INTERNAL REPORT 125

A THERMAL STUDY OF THE SOUTH END OF LAKE WASHINGTON DURING OPERATION OF THE SHUFFLETON POWER PLANT IN JANUARY AND DECEMBER 1972

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PART I: RESULTS OF JANUARY 1972 STUDY

Water temperatures were taken in the south end of Lake Washington to delineate the surface area of the lake that was influenced by the thermal plume from the operation of the Shuffleton Power Plant. Temperatures were taken on four days while the plant was in operation, and also on one day when the plant was not operating.

A thermistor thermometer (Yellow Springs Instrument Co., Inc.) was used to record the temperature in Centigrade. These were converted to Farenheit for direct comparisons with previous measurements. The surface water temperatures at the mouth of the Cedar River and at the entrance to the intake and the end of the outfall of the Shuffleton Plant are given in Table 1. The rise in water temperature between the intake and outfall varied between 4.3 to 10.3°F for the four days that the plant was operating and 0.2°F on the day that the plant was not operating. The plant power output was directly related to the difference in temperature between the intake and outfall. The highest output (483,000 KWH) was associated with the greatest difference in temperature (10.3°F) while the lowest output (260,000 KWH) was associated with the least difference in temperature (4.3°F).

The water temperature measurements that were made July 1971 (Erickson and Whitney 1971) and January 1972 indicated that the Cedar River forms an eddy to the east of its mouth in the vicinity of the Shuffleton Plant. The eddy was roughly delineated from temperature measurements that were taken on 29 January 1972 when the plant was not operating (Figure 1). The fact that the temperature at the intake matched the temperature of the Cedar River, while the ambient temperature of the lake was 2 to 3 degrees warmer, indicates that there is an eddy circulation which carries the river water eastward to the intake. The general outlines of the eddy under the flow conditions at that time are indicated in Figure 2. The flow of the Cedar River forces the water northward. The flow appeared to rise up along the sand bar at the east of the river channel, circulate under the log storage area, and extend to the area of the plant intake. The area influenced by this eddy was approximately 62 acres, as determined from USGS Nautical Chart 690-SC and aerial photographs of the south end of Lake Washington.

The mean difference between the intake and outfall temperatures for January 1972 (Table 2) are compared with the mean differences that were calculated from the data in Table 1 of Fraser (1971). The mean difference for 27-30 January 1969, is higher than the mean difference for 26-31 January 1972, and is related to the power output of the plant. Other factors such as ambient water temperature and flow from the Cedar River would also influence the differences in temperature. The mean differences for October and November of 1966 are considerably higher when the power output of the plant was also much higher (Table 2). The higher water temperatures (Figure 7) and lower flow (Table 6) from the Cedar River during October and November would also have an influence on the temperatures in the thermal plume.

Temperature profiles in the vicinity of the Shuffleton Plant show that the water is thoroughly mixed in this area (Tables 3, 4, and 5). Apparently, turbulence in the eddy is sufficient to cause mixing from the surface to the bottom. We had expected the thermal plume to float due to density differences, but these are obviously overcome by turbulence within the eddy. The overall effect of this water movement is to contain the plume to a smaller area of the lake.

Surface water temperatures while the plant was operating are shown in Figures 3, 4, 5, and 6. The approximate area that was affected by the thermal plume was calculated for each of the four days the plant was operating (right column of Table 1). Between 4-15 acres of water were affected by the plume. However, the greatest temperature difference of 10°F on 27 January and 31 January was confined to approximately 2 acres near the outfall. Of course, the area that would be affected by the warm effluent would be related to the power output of the plant as mentioned earlier.

The circulation of river water in January 1972 (Figure 2) apparently kept the effluent from the Shuffleton Plant confined to a small area where the heat was dissipated rapidly by mixing with cold river water and by convection into the cold air. Just one day before this study was undertaken, Seattle had its largest snowfall for the 1971-72 winter, and the weather becmme colder during the study. Air temperatures, obtained from the H & N Company, Inc., Kirkland, Washington, for the end of January 1972 are as follows;

DATE	AIR TEMPERATURE (°F)	
	Low	High
January 26	12	28
27	10	39
28	10	36
29	18	44
30	22	46
31	22	36

During the winter months, the extent of the eddy at the mouth of the Cedar River may be influenced by the flow. The river flow is highest in December, January, and February (Table 6). If the river flow has an effect on the size of the eddy, then the largest area that would be influenced by the river flow would occur during these months. At this same time, the water temperatures of the Cedar River are at the lowest for the year. The average monthly maximum and minimum temperatures for the Cedar River are plotted in Figure 7. Although these data cover the period between October 1965 and February 1967, they are the only recent data available for the lower Cedar River and provide the trend in water temperatures over a period of a year.

Temperature profiles in the south end of the lake during July 1971 show the extent that the Cedar River influences the water temperature of the lake in summer (Figure 8). Surface water temperatures were coolest off the mouth of the river and became higher with a greater distance from the mouth. The influence of the river extends a considerable distance into the lake, as is graphically illustrated for the surface, 10-foot depth, and 20-foot depth in Figures 6, 7, and 8 of Erickson and Whitney (1971). This influence is also illustrated in Tables 7, 8, and 9, where temperature profiles for various months of 1971 are given for the mouth of the Cedar River in 60 feet of water, the northwest corner of the log storage in the south end of Lake Washington, and the south tip of Mercer Island. The tables also depict summer stratification for these areas.

Erickson and Whitney (1971) and our present observations showed that the water is cooler in the southeastern corner of the lake during July and January. It is clear that this cooler water is due to the influence of the river. However, we need to know more about this influence of the river at other times of the year. Any alterations in water temperatures could affect the movement of fish, particularly during the fall and winter when the adults ascend the Cedar River to spawn and when the fingerlings and smolts leave the river during late winter and spring.

In summary, the thermal plume from the Shuffleton Plant appears to be influenced by the power output of the plant, and by the flow and water temperature of the Cedar River. The temperature plume from the plant operation would be confined to the smallest area of the lake during January and February. In January, the eddy that was formed from river water was cooler than the lake water and the warm effluent from the plant increased the temperature within the eddy to the ambient temperature of the lake. The largest increase in temperature (10°F) above the ambient temperature of the lake was confined to an area of approximately 2 acres.

Operation of the plant at other times should be studied to determine the area of water and aquatic organisms that might be affected by the plume. It remains to be seen, for example, whether turbulence from the eddy could be sufficient to cause mixing, or if the warmer effluent would remain on the surface and therefore cover a larger area during the summer. Also, we need to know which species of fish are in the area that might be affected by the thermal plume.

The recommended approaches that were outlined on page 7 of Erickson and Whitney (1971) should be used as a guide to determine the effects of the thermal plume at times other than January or February when conditions appear to be most favorable for operation of the plant.

REFERENCES

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Table 1. Surface water temperatures at mouth of the Cedar River, at the intake and outfall of the Shuffleton Power Plant, and approximate area of the thermal plume during the last week of January,1972.

Date	Temp. at mouth of Cedar R. °F	Temp. at intake °F	Temp. at outfall °F	Temp.	Plant power output (KWH)*	Approximate surface area of plume in acres
Jan. 26	42.5	44.5	48.8	4.3	260,000	4
27	37.8	40.5	50.8	10.3	483,000	12
28	37.8	40.2	46.8	6.6	382,000	12
29	40.0	39.8	40.0	0.2	0	0 (plant not operating)
30	(No temperatures taken - plant not operating)					
31	39.2	40.3	50.6	10.3	475,000	15

*Data from Puget Power Company, Bellevue, Washington, per telephone conversation 29 March 1972.

Table 2. Mean, standard deviation of m an, and range of difference between intake and outfall temperatures at the shuffleton Power Plant. (Date for 1966 and 1969 from Fraser, 1971].)

Date	Number of days	Power Plant output (KWH)*	Mean difference °F	Standard deviation	Range °F
October 1966	20	30,126,000	12.9	2.31	8 - 15
November 1966	15	26,224,500	14.8	0.41	14 - 15
January 1969	9	3,788,000	8.6	3.54	2 - 12
January 1972	4	1,722,000	7.9	2.98	4.3 - 10.3

*Date from Puget Power Company, per telephone conversation 28 March 1972.

Table 3. Temperature profiles taken approximately midway between the center of log storage and the center of the Boeing Hangar at the south end of Lake Washington during January 1972.

	Date				
Depth in feet	26 Jan	27 Jan	28 Jan	29 Jan	31 Jan
0	45.3	41.8	40.5	40.4	41.3
5	45.3		40.4	40.4	41.3
10	45.3	41.3	40.2	40.2	41.3
15	44.8	41.3	40.2		
20	44.8	41.1		40.2	41.3
25	44.5	41.1			

Table 4. Temperature profiles at the southeast corner of the log storage at the south end of Lake Washington during January 1972.

	Date				
Depth in feet	26 Jan	27 Jan	28 Jan	29 Jan	31 Jan
0	44.0	40.2	40.7	40.4	40.5
5	44.7	40.4	40.5	40.4	40.5
10	45.0	40.4	40.2	40.4	40.5
15	44.7	40.4			
20	44.7	40.4	39.8	40.2	40.5
25	44.7				
30	44.5				

Table 5. Temperature profiles aththe southwest corner of the log storage at the south end of Lake Washington during January 1972.

Depth in feet	Date 26 Jan	27 Jan	28 Jan	29 Jan	31 Jan
0	44.5	40.8	39.8	40.0	41.2
5			40.0	40.0	41.2
10	44.5	40.8	40.0	40.0	41.2
15					
20		40.8	40.0	40.0	41.0

Table 6. Monthly water flow in cubic feet per second for the Cedar River. Data from U.S. Geological Survey Station 12-1190, at Renton, Washington*.

	1966-1967			1967-1968			1968-1969			1969-1970		
Month	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.
Oct	255	411	190	209	647	86	532	685	316	338	531	223
Nov	452	1,070	183	293	585	183	942	1,430	361	409	955	303
Dec	1,159	2,100	850	983	2,260	343	1,160	2,340	502	677	1,400	294
Jan	1,721	2,840	1,280	1,349	2,510	876	1,332	3,180	415	1,102	2,130	299
Feb	1,370	1,800	1,090	1,435	2,410	831	613	860	405	1,085	1,460	733
Mar	848	1,240	521	956	1,710	475	497	687	335	715	1,150	414
Apr	552	763	317	884	1,220	740	1,072	1,340	799	1,030	1,670	423
May	635	845	294	686	929	348	985	1,930	526	732	1,130	328
Jun	432	729	179	423	1,438	167	758	1,630	169	544	899	247
Jul	139	338	90	286	758	62	377	574	213	186	520	44
Aug	94	202	61	182	483	45	237	519	115	104	145	84
Sep	112	308	64	376	675	172	218	529	109	200	487	102

*Data from U.S. Geological Survey "Water Resources Data for Washington. Part I. Surface Water Records," for 1967, 1968, 1969, and 1970.

Table 7. Temperature profiles (°F) during 1971 at the mouth of the Cedar River in 60 feet of water. (Station 14 of Fraser and Weaver, and Station II-5 of Erickson and Whitney.)

Depth in feet	Month				
	Jan	Feb	Mar	Apr	Jul
0				45	62
6	44	43	41	43	61
15	44	43	41		
20				43	61
30	44			43	60
40				43	57
50				43	54
60	43				

Table 8. Temperature profiles (°F) at the northwest corner of the storage at the south end of Lake Washington during 1971. (Station 13 of Fraser and Weaver, and Station IV-14 of Erickson and Whitney.)

Depth in feet	Month					
	Jan	Feb	Mar	Apr	Jun	Jul
0				46	51	63
6	44	43	42			
10				44	51	63
15	44	43	42			
20				43	50	61
30	44	42	42	43	50	60
40				43	49	57
50				43	48	54
60	44	42	42	43	48	

Table 9. Temperature profiles (°F) at south tip of Mercer Island (University of Washington RV COMMANDO Station 4).

Depth in feet	Date (1971)				
	14 May	24 Jun	17 Aug	25 Oct	17 Dec
0	46.4	57	71.5	52.5	43.5
6	46.4	57	71.5	52.5	43.5
15	44.6	56.5	71.5	52.5	43.5
30	44.0	55.5	60.0	52.5	43.5
45	43.5	49.0	51.0	49.0	43.5
60		46.5	47.5	47.5	43.5
75		45.5	45.5	46.0	43.5
90		44.5	45.0	46.0	43.5

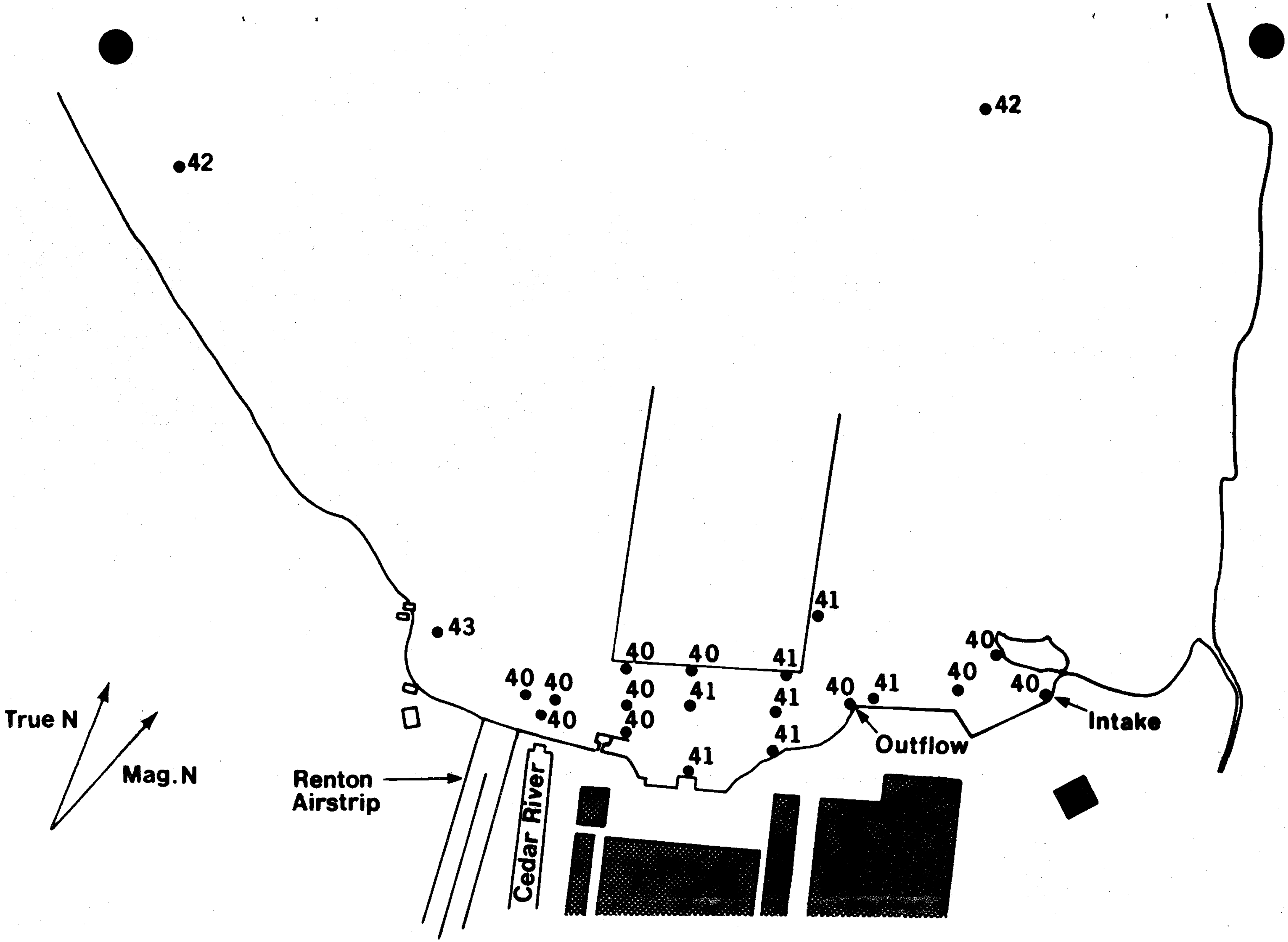

FIGURE 1. Surface water temperatures in the vicinity of the Shuffleton Power Plant at 1:30-2:30 p.m. PST on 29 January 1972, when the plant was not operating (wind conditions - N at approximately 3-6 mph.).

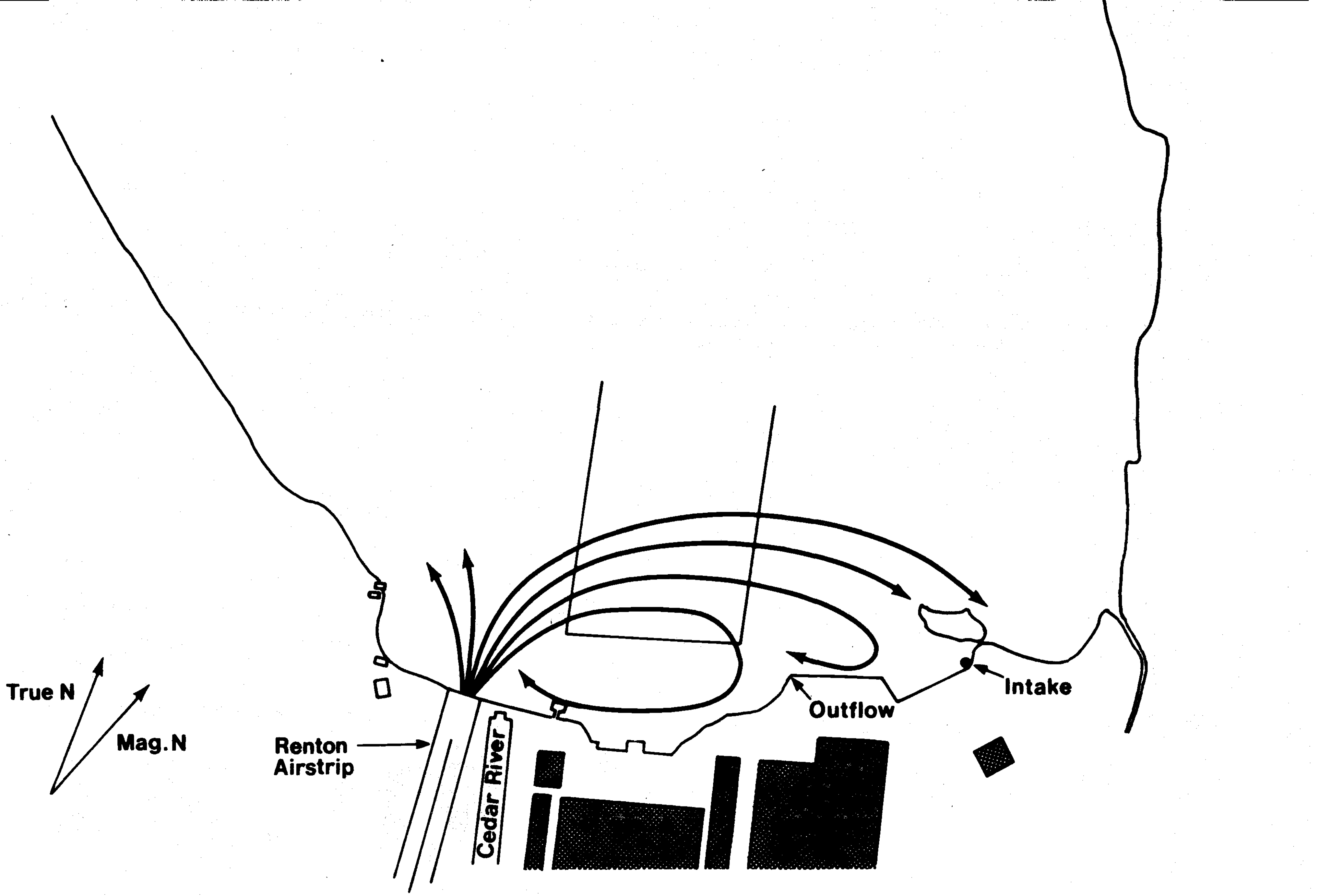

FIGURE 2. Surface water movement and general circulation in the vicinity of the Shuffleton Power Plant in January 1972.

