WINTER ICE REMOVAL FROM STOCK PONDS

By

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PREFACE

This report is concerned with two winters of research on ice removal from stock water ponds. During the first winter the research was conducted on Sangre Lake, a recreation lake. Electricity was available to the site. The winter was characterized by low temperatures for a much longer period of time than is usual for Oklahoma. This research was of an exploratory and equipment development nature.

As the results from the first year were encouraging, the equipment was altered and moved to more typical stock water ponds on a ranch approximately 15 miles southwest of Stillwater, Oklahoma. Electricity was run to two of the ponds. To simulate conditions in more remote locations, a wind-electric generator was directly connected to an electric trolling motor on the third pond. A significant change in jet direction was used on all three ponds. The water jet was directed upward at a 45° angle toward the shore on all three ponds.

This last winter was a milder than usual winter for Oklahoma, and as a result fewer than usual data were collected.

A popular article on the first year's experiment was given nation-wide coverage by the agricultural press. Numerous inquiries resulted from this article, indicating that the research was addressing a real problem, and that people were eager for answers. Most of the inquiries were from people in states north of Oklahoma.

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INTRODUCTION

The purpose of this study was to find a practical, reliable, and inexpensive method of melting ice on farm ponds. In many places ice forms on the surface of water basins during the winter. The ice layer often impedes or prevents livestock from obtaining water, so farmers and ranchers routinely chop holes in the ice to allow accessibility to water for livestock. This study suggests an alternative means of removing ice from the near-shore surface of ponds.

The objective of the study was to test the performance of two methods of melting ice in farm ponds. A trolling motor and two submersible pumps were used to circulate warmer water from greater depths to the surface of the pond.

The study included measuring the area of the hole opened in the ice, ice thickness, and occasionally the temperature profile of the pond. Daily temperature and wind travel information were recorded at the Agronomy Weather Station in Stillwater.

EXPERIMENTAL APPARATUS - 1979

Two different apparatuses were used. They were the Thruster Electric Outboard and the submersible pump. The common concept was to pump water of higher temperature from deeper depths to melt ice on the surface of the pond. Since temperature below the ice layer is relatively uniform, it was not necessary to pump water from great depths.

Thruster Electric Outboard

This apparatus consisted of the Thruster Electric Outboard motor and switch, a battery, a battery charger, and a raft. Figure 1 shows the raft to which the Thruster Electric Outboard motor is attached and the housing for the battery and the battery charger.

The Thruster Electric Outboard was powered by the 12-volt battery which was enclosed in the white box as shown in Figure 2. The raft that carried the propeller (Figure 3) was connected to the anchor-pole by two connecting rods. The pole was driven into the pond bottom. This connection was made in such a way as to allow free movement of the raft as the elevation of the water level changes. Free movement of the raft was achieved by hinging the connecting rods to the raft and the anchor-pole and allowing enough height of the anchor-pole above the water level so the lower connecting rod would not interfere with the raft movement.

Submersible Pump

The experimental apparatus for this method consisted of a submersible pump, galvanized pipe and a timer. Figure 4 shows the submersible pump apparatus just before installation. The power of the pump was 248.6 W. A rectangular piece of metal sheet was tied to the pump to prevent mud and other dirt from being sucked by the pump. The pump was set 18 m from the shore. A 12 m long galvanized pipe was connected to the pump to convey water from deeper sections of the pond to the surface water, 6 m away from the shore. A 90^{o} elbow was connected to the tip of the pipe to direct water flow upwards. Maybe this would not have been necessary had there been a greater difference in depth between the point at which water was sucked to the point the water was discharged.

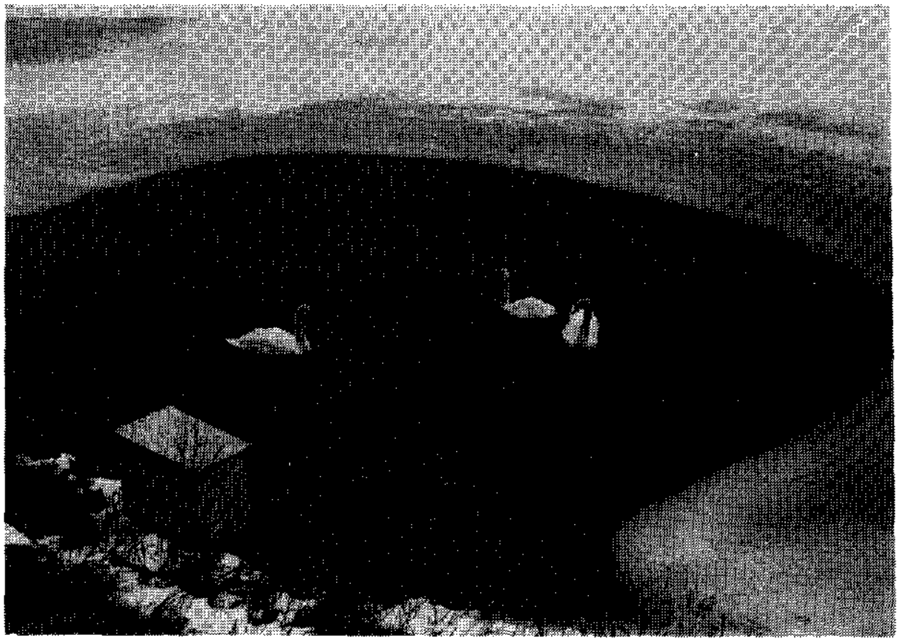

Figure 1. On-Site View of the Thruster Electric Outboard Apparatus. 1979.

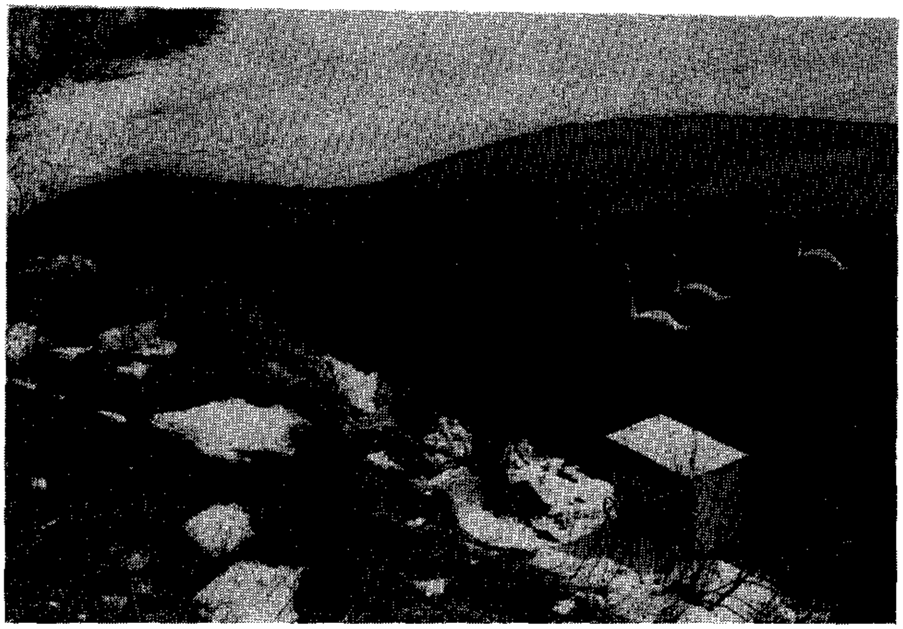

Figure 2. Instrument Shelter for Battery, Charger, and Control for Thruster Motor. 1979.

