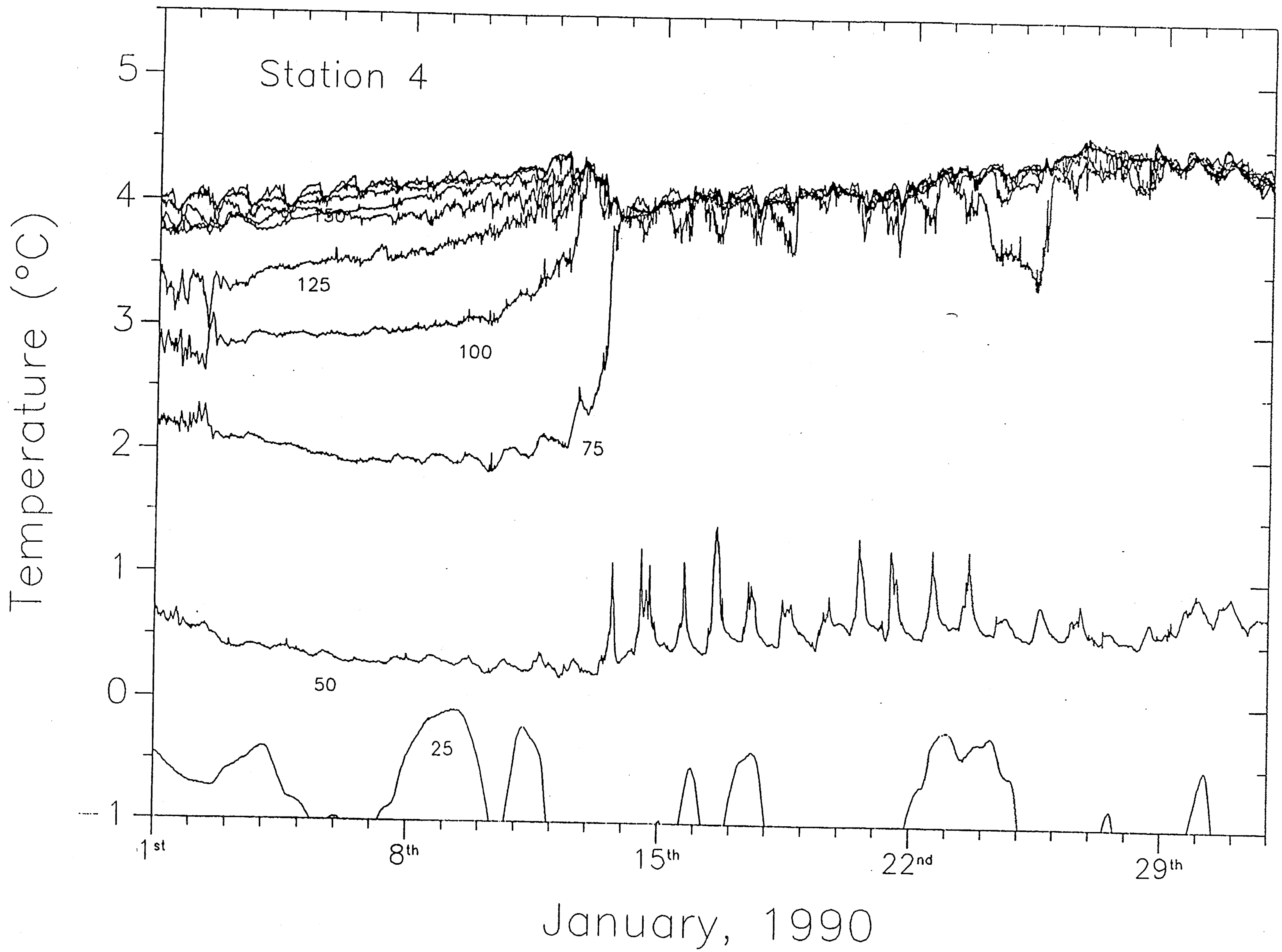

Station 2
7
6
5
4
3
2
1
0
-1
150
125
100
75
50
25
Dec 1
Dec 15
Dec 29
Jan 12
Jan 26
Feb 9
Feb 23
Mar 9
Mar 23