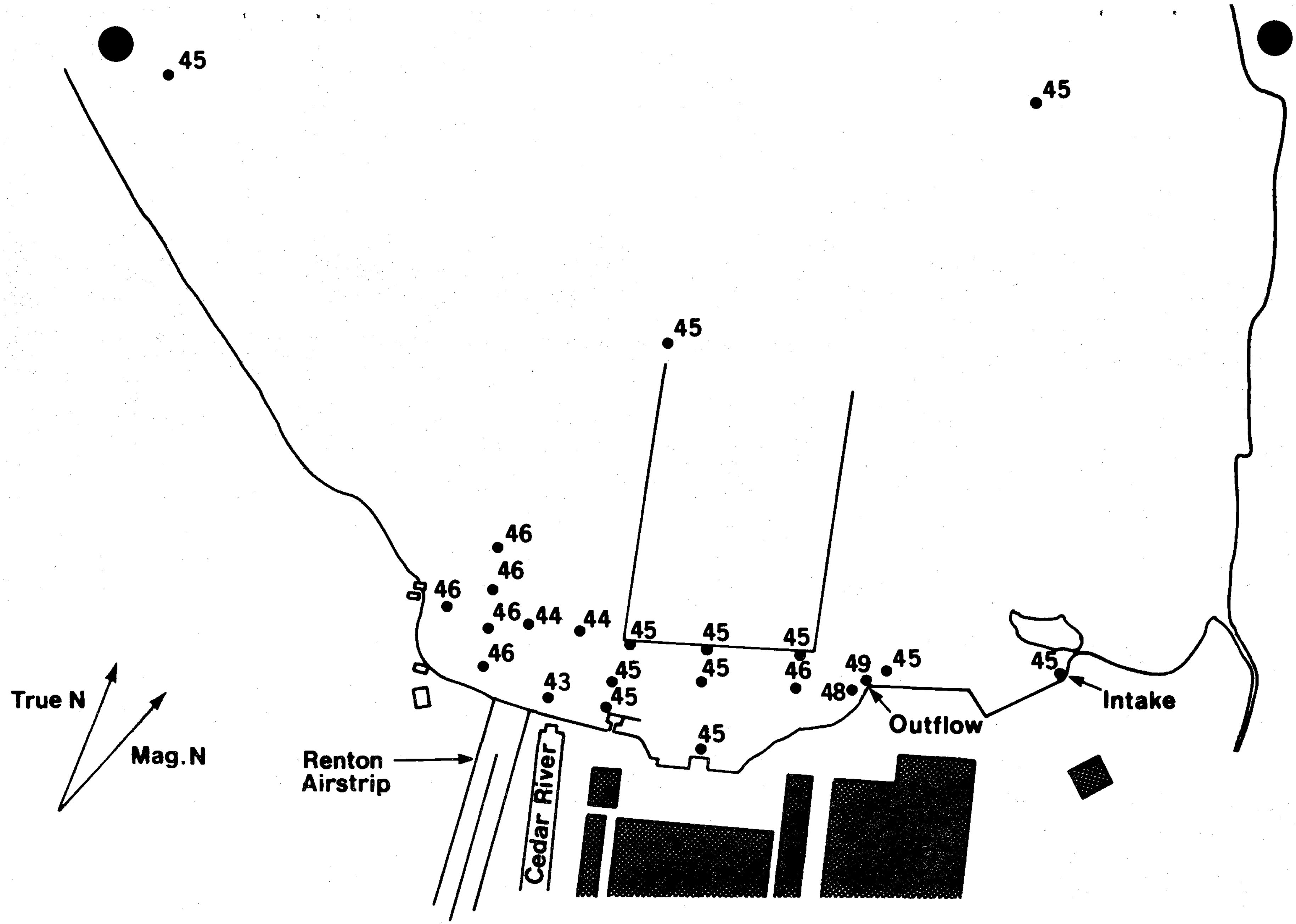

FIGURE 3. Surface water temperatures in the vicinity of the Shuffleton Power Plant at 2:00-3:00 p.m. PST on 26 January 1972 (wind conditions - SE at approximately 5 mph.).

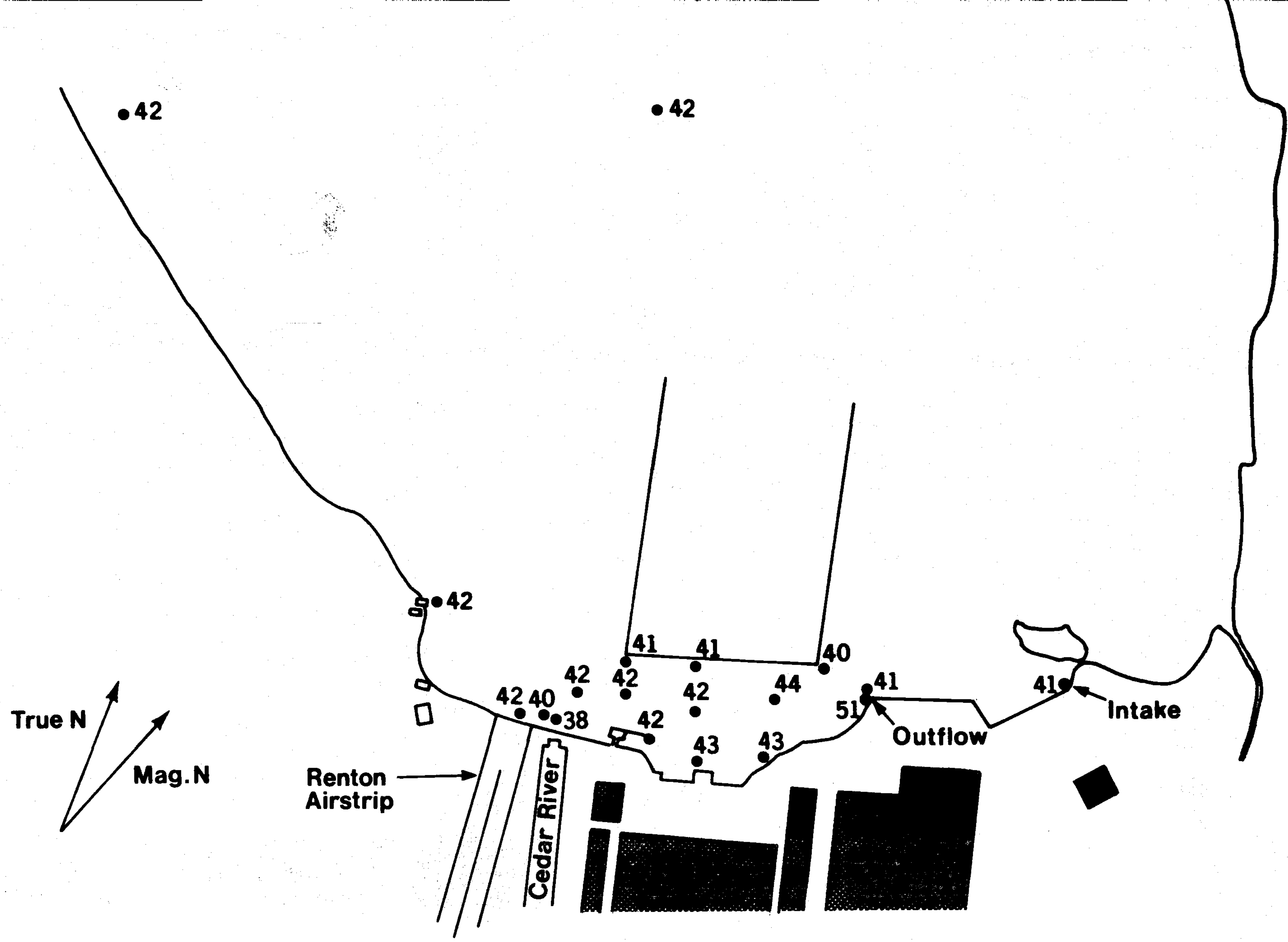

FIGURE 4. Surface water temperatures in the vicinity of the Shuffleton Power Plant at 1:30-3:30 p.m. PST on 27 January 1972 (wind conditions - NE at approximately 5 mph.).

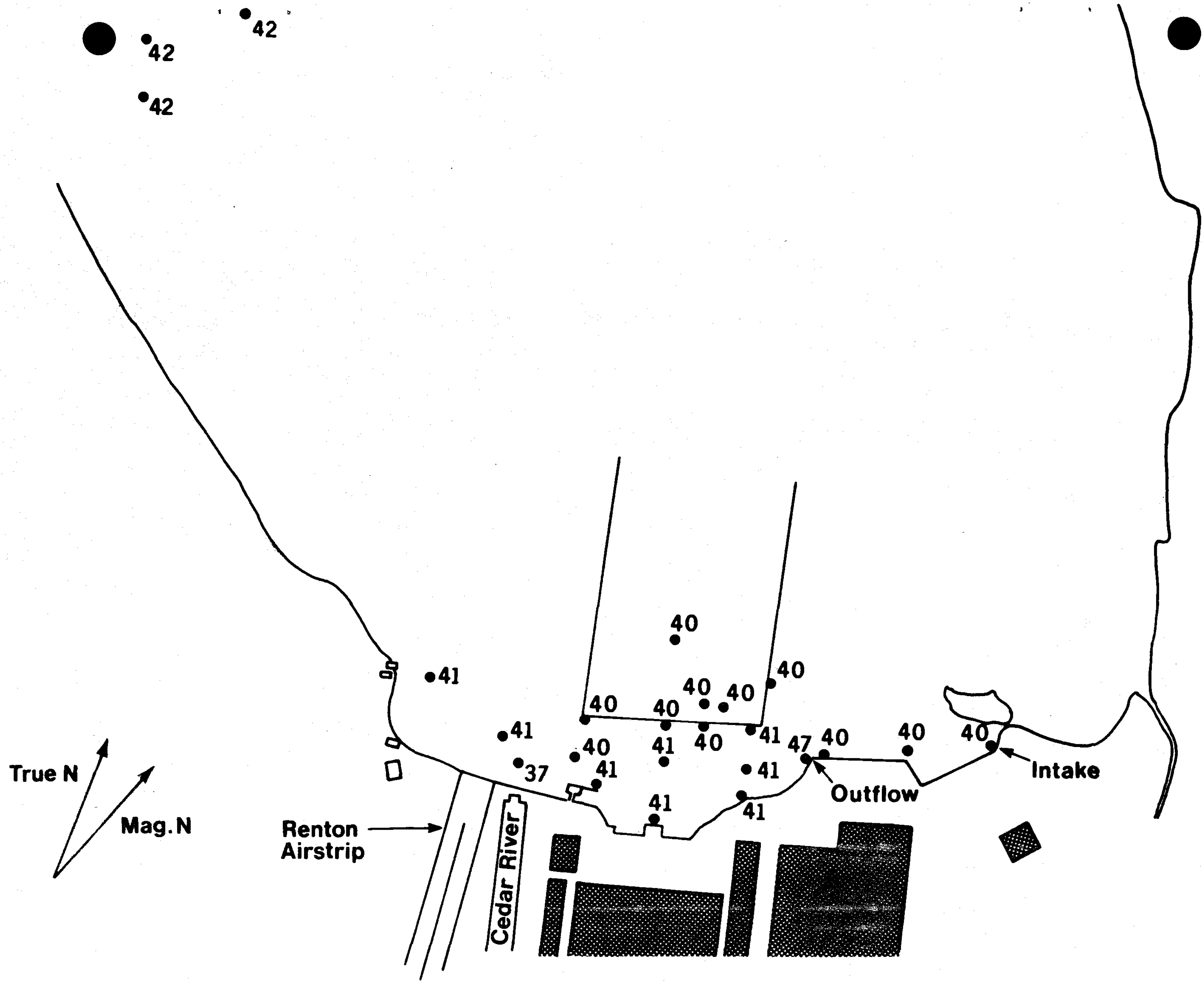

FIGURE 5. Surface water temperatures in the vicinity of the Shuffleton Power Plant at 1:30-3:30 p.m. PST on 28 January 1972 (wind conditions - calm).

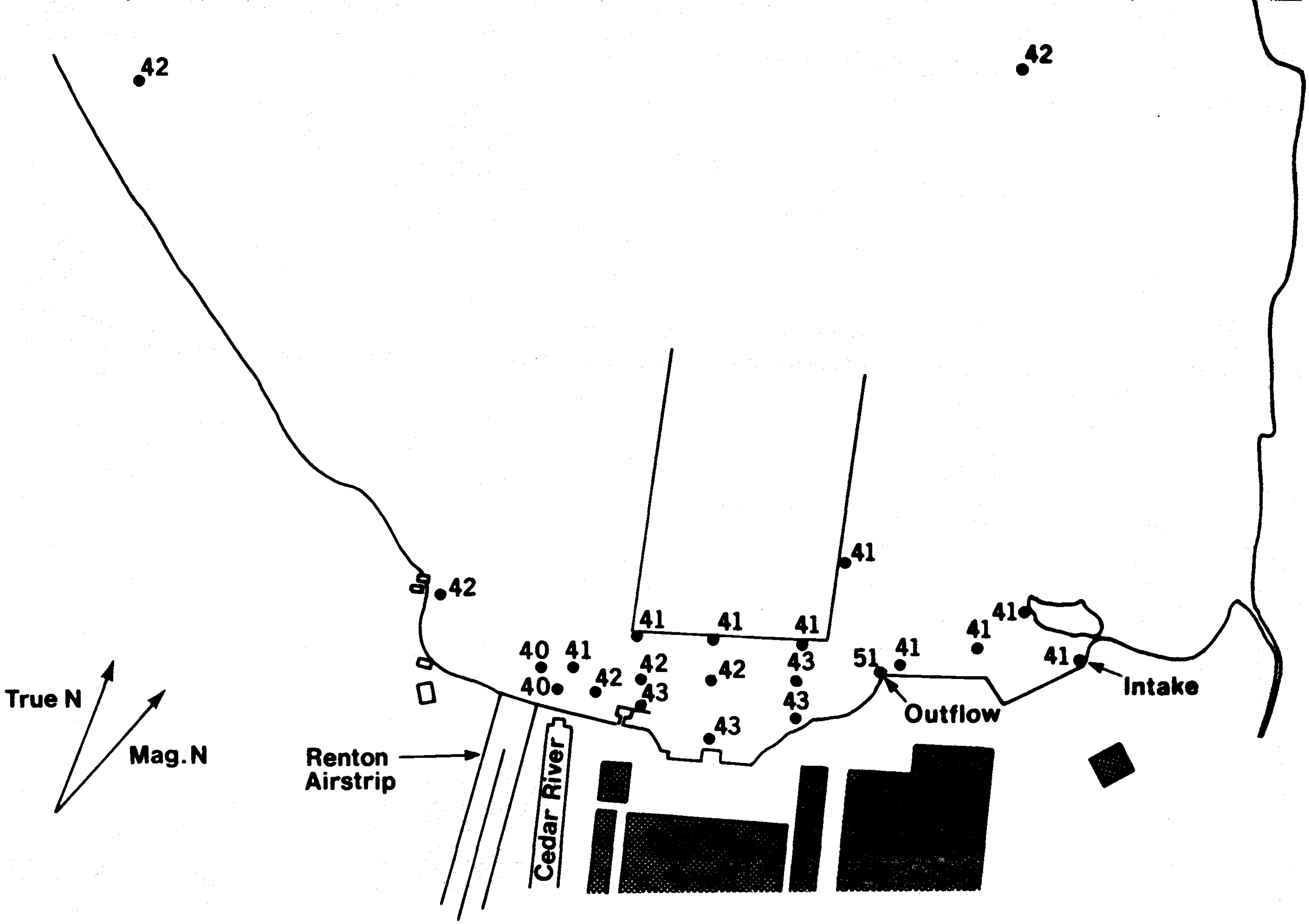

FIGURE 6. Surface water temperatures in the vicinity of the Shuffleton Power Plant at 4:00-5:00 p.m. PST on 31 January 1972 (wind conditions - N at approximately 10-15 mph.).

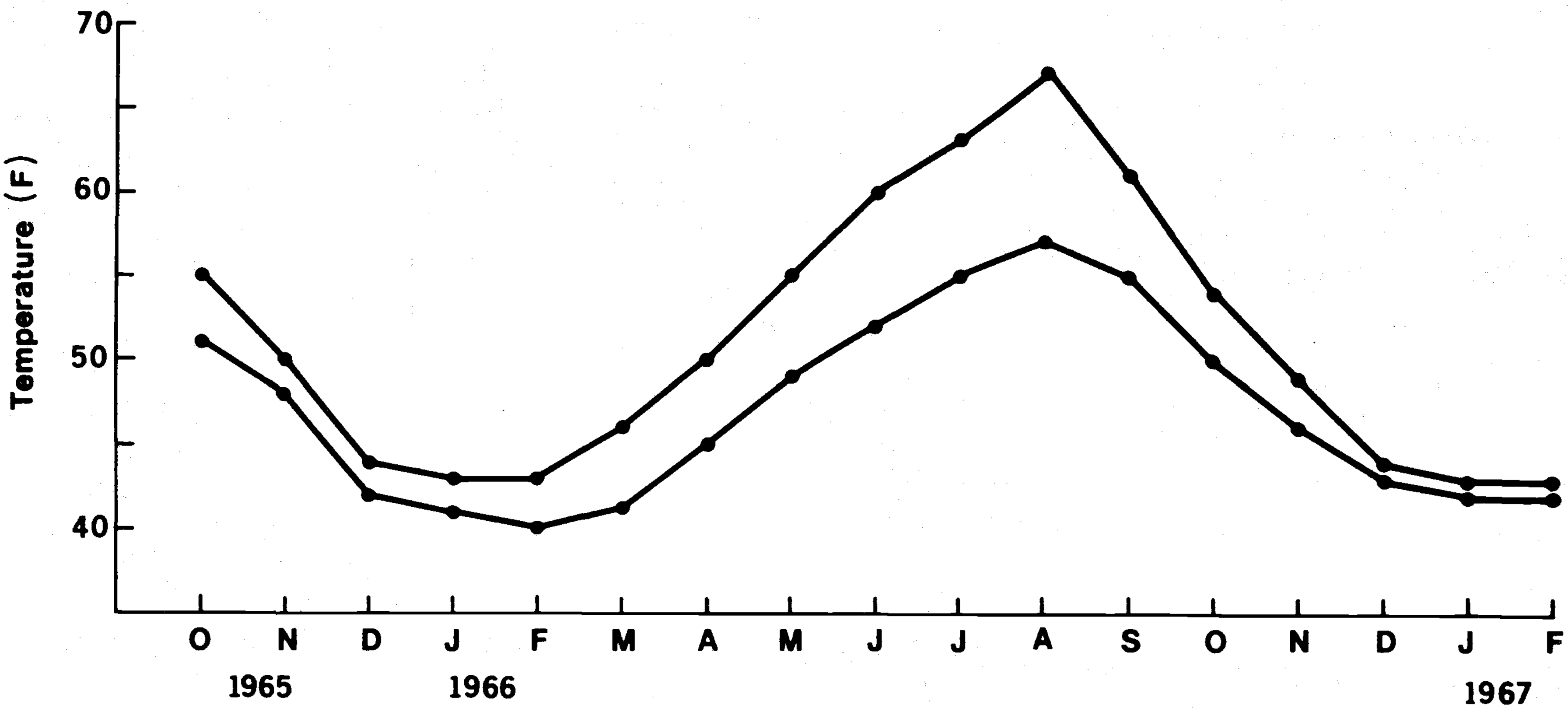

FIGURE 7. Average monthly maximum and minimum water temperatures for the Cedar River between October 1965 and February 1967.