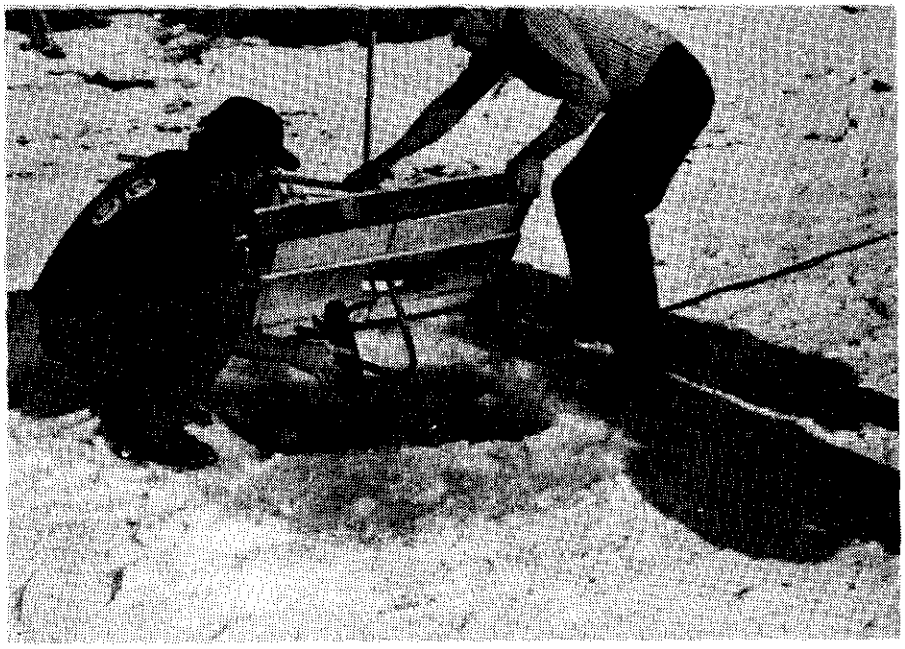

Figure 3. Installing the Thruster Electric Outboard. 1979.

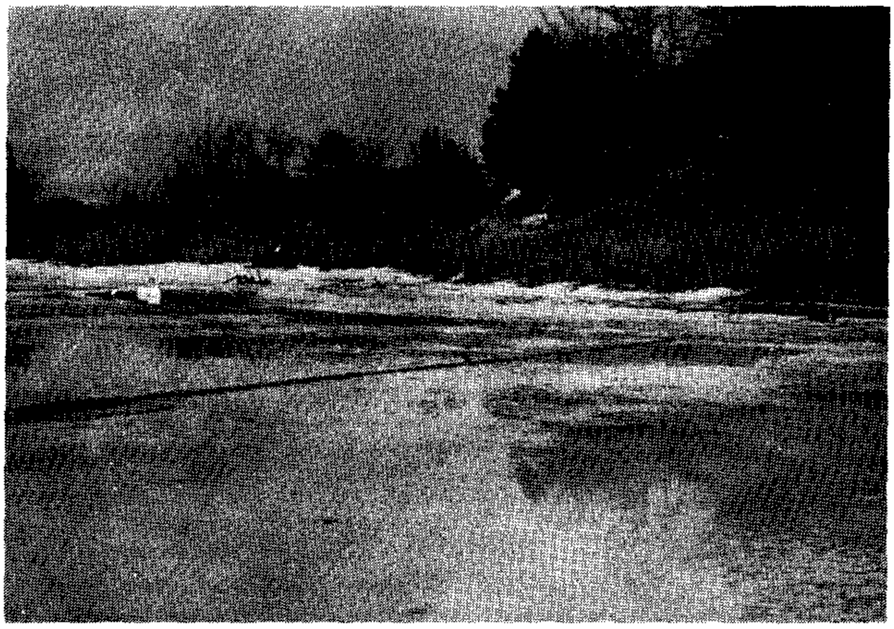

Figure 4. Experimental Apparatus of the Submersible Pump. 1979.

The pump was connected to the power supply by the use of underwater cable. Figure 4 shows the pump on top of the ice under which it was installed. A valve was also installed to regulate flow so the motor would not be overloaded.

EXPERIMENTAL APPARATUS - 1980

Three ponds located approximately 22 kilometers west of Stillwater on the Durham Ranch were selected for the study location. Two different techniques were used to circulate water of higher temperature from deeper parts of the pond.

Wind Powered Pump

A 12 volt wind-driven generator (Wincharger - Figure 5 and 6) was used to power an electric outboard trolling motor (Figures 7, 8, and 9). The trolling motor was attached to a redwood raft which was 0.6 meters wide and 0.9 meters long. The trolling motor propellor extended approximately 0.4 meters below the water surface and was directed toward shore at an angle of 45 degrees from the horizontal. The raft that supported the trolling motor was connected to an anchor pole by two 1.1 meter connecting links. The connector links allowed vertical movement of the raft as the water level changed. The trolling motor speed control was mounted on another pole above maximum water level. The Wincharger was mounted on a 7.6 meter tower to place it above surrounding obstructions to air flow. Heavy duty waterproof conductor was buried between the Wincharger and trolling motor control, Figure 10. The wire was encased in pipe at the shoreline to prevent cattle from "tramping" it out. The wind generator was connected directly to the