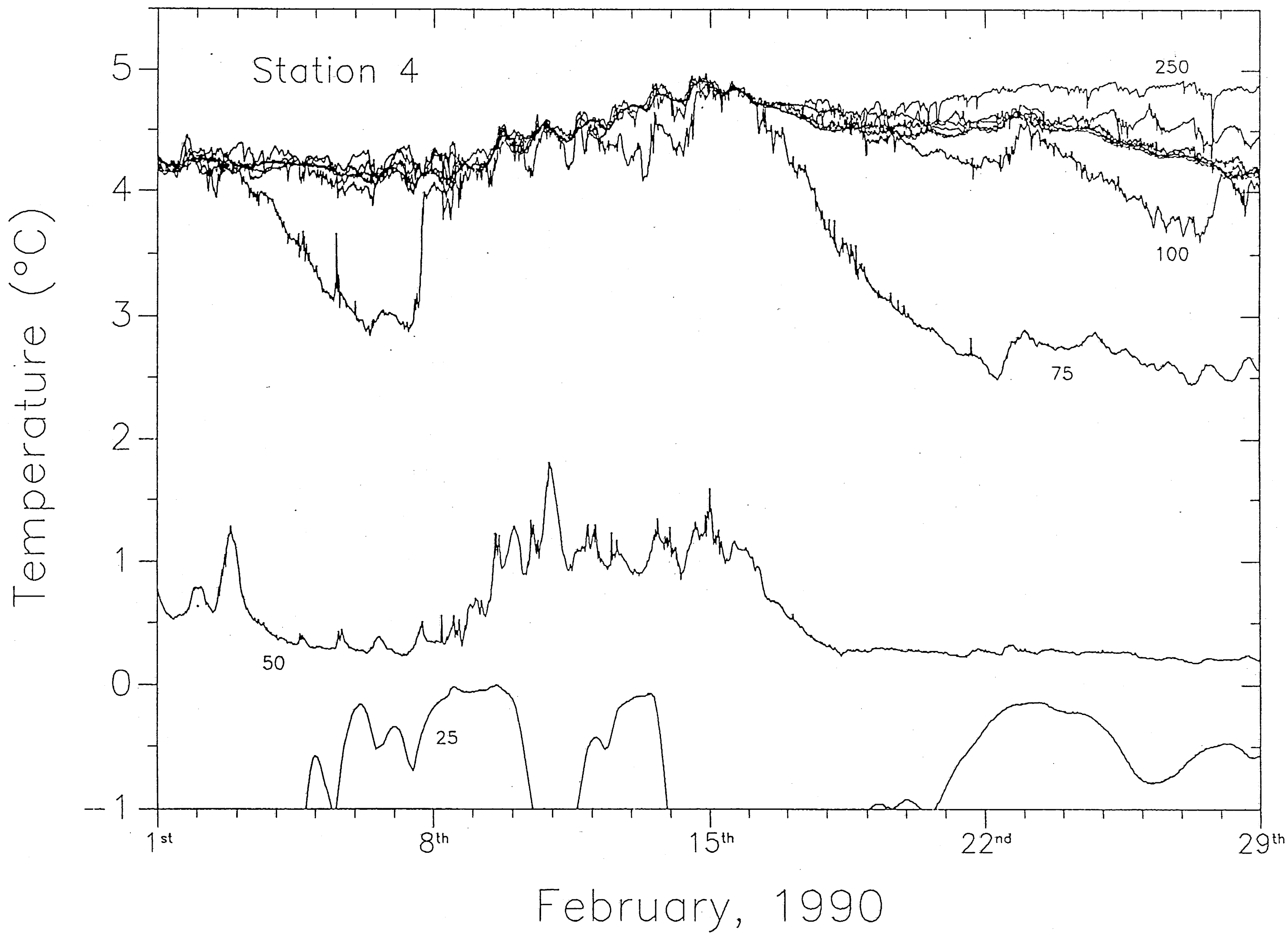

Station 2
Temperature (°C)
5
4
3
2
1
0
−1
150
125
100
75
50
25
1st
8th
15th
22nd
29th
January, 1990