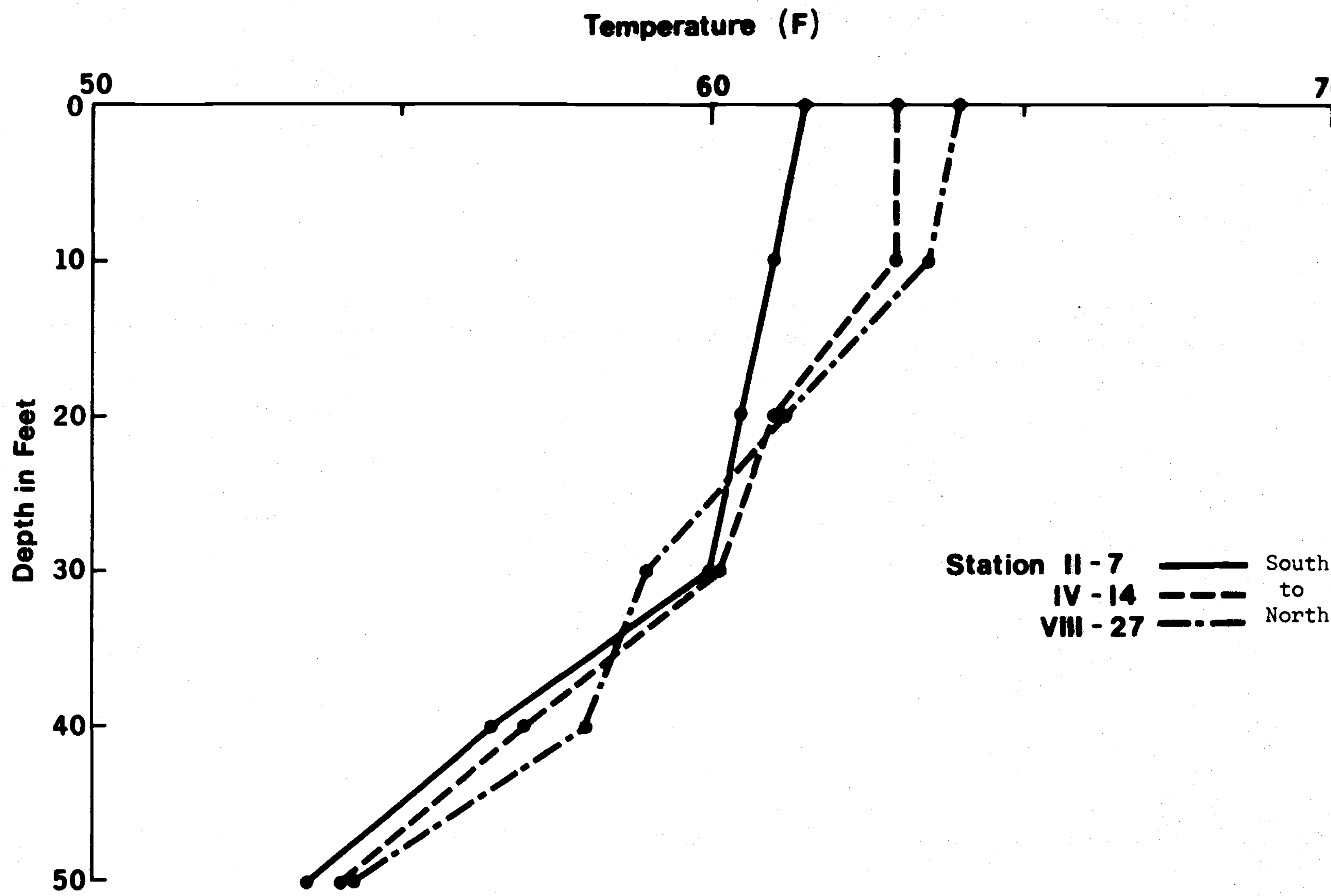

FIGURE 8. The influence of the Cedar River on temperature profiles in the south end of Lake Washington during July 1971.

PART II: RESULTS OF DECEMBER 1972 STUDY

The Shuffleton Power Plant, located at the south end of Lake Washington, is operated on a standby basis by the Puget Sound Power and Light Company, Bellevue, Washington. This plant has been operated infrequently for a total of 75 days since December of 1964, including the 16-day period that is summarized in this report. In addition to the dates summarized in Table 2, the plant was operated for 3 days in December 1964, 1 day in December 1967, 3 days in December 1968, and 4 days in January 1973. It should be pointed out that the Shuffleton Plant has operated only during the fall and winter months in recent years (Table 2).

The Washington Cooperative Fishery Unit was requested by the Puget Sound Power and Light Company to monitor the extent of the thermal plume from the Shuffleton Plant during the operation of the plant from 5-19 December 1972. Water temperatures were taken at selected stations in the south end of Lake Washington (Figure 1) for eleven days when the plant was operating and one day when the plant was not operating.

Water temperatures were measured in Centigrade with a thermistor thermometer (Yellow Springs Instrument Co., Inc.). These measurements were converted to the nearest Farenheit values for direct comparison with previous reports. For most of the December period of study, air temperatures were low and remained below 32°F on many of the days (Table 1). The plant was operated near its maximum output of 69,000-70,000 kilowatts per hour for all days listed in Table 1, with the exception of 14 December when the power output dropped for several hours. For 10 days when the plant was operating (Table 1) the water temperature increased 7 to 12°F between the intake and outfall. The complete series of water measurements was not made on 10 December, when the thermometer became inoperable due to a break in the thermistor cord.

The mean difference between the intake and outfall temperatures for December 1972 was compared with other dates (Table 2). While the temperature of the Cedar River ranged 11°F (32 to 43°F) from 6-18 December, the temperatures of the intake water varied only 4°F (43 to 47°F) and the temperature of the outfall water varied 6°F (52 to 58°F) for the same period (Table 1). The mean difference of the surface water temperatures at the intake and outfall was 10.9°F (range 7 to 12°F, Table 2). Puget Sound Power and Light Company also measured water temperatures at the intake and discharge of the condensers in the Shuffleton Power Plant (Table 3). The water temperatures of both the intake and discharge of the condensers are warmer (Table 3) than the water temperatures at the intake and outfall in the lake (Table 1). The mean difference between intake and discharge water temperatures (Δt = 8.9°F) at the condensers in the plant was 2°F less than the mean difference in temperature (Δt = 10.9°F) at the intake and outfall in the lake. Factors such as the power output of the plant, the ambient water temperatures, and flow from the Cedar River would influence the difference in temperature. The greater differences between intake and outfall temperatures at the

Shuffleton Plant in October 1966, and November 1966, when power output of the plant was similar to that in December 1972, can be explained by the higher water temperatures and lower flows from the Cedar River during October and November. During December, the flow of the Cedar River increase and, at the same time, water temperature of the river becomes lower. (See Figure 7 and Table 6, Wydoski [1972a], for water temperatures and flows from the Cedar River, respectively.)

In January 1972, an eddy was formed to the east of the Cedar River mouth in the vicinity of the Shuffleton Plant (Figure 2, Wydoski 1972a). This eddy appeared to keep the effluent from the Shuffleton Plant in a confined area where the heat was dissipated by convection into the cold air and by mixing with the cold river water. Dredging and deposition of the bottom material along the channel of the Cedar River in 1972 for a distance from the mouth of the river brought about a change in the water movement. On 27 December 1972, the surface water temperatures (Figure 2) indicated that the newly formed bar at the river mouth prevented formation of an eddy as in January of 1972, but instead formed a wedge of colder water to the east of the river mouth (Figure 3). The wedge formed by the colder river water was found along the southern border of the log storage area. The river flow forced the colder water forward also but had little effect on the surface water of the lake to the west of the channel (Figures 2 and 3).

Surface water temperatures while the plant was operating are shown in Figures 4 through 13. The approximate area that was affected by the thermal plume (water temperatures 1°F or more above ambient) was outlined by a line for each day. The shaded areas indicate water temperatures greater than 2°F above ambient. The highest temperature of the plume (52 to 58°F) was restricted to a very small area near the outfall (indicated on the figures by a circle). The approximate surface area of the thermal plume was calculated from aerial photographs that were used to outline the south end of Lake Washington on the figures and USGS Nautical Chart 690-C. The surface area of the plume with water temperatures 1°F or more above ambient varied between 13.5 and 33.1 acres (Table 1). The surface area of the plume with water temperatures greater than 2°F above ambient (shaded area on the figures) was considerably less and varied between 4.9 and 18.5 acres. Note that the shape of the thermal plume varied considerably on the different days and that the warmer water is generally found along the shoreline to the south and west of the outfall. The velocity and direction of the wind would influence the area that would be affected by the warm effluent. In addition, the air temperature would also have an effect on the size of the plume because of temperature loss by convection. Since the wind velocity and direction may change considerably in a short period of time, the area of the thermal plume would no doubt change accordingly. The Renton Municipal Airport maintains records of wind direction and velocity for short periods of time, but these records were sent to a central storage area and were not available when this report was being written.

The temperature profiles at the south end of Lake Washington for 6-27 December 1972 are summarized by station in Centigrade and Farenheit (Table 4). While the water temperatures varied from day to day at stations not influenced by the thermal effluent of the plant, good mixing of the water occurred to a depth of 25 feet. The Centigrade values show differences in the vertical temperature profile more clearly than the Farenheit values that tend to minimize these differences. The water temperature profile at the outfall (Station 21) was isothermous on 8 December and 11 December 1972 when the outfall temperatures were 54°F and 58°F, respectively (Figure 14). The influence of the thermal effluent extended to a depth of 10 feet at Station 16, which is directly in line and to the west of the outfall (Figure 1). The temperature profile of Station 10 was nearly identical with that of Station 16 (Table 4) even though Station 10 is the farthest point to be influenced by the effluent. Station 16 is approximately 150 yards or 0.09 miles from the outfall, while Station 10 is approximately 430 yards or 0.25 miles from that location. Often the warm effluent tends to move southerly toward Station 17 and results in warmer surface temperatures. Compare the temperature profiles for Stations 16 and 17 on December 8 and 11 (Table 4). Note that the warm effluent at Station 17 was also confined to the upper 10 feet of water.

When the Shuffleton Plant was again operating in January, it seemed desirable to define the influence of the thermal plume and the Cedar River more clearly. The surface water temperatures in the vicinity of the Shuffleton Plant on 11 January 1973 are given in Figure 15. The thermal plume with water temperatures 1°F or more above ambient was approximately 22.3 acres. The area greater than 2°F above ambient on that date was approximately 11.6 acres. The influence of the thermal plume and Cedar River are shown in detail in Figure 16. Note that the warmest water was found to the south and to the west of the outfall. This area of the plume that was 3°F or more above ambient as about 1.4 acres. The dotted line to the west of the outfall in Figure 16 indicates the area where the outfall water was rapidly mixed with the ambient lake water. In this area, the temperature was continually changing although the thermistor probe was held in a stationary position. Temperature profiles by stations in Figure 1 are summarized in Table 7 for 11 January 1973. Supplementary temperature profiles are summarized in Table 8. The locations of the supplementary stations are identified by letter on Figure 16. The Shuffleton Plant was operated for 4 days during the period of 9-12 January 1973.

Erickson and Whitney (1971) point out the need for studies of the fish that might be found in the vicinity of the Shuffleton Power Plant. Although our knowledge concerning the ecology of the lake is growing (Wydoski 1972b) we know little about the fish distribution in the south end of the lake with the exception of the Cedar River. For this reason, experimental gill nets were set off the mouth of the Cedar River and off the outfall of the Shuffleton Plant for a 24-hour period on 8-9 December 1972, and at the intake and outfall of the plant on 11-12 December 1972. Longfin smelt and adult sockeye salmon comprised the bulk of the catch (Tables 5 and 6). The species composition of the fish captured near the outfall was similar to those caught at the mouth of the Cedar River. On 7 December 1972, University of Washington student, Michael Nishimoto, observed that longfin smelt were being cleaned from the intake screen by a worker. However, on the following day a large number (54) of smelt were taken in a net at the mouth of the Cedar River, but only one smelt was taken in the net at the intake (Table 5).

The adult sockeye salmon were evidently fish that comprise the end of the sockeye run into the Cedar River, since both sexes were ripe. Although sockeye exhibit the peak of their spawning activity in the Cedar River in October (Woodey 1966), the spawning run continues into January. In addition, some sockeye will spawn on certain beaches of Lake Washington from early November until the middle of January (Buckley 1964, Woodey 1961). The water temperature at the outfall was greater than 54°F during this study and was, therefore, slightly higher than that preferred by the sockeye. Foerster (1968) reports that the preferred temperature by the sockeye is about 9°C or 48°F. However, it should be pointed out that the warm effluent above 54°F was confined to a very small area near the outfall. Adult sockeye were captured in the gill nets on both days (Tables 5 and 6) indicating that they were moving throughout the south end of Lake Washington. Water temperatures on the bottom, where the sockeye were captured, were less than 47°F for all days at stations near the outfall (see Stations 15, 16, 17, 18, and 22 in Table 4).

The young sockeye migrate from the Cedar River into the lake from January until April, with a peak movement during March (Woodey 1972). During this stage of its life cycle, sudden increases in water temperature may cause greater predation on the young sockeye (Sylvester 1972). A current study of the food habits of the northern squawfish by University of Washington student, Fred Olney, has revealed that this large minnow feeds on young sockeye in Lake Washington. Operation of the Shuffleton Plant at times when the young sockeye are migrating should be avoided to prevent increased predation by species such as the northern squawfish unless it can be demonstrated that these young sockeye do not move through the area of the thermal discharge.

Dryfoos (1965) described the life history of the landlocked population of longfin smelt in Lake Washington, and Moulton (1970) studied the spawning of this species. In 1970, the spawning run of longfin smelt extended from at least mid-January through mid-April, with the major spawning period between late February and late March. Water temperatures of the Cedar River were increasing from 4.4 to 7.2°C (40 to 45°F) when the major part of the 1970 spawning run occurred. The longfin smelt has a 2-year life cycle and the peak abundance of this species occurs in even years. During the odd years when the smelt population is low, the average size of the fish is larger (Dryfoos 1965). In addition, the larger fish spawn earlier than smaller fish (Moulton 1970). Therefore, the large number of smelt taken off the mouth of the Cedar River (Table 5) was undoubtedly due to their spawning migration. These fish were larger and were at the mouth of the Cedar River earlier than the even-year fish that were studied by Moulton (1970).

Other important species that use the Cedar River for spawning include the steelhead, coastal cutthroat trout (*Salmo clarki*), coho salmon (*Oncorhynchus kisutch*), and chinook salmon (*Oncorhynchus tshawytscha*).

Of these species, two steelhead were taken in the nets at the intake (Table 6). The primary spawning period for the salmon would be fall, while the primary spawning period for the other two species would be winter in this watershed. From late winter through the spring, the young salmonids migrate from the Cedar River and remain in the southern part of the lake for an undetermined period of time. Studies are needed to determine how long these fish remain in the south end of the lake.

In summary, the thermal plume from the Shuffleton Power Plant can be affected by the power output of the plant, by the flow and water temperature of the Cedar River, and by the velocity and direction of the wind. The greatest increase in temperature (7 to 12°F) above the ambient lake temperature that was caused by the operation of the plant in December 1972, was confined to a relatively small area (see circles around outfall on Figures 4-13, 15, and 16). The surface area of the thermal plume greater than 2°F above the ambient water temperature varied between 4.9 and 18.5 acres. The surface area of the thermal plume more than 1°F above ambient varied between 13.5 and 33.1 acres. The thermal influence extended to a depth of about 10 feet. Fish species that were captured in experimental gill nets were similar in the area of the power plant intake and outfall and off the mouth of the Cedar River.

ACKNOWLEDGMENT

The work reported in this paper was supported by the Puget Sound Power and Light Company, Bellevue, Washington.

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TABLE 1. Summary of surface water temperatures near the intake and at the outfall of the Shuffleton Power Plant, the power output of the plant, and the approximate area of the thermal plume during December, 1972.

Date	Air Temp.* F Min.	Max.	Temp. at mouth of Cedar R. C	F	Temp. at Station 25 near intake C	F	Temp. at outfall C	F	Δ Temp. F	Plant power output (KWH)**	Approx. Surface area of plume in acres
6	23	30	1.4	35	6.3	43	12.6	55	12	1,656,000	24.4
7	18	25	0.2	32	6.0	43	12.4	54	11	1,656,000	15.4
8	13	25	0.1	32	6.1	43	12.0	54	11	1,656,000	23.9
9	21	32	1.5	35	6.8	44	12.6	55	11	1,656,000	13.5
10	21	31	0.7	33	-	-	-	-	-	1,656,000	-
11	26	31	2.9	37	7.9	46	14.2	58	12	1,656,000	27.6
12	22	31	3.2	38	7.6	46	13.8	57	11	1,656,000	26.3
13	19	36	2.2	36	7.4	45	13.7	57	12	1,656,000	33.1
14	32	39	4.5	40	8.1	47	14.0	57	10	1,630,000	15.4
15	29	40	4.0	39	7.4	45	13.9	57	12	1,656,000	30.5
18	45	54	6.0	43	7.2	45	13.8	52	7	1,656,000	16.6
27	40	48	5.4	42	6.5	44	6.5	44	0***	0***	0***

*Air temperatures from U.S. Weather Bureau Station at Sea-Tac Airport
**Data from Puget Sound Power & Light Co. per telephone conversation, Dec. 26, 1972
***Plant not operating

TABLE 2. Mean, standard deviation, and range of the difference between intake and outfall temperatures at the Shuffleton Power Plant.*

Date	No. of days	Plant power output (KWH)	Mean difference in temp. (F)	Standard deviation	Range (F)
Oct. 1966	20	30,126,000	12.9	2.31	8-15
Nov. 1966	15	26,224,500	14.8	0.41	14-15
Jan. 1969	9	3,788,000	8.6	3.54	2-12
Jan. 1972	4	1,722,000	7.9	2.98	4.3-10.3
Dec. 1972	16	24,034,980**	10.9***	1.52***	7-12***

*All data except December, 1972, from Table 2 of Wydoski (1972-A)
**Data from Puget Sound Power & Light Co. per telephone conversation Dec. 26, 1972
***Calculations based on records from 10 days (See Table 1)

TABLE 3. Differences in the average daily temperatures (F) of the intake and discharge water from Condenser Unit 1 at the Shuffleton Power Plant for December 5-19, 1972*.