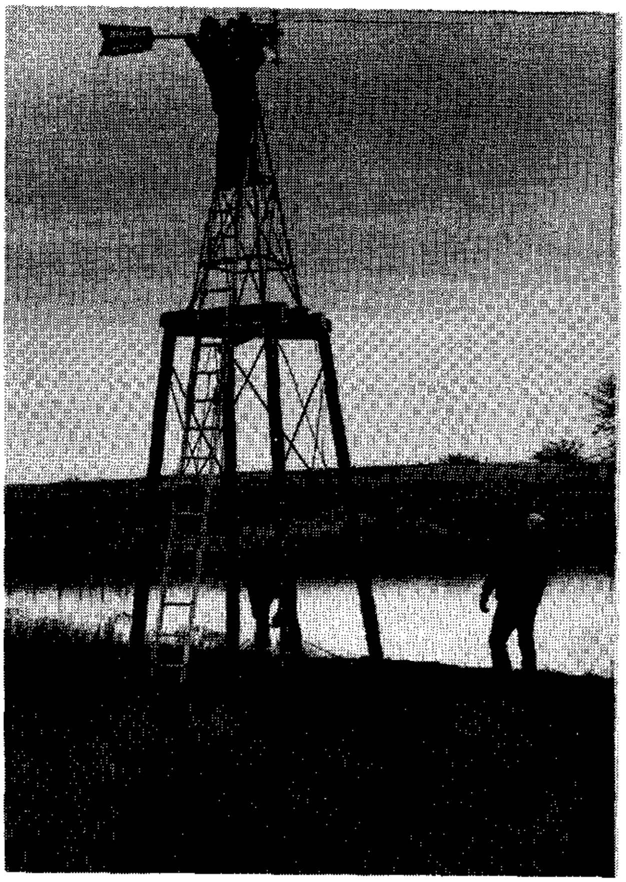

Figure 5. View of Installation of Wind Generator on Tower

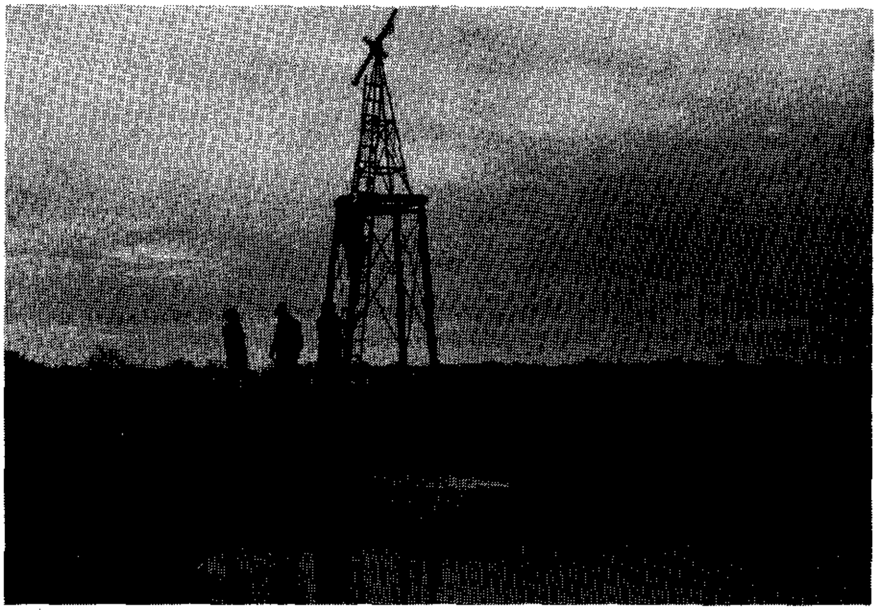

Figure 6. View of Completed Wind Generator Installation

Figure 7. Installing Anchor Pole

Figure 8. View of Raft and Troller Motor

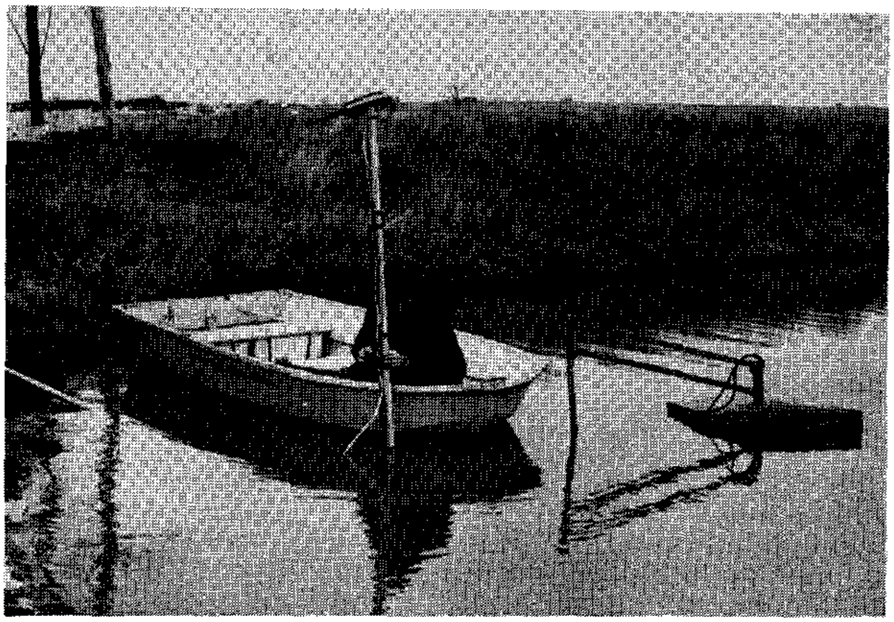

Figure 9. View of Control and Raft in the Water

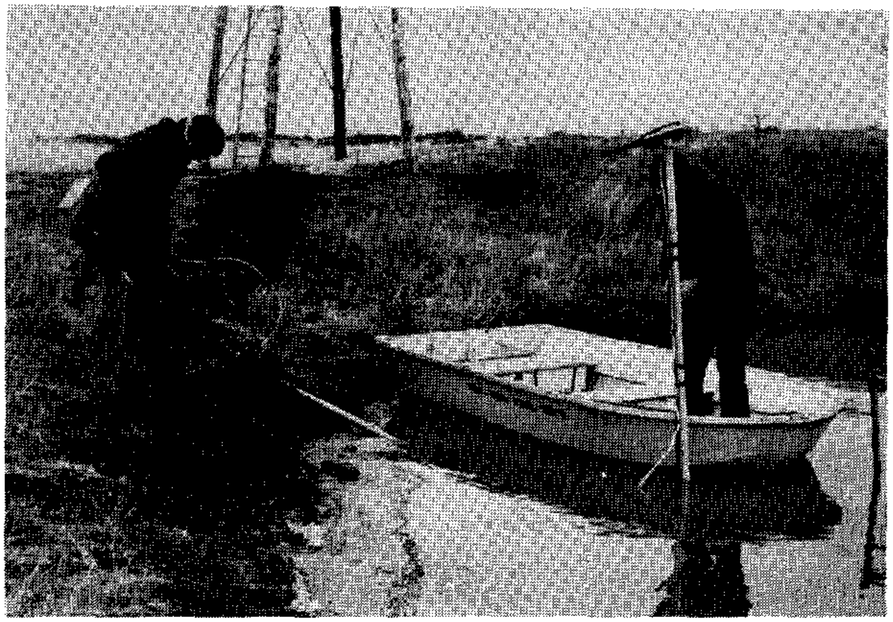

Figure 10. View of Wiring Burial

trolling motor. No intermediate storage batteries were used.

Submersible Pumps

Two one-third horsepower (249 watt) submersible pumps discharging through approximately 10 meters of 3.8 cm diameter (1½ inch) galvanized pipe were placed in two other ponds. These 115-volt pumps were equipped with time clocks to allow variations in operating time per day. The submersible pumps were mounted on a rectangular piece of thin gauge metal to support the pump on the pond bottom and to prevent mud and other debris from entering the pump. The discharge was oriented toward the shoreline. Again, heavy-duty waterproof conductor was buried between the electric meter and pond. The wire was encased in pipe at the shoreline.

PROCEDURE - 1979

Observation started on January 10, 1979 and ended on February 21, 1979. The first observation for the submersible pump, however, was made on January 24, 1979. The Thruster Electric Outboard was turned off on January 16, 1979 until January 26, 1979.

It was attempted to measure area of melted ice, ice-thickness and temperature profile of the water regularly. Generally, it was not possible to make observations on a regular basis because of bad weather and bad road conditions. It was impossible to measure ice-thickness and water temperature profiles regularly because of the danger that the ice layer might break in.

On each observation date pictures of the melted ice by both methods were taken. The pictures in each case were approximately taken from the same spot. The area of melted ice was planimetered from these pictures.

The Thruster Electric Outboard set-up had a raft of known dimensions, whereas the submersible pump did not. In the case of the Thruster Electric Outboard, the raft was used to compute the area of melted ice by proportion. In the case of ice melted by the submersible pump, the area of the ice melted for January 31, 1979 was physically measured and the rest were computed proportionally.

Maximum and minimum daily temperatures and daily wind travel were obtained from the Agronomy Weather Station in Stillwater, Oklahoma. The daily average temperature (Table 1) was computed as the average of the daily maximum and minimum.

PROCEDURE - 1980

All pumps were started on January 28, 1980 after ice covered all three ponds for the first time of the year on January 27. Observations were made almost every day thereafter when ice was present. The pumps were turned off on February 20 and then started again on February 29. The Wincharger was out of service from February 11-13. All pumps were stopped for the season on March 7, 1980.

The area of the hole kept open in the ice was physically measured on each observation day. The areas were calculated by matching the hole dimensions to geometric shapes or by drawing the hole to scale and measuring the internal area.

Ice thickness measurements were made on each observation day at a location on the opposite side of the pond from the pump. These measurements were made approximately one meter from the shoreline.

Temperature profiles were recorded only on January 31 and February 1. The ice thickness would not support a person's weight safely on any

Table 1. Daily Average Temperature and Wind Travel for Stillwater for the Months of January and February, 1979

Date	January		February	
	Ave. Temp. (°C)	Wind Travel (Km/day)	Ave. Temp. (°C)	Wind Travel (Km/day)
1	-11.4	-	-14.4	40
2	-14.4	270	-6.7	241
3	-9.2	77	-8.9	135
4	-5.6	43	-8.3	151
5	-6.1	217	-8.9	163
6	-10.3	183	-8.6	71
7	-8.6	200	-6.4	230
8	-11.9	77	-5.6	177
9	-9.4	121	-11.1	277
10	-1.9	64	-6.1	105
11	-5.3	177	2.2	76
12	-3.9	182	3.9	150
13	-3.6	264	-3.9	98
14	-14.7	468	-1.1	61
15	-9.7	132	5.0	100
16	-1.4	171	-4.2	235
17	2.5	138	-8.3	174
18	2.5	123	-6.7	251
19	6.1	143	-0.3	261
20	2.8	88	4.4	272
21	3.9	344	1.7	127
22	3.3	262	5.8	138
23	3.1	82	10.8	227
24	-7.8	547	3.6	288
25	-1.1	121	1.1	241
26	1.9	198	3.1	241
27	-4.4	351	5.3	182
28	-10.3	169	10.6	312
29	-11.9	92		
30	-8.9	158		
31	-13.6	172		

other observation day.

Maximum and minimum daily temperatures and daily wind travel were obtained from the Agronomy Weather Station in Stillwater, Oklahoma. The daily average temperature (Table 2) was computed as the arithmetic average of the daily maximum and minimum.

RESULTS, DISCUSSION, AND CONCLUSIONS - 1979

Table 3 shows the areas of ice melted by each method and the daily average temperature and wind travel for the indicated date of observation. The ice-thickness for most of the study period varied between ten and twenty centimeters. Temperature profile ranged from $0^{o}C$ to $2.5^{o}C$. However, only a few measurements of ice thickness and temperature profile were made during the study period. More ice-thickness measurements than temperature profiles were taken.

Thruster Electric Outboard

Figure 11 shows the area of melted ice by the Thruster Electric Outboard, the daily average temperature, and daily wind travel. As shown in Table 3 and Figure 11, the area of melted ice increased by about 23 m^2 from January 10 to January 12. But the increase in area from January 12 to January 15 was only 8 m^2. This is partly due to low average temperature on January 14 and partly due to reduced extent of influence as the area of melted ice increased. The variation in wind travel did not seem to have any noticeable effect on the area of melted ice.