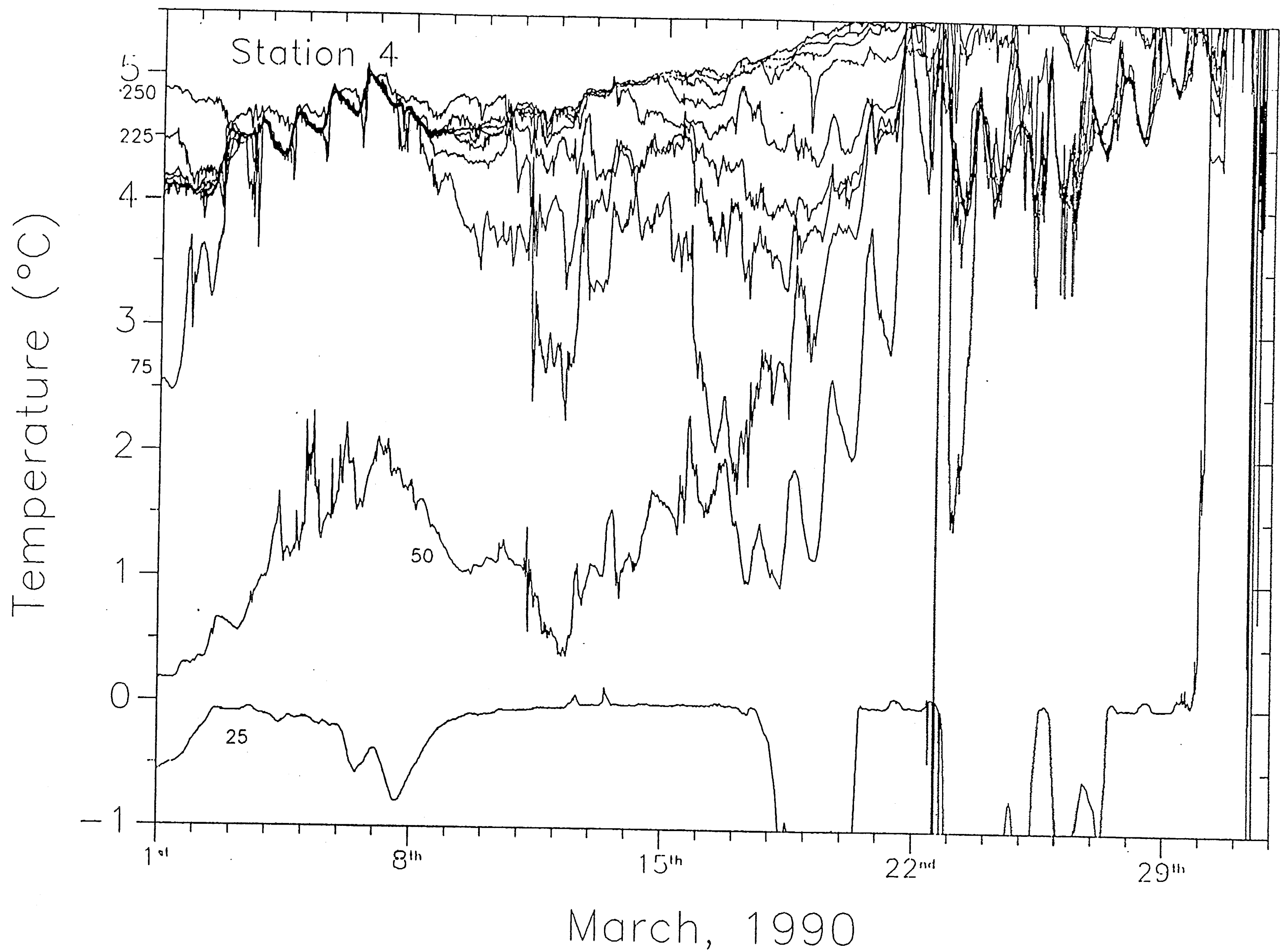

Station 2
Temperature (°C)
February, 1990
1st
8th
15th
22nd
29th
-1
0
1
2
3
4
5
25
50
75
100
125
150
175
200


Station 2
Temperature (°C)
5
4
3
2
1
0
-1
225
200
150
125
75
50
25
1st
8th
15th
22nd
29th
March, 1990