Date	Intake temp.	Discharge temp.	Δ Temp.
5	50	58	8
6	50	59	9
7	49	59	10
8	49	59	10
9	50	58	8
10	50	58	8
11	50	58	8
12	49	58	9
13	48	58	10
14	48	58	10
15	48	58	10
16	48	58	10
17	50	58	8
18	50	58	8
19	50	58	8
Mean t (F)			8.9
Standard deviation			0.96
Number of days			15
Range (F)			8-10

*Data supplied by Puget Sound Power and Light Company in letter dated January 2, 1973.

TABLE 4. Temperature profiles at the south end of Lake Washington for December 6-27, 1972. Temperatures are shown in Centigrade (C) and Fahrenheit (F) (in parenthesis). Station locations by number are shown on Figure 1.

Depth (ft.)	Dec. 6	Dec. 7	Dec. 8	Dec. 9	Dec. 10	Dec. 11	Dec. 12	Dec. 13	Dec. 14	Dec. 15	Dec. 18	Dec. 27
						Station 1						
0	6.4(44)	6.4(44)	6.0(43)	6.3(43)	7.2(45)	7.6(46)	7.8(46)	7.4(45)	7.3(45)	7.5(46)	7.9(46)	6.6(44)
5	6.5(44)	6.4(43)	6.0(43)	6.3(43)	7.0(45)	7.6(46)	7.8(46)	7.4(45)	7.3(45)	7.5(46)	7.9(46)	6.6(44)
10	6.5(44)	6.4(43)	6.0(43)	6.3(43)	6.9(45)	7.6(46)	7.8(46)	7.4(45)	7.3(45)	7.5(46)	7.5(46)	6.5(44)
15	6.5(44)	6.4(43)	6.0(43)	6.3(43)	6.9(45)	7.6(46)	7.8(46)	7.4(45)	7.3(45)	7.4(46)	7.4(45)	6.5(44)
20	6.5(44)	6.4(43)	6.0(43)	6.3(43)	6.9(45)	7.6(46)	7.8(46)	7.4(45)	7.3(45)	7.4(46)	7.3(45)	6.5(44)
25	6.5(44)	6.4(43)	6.0(43)	6.3(43)	6.8(44)	7.6(46)	7.8(46)	7.4(45)	7.3(45)	7.3(45)	7.3(45)	6.5(44)
						Station 2						
0	6.4(44)	6.4(44)	5.9(43)	6.4(44)	6.9(45)	7.8(46)	7.6(46)	7.4(45)	7.3(45)	7.2(45)	7.9(46)	6.9(45)
5	6.4(44)	6.4(44)	5.9(43)	6.4(44)	6.9(45)	7.8(46)	7.6(46)	7.4(45)	7.3(45)	7.2(45)	7.8(46)	6.9(45)
10	6.5(44)	6.4(44)	5.9(43)	6.4(44)	6.9(45)	7.8(46)	7.6(46)	7.4(45)	7.3(45)	7.2(45)	7.7(46)	6.9(45)
15	6.5(44)	6.4(44)	5.9(43)	6.4(44)	6.9(45)	7.8(46)	7.6(46)	7.4(45)	7.3(45)	7.2(45)	7.7(46)	6.8(44)
20	6.5(44)	6.4(44)	6.0(43)	6.4(44)	6.8(44)	7.8(46)	7.6(46)	7.4(45)	7.3(45)	7.2(45)	7.7(46)	6.8(44)
25	6.5(44)	6.4(44)	6.0(43)	6.4(44)	6.8(44)	7.8(46)	7.6(46)	7.4(45)	7.3(45)	7.2(45)	7.6(46)	6.8(44)
						Station 3						
0	6.2(43)	6.3(43)	5.9(43)	6.4(44)	8.2(47)	7.7(46)	7.8(46)	7.4(45)	7.4(45)	7.2(45)	7.7(46)	6.8(44)
5	6.3(43)	6.3(43)	5.9(43)	6.4(44)	8.2(47)	7.7(46)	7.8(46)	7.4(45)	7.4(45)	7.2(45)	7.6(46)	6.8(44)
10	6.3(43)	6.3(43)	5.9(43)	6.4(44)	8.2(47)	7.7(46)	7.8(46)	7.4(45)	7.4(45)	7.2(45)	7.6(46)	6.8(44)
15	6.2(43)	6.3(43)	5.9(43)	6.4(44)	8.2(47)	7.7(46)	7.8(46)	7.4(45)	7.4(45)	7.2(45)	7.6(46)	6.8(44)
20	- -	6.3(43)	5.9(43)	6.4(44)	8.1(47)	7.7(46)	7.8(46)	7.4(45)	7.4(45)	7.2(45)	7.3(45)	6.8(44)
25	- -	6.3(43)	5.9(43)	6.4(44)	8.1(47)	7.7(46)	7.8(46)	7.4(45)	7.4(45)	7.2(45)	7.3(45)	6.8(44)
						Station 4						
0	6.2(43)	6.2(43)	5.8(43)	6.2(43)	6.5(44)	7.6(46)	7.4(45)	7.0(45)	7.3(45)	7.2(45)	7.6(46)	6.6(44)
5	6.2(43)	6.3(43)	5.8(43)	6.2(43)	6.5(44)	7.5(46)	7.5(46)	7.0(45)	7.3(45)	7.2(45)	7.5(46)	6.6(44)
10	6.3(43)	5.4(43)	5.8(43)	6.2(43)	6.5(44)	7.5(46)	7.5(46)	7.0(45)	7.3(45)	7.2(45)	7.4(45)	6.6(44)
15	6.3(43)	- -	5.8(43)	6.2(43)	6.5(44)	7.5(46)	7.5(46)	7.0(45)	7.3(45)	7.2(45)	7.4(45)	6.6(44)
20	6.3(43)	- -	5.8(43)	- -	6.4(44)	7.5(46)	7.4(45)	7.0(45)	7.3(45)	7.2(45)	7.4(45)	6.6(44)
25	6.3(43)	- -	5.8(43)	- -	6.4(44)	7.5(46)	- -	- -	7.3(45)	7.2(45)	7.4(45)	6.5(44)

TABLE 4. (Continued)

Depth (ft.)	DATE Dec. 6	Dec. 7	Dec. 8	Dec. 9	Dec. 10	Dec. 11	Dec. 12	Dec. 13	Dec. 14	Dec. 15	Dec. 18	Dec. 27
						Station 5						
0	1.4(34)	0.2(32)	0.1(32)	1.5(35)	0.7(33)	2.9(37)	3.2(37)	2.2(36)	4.5(40)	4.0(39)	6.0(43)	5.4(42)
						Station 6						
0	7.0(45)	6.6(44)	6.1(43)	6.8(44)	6.4(44)	8.3(47)	8.1(47)	7.8(46)	8.1(47)	8.1(47)	8.0(46)	6.7(44)
5	7.0(45)	6.6(44)	6.1(43)	6.7(44)	6.5(44)	8.1(47)	8.0(46)	7.8(46)	7.5(46)	7.8(46)	7.9(46)	6.7(44)
10	6.6(44)	6.4(44)	6.1(43)	6.4(44)	6.5(44)	7.7(46)	7.8(46)	7.4(45)	7.4(45)	7.4(45)	7.6(46)	6.6(44)
15	6.5(44)	6.3(43)	5.9(43)	6.2(43)	6.5(44)	7.6(46)	7.6(46)	7.4(45)	7.3(45)	7.4(45)	7.4(45)	6.6(44)
20	6.5(44)	6.3(43)	5.9(43)	6.2(43)	6.5(44)	7.6(46)	7.6(46)	7.3(45)	7.3(45)	7.4(45)	7.4(45)	6.6(44)
25	6.4(44)	6.3(43)	5.8(43)	6.2(43)	6.5(44)	7.5(46)	7.5(46)	7.3(45)	7.3(45)	7.4(45)	7.3(45)	6.6(44)
						Station 7						
0	6.4(44)	6.3(43)	5.8(43)	6.6(44)	- -	7.8(46)	7.7(46)	7.4(45)	8.0(46)	7.8(46)	8.0(46)	- -
5	6.4(44)	6.3(43)	5.8(43)	6.4(44)	- -	7.8(46)	7.7(46)	7.4(45)	7.9(46)	7.8(46)	7.9(46)	- -
10	6.4(44)	6.3(43)	5.8(43)	6.3(43)	- -	7.8(46)	7.6(46)	7.4(45)	7.4(45)	7.8(46)	7.4(45)	- -
15	6.4(44)	- -	5.8(43)	6.2(43)	- -	7.8(46)	7.6(46)	7.4(45)	7.3(45)	7.7(46)	7.4(45)	- -
20	6.4(44)	- -	5.8(43)	6.2(43)	- -	7.8(46)	7.6(46)	7.4(45)	7.3(45)	7.6(46)	7.4(45)	- -
25	6.4(44)	- -	5.8(43)	6.2(43)	- -	7.7(46)	7.5(46)	7.4(45)	7.3(45)	7.5(46)	7.4(45)	- -
						Station 8						
0	-	-	-	-	-	-	-	-	7.9(46)	7.5(46)	- -	- -
5	-	-	-	-	-	-	-	-	7.8(46)	7.5(46)	- -	- -
10	-	-	-	-	-	-	-	-	7.6(46)	7.5(46)	- -	- -
15	-	-	-	-	-	-	-	-	7.4(45)	7.5(46)	- -	- -
20	-	-	-	-	-	-	-	-	7.3(45)	7.4(45)	- -	- -
25	-	-	-	-	-	-	-	-	7.3(45)	7.4(45)	- -	- -
						Station 9						
0	7.2(45)	6.8(44)	6.8(44)	7.3(45)	6.8(44)	8.6(48)	8.4(47)	8.1(47)	8.5(47)	8.5(47)	8.4(47)	6.0(43)
5	7.2(45)	6.8(44)	6.8(44)	7.3(45)	6.8(44)	8.8(48)	8.4(47)	8.1(47)	8.4(47)	8.5(47)	8.2(47)	6.0(43)
10	6.8(44)	6.3(43)	6.8(44)	6.5(44)	6.8(44)	8.3(47)	7.9(46)	8.1(47)	7.4(45)	8.4(47)	8.1(47)	6.0(43)
15	6.5(44)	6.1(43)	5.9(43)	6.2(43)	6.5(44)	7.7(46)	7.6(46)	7.3(45)	7.3(45)	7.5(46)	7.9(46)	6.0(43)
20	6.4(44)	6.0(43)	5.7(42)	6.1(43)	6.0(43)	7.6(46)	7.4(45)	7.1(45)	7.3(45)	7.4(45)	7.4(45)	5.9(43)
25	6.2(43)	5.8(43)	5.3(42)	5.8(43)	5.9(43)	7.5(46)	7.3(45)	7.0(45)	7.2(45)	7.2(45)	7.2(45)	5.8(43)

TABLE 4. (Continued)

Depth (ft.)	Dec. 6	Dec. 7	Dec. 8	Dec. 9	Dec. 10	Dec. 11	Dec. 12	Dec. 13	Dec. 14	Dec. 15	Dec. 18	Dec. 27
						DATE						
						Station 10						
0	7.4(45)	7.1(45)	7.2(45)	7.6(46)	7.4(45)	9.0(48)	8.4(47)	8.4(47)	8.9(48)	8.2(47)	8.4(47)	6.1(43)
5	7.4(45)	7.1(45)	7.0(45)	7.6(46)	7.4(45)	8.8(48)	8.4(47)	8.1(47)	8.2(47)	8.2(47)	8.0(46)	6.1(43)
10	7.2(45)	6.8(44)	5.9(43)	7.2(45)	6.8(44)	7.8(46)	8.4(47)	7.4(45)	7.9(46)	7.6(46)	7.5(46)	6.0(43)
15	6.9(45)	6.3(43)	5.7(42)	6.4(44)	6.6(44)	7.6(46)	7.6(46)	7.4(45)	7.4(45)	7.4(45)	7.4(45)	6.0(43)
20	6.7(44)	6.1(43)	5.4(42)	6.1(43)	6.5(44)	7.6(46)	7.4(46)	7.2(45)	7.3(45)	7.4(45)	7.2(45)	6.0(43)
25	6.5(44)	6.0(43)	5.1(41)	6.0(43)	6.1(43)	7.3(45)	7.2(45)	7.1(45)	7.3(45)	7.2(45)	7.2(45)	6.0(43)
						Station 11						
0	7.4(45)	7.4(45)	6.0(43)	8.0(46)	6.9(45)	8.6(48)	8.8(48)	7.9(46)	9.1(48)	8.0(46)	7.9(46)	6.4(44)
5	7.4(45)	7.4(45)	6.0(43)	7.7(46)	6.8(44)	8.0(46)	8.8(48)	7.8(46)	8.8(48)	7.6(46)	7.8(46)	6.3(43)
10	7.4(45)	6.7(44)	5.9(43)	6.7(44)	6.8(44)	7.8(46)	8.0(46)	7.6(46)	7.8(46)	7.5(46)	7.2(45)	6.1(43)
15	6.8(44)	6.1(43)	5.8(43)	6.5(44)	6.5(44)	7.6(46)	7.6(46)	7.0(45)	7.6(46)	7.4(45)	7.2(45)	6.1(43)
20	- -	5.6(42)	5.4(42)	6.3(43)	6.2(43)	7.3(45)	7.4(46)	6.8(44)	7.4(45)	7.4(45)	7.2(45)	5.9(43)
						Station 12						
0	8.0(46)	7.2(45)	7.4(45)	8.5(47)	- -	9.0(48)	8.8(48)	8.9(48)	9.6(49)	8.2(47)	8.3(47)	6.4(44)
5	7.9(46)	7.2(45)	6.8(44)	8.0(46)	- -	8.7(48)	8.8(48)	7.7(46)	8.7(48)	7.8(46)	- -	6.2(43)
10	7.4(45)	7.2(45)	5.9(43)	6.6(44)	- -	7.8(46)	8.2(47)	7.4(45)	7.7(46)	7.5(46)	- -	6.1(43)
15	6.8(44)	6.3(43)	5.8(43)	- -	- -	7.7(46)	8.0(46)	7.3(45)	- -	7.4(45)	- -	6.0(43)
20	6.6(44)	6.3(43)	5.8(43)	- -	- -	- -	7.6(46)	7.2(45)	- -	- -	- -	6.0(43)
25	- -	- -	5.3(42)	- -	- -	- -	- -	7.0(45)	- -	- -	- -	- -
						Station 13						
0	7.5(46)	7.2(45)	7.4(45)	7.6(46)	- -	8.6(48)	8.5(47)	8.3(47)	8.8(48)	9.0(48)	8.5(47)	6.4(44)
5	7.5(46)	7.2(45)	7.0(45)	7.3(45)	- -	8.5(47)	8.5(47)	8.3(47)	8.2(47)	8.8(48)	- -	6.1(43)
10	7.3(45)	6.6(44)	5.9(43)	6.9(45)	- -	7.8(46)	8.5(47)	8.0(46)	7.7(46)	8.0(46)	- -	6.1(43)
15	6.9(45)	6.3(43)	5.8(43)	6.3(43)	- -	7.6(46)	7.7(46)	7.3(45)	7.4(45)	7.5(46)	- -	6.0(43)
20	6.5(45)	6.2(43)	5.7(42)	6.3(43)	- -	7.6(46)	7.5(46)	7.2(45)	7.4(45)	7.4(45)	- -	6.0(43)
25	6.4(44)	5.9(43)	5.4(42)	6.1(43)	- -	7.4(45)	7.4(45)	6.9(45)	7.3(45)	7.4(45)	- -	6.0(43)

TABLE 4. (Continued)

Depth (ft)	Dec. 6	Dec. 7	Dec. 8	Dec. 9	Dec. 10	Dec. 11	Dec. 12	Dec. 13	Dec. 14	Dec. 15	Dec. 18	Dec. 27
						Station 14						
0	7.4(45)	7.2(45)	7.1(45)	7.4(45)	- -	8.6(48)	8.5(47)	8.3(47)	8.6(48)	8.5(47)	9.0(48)	6.3(43)
5	7.3(45)	7.2(45)	7.0(45)	7.4(45)	- -	8.5(47)	8.5(47)	8.3(47)	8.3(47)	8.4(47)	- -	6.2(43)
10	7.0(45)	7.0(45)	6.4(44)	7.2(45)	- -	7.8(46)	8.5(47)	8.0(46)	8.0(46)	8.2(47)	- -	6.1(43)
15	6.5(44)	6.8(44)	6.0(43)	6.3(43)	- -	7.6(46)	7.7(46)	7.3(45)	7.4(45)	7.5(45)	- -	6.0(43)
20	6.4(44)	6.2(43)	5.7(42)	6.3(43)	- -	7.6(46)	7.5(46)	7.2(45)	7.4(45)	7.4(45)	- -	6.0(43)
25	6.4(44)	6.2(43)	5.5(42)	6.2(43)	- -	7.4(45)	7.4(45)	6.9(45)	7.3(45)	7.3(45)	- -	6.0(43)
						Station 15						
0	7.6(46)	7.8(46)	7.4(45)	7.8(46)	- -	9.4(49)	9.0(48)	8.4(47)	9.1(48)	8.9(48)	8.3(47)	6.1(43)
5	7.5(46)	7.8(46)	7.4(45)	7.8(46)	- -	9.0(48)	8.5(47)	8.4(47)	8.3(47)	8.9(48)	- -	6.1(43)
10	6.7(44)	7.0(45)	6.1(43)	6.9(45)	- -	8.1(47)	7.8(46)	8.2(47)	7.8(46)	8.0(46)	- -	6.1(43)
15	6.5(44)	6.4(44)	5.8(43)	6.4(44)	- -	7.8(46)	7.5(45)	7.8(46)	7.4(45)	7.5(45)	- -	6.1(43)
20	6.4(44)	6.3(43)	5.7(42)	6.3(43)	- -	7.8(46)	7.4(45)	7.3(45)	7.3(45)	7.4(45)	- -	6.1(43)
25	6.4(44)	6.2(43)	5.7(42)	6.3(43)	- -	7.6(46)	7.4(45)	7.3(45)	7.3(45)	7.4(45)	- -	6.1(43)
						Station 16						
0	7.8(46)	7.8(46)	7.4(45)	8.0(46)	- -	9.1(48)	9.0(48)	9.1(48)	9.1(48)	9.0(48)	9.0(48)	6.5(44)
5	7.4(45)	7.2(45)	7.0(45)	7.4(45)	- -	8.6(48)	8.8(48)	8.5(47)	8.3(47)	8.5(47)	- -	6.5(44)
10	6.7(44)	6.4(44)	6.0(43)	6.5(44)	- -	7.8(46)	7.8(46)	7.6(46)	7.4(45)	7.5(45)	- -	6.0(43)
15	6.5(44)	6.2(43)	5.8(43)	6.4(44)	- -	7.7(46)	7.6(46)	7.3(45)	7.4(45)	7.4(45)	- -	6.0(43)
20	6.4(44)	6.2(43)	5.8(43)	6.3(43)	- -	7.6(46)	7.4(45)	7.3(45)	7.4(45)	7.4(45)	- -	6.0(43)
25	6.4(44)	6.2(43)	5.0(41)	6.3(43)	- -	7.6(46)	7.4(45)	7.2(45)	7.3(45)	7.4(45)	- -	6.0(43)
						Station 17						
0	8.1(47)	7.6(46)	8.4(47)	8.0(46)	- -	9.6(49)	8.9(48)	9.5(49)	9.1(48)	9.7(50)	9.4(49)	7.0(45)
5	8.1(47)	7.4(45)	7.4(45)	7.8(46)	- -	8.8(48)	8.6(48)	8.9(48)	9.0(48)	9.0(48)	- -	6.2(43)
10	7.0(45)	6.4(44)	6.2(43)	6.4(44)	- -	7.7(46)	8.0(46)	7.6(46)	7.5(45)	7.4(45)	- -	6.2(43)
15	6.6(44)	6.3(43)	6.0(43)	6.4(44)	- -	7.6(46)	7.6(46)	7.4(45)	7.4(45)	7.4(45)	- -	6.0(43)
20	6.4(44)	6.0(43)	5.5(42)	6.3(43)	- -	7.6(46)	7.5(46)	7.0(45)	7.3(45)	7.4(45)	- -	6.0(43)
25	6.4(44)	5.7(42)	5.0(41)	6.1(43)	- -	7.4(45)	7.4(45)	6.8(44)	7.2(45)	7.4(45)	- -	6.0(43)