From January 31 to February 9, the daily average temperature was less than $-5^{o}C$. During this period, the increase in area of the melted

Table 2. Daily Average Temperature and Wind Travel for Stillwater from 20 January to March, 1980

Date	Temperature °C Max	Min	Avg	Km/day	Date	Temperature °C Max	Min	Avg	Km/day
20 Jan	8.9	2.8	5.8	167.4	15 Feb	16.1	2.8	9.4	180.2
21	5.0	2.8	3.9	172.2	16	2.8	-9.4	-3.3	368.5
22	6.1	1.7	3.9	230.1	17	-2.2	-12.8	-7.5	189.9
23	5.6	-2.2	1.7	130.4	18	3.3	-12.2	-4.4	204.4
24	12.8	3.3	8.0	140.0	19	9.4	-1.1	4.2	315.4
25	20.0	2.8	11.4	143.2	20	13.3	0.0	6.6	104.6
26	11.1	1.1	6.1	257.5	21	24.4	11.1	17.8	230.1
27	1.1	-6.1	-2.5	231.7	22	17.2	-0.6	8.3	254.3
28	-2.8	-8.9	-5.8	249.4	23	25.0	-2.2	11.4	222.1
29	-2.8	-8.3	-5.6	235.0	24	11.7	1.7	6.7	138.4
30	-1.1	-7.8	-4.4	165.8	25	7.8	1.1	4.4	173.8
31	-0.6	-12.2	-6.4	273.6	26	5.6	-6.1	-0.2	218.9
1 Feb	-3.9	-12.8	-8.4	78.8	27	14.4	-3.3	5.6	135.2
2	3.9	-1.7	1.1	239.8	28	23.3	2.8	13.0	181.8
3	10.6	-1.7	4.4	217.2	29	25.0	-1.7	11.6	223.7
4	9.4	-1.7	3.8	180.2	1 Mar	1.1	-12.2	-5.6	397.5
5	6.7	-1.7	2.5	45.1	2	-4.4	-17.8	-11.1	169.0
6	11.7	-5.6	3.0	130.4	3	4.4	-14.4	-5.0	383.0
7	7.8	-2.8	2.5	246.2	4	12.8	2.2	7.5	394.3
8	0.6	-2.8	-1.1	196.3	5	17.8	-7.8	5.0	309.0
9	-0.6	-7.2	-3.9	263.9	6	5.6	-3.9	0.8	304.2
10	-1.7	-12.8	-7.2	144.8	7	20.0	6.1	13.0	246.2
11	7.8	-8.9	-0.6	181.8	8	15.0	0.6	7.8	117.5
12	6.1	-10.0	-2.0	125.5	9	13.9	-0.6	6.6	123.9
13	6.7	-0.6	3.0	8.0	10	19.4	-0.6	9.4	112.6
14	13.9	4.4	9.2	98.2					

Table 3. Area of Melted Ice by the Thruster Electric Outboard and the Submersible Pump, and the Daily Average Temperature and Wind Travel for the Indicated Observation Dates

Date	Daily Average Temperature (°C)	Wind Travel (Km/day)	Thruster Electric Outboard	Submersible Pump
1/10/79	-1.9	64	5	-
1/12/79	-3.9	182	28	-
1/15/79	-9.7	132	36	-
1/24/79	-7.8	547	-	9
1/26/79	1.9	198	-	8
1/31/79	-13.6	172	61	3
2/1/79	-14.4	40	62	4
2/2/79	-6.7	241	65	5
2/5/79	-8.9	163	68	4
2/9/79	-11.1	277	76	3
2/12/79	3.9	150	97	4
2/15/79	5.0	100	101	8
2/19/79	-0.3	261	-	9

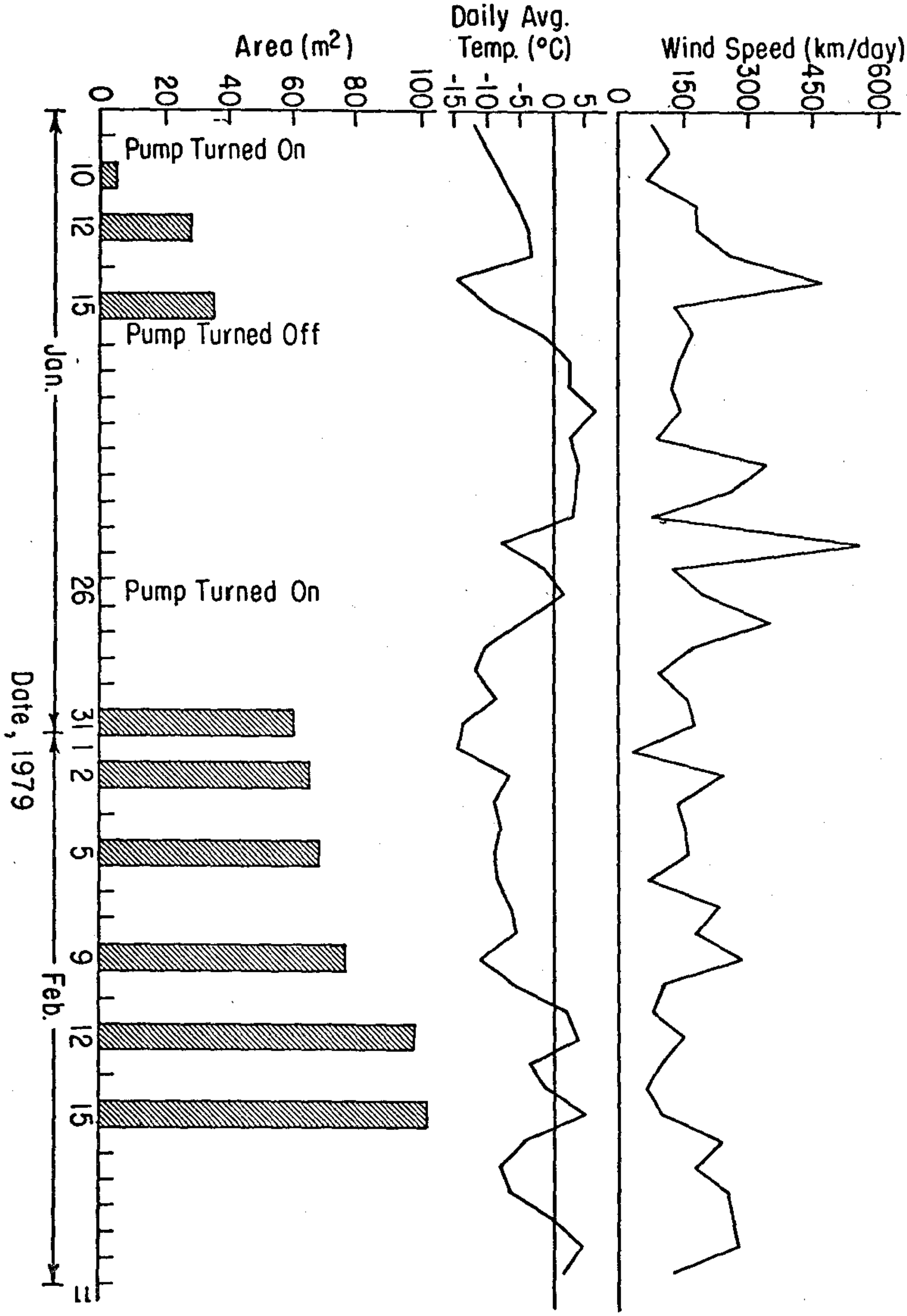

Figure 11. Wind Travel, Average Daily Temperature and Area of Ice by the Thruster Electric Outboard Versus Time.

ice was solely due to the influence of the device and the biggest area of melted ice was 76 m^2. However, for dates when daily average temperature was at times greater than 0^oC, it was difficult to assess the performance of the device in melting ice. What is important in regard to the purpose of the study, however, was the fact that ice can be melted satisfactorily for the farmer to have a free access to the water in a pond. The average area of melted ice was 60 m^2.

The Thruster Electric Outboard can be used to remove ice from stock water ponds. The electric motor was thought to have a short brush life. Measurement of the brush wear indicated about 1/6 of the brushes were used during the season. This apparatus was easy to construct and install, and inexpensive to operate.