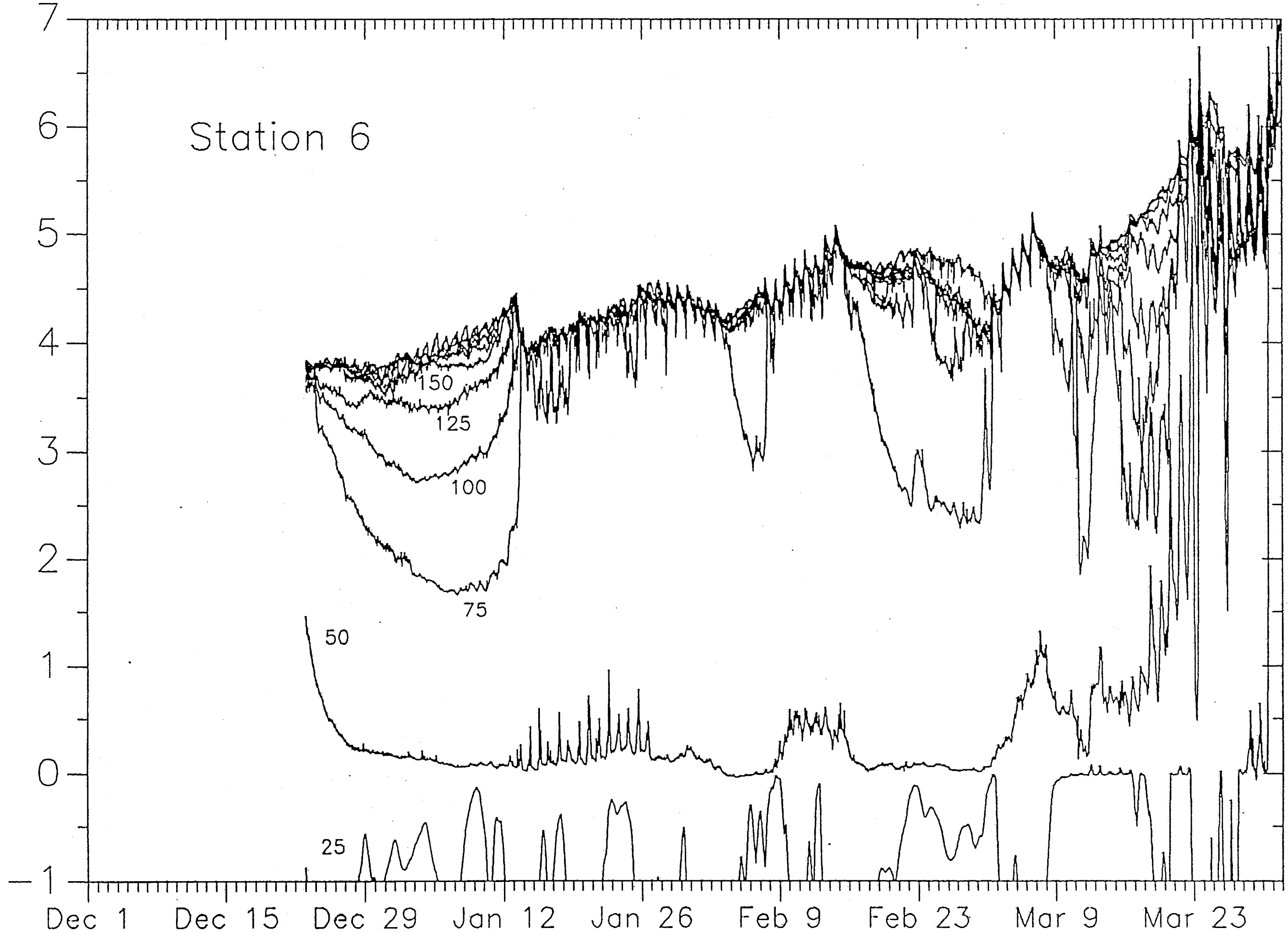

Station 4
7
6
5
4
3
2
1
0
−1
150
125
100
75
50
25
Dec 1
Dec 15
Dec 29
Jan 12
Jan 26
Feb 9
Feb 23
Mar 9
Mar 23

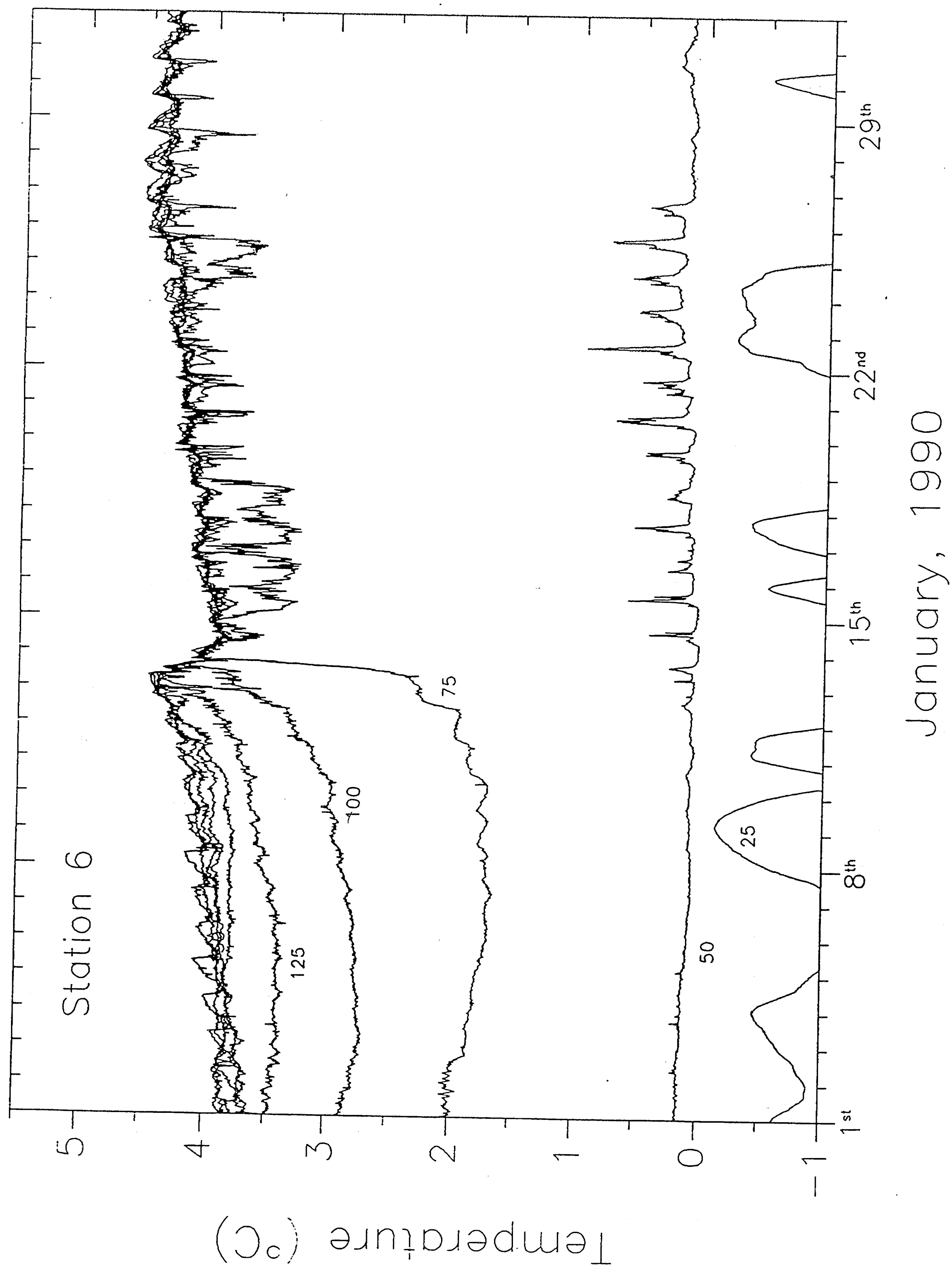

Station 4
5
4
3
2
1
0
-1
Temperature (°C)
150
125
100
75
50
25
1st
8th
15th
22nd
29th
January, 1990