TABLE 4. (Continued)

Depth (ft.)	DATE Dec. 6	Dec. 7	Dec. 8	Dec. 9	Dec. 10	Dec. 11	Dec. 12	Dec. 13	Dec. 14	Dec. 15	Dec. 18	Dec. 27
Station 18												
0	6.5(44)	6.7(44)	6.6(44)	7.3(45)	- -	8.4(47)	8.4(47)	8.0(46)	8.1(47)	8.2(47)	7.6(46)	6.5(44)
5	6.5(44)	6.8(44)	6.5(45)	7.1(45)	- -	8.4(47)	8.4(47)	8.0(46)	8.0(46)	8.2(47)	- -	6.3(43)
10	6.5(44)	6.5(45)	6.1(43)	6.6(44)	- -	8.3(47)	7.8(46)	8.0(46)	7.5(46)	8.1(47)	- -	6.3(43)
15	6.5(44)	6.4(44)	6.0(43)	6.4(44)	- -	8.0(46)	7.6(46)	7.5(46)	7.5(46)	7.6(46)	- -	6.1(43)
20	- -	6.4(44)	5.9(43)	6.4(44)	- -	7.8(46)	7.6(46)	7.4(45)	7.4(45)	7.5(46)	- -	6.1(43)
25	- -	6.4(44)	5.9(43)	6.4(44)	- -	7.7(46)	7.6(46)	7.4(45)	7.4(45)	7.5(46)	- -	6.1(43)
Station 19												
0	- -	6.3(43)	6.2(43)	6.9(45)	- --	7.7(46)	8.0(46)	7.6(46)	7.7(46)	8.2(47)	7.8(46)	- -
5	- -	6.3(43)	62.(43)	6.7(44)	- -	7.7(46)	8.0(46)	7.6(46)	7.7(46)	8.2(47)	- -	- -
10	- -	6.3(43)	6.1(43)	6.5(44)	- -	7.7(46)	7.7(46)	7.6(46)	7.6(46)	7.9(46)	- -	- -
15	- -	- -	6.0(43)	6.5(44)	- -	7.7(46)	7.6(46)	7.5(46)	7.5(46)	7.6(46)	- -	- -
20	- -	- -	6.0(43)	6.5(44)	- -	7.7(46)	7.6(46)	7.5(46)	7.4(45)	7.6(46)	- -	- -
25	- -	- -	5.9(43)	6.5(44)	- -	7.7(46)	7.6(46)	7.4(45)	7.4(45)	7.5(46)	- -	- -
Station 20												
0	-	-	-	6.5(44)	-	-	-	-	-	7.6(46)	-	-
5	-	-	-	6.5(44)	-	-	-	-	-	7.6(46)	-	-
10	-	-	-	6.5(44)	-	-	-	-	-	7.6(46)	-	-
15	-	-	-	6.5(44)	-	-	-	-	-	7.6(46)	-	-
20	-	-	-	6.5(44)	-	-	-	-	-	7.5(46)	-	-
25	-	-	-	6.5(44)	-	-	-	-	-	7.5(46)	-	-
Station 21												
0	12.6(55)	12.4(54)	12.0(54)	12.6(55)	- -	14.2(58)	13.8(57)	13.7(57)	14.0(57)	13.9(57)	13.8(57)	6.5(44)
15	12.6(55)	12.4(54)	12.0(54)	12.6(55)	- -	14.2(58)	13.8(57)	13.7(57)	14.0(57)	13.9(57)	13.8(57)	6.5(44)

TABLE 4. (Continued)

Depth (ft.)	Dec. 6	Dec. 7	Dec. 8	Dec. 9	Dec. 10	Dec. 11	Dec. 12	Dec. 13	Dec. 14	Dec. 15	Dec. 18	Dec. 27
						Station 22						
0	6.5(44)	6.8(44)	6.2(43)	7.4(45)	- -	7.8(46)	8.0(46)	7.4(45)	7.6(46)	7.4(45)	7.4(45)	6.5(44)
5	6.4(44)	6.8(44)	6.2(43)	7.4(45)	- -	7.8(46)	8.2(47)	7.4(45)	7.6(46)	7.4(45)	- -	6.5(44)
10	6.4(44)	6.8(44)	6.0(43)	- -	- -	7.8(46)	8.2(47)	7.4(45)	7.6(46)	7.4(45)	- -	6.5(44)
						Station 23						
0	6.3(43)	6.7(44)	6.2(43)	7.1(45)	- -	7.8(46)	7.9(46)	7.3(45)	7.9(46)	7.4(45)	7.2(45)	6.4(44)
5	6.3(43)	6.7(44)	6.2(43)	7.0(45)	- -	7.8(46)	7.9(46)	7.3(45)	7.9(46)	7.4(45)	- -	6.4(44)
10	- -	6.6(44)	6.1(43)	6.6(44)	- -	7.8(46)	7.9(46)	7.3(45)	7.9(46)	7.4(45)	- -	6.3(43)
15	- -	6.4(44)	- -	- -	- -	7.8(46)	7.9(46)	- -	7.7(46)	7.4(45)	- -	6.3(43)
						Station 24						
0	- -	6.3(43)	5.7(42)	6.8(44)	-	-	-	-	7.9(46)	-	-	-
5	- -	6.3(43)	5.7(42)	6.8(44)	-	-	-	-	7.9(46)	-	-	-
10	- -	- -	5.7(42)	6.8(44)	-	-	-	-	7.8(46)	-	-	-
						Station 25						
0	6.3(43)	6.0(43)	6.1(43)	6.8(44)	- -	7.9(46)	7.6(46)	7.4(45)	8.1(47)	7.4(45)	7.2(45)	6.5(44)
5	6.3(43)	6.0(43)	6.1(43)	6.8(44)	- -	7.9(46)	7.6(46)	7.4(45)	8.1(47)	7.4(45)	- -	6.4(44)
10	- -	- -	6.1(43)	6.8(44)	- -	7.9(46)	7.6(46)	7.4(45)	8.0(46)	7.4(45)	- -	6.2(43)
15	- -	- -	6.1(43)	6.6(44)	- -	7.6(46)	7.6(46)	7.4(45)	7.5(46)	7.4(45)	- -	6.1(43)
20	- -	- -	6.0(43)	6.5(44)	- -	7.6(46)	7.5(46)	7.2(45)	7.3(45)	7.4(45)	- -	6.1(43)
25	- -	- -	5.9(43)	6.3(43)	- -	7.4(45)	7.4(45)	7.0(45)	7.2(45)	7.4(45)	- -	6.1(43)

TABLE 5. Summary of fish captured in experimental gill nets* in the vicinity of the Shuffleton Power Plant on December 8-9, 1972.

Species Common name - (Scientific name in parenthesis)	Sex	No.	Fork Length Mean (mm)	Mean (in)	Range (mm)	Range (in)
OFF MOUTH OF THE CEDAR RIVER:						
Sockeye salmon (*Oncorhynchus nerka*)	M	14	575	22.6	474-653	18.6-25.7
" "	F	5	539	21.2	419-557	16.4-21.9
Longfin smelt (*Spirinchus thaleichthys*)	M	36	131	5.2	120-145	4.7- 5.7
" "	F	18	126	5.0	121-132	4.8- 5.2
Largescale sucker (*Catostomus macrocheilus*)	M	1	408	16.1	-	-
" "	F	1	415	16.3	-	-
Peamouth (*Mylocheilus caurinus*)	F	2	273	10.7	265-280	10.4-11.0
OFF OUTFALL OF THE SHUFFLETON POWER PLANT:						
Sockeye salmon	M	3	560	22.0	530-610	20.9-24.0
Longfin smelt	M	1	137	5.4	-	-
Largescale sucker	M	1	367	14.4	-	-
" "	F	1	418	16.5	-	-
Northern squawfish (*Ptychocheilus oregonensis*)	F	3	335	13.2	225-422	8.9-16.6
Yellow perch (*Perca flavescens*)	M	1	131	5.2	-	-

*Each gill net consists of nine mesh sizes from 1.0 through 5.0-inches by 1/2-inch intervals (stretched measure). The panels are 6 feet deep by 11 feet long and are set horizontally along the bottom. The sets were made for a 24-hour period and were made perpendicular to the shoreline.

TABLE 6. Summary of fish captured in experimental gill nets* in the vicinity of the Shuffleton Power Plant on December 11-12, 1972.

Species Common name - (Scientific name in parenthesis)	Sex	No.	Fork Length* Mean (mm)	Fork Length* Mean (in)	Fork Length* Range (mm)	Fork Length* Range (in)
AT INTAKE TO SHUFFLETON POWER PLANT:						
Sockeye salmon (*Oncorhynchus nerka*)	M	11	585	23.0	545-658	21.5-25.9
"	F	1	600	23.6	-	-
Steelhead (*Salmo gairdneri*)	M	1	667	26.3	-	-
"	F	1	562	22.1	-	-
OFF OUTFALL OF THE SHUFFLETON POWER PLANT:						
Sockeye salmon	M	5	580	22.8	518-652	20.4-25.7
"	F	3	513	20.2	444-572	17.5-22.5
Largescale sucker (*Catostomus macrocheilus*)	M	4	415	16.4	386-432	15.2-17.0
"	F	2	423	16.7	422-423	16.6-16.7
Northern squawfish (*Ptychocheilus oregonensis*)	F	1	418	16.5	-	-

*See footnote on Table 3 for a description of the nets and how the sets were made.

TABLE 7. Temperature profiles at the south end of Lake Washington at 1300-1500 PST on January 11, 1973. Temperatures are given in Centigrade and in Farenheit (in parentheses). Station locations are shown on Figure 1.

Depth (ft.)	STATION 6	7	8	9	10	11	12	13	14	15	16	17	21
0	5.5(42)	5.4(42)	5.4(42)	5.9(43)	6.7(44)	6.1(43)	6.5(44)	6.5(44)	6.0(43)	6.1(43)	6.5(44)	8.0(46)	12.0(54)
5	5.4(42)	5.1(41)	5.2(41)	5.6(42)	5.9(43)	5.7(42)	5.9(43)	6.0(43)	5.9(43)	5.6(42)	5.7(42)	6.1(43)	-
10	5.0(41)	4.8(41)	5.0(41)	5.3(42)	5.7(42)	5.3(42)	5.1(41)	5.5(42)	5.5(42)	5.1(41)	5.5(42)	4.9(41)	-
15	4.6(40)	4.8(41)	4.7(41)	4.9(41)	5.0(41)	5.1(41)	5.1(41)	5.2(41)	5.2(41)	4.6(40)	5.0(41)	4.6(40)	12.0(54)
20	4.6(40)	4.6(40)	4.6(40)	4.9(41)	4.9(41)	5.0(41)	4.8(41)	4.7(41)	4.7(41)	4.6(40)	4.6(40)	4.6(40)	-
25	4.6(40)	4.6(40)	4.6(40)	4.8(41)	4.9(41)	4.9(41)	4.8(41)	4.7(41)	4.7(41)	4.6(40)	4.6(40)	4.6(40)	-

TABLE 8. Supplementary temperature profiles at the south end of Lake Washington on January 11, 1973. Temperatures are given in Centigrade and in Farenheit (in parentheses). Station locations by letter are shown on Figure 16.

Depth (ft.)	STATION A	B	C	D	E	F	G	H	I
0	5.5(42)	5.9(43)	6.0(43)	6.8(44)	6.2(43)	7.0(45)	5.9(43)	5.9(43)	8.8(48)
5	5.2(41)	5.5(42)	5.8(43)	5.5(42)	5.9(43)	5.9(43)	5.7(42)	5.5(42)	5.6(42)
10	4.8(41)	4.5(40)	5.5(42)	5.1(41)	5.2(41)	5.5(42)	5.0(41)	5.1(41)	5.1(41)
15	4.7(41)	4.6(41)	5.2(41)	5.3(42)	5.1(41)	4.9(41)	4.9(41)	4.6(40)	-
20	4.7(41)	4.7(41)	5.0(41)	4.9(41)	-	4.7(41)	4.8(41)	4.6(40)	-
25	4.6(40)	4.6(41)	4.8(41)	4.9(41)	-	4.6(41)	4.6(41)	4.6(40)	-

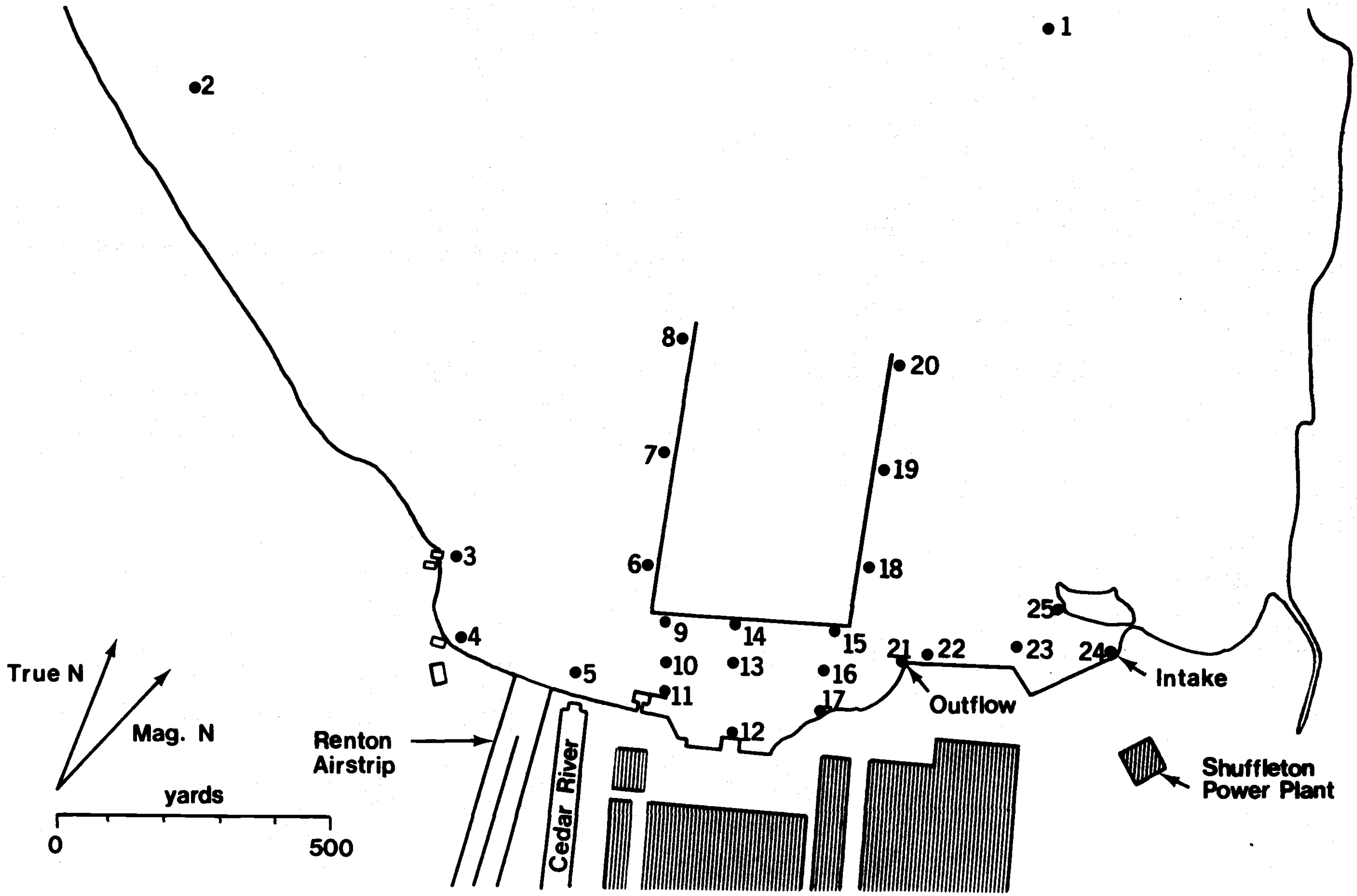

FIGURE 1. Locations of stations for thermal study of the Shuffleton Power Plant operation in December 1972.