Submersible Pump

The tip of the pipe that extended from the submersible pump was about 6 m away from the shore. This was done because it was expected to melt ice up to the shore. However, during the course of the experiment, it never melted ice up to the shore. The biggest area of melted ice was observed on January 24 and February 19 as shown in Table 3 and Figure 12. The ice melting for January 24 could not be used to strongly assess the performance of the pump, because the average daily temperature was above the freezing point for the previous seven days. The performance of the submersible pump to melt ice can be observed in the period from January 31 to February 9. During this period, the biggest area of melted ice as 5 m^2.

The submersible pump was successful in melting ice of limited area while operating at one-fourth time. If used for stock water ponds, the

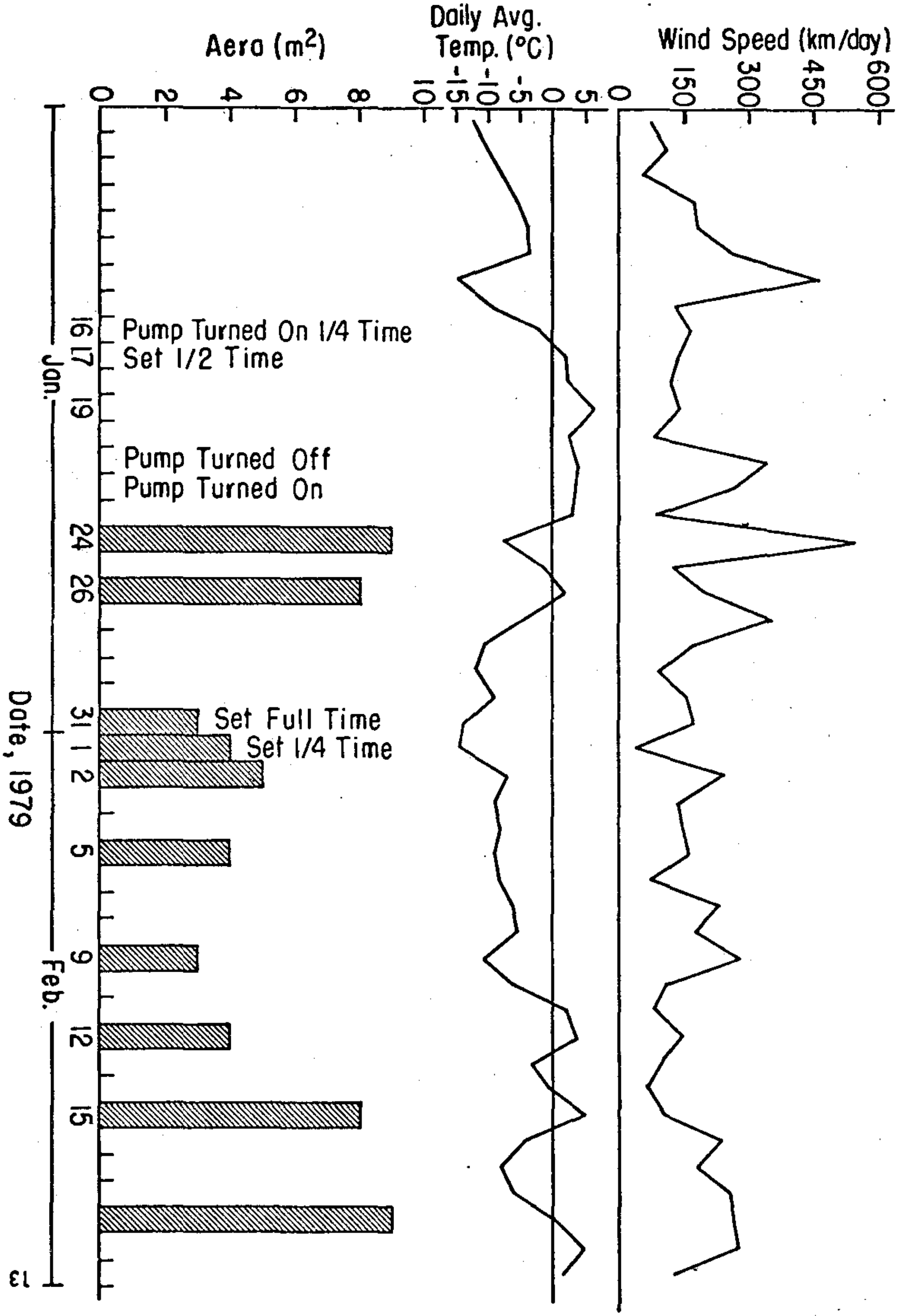

Figure 12. Wind Travel Average Daily Temperature and Area of Melted Ice by the Submersible Pump Versus Time.

outlet would need to be closer to the shore. A 2.5 m diameter hole could be expected with this device operating at one-fourth time. Two meters from the shore would be the recommended distance for the outlet.

RESULTS AND DISCUSSION - 1980

The areas of ice melted by each methods, the daily average temperature, and daily wind travel for the indicated observation days are presented in Table 4. The ice thickness varied between 0 and 8.9 centimeters during the study. Table 5 lists ice thicknesses on indicated observation days for each pond. Temperature profiles for Janaury 31 and February 1 during the period of thickest ice cover are shown in Table 6.

Wind Powered Pump

The area of melted ice, average daily temperature, and daily wind travel for the wind powered pump are shown in Figure 13. The troller motor opened a 33.0 m^2 hole after 24 hours of operation. During the next two days (January 30, 31), the hole increased slightly to 34.7 m^2; however, wind speeds at observation times were not sufficient to operate the pump. These short periods of no pumping allowed a thin layer of ice to form over the hole (Figure 14). The thin ice did not prevent livestock from watering.

Daily wind travel on February 1 dropped to 78.8 km/day, and the open area reduced to 13.8 m^2. The period of January 28 to February 1 best represents the Wincharger's capabilities, since the temperature was below freezing for the entire period.

On January 30 the Wincharger propellor was covered with a thin layer of ice which appeared to reduce the propellor speed. The ice was

Table 4. Area of Melted Ice by the Wind Powered Pump and Two Submersible Pumps, and the Daily Average Temperature and Wind Travel for the Indicated Observation Dates

Observation Date	Daily Average Temperature (°C)	Wind Travel (Km/day)	Area of Melted Ice (m^2)		
			Wincharger Pump	Submersible Pump East Pond	Submersible Pump West Pond
1-28-80	-5.8	249.4	Start	Start	Start
1-29-80	-5.6	235.0	33.0	3.1	1.0
1-30-80	-4.4	165.8	33.0 (1)	14.2	2.9
1-31-80	-6.4	273.6	34.7 (1)	18.4	5.8
2- 1-80	-8.4	78.8	13.8	32.7	23.5
2- 2-80	1.1	239.8	38.1	40.9	26.0
2- 9-80	-3.9	263.9	16.4 (2)	0.2	- (4)
2-10-80	-7.2	144.8	0 (2)	5.3	2.2
2-12-80	-2.0	125.5	- (3)	24.9	39.5
2-17-80	-7.5	189.9	0	2.0	0.1
3- 2-80	-11.1	169.0	8.1	0.4	1.5
3- 3-80	-5.0	383.0	115.7	16.5	87.0

(1) - Thin ice of approximately ¼" thickness or less covered the entire area at observation time.

(2) - Damage to propellor leading edge, which slowed propellor. Propellor repaired and placed back in operation on 13 February 1980.

(3) - Wincharger out of service

(4) - West Pond was only 80% covered with ice and pump discharge was within the open area, so no area measurement was made.