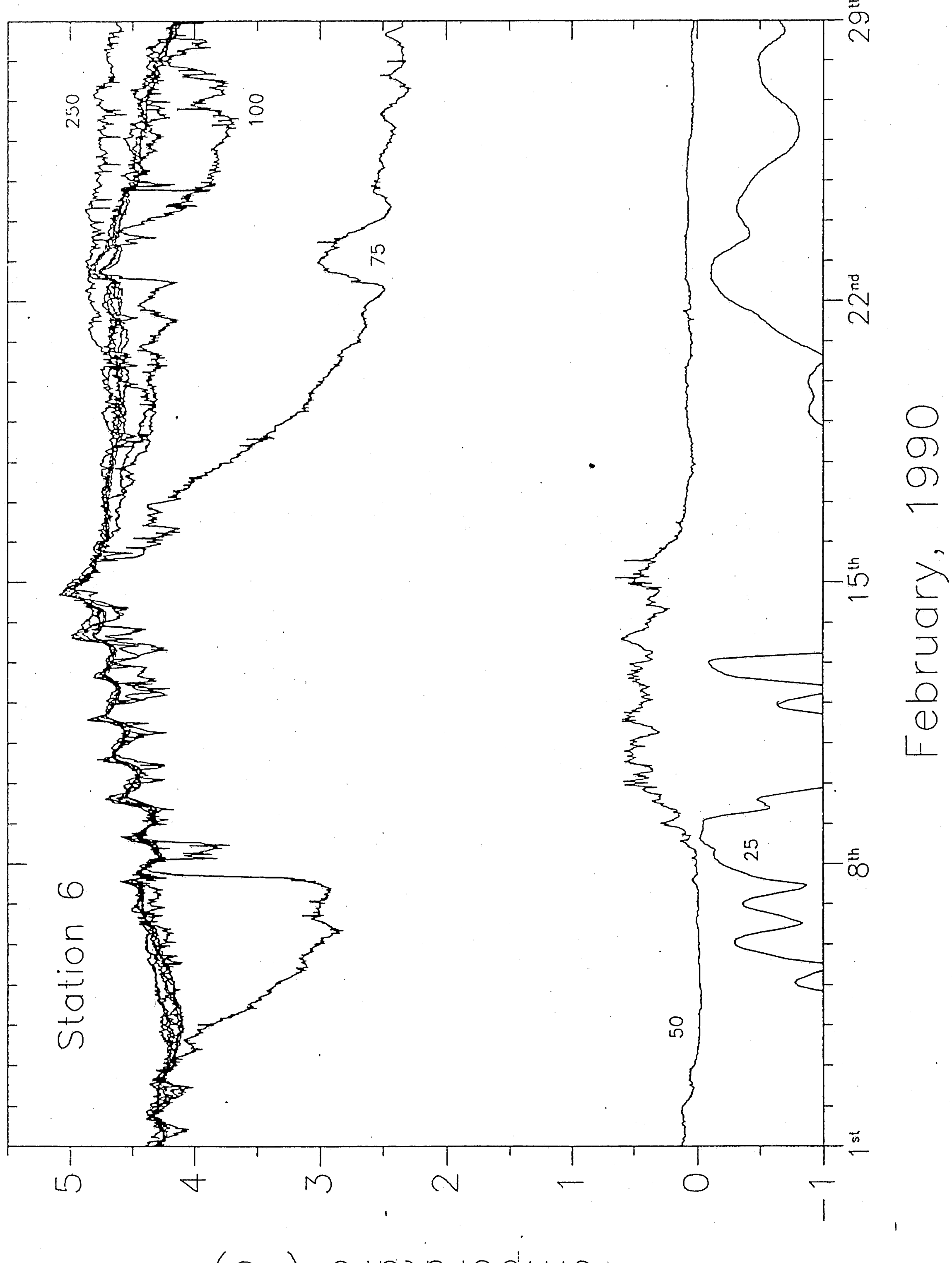

Station 4
250
100
75
50
25
Temperature (°C)
5
4
3
2
1
0
-1
1st
8th
15th
22nd
29th
February, 1990