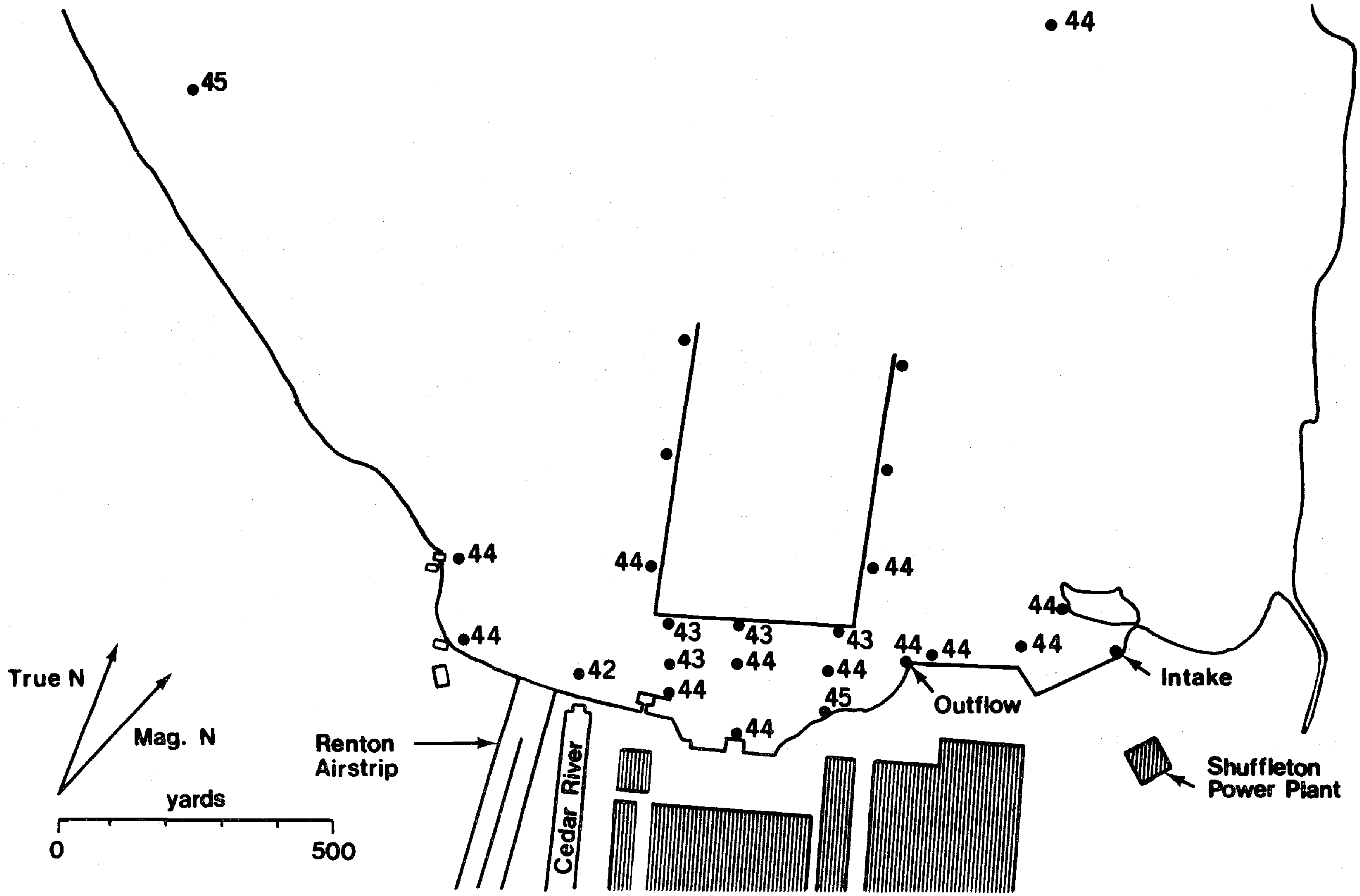

FIGURE 2. Surface water temperatures (F) in the south end of Lake Washington at 1100-1300 PST on 27 December 1972, when the Shuffleton Power Plant was not operating.

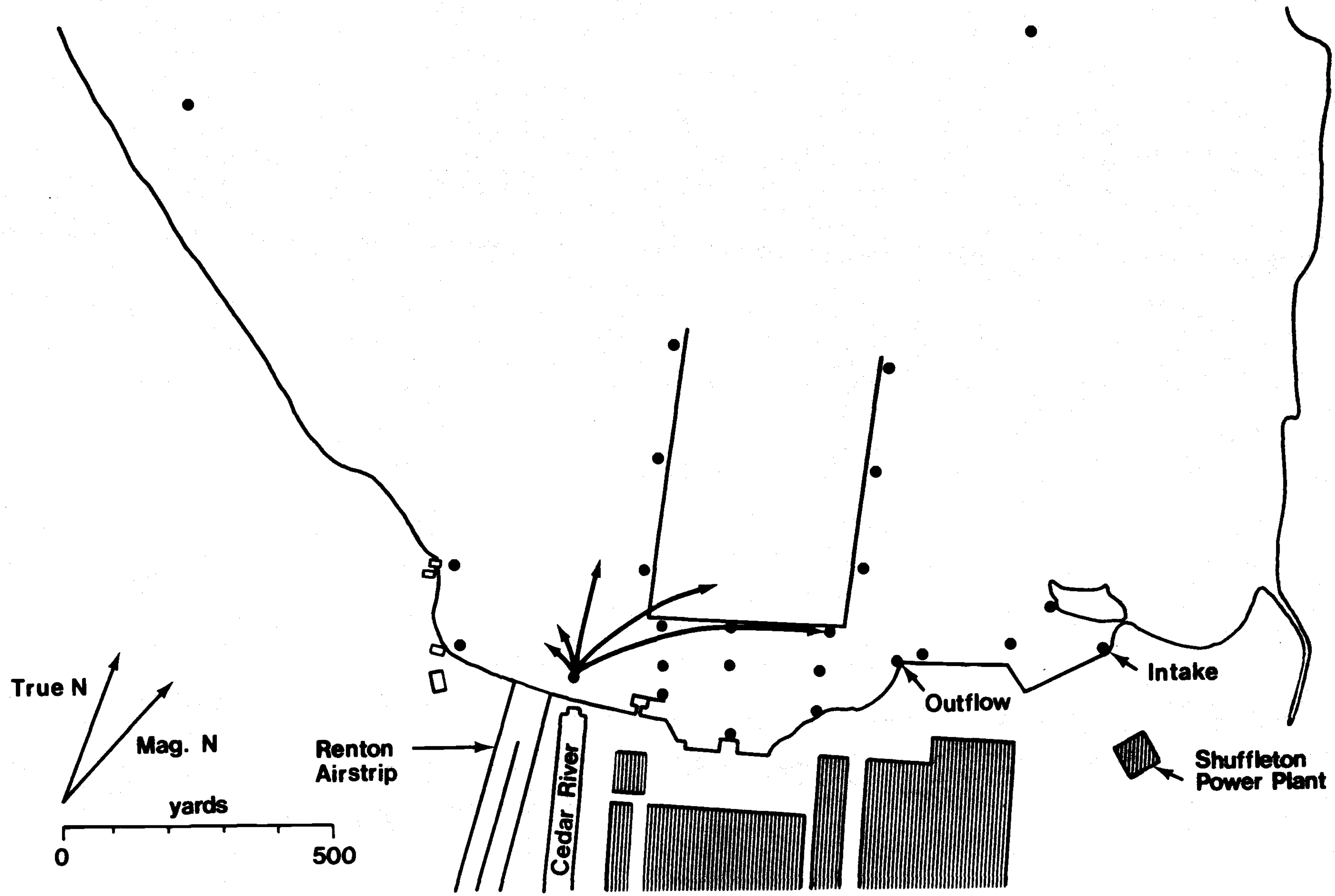

FIGURE 3. Influence of the Cedar River on surface water movement in the vicinity of the Shuffleton Power Plant on 27 December 1972.

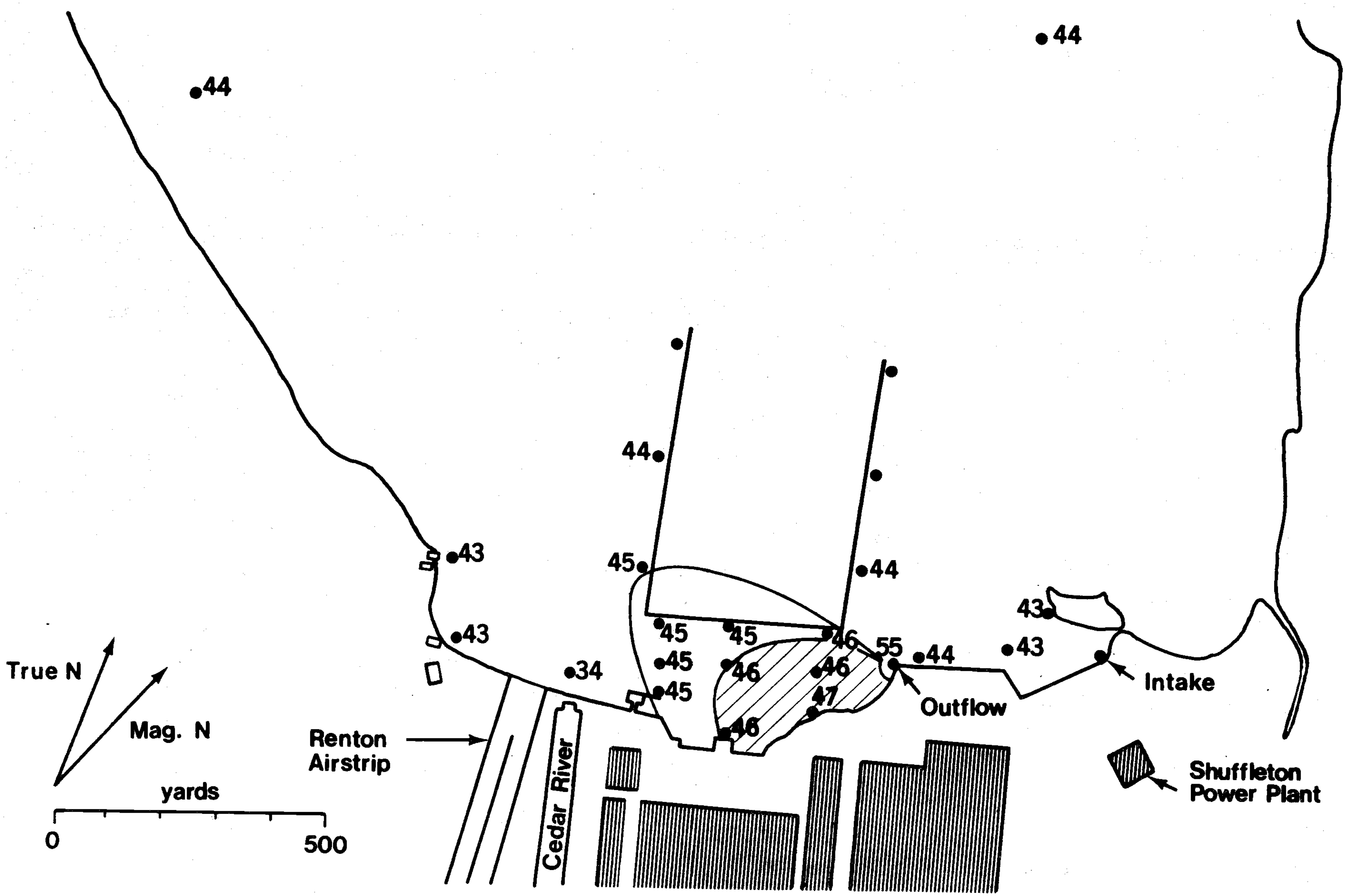

FIGURE 4. Surface water temperatures (F) in the south end of Lake Washington at 1300-1500 PST on 6 December 1972.

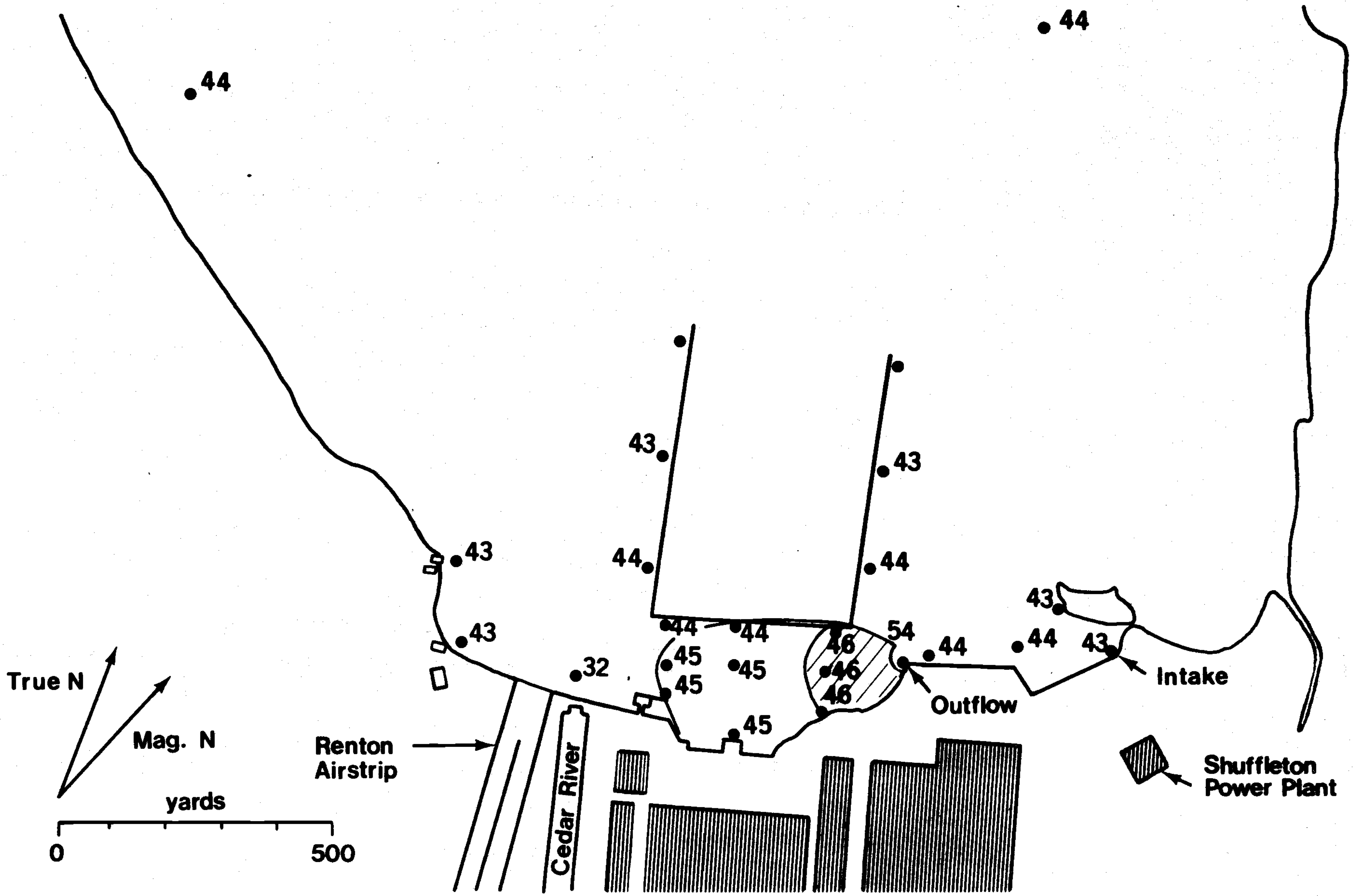

FIGURE 5. Surface water temperatures (F) in the south end of Lake Washington at 1100-1245 PST on 7 December 1972.

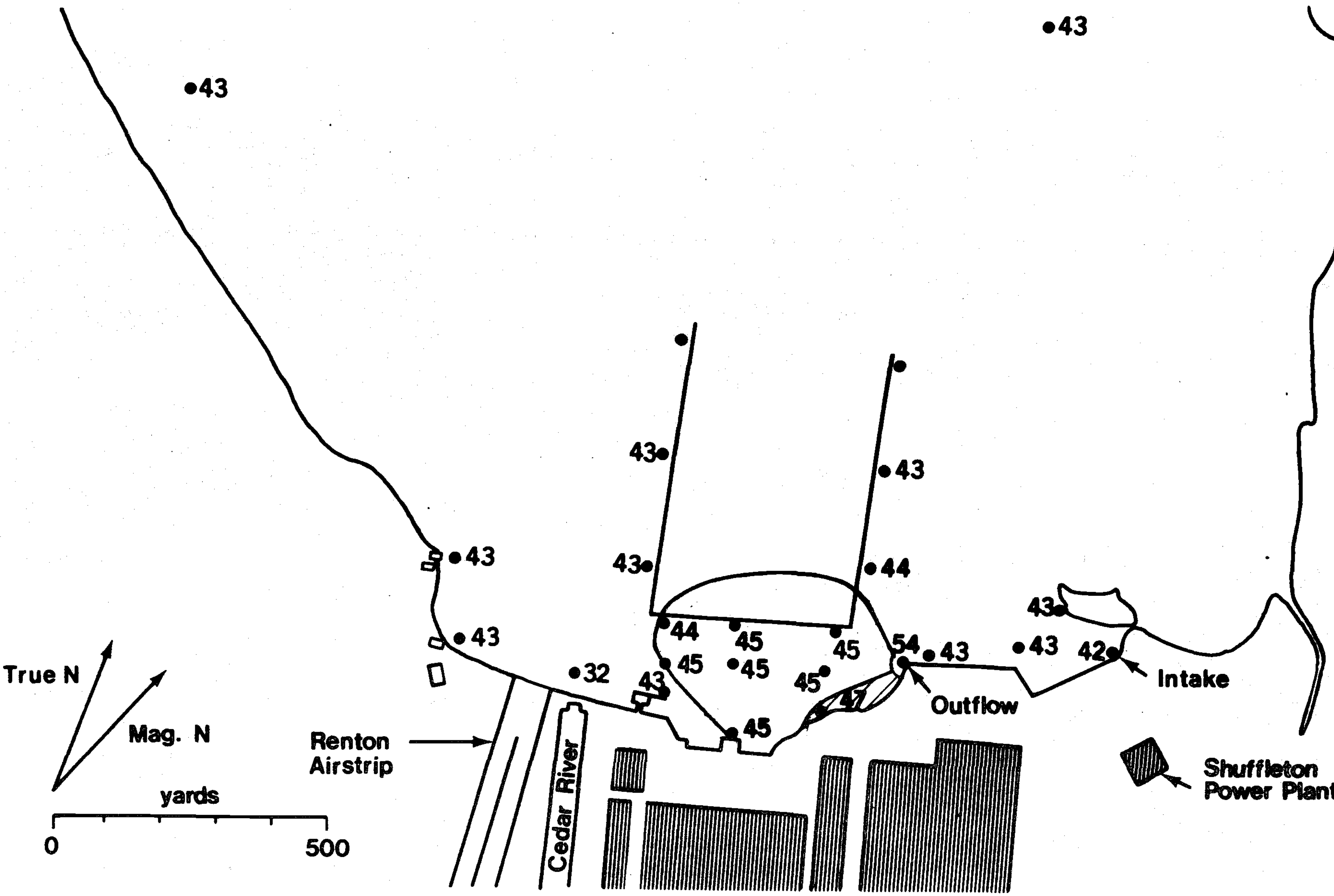

FIGURE 6. Surface water temperatures (F) in the south end of Lake Washington at 1130-1325 PST on 8 December 1972.