Table 5. Ice Thickness for Indicated Observation Dates

Observation Date	Ice Thickness, cm Wincharger Pond	East Pond	West Pond
1-28-80	1.9	-	-
1-29-80	1.5	-	-
1-30-80	-	-	5.4
1-31-80	7.8	7.3	7.6
2- 1-80	8.3	7.3	8.9
2- 2-80	8.3	6.7	8.9
2- 9-80	-	1.3	1.3
2-10-80	4.8	3.5	3.8
2-12-80	4.1	2.9	1.9
2-17-80	2.9	1.9	2.1
3- 2-80	2.2	2.5	2.2
3- 3-80	3.2	3.2	2.5

Table 6. Temperature Profiles for All Ponds on 31 January and 1 February, 1980

Depth Ft.	Temperature °C Wincharger Pond	East Pond	West Pond
0	1.0	1.0	1.5
1	2.0	1.4	2.7
2	2.0	1.5	2.9
3	1.9	1.5	3.0
4	2.0	1.6	3.0
5	2.1	1.7	3.2
6	2.6	1.7 (@ 5.5')	3.3 (@ 5.5')
7	2.8	-	-
8	3.2	-	-

Depth Ft.	Temperature °C Wincharger Pond	East Pond	West Pond
0	1.7	1.0	1.0
1	2.6	1.7	3.2
2	2.8	1.7	3.1
3	2.8	1.7	3.0
4	2.8	1.8	3.1
5	-	-	3.2

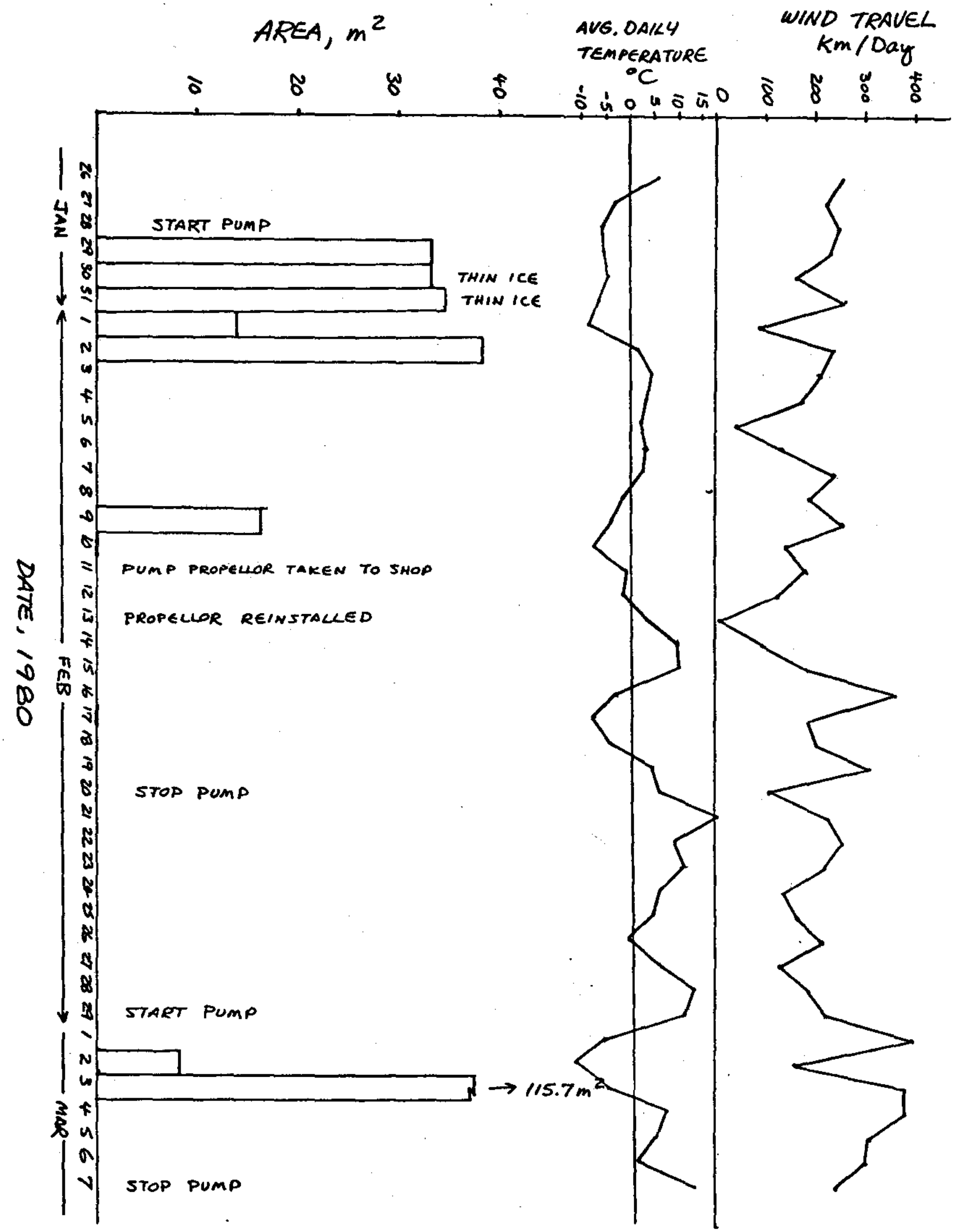

Figure 13. Wind Travel, Average Daily Temperature, and Area of Melted Ice for the Wind Powered Pump Versus Time.

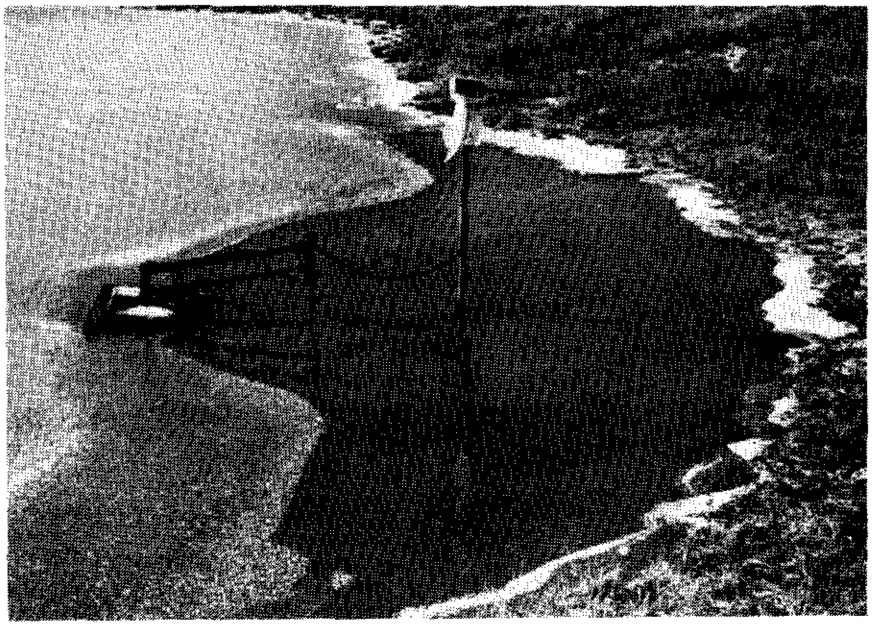

Figure 14. View of Ice Hole on 31 January 1980 for the Wind-Powered Pump

not present on January 31. Ice formed on the propellor again on February 8 and was thick enough to significantly reduce the propellor speed. The ice was mechanically removed from the propellor, and a hole was opened in the fringe ice in less than 30 minutes.

On February 9 damage to the protective metal on the leading edge of one end of the propellor was noticed. The brass covering split along the propellor's leading edge disrupting air flow and reducing propellor speed. The metal was flared much worse on February 10, and the propellor was not turning; therefore no hole was maintained. The propellor was removed on February 11, repaired, and placed back in service on February 13.

On February 17 the Wincharger did not maintain an opening in the ice at observation time. The pond control ice thickness was 2.9 centimeters, and the ice thickness near the trolling motor was 1.9 centimeters. The daily wind travel was 189.9 km/day. A reduction of wind speed prior to observation time allowed the ice to reform.

On March 2, the coldest day of the winter, the Wincharger had a 8.1 m^2 opening with a wind travel of 169.0 km/day. The reader is reminded that wind speed at time of observation is not necessarily equal to the average wind speed.

While a large area, 115 m^2 was opened on March 3, the daily maximum temperature was above freezing. On all recorded observation dates except February 2, February 12, and March 3, the daily maximum temperature was below freezing.

Submersible Pumps

The area of melted ice and average daily temperatures for both submersible pumps are shown in Figures 15 and 16. The two ponds, designated as East and West Ponds, were equipped with similar equipment; but the installation conditions were somewhat different. The East Pond was located at a point where the shoreline slope was relatively steep. The West Pond installation was made at a point where the shoreline slope was relatively flat. That is, the pump discharge was approximately 0.5 m below the water surface at the East Pond; while the West Pond discharge was only a few centimeters below the water surface in shallow water.

The amount of pumping time per hour was varied between 15 minutes per hour and full-time operation during this study. Figures 15 and 16 indicate the pump setting on respective observation days.