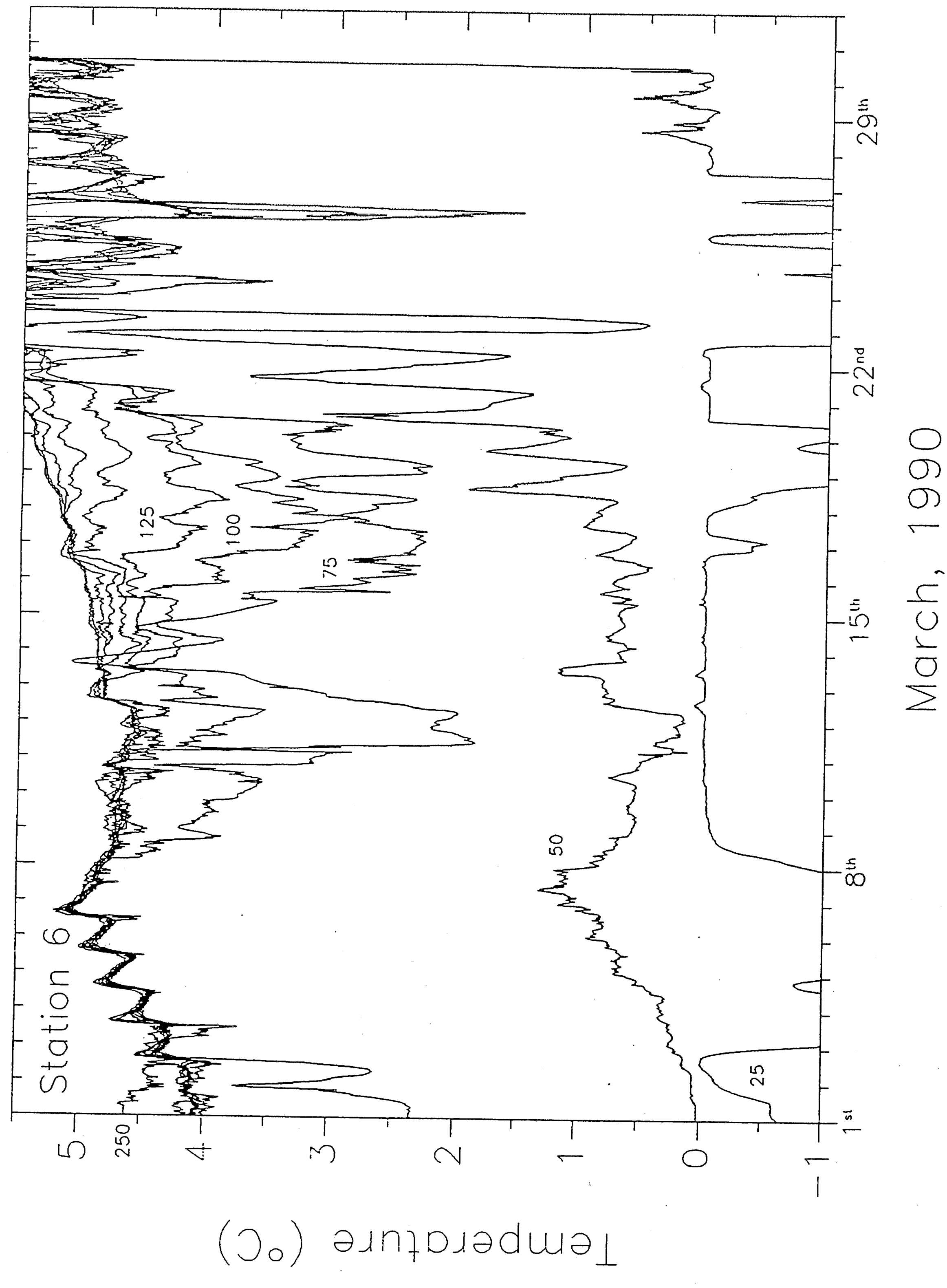


Station 4
Temperature (°C)
5
4
3
2
1
0
−1
250
225
75
50
25
1st
8th
15th
22nd
29th
March, 1990


Station 6
7
6
5
4
3
2
1
0
−1
150
125
100
75
50
25
Dec 1
Dec 15
Dec 29
Jan 12
Jan 26
Feb 9
Feb 23
Mar 9
Mar 23


Station 6
Temperature (°C)
5
4
3
2
1
0
−1
125
100
75
50
25
1st
8th
15th
22nd
29th
January, 1990


Station 6
250
100
75
50
25
5
4
3
2
1
0
−1
1st
8th
15th
22nd
29th
February, 1990
Temperature (°C)



Station 6
250
125
100
75
50
25
5
4
3
2
1
0
-1
Temperature (°C)
1st
8th
15th
22nd
29th
March, 1990

APPENDIX F

Surface and underwater photosynthetically active radiation (PAR) measurements: 1989–1990, 1990–1991.

Date: 021590 Ice: 49 cm Snow: 0.0 cm

Hs = H0*exp(-alpha(z))

alpha= 0.548 m-1 H0= 0.521

where Hs is downwelling/surface PAR
H0 is downwelling/surface PAR at underside of ice
z is depth below ice cover [m]

Depth below W.S. [m]	Depth below ice [m]	Surface PAR [*]	Down-welling PAR [*]	Fraction of surface PAR	Spher-ical PAR [*]	Fraction of surface PAR
0.00	-0.49			1.000		
0.49	0.00					
0.60	0.11	150.0	65.3	0.435	91.0	0.607
0.80	0.31	152.1	66.0	0.434	89.6	0.589
1.20	0.71	146.2	50.6	0.346	70.4	0.482
1.60	1.11	142.9	41.1	0.288	51.9	0.363
2.00	1.51	138.4	31.4	0.227	38.9	0.281
2.00	1.51	132.3	29.8	0.225	36.3	0.274
1.20	0.71	131.2	47.7	0.364	60.5	0.461
0.60	0.11	129.6	52.4	0.404	76.5	0.590

*note: units of PAR are micro-Einsteins s-1 m-2

Date: 020791 Ice: 48 cm Snow: 0.0 cm

Hs = H0*exp(-alpha(z))

alpha= 0.754 m-1 H0= 0.289

where Hs is downwelling/surface PAR
H0 is downwelling/surface PAR at underside of ice
z is depth below ice cover [m]