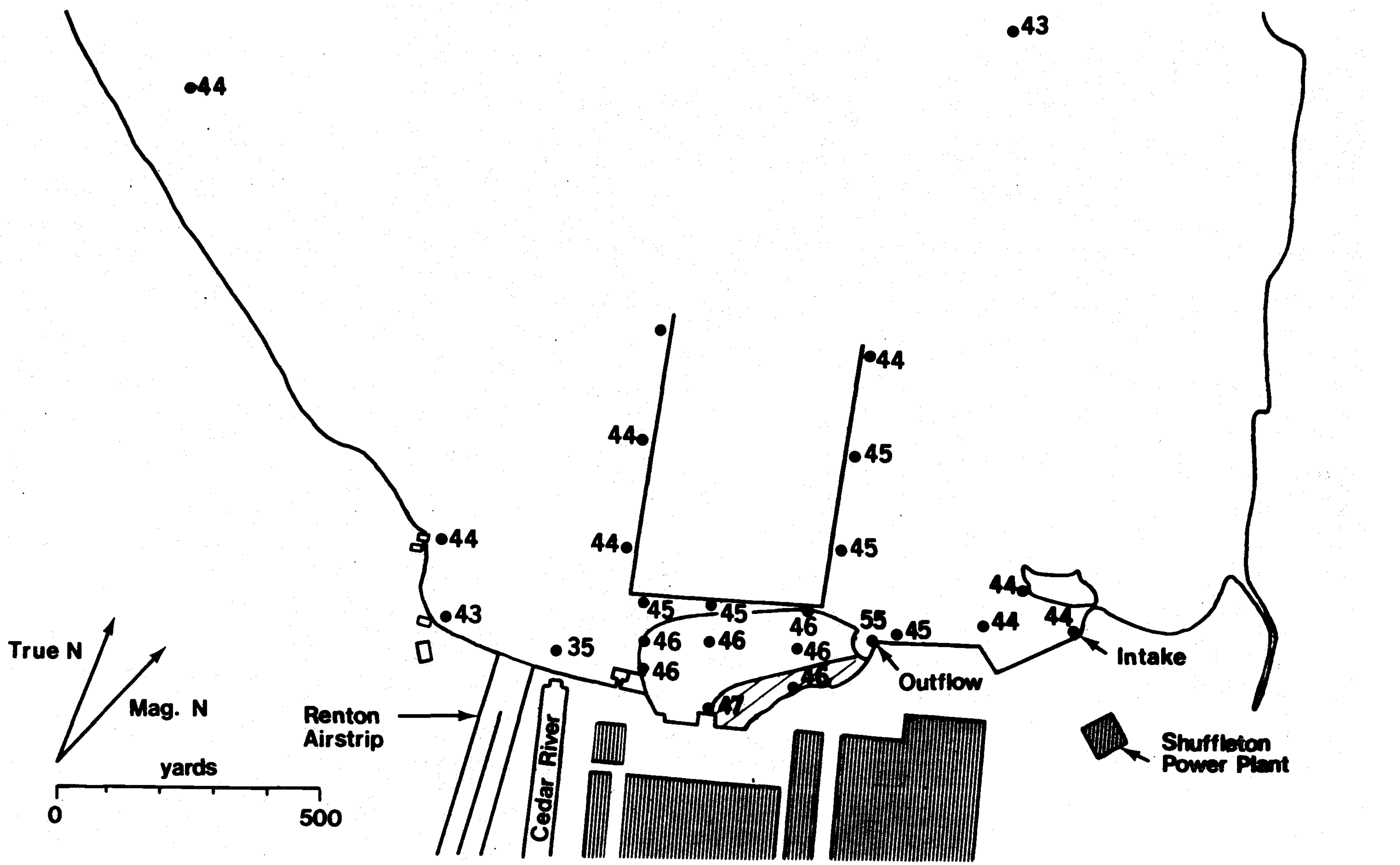

FIGURE 7. Surface water temperatures (F) in the south end of Lake Washington at 1200-1330 PST on 9 December 1972.

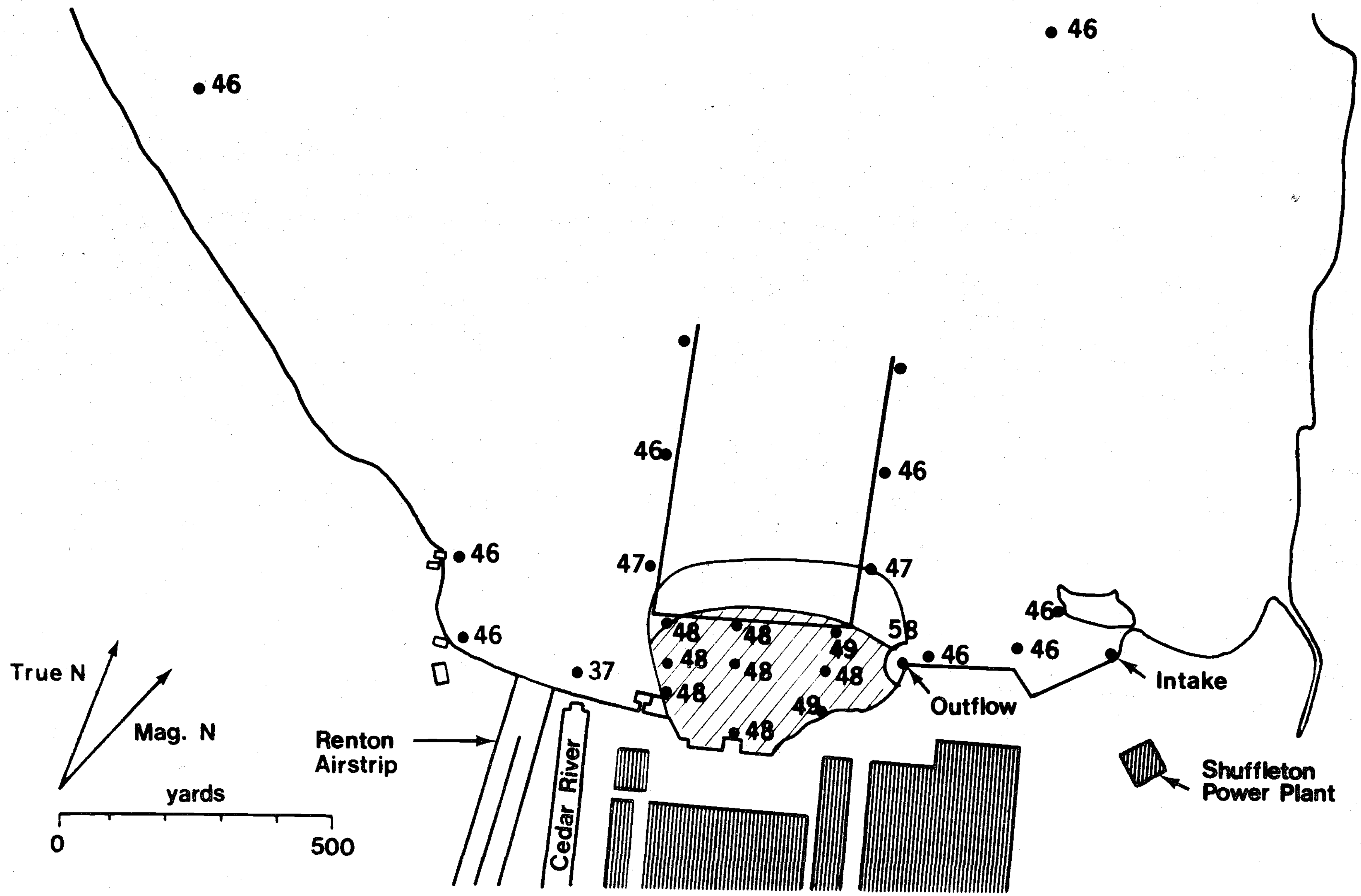

FIGURE 8. Surface water temperatures (F) in the south end of Lake Washington at 1130-1330 PST on 11 December 1972.

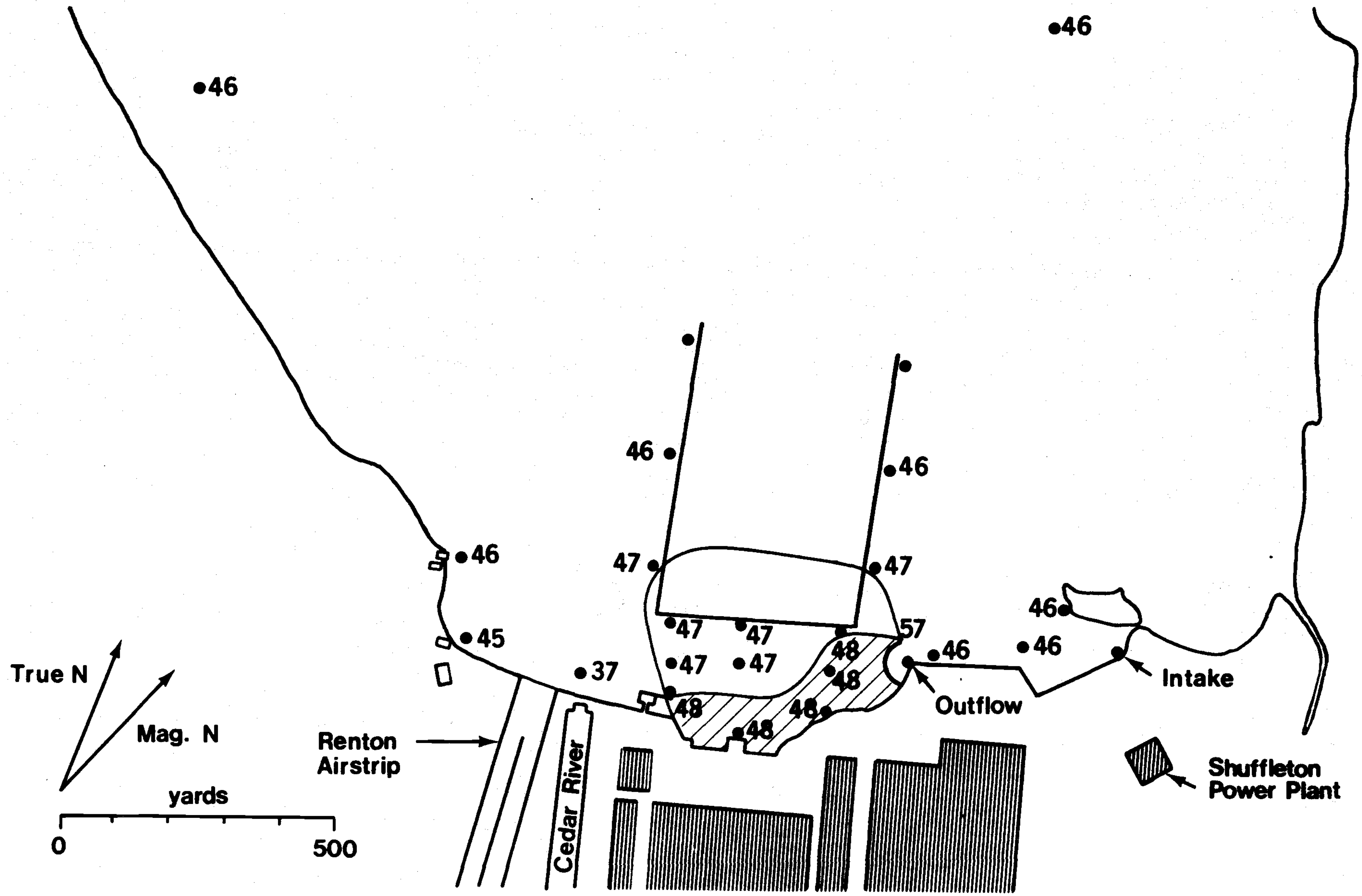

FIGURE 9. Surface water temperatures (F) in the south end of Lake Washington at 1100-1300 PST on 12 December 1972.

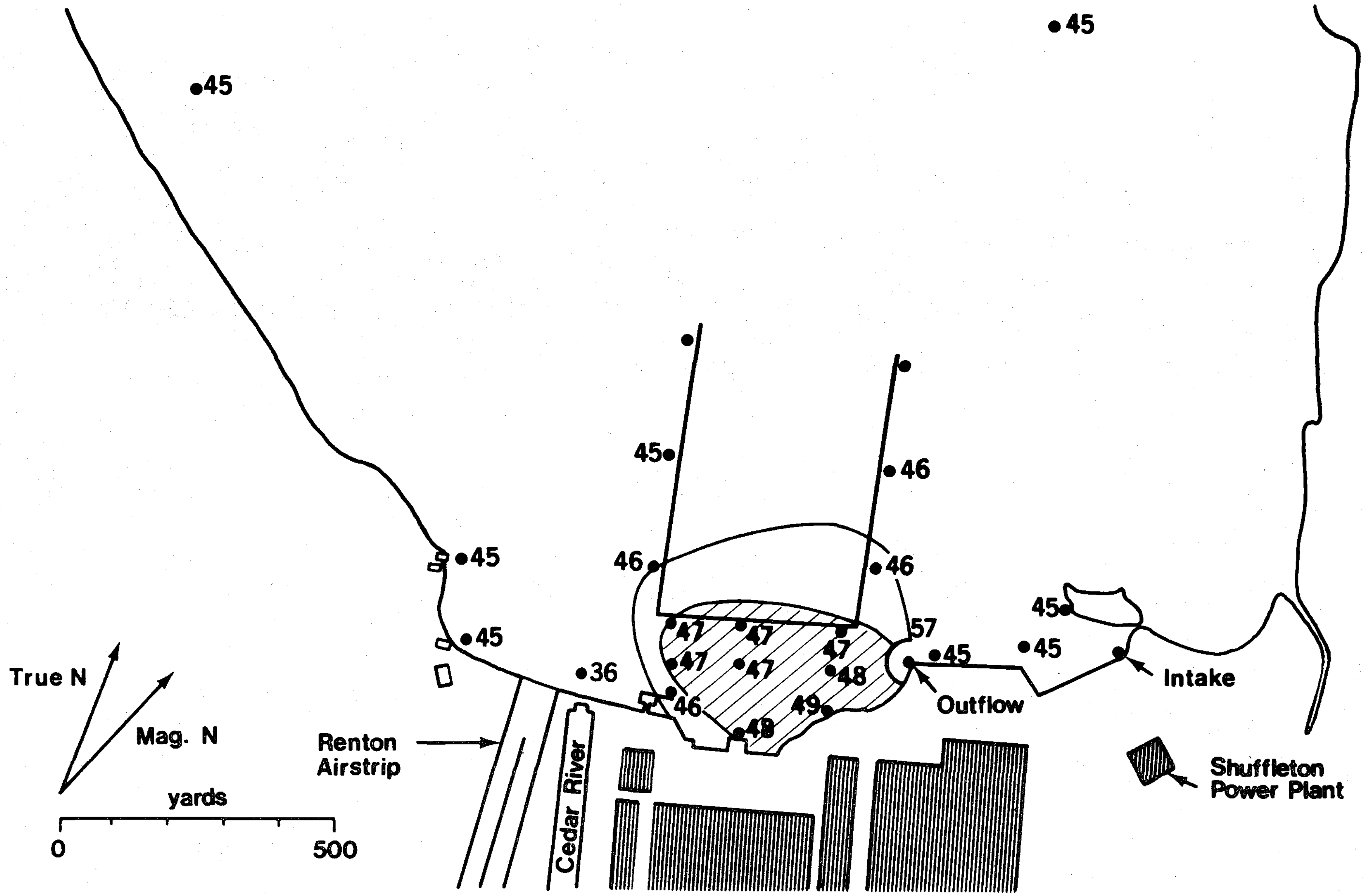

FIGURE 10. Surface water temperatures (F) in the south end of Lake Washington at 1130-1335 PST on 13 December 1972.

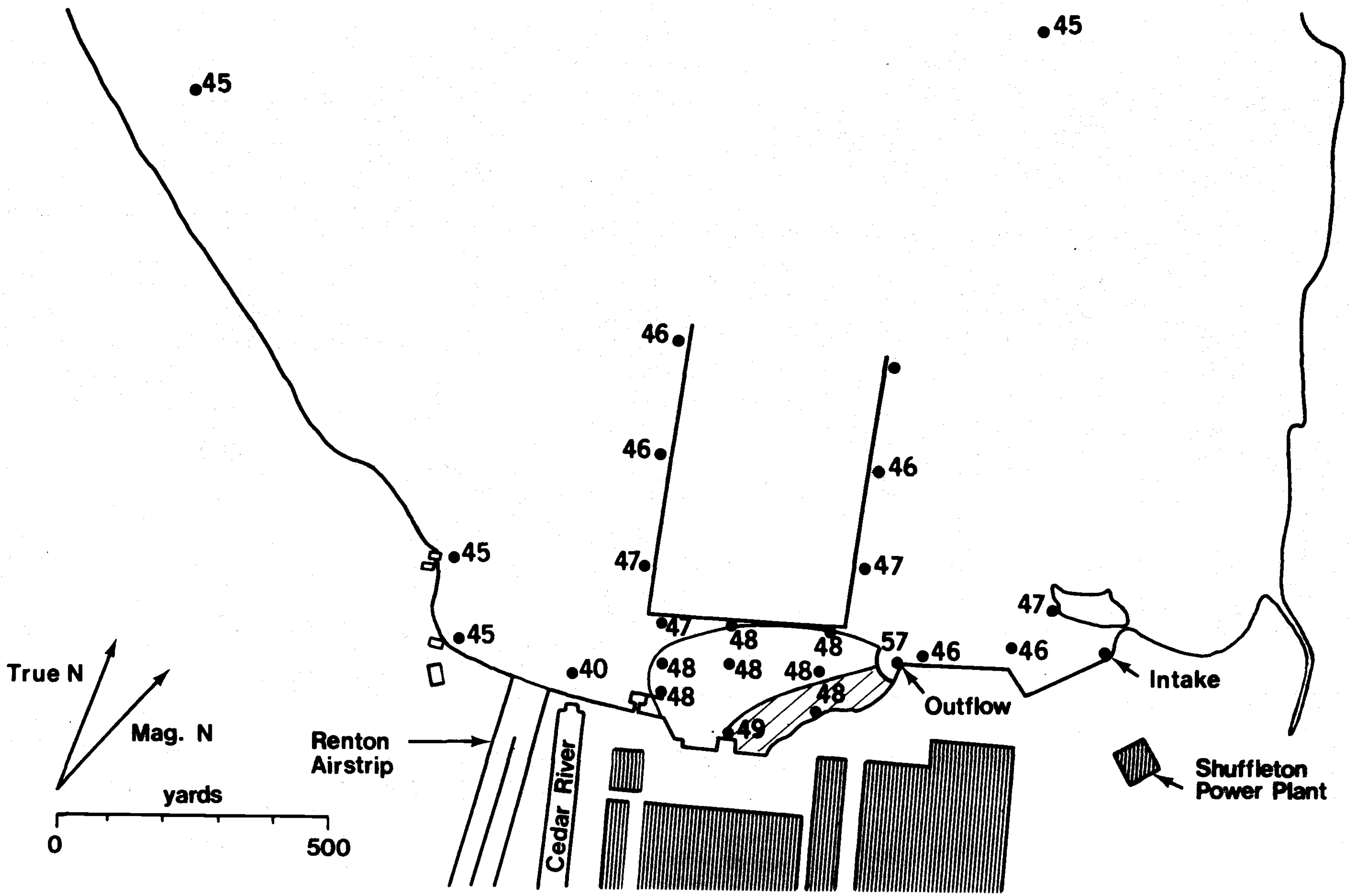

FIGURE 11. Surface water temperatures (F) in the south end of Lake Washington at 1040-1240 PST on 14 December 1972.