Both pumps were started at 15 minutes pumping per hour on January 28 after a 1.9 centimeter ice layer formed on the ponds. The East Pond opened a 3.1 m^2 hole, and the West Pond opened a 1.0 m^2 hole by January 29. As the pump settings were increased, the size of the open area increased. On February 2 after four days in which the maximum daily temperature never rose above the freezing point, the East pump operating at full time had opened a 32.7 m^2 hole. The West pump, set at 45 minutes pumping per hour, had opened a 23.5 m^2 hole. Figures 17 and 18 show the configuration of the melted area. On the coldest day of the year, March 2, the East Pond pumping 45 minutes per hour, opened a 0.4 m^2 area. The West Pond also pumping at 45 minutes per hour, opened a 1.5 m^2 hole.

SUMMARY - 1979

The objective of the study was to determine the performance of two ice removing devices from stock water ponds. The devices used were the

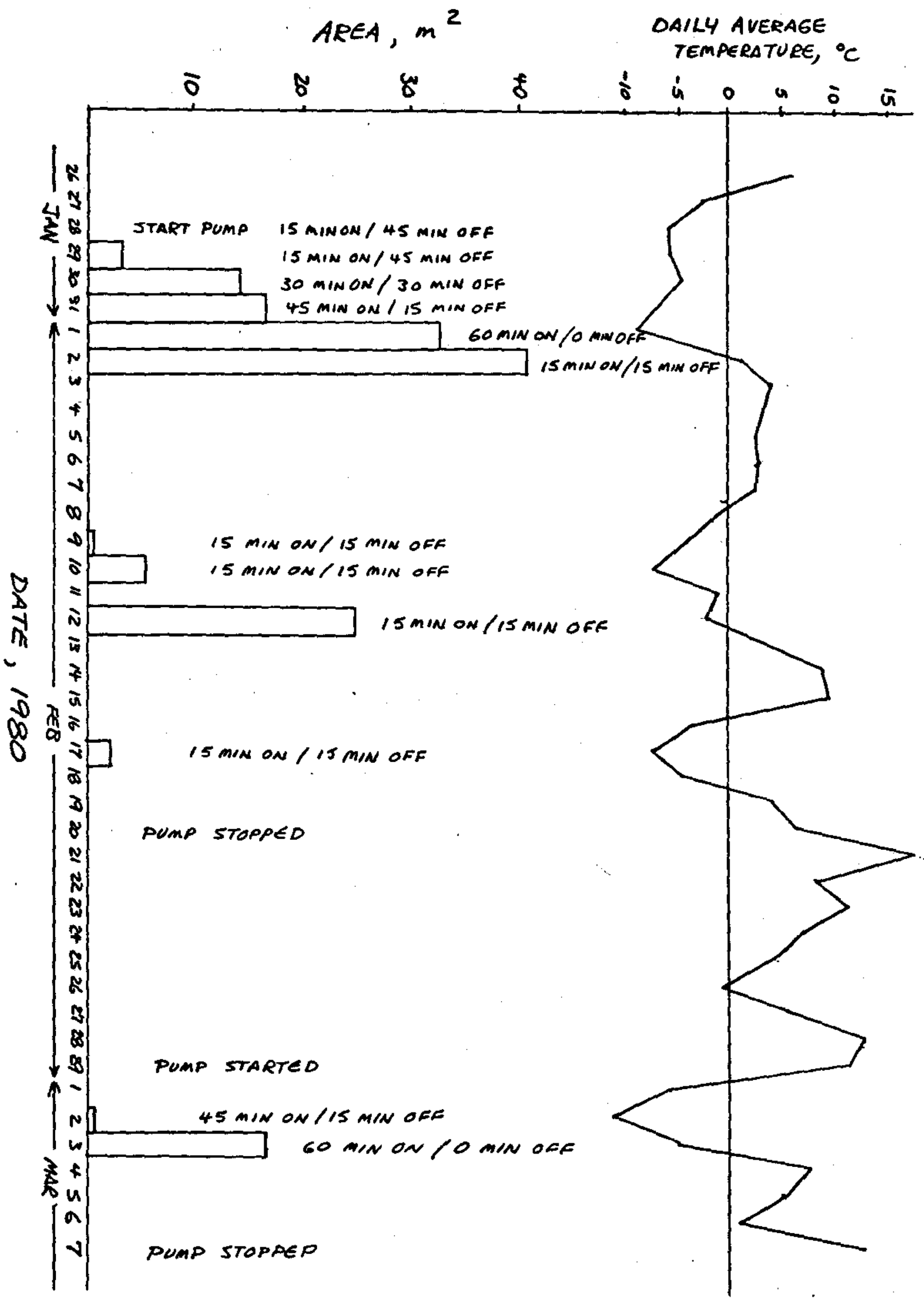

Figure 15. Average Daily Temperature and Area of Melted Ice for the East Pond Submersible Pump Versus Time.

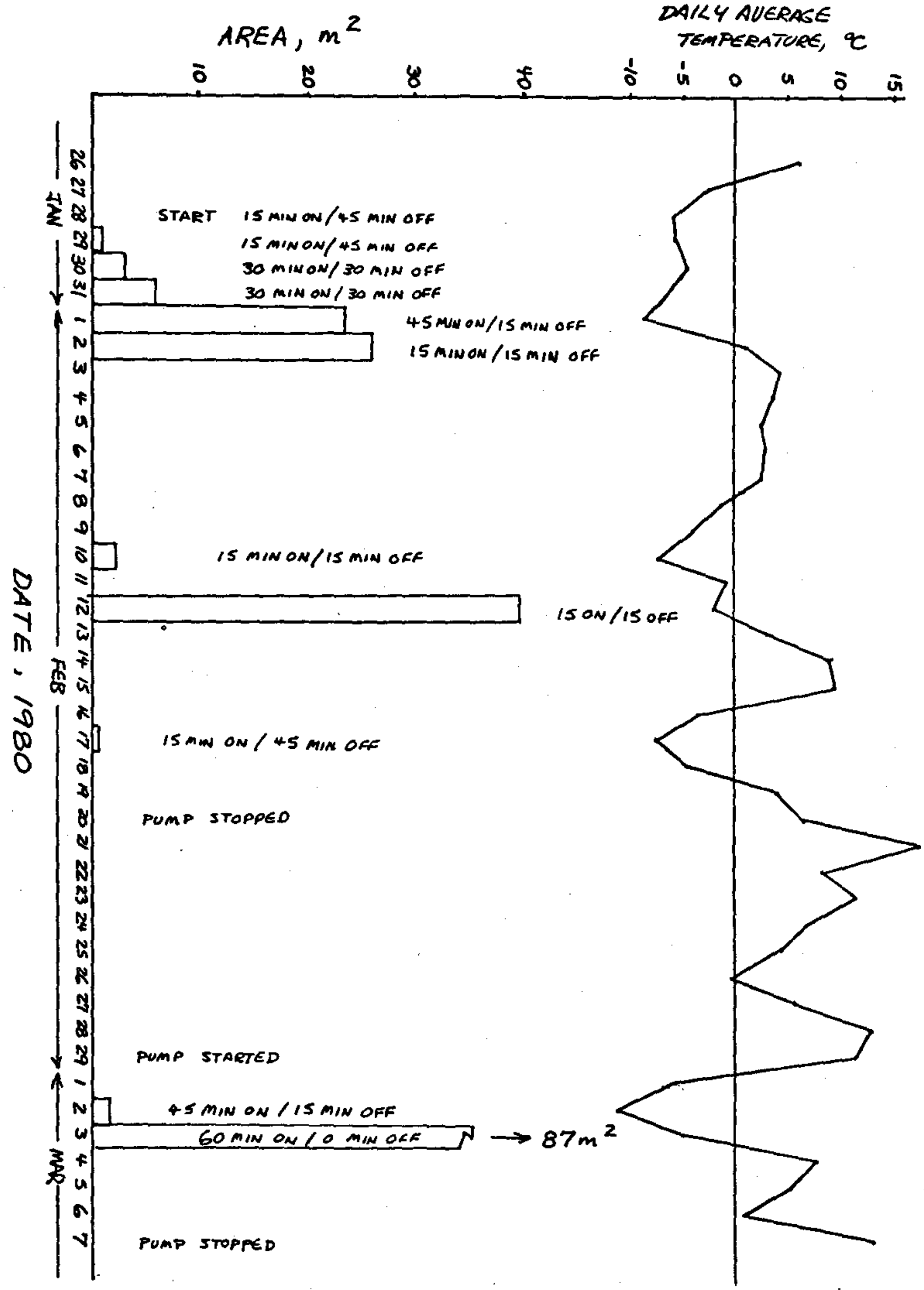

Figure 16. Average Daily Temperature and Area of Melted Ice for the West Pond Submersible Pump Versus Time.