Depth below W.S. [m]	Depth below ice [m]	Surface PAR [*]	Down-welling PAR [*]	Fraction of surface PAR	Spher-ical PAR [*]	Fraction of surface PAR
-0.03	-0.48			1.000		
0.45	0.00					
0.50	0.05	977.4	270.3	0.277	436.2	0.446
0.60	0.15	977.4	246.7	0.252	399.8	0.409
0.80	0.35	977.4	221.5	0.227	359.6	0.368
1.00	0.55	977.4	186.8	0.191	299.0	0.306
1.20	0.75	977.4	163.5	0.167	254.3	0.260
1.40	0.95	977.4	140.5	0.144	213.1	0.218
1.60	1.15	977.4	118.6	0.121	178.5	0.183
1.80	1.35	977.4	101.5	0.104	153.4	0.157
2.00	1.55	977.4	86.9	0.089	131.4	0.134
2.50	2.05	977.4	60.3	0.062	77.0	0.079

*note: units of PAR are micro-Einsteins s-1 m-2

Date: 030791 Ice: 53 cm Snow: 0.0 cm

Hs = H0*exp(-alpha(z))

alpha= 0.759 m-1 H0= 0.172

where Hs is downwelling/surface PAR
H0 is downwelling/surface PAR at underside of ice
z is depth below ice cover [m]

Depth below W.S. [m]	Depth below ice [m]	Surface PAR [*]	Down-welling PAR [*]	Fraction of surface PAR	Spher-ical PAR [*]	Fraction of surface PAR
-0.03	-0.52			1.000		
0.49	0.00					
0.50	0.01	1379	178.4	0.129	325.2	0.236
0.60	0.11	1373	183.9	0.134	331.9	0.242
0.70	0.21	1374	187.0	0.136	313.6	0.228
0.80	0.31	1376	184.6	0.134	289.0	0.210
0.90	0.41	1381	176.7	0.128	268.4	0.194
1.00	0.51	1385	166.2	0.120	248.3	0.179
1.20	0.71	1383	141.6	0.102	210.4	0.152
1.40	0.91	1383	119.4	0.086	175.5	0.127
1.60	1.11	1383	101.7	0.074	147.7	0.107
1.80	1.31	1382	87.2	0.063	125.3	0.091
2.00	1.51	1382	75.7	0.055	107.9	0.078
2.50	2.01	1383	50.9	0.037	65.1	0.047
2.00	1.51	1386	75.5	0.054	109.0	0.079
1.50	1.01	1387	110.7	0.080	163.5	0.118
1.00	0.51	1384	165.8	0.120	248.7	0.180
0.80	0.31	1386	189.2	0.137	295.9	0.213
0.60	0.11	1379	191.8	0.139	345.9	0.251

*note: units of PAR are micro-Einsteins s-1 m-2

Date: 030791   Ice: 53 cm   Snow: 4.0 cm

Hs = H0*exp(-alpha(z))

alpha= 0.558 m-1   H0= 0.021

where Hs is downwelling/surface PAR
H0 is downwelling/surface PAR at underside of ice
z is depth below ice cover [m]

Depth below W.S. [m]	Depth below ice [m]	Surface PAR [*]	Down-welling PAR [*]	Fraction of surface PAR	Spher-ical PAR [*]	Fraction of surface PAR
-0.03	-0.52			1.000		
0.49	0.00					
0.50	0.01	1292	32.5	0.025	37.7	0.029
0.60	0.11	1389	28.7	0.021	42.9	0.031
0.70	0.21	1297	24.1	0.019	40.3	0.031
0.80	0.31	1367	23.6	0.017	41.9	0.031
0.90	0.41	1253	20.3	0.016	37.4	0.030
1.00	0.51	1214	18.4	0.015	34.0	0.028
1.20	0.71	1292	17.8	0.014	32.0	0.025
1.40	0.91	1238	15.3	0.012	26.5	0.021
1.60	1.11	1353	15.1	0.011	25.2	0.019
1.80	1.31	1284	13.0	0.010	20.8	0.016
2.00	1.51	1345	12.0	0.009	18.7	0.014
2.50	2.01	1364	9.7	0.007	10.8	0.008
2.00	1.51	1360	12.3	0.009	18.6	0.014
1.50	1.01	1392	16.3	0.012	27.1	0.019
1.00	0.51	1230	18.8	0.015	34.8	0.028
0.80	0.31	1295	21.7	0.017	42.2	0.033
0.60	0.11	1264	22.1	0.017	43.0	0.034

*note: units of PAR are micro-Einsteins s-1 m-2

Date: 031391 Ice: 50 cm Snow: 0.1 cm

Hs = H0*exp(-alpha(z))

alpha= 0.760 m-1 H0= 0.296

where Hs is downwelling/surface PAR
H0 is downwelling/surface PAR at underside of ice
z is depth below ice cover [m]