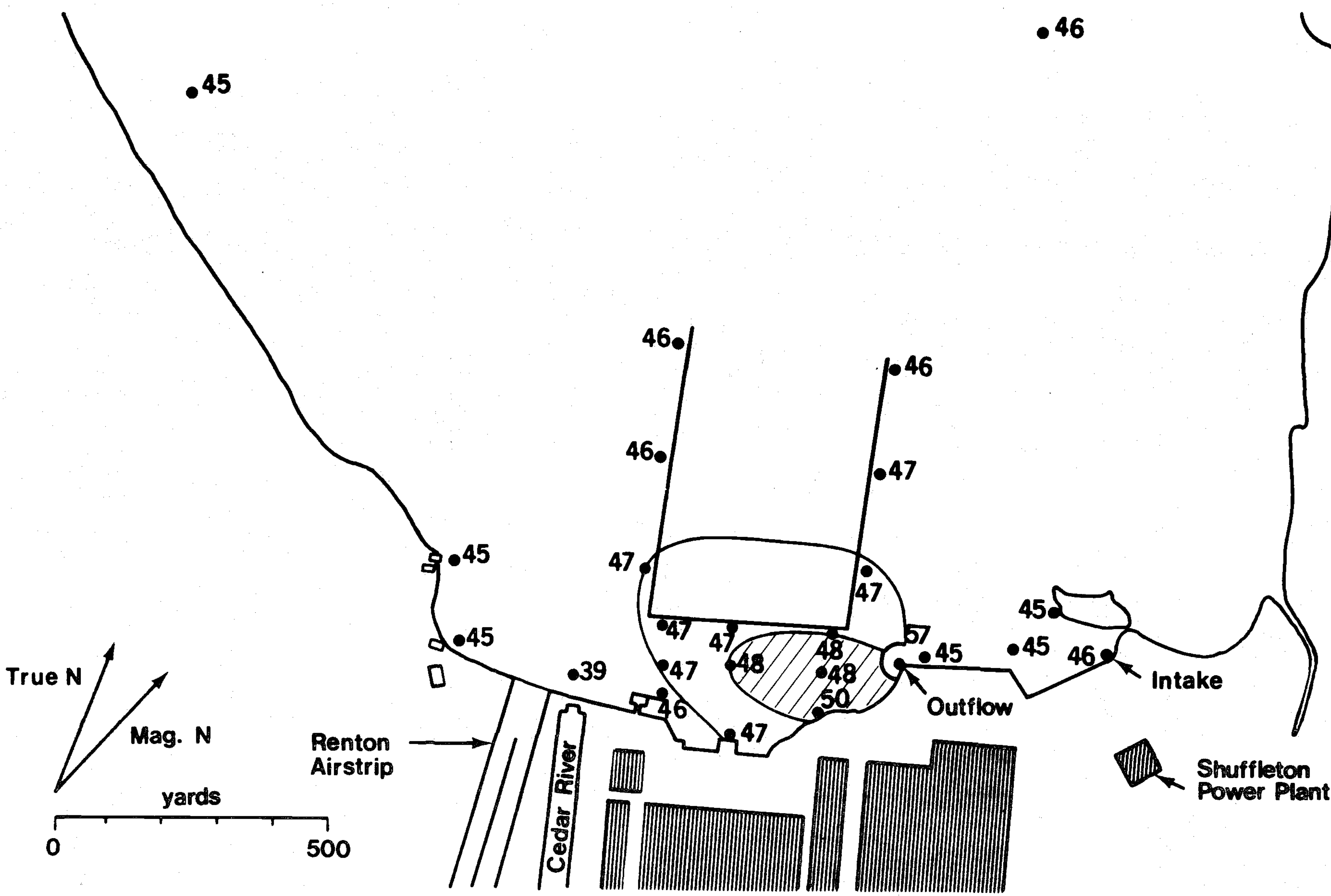

FIGURE 12. Surface water temperatures (F) in the south end of Lake Washington at 1200-1400 PST on 15 December 1972.

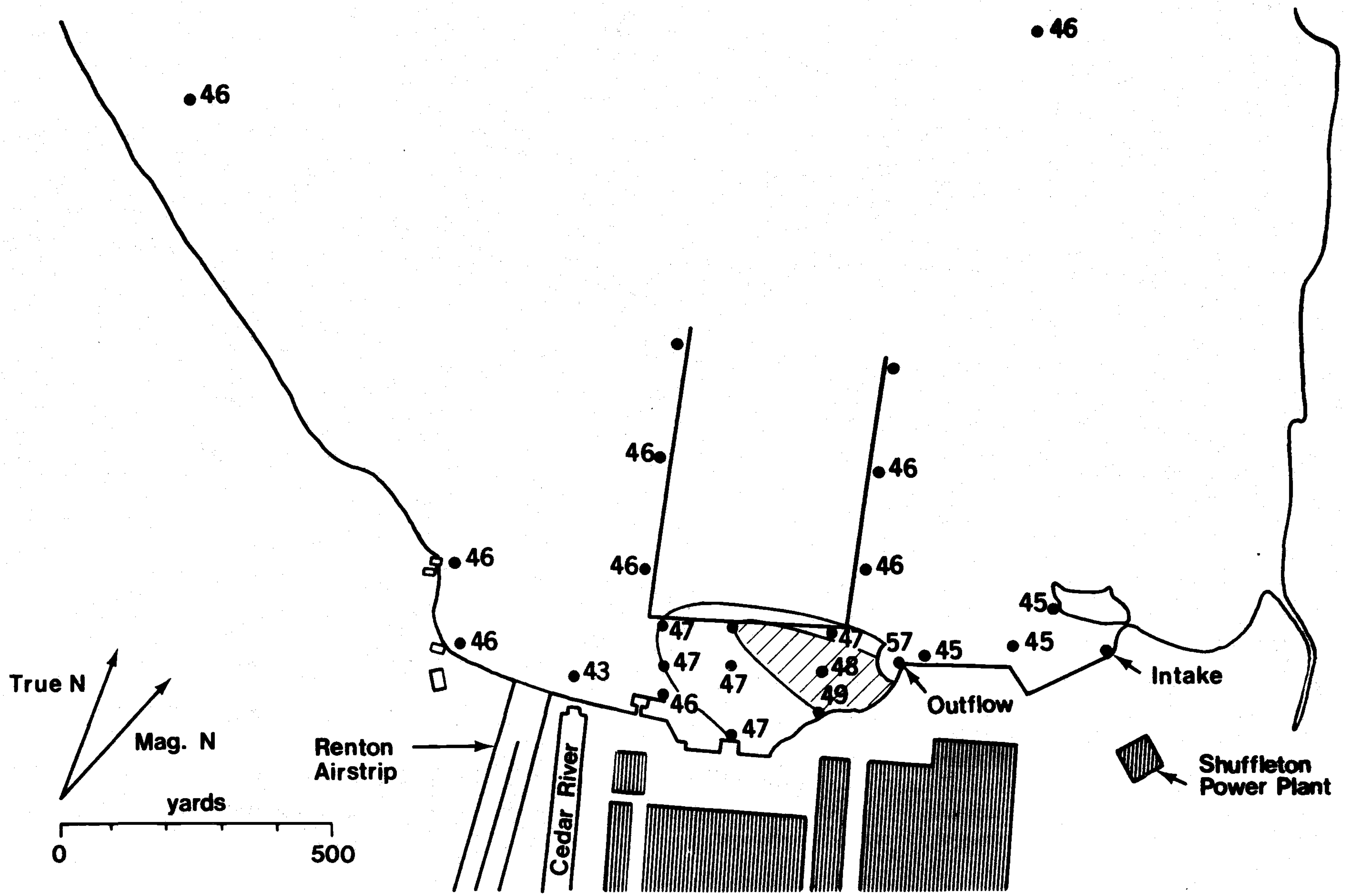

FIGURE 13. Surface water temperatures (F) in the south end of Lake Washington at 1100-1245 PST on 18 December 1972

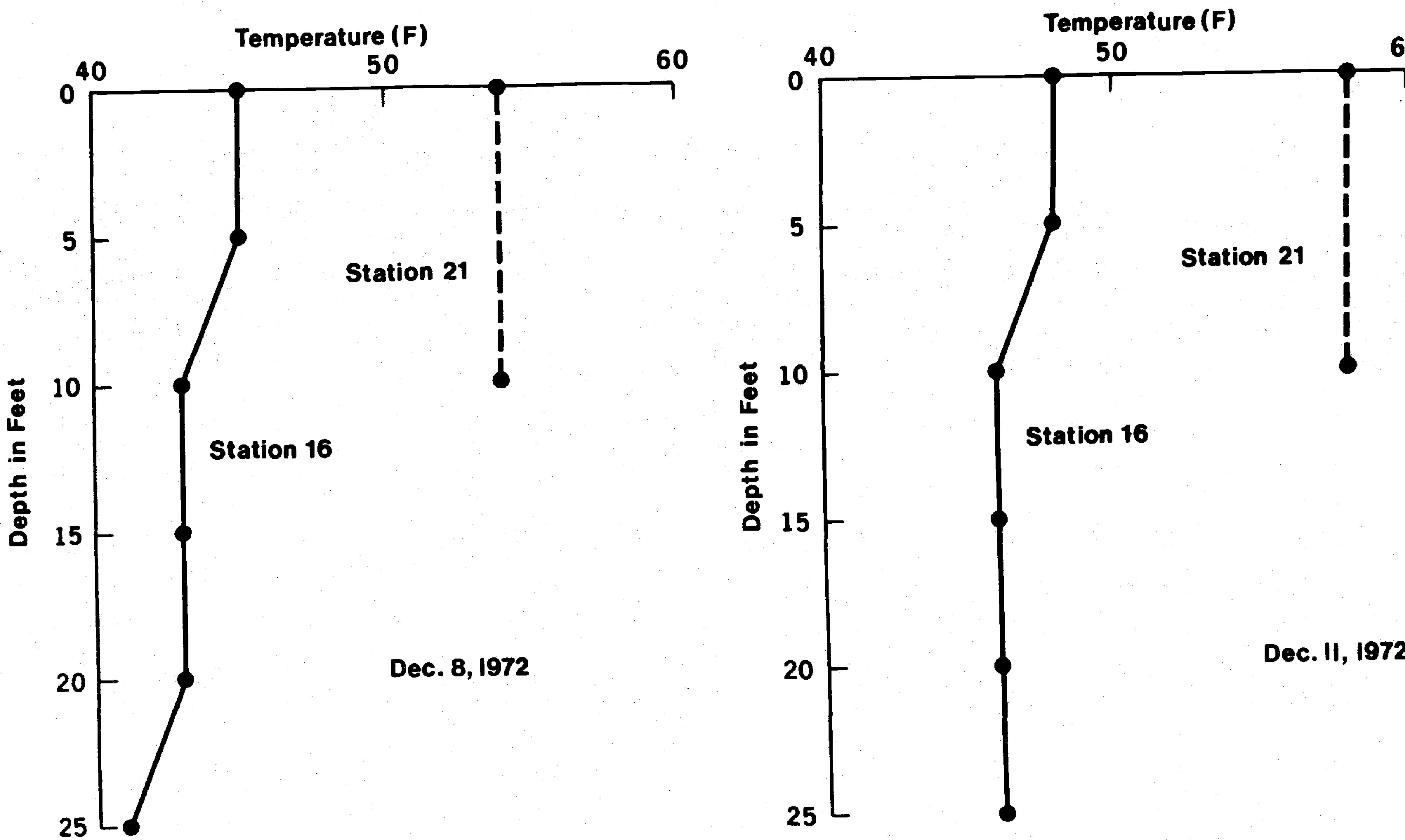

FIGURE 14. Water temperature profiles at the outfall (Station 21) of the Shuffleton Power Plant and at Station 16 showing the vertical influence of the effluent.

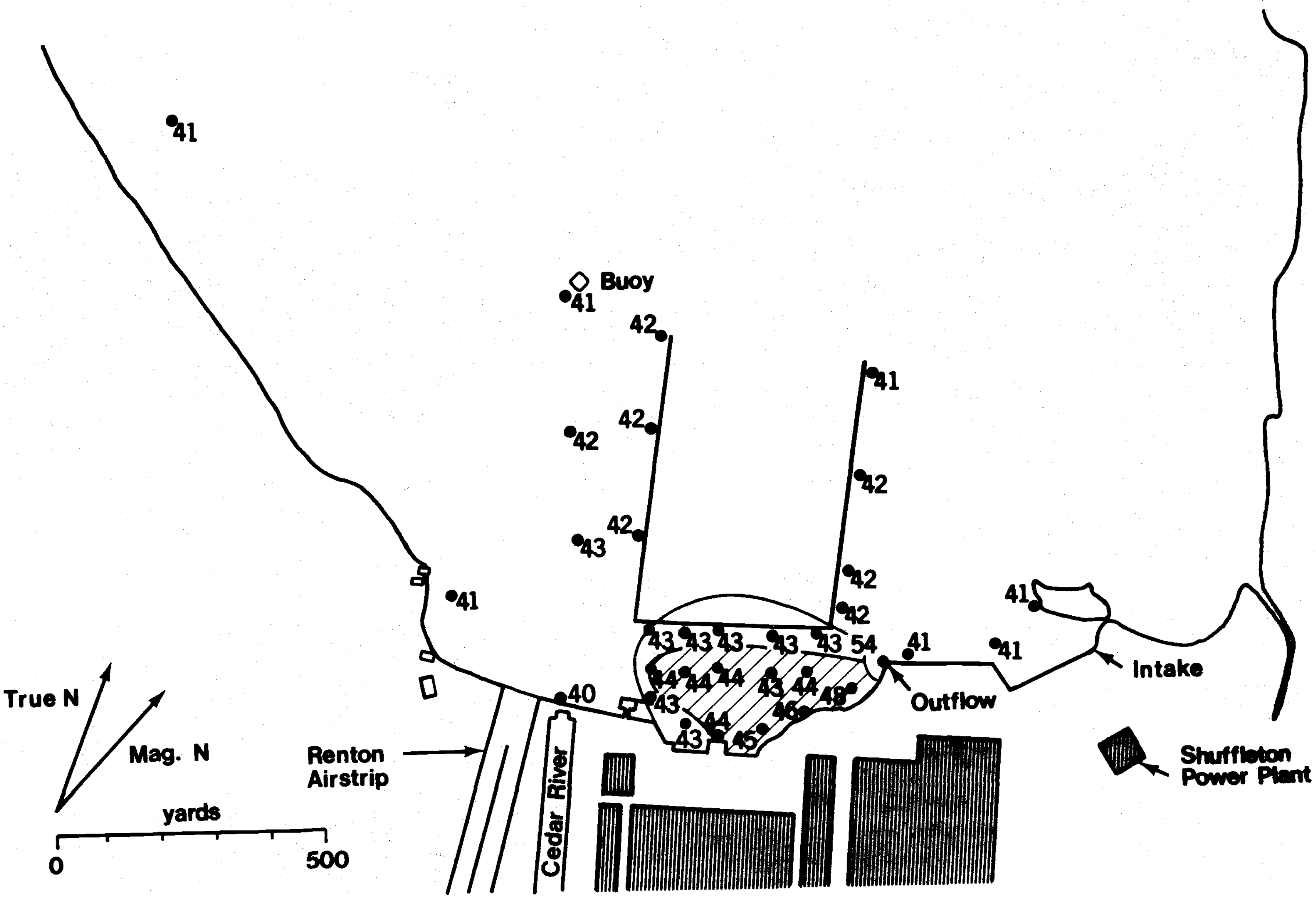

FIGURE 15. Surface water temperatures (F) in the south end of Lake Washington at 1300-1500 PST on 11 January 1973.

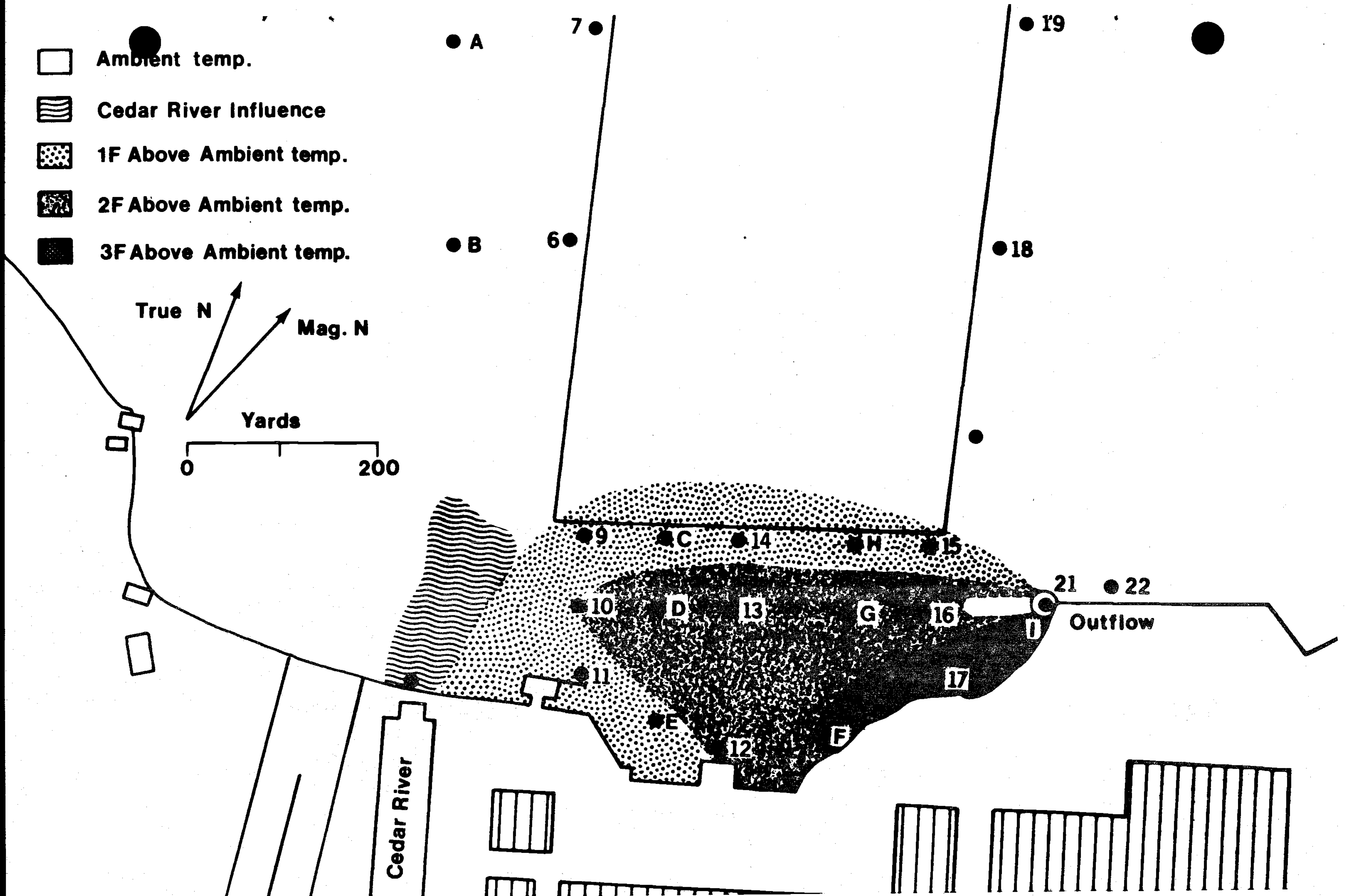

FIGURE 16. Detailed summary of the surface water temperatures in the south end of Lake Washington at 1300-1500 PST on 11 January 1973, showing influence of the Cedar River and thermal plume from the Shuffleton Power Plant. Numbers refer to stations in Figure 1, and letters refer to supplementary stations summarized in Table 8.