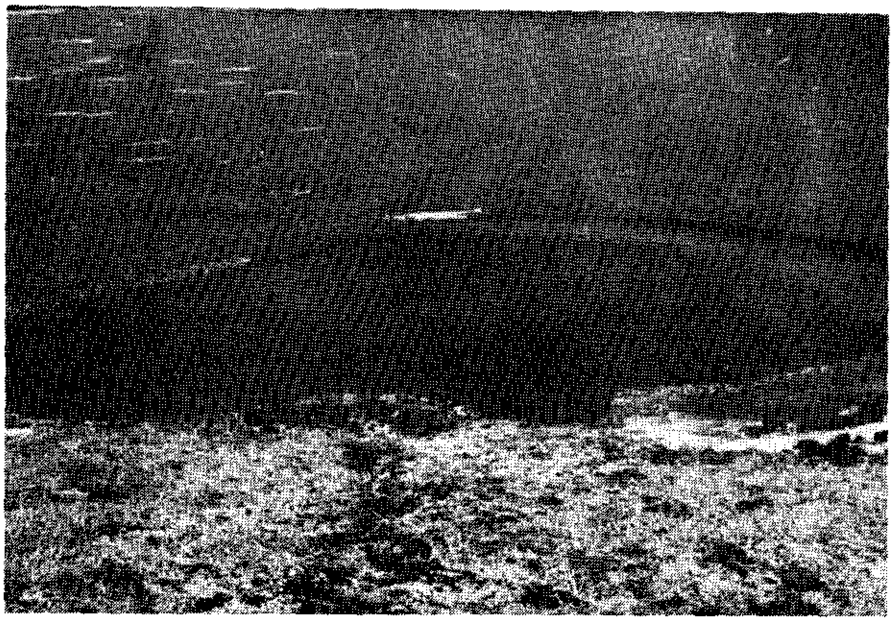

Figure 17. View of Ice Hole Configuration on 31 January 1980 for the East Pond Submersible Pump

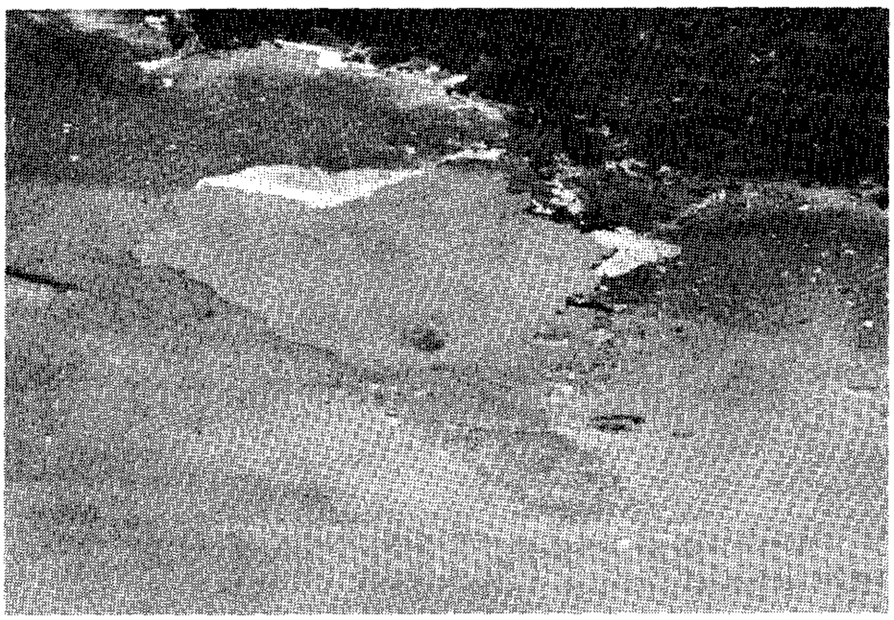

Figure 18. View of Ice Hole Configuration on 30 January 1980 for the West Pond Submersible Pump

Thruster Electric Outboard powered by 12-V battery, and the submersible pump with a power of 248.6 W. The study was conducted in Sangre Pond located 3.9 km west of Stillwater, Oklahoma.

In this study, area of melted ice, ice-thickness, water temperature profile, daily average temperature, and wind travel were measured. Photographs were used to determine area of melted ice. The ice-thickness, for most of the study period, varied between ten and twenty centimeters, and the temperature profile ranged from 0^oC to 2.5^oC.

The Thruster Electric Outboard melted ice satisfactorily and the average area of melted ice for the study period was 60 m^2. The submersible pump, operating at one-fourth time, did not melt ice in as big an area as expected but big enough to meet the purpose of the study. The average area of melted ice was 6 m^2. In both cases the size of melted ice varied with temperature variation, but no variation in size of melted ice was observed with wind travel variation.

SUMMARY AND CONCLUSIONS - 1980

The objective of this study was to evaluate the performance of two devices for removing ice from farm ponds. The devices used were an electric trolling motor powered by a wind driven generator and two 248-watt submersible pumps. The study was conducted on three ponds on the Durham Ranch located approximately 22 kilometers west of Stillwater, Oklahoma.

The area of melted ice, ice thickness, water temperature profile, daily temperature, and daily wind travel were measured. The ice hole dimensions were physically measured. The ice thickness varied between 0 and 8.9 centimeters, and the temperature profile ranged from 0^oC to 33.3^oC.

While a relatively mild winter reduced the availability of ice, data were collected for eleven days. On eight of those days the maximum temperature was below 0°C. The average area kept open by the wind-powered trolling motor for those eight days was 17.4 m^2, which included two days in which wind power could not maintain a hole in the ice because of low wind speed. The submersible pumps in the East and West Ponds maintained an average open area of 9.5 m^2 and 5.3 m^2, respectively, for the days the maximum temperature was below 0°C. In each case the area of the ice hole varied with temperature.

The wind-powered trolling motor can be used to remove ice from stock water ponds. The relatively mild winter precluded establishing definite relationships between melted area, wind speed, and temperature. Of the eight observation days with maximum temperatures below freezing, an open area of 8.1 to 34.7 m^2 was maintained for six of those days. On one of the remaining days, the Wincharger propellor was damaged, which contributed toward no ice melting. On the remaining day no hole was observed.

Ice buildup on the generator propellor reduced pumping performance, and physical removal of ice from the propellor was hazardous. However, the ice buildup was a problem only during periods of freezing rains or ice storms.

Low wind speeds prevented pump operation and allowed ice to reform over the hole. When refreezing occurred during periods of low wind speed, the ice thickness was less than the ice away from the pump.

The wind driven pump circulated significantly more water than the submersible pumps. The location of the wind powered pump, approximately 4.3 m from the shoreline, and the pump propellor orientation of 45 degrees from horizontal kept ice melted very close to the shoreline.

Both submersible pumps operated well with no mechanical problems throughout the study period. While the open area was somewhat small in extremely cold weather, the ponds were never completely frozen over during any observation.

The discharge outlet of both submersible pumps had to be moved closer toward the shore after they were initially installed. The discharge outlets were repositioned approximately 2.0 meters from shore to maintain the open area as close to the shore as possible.

The discharge was directed toward the shore at a 45 degree angle from the horizontal. Generally, the resulting ice hole was eliptical-shaped, with the long axis toward shore.

GENERAL CONCLUSIONS

If electricity is available to the pond site, the submersible pumps would be a more economical solution to the problem of obtaining a hole in the ice. The size of the hole will be relatively small, but possibly not much smaller than if one had to chop a hole in the ice.

A larger hole could be maintained with the electric trolling motor, trickle charger and battery, but the cost of equipment, and probably the maintenance cost, would be higher.

If the pond site is remote from an electric service, the wind-electric plant can be directly connected to the trolling motor. On windy days a larger hole will probably be maintained than with the battery and charger, because the speed control is at a higher setting. On calm days the melted hole will refreeze. If the thickness of the ice becomes excessive, it may have to be removed. This never happened during the one winter of testing. When ice refreezes, the thickness is less than at other parts of the pond. Cattle are able to break relatively thin ice to obtain water.