Depth below W.S. [m]	Depth below ice [m]	Surface PAR [*]	Down-welling PAR [*]	Fraction of surface PAR	Spher-ical PAR [*]	Fraction of surface PAR
-0.05	-0.50			1.000		
0.45	0.00					
0.50	0.05	1115	305.7	0.274	537.9	0.482
0.60	0.15	1246	319.1	0.256	540.6	0.434
0.70	0.25	1211	298.5	0.246	490.6	0.405
0.80	0.35	1162	267.3	0.230	431.3	0.371
0.90	0.45	1100	236.7	0.215	374.9	0.341
1.00	0.55	1274	249.9	0.196	390.8	0.307
1.20	0.75	1280	216.9	0.169	333.0	0.260
1.40	0.95	1287	185.6	0.144	281.1	0.218
1.60	1.15	1296	162.6	0.125	243.0	0.188
1.80	1.35	1301	139.6	0.107	207.1	0.159
2.00	1.55	1292	119.8	0.093	176.7	0.137
2.50	2.05	1298	77.2	0.059	119.6	0.092
2.00	1.55	1305	119.7	0.092	177.3	0.136
1.50	1.05	1327	176.8	0.133	226.3	0.171
1.00	0.55	1323	259.0	0.196	401.7	0.304
0.80	0.35	1318	298.4	0.226	481.9	0.366
0.60	0.15	1296	331.2	0.256	565.7	0.436

*note: units of PAR are micro-Einsteins s-1 m-2

Date: 031991 Ice: 45 cm Snow: 0.0 cm

Hs = H0*exp(-alpha(z))

alpha= 0.791 m-1 H0= 0.375

where Hs is downwelling/surface PAR
H0 is downwelling/surface PAR at underside of ice
z is depth below ice cover [m]

Depth below W.S. [m]	Depth below ice [m]	Surface PAR [*]	Down-welling PAR [*]	Fraction of surface PAR	Spher-ical PAR [*]	Fraction of surface PAR
-0.04	-0.45			1.000		
0.41	0.00					
0.50	0.09	1363	446.0	0.327	776.0	0.569
0.60	0.19	1374	428.7	0.312	740.3	0.539
0.70	0.29	1373	404.9	0.295	683.5	0.498
0.80	0.39	1381	379.1	0.275	627.8	0.455
0.90	0.49	1381	350.0	0.253	565.8	0.410
1.00	0.59	1382	324.8	0.235	514.4	0.372
1.20	0.79	1390	280.2	0.202	432.7	0.311
1.40	0.99	1390	238.4	0.172	363.9	0.262
1.60	1.19	1398	207.1	0.148	312.2	0.223
1.80	1.39	1391	176.0	0.127	262.0	0.188
2.00	1.59	1403	152.4	0.109	225.3	0.161
2.50	2.09	1407	95.2	0.068	146.9	0.104
2.00	1.59	1408	154.3	0.110	228.1	0.162
1.50	1.09	1411	226.4	0.160	343.3	0.243
1.00	0.59	1411	334.5	0.237	529.0	0.375
0.80	0.39	1412	391.7	0.277	640.7	0.454
0.60	0.19	1413	453.8	0.321	763.2	0.540

*note: units of PAR are micro-Einsteins s-1 m-2

APPENDIX G

Cascade aerator performance, 1991

Julian Day	System Flowrate (l/s)	C,in (mg/l)	C,out (mg/l)	Cascade Efficiency (%)	D.O. Input (kg/d)
31	0.00	0.00	0.00	0.0	0.00
32	0.00	1.95 *	9.55 *	75.2	0.00
33	64.28 *	2.34	9.66	75.4	40.66
34	64.28	2.72	9.77	75.5	39.12
35	64.28	3.11	9.87	75.7	37.57
36	64.28	3.50	9.98	75.8	36.03
37	64.28	3.88	10.09	76.0	34.48
38	64.28	4.27 *	10.20 *	76.2	32.93
39	69.37 *	4.93	10.30	75.4	32.18
40	69.37	5.59	10.40	74.4	28.82
41	69.37	6.25	10.50	73.2	25.45
42	69.37	6.91	10.60	71.7	22.09
43	69.37	7.57 *	10.70 *	69.8	18.73
44	69.37	7.52	10.66	69.2	18.80
45	69.37	7.47	10.62	68.7	18.87
46	69.37	7.42 *	10.58 *	68.3	18.94
47	0.00	0.00	0.00	0.0	0.00
62	0.00	0.00	0.00	0.0	0.00
63	0.00	5.00 *	10.39 *	76.4	0.00
64	49.05 *	5.31	10.43	76.0	21.70
65	49.05	5.62	10.48	75.5	20.58
66	49.05	5.94 *	10.53 *	75.1	19.45
67	49.05	6.39	10.65	75.3	18.08
68	49.05	6.84	10.78	75.7	16.70
69	49.05	7.29	10.91	76.0	15.33
70	49.05	7.75	11.04	76.5	13.96
71	49.05	8.20	11.17	77.1	12.58
72	49.05	8.65 *	11.30 *	77.8	11.21
73	49.05	9.21	11.42	77.8	9.36
74	49.05	9.77	11.55	77.8	7.51
75	49.05	10.34	11.67	77.8	5.65
76	49.05	10.90	11.80	77.9	3.80
77	49.05	11.46 *	11.92 *	78.0	1.95

* note: measured values