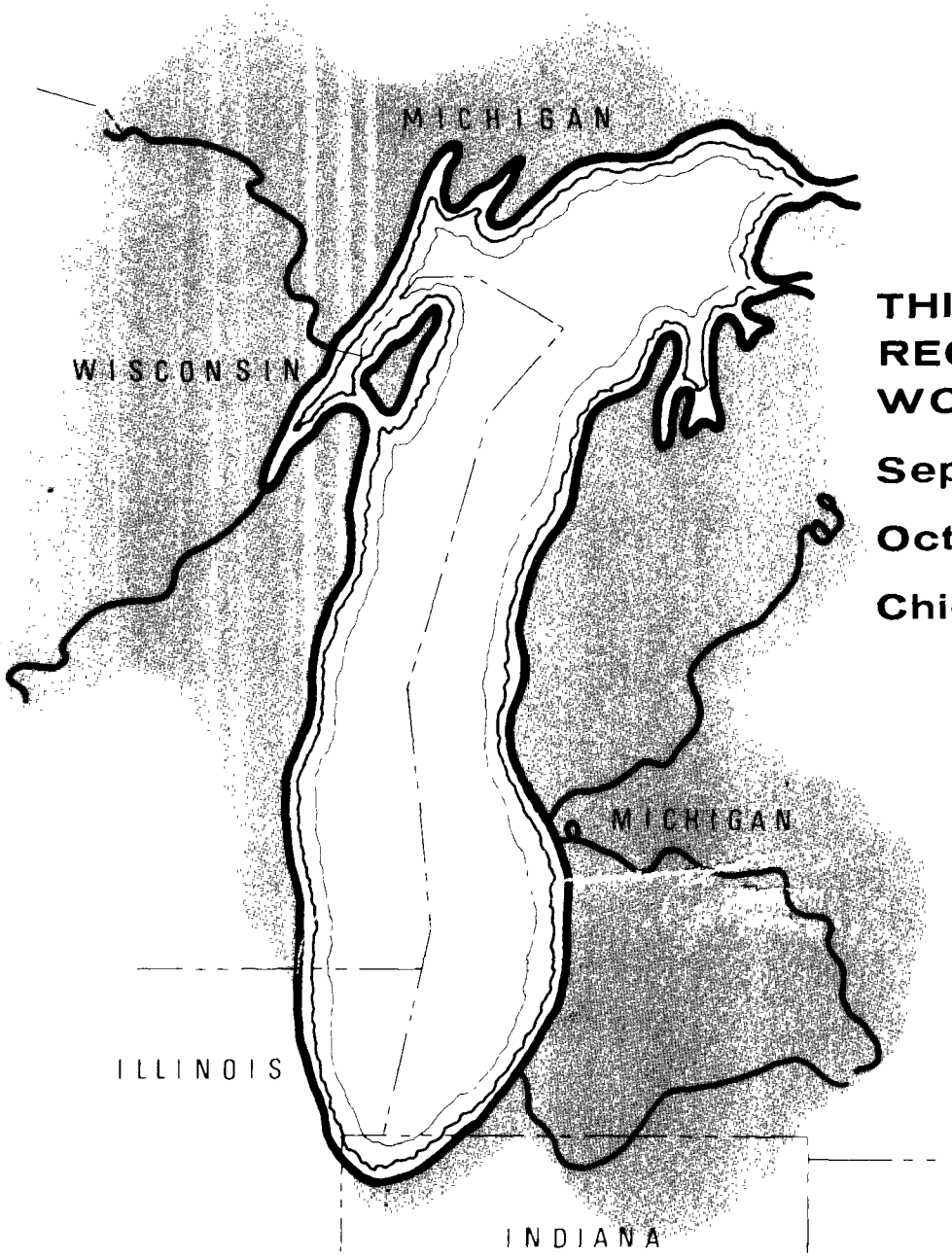
PROCEEDINGS



THIRD SESSION
RECONVENED IN
WORKSHOP SESSIONS

September 28, 29, 30,

October 1, 2, 1970.

Chicago, Illinois

Vol. 1,

CONFERENCE

Pollution of Lake Michigan and Its Tributary Basin

U.S. DEPARTMENT OF THE INTERIOR . . . FEDERAL WATER QUALITY ADMINISTRATION

WORKSHOP SESSION FOR THE THIRD SESSION OF THE CONFERENCE IN THE MATTER OF POLLUTION OF LAKE MICHIGAN AND ITS TRIBUTARY BASIN IN THE STATES OF WISCONSIN, ILLINOIS, INDIANA, AND MICHIGAN - - - VOLUME I

Bal Tabarin Room
Sherman House
Chicago, Illinois
September 28, 1970

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THROUGHOUT SEPTEMBER AND OCTOBER WORKSHOP

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Workshop Session for the Third Session of the Conference in the Matter of Pollution of Lake Michigan and its Tributary Basin, in the States of Wisconsin, Illinois, Indiana, and Michigan, held in the Bal Tabarin Room of the Sherman House, Chicago, Illinois, on Monday, September 28, 1970, at 9:30 a.m.

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Opening Statement - Murray Stein

P R O C E E D I N G S

OPENING STATEMENT

BY

MURRAY STEIN

MR. STEIN: The meeting is open.

This is a workshop session for the third session of the conference in the matter of pollution of Lake Michigan and its tributary basin, in the States of Wisconsin, Illinois, Indiana, and Michigan.

The first session of this conference was held in 1968, in accordance with a request from the Honorable Otto Kerner, then Governor of Illinois, as well as on the basis of reports, surveys, or studies, under the provisions of the Federal Water Pollution Control Act. The second session of the conference was held in February of 1969, and the third session first convened on March 31 and April 1, 1970, and was reconvened in executive session on May 7, 1970.

We had a very active program in developing remedial schedules together with specific dates and kinds of waste treatment for all the sources discharging into

Lake Michigan. This includes many municipal and industrial sources. I think it is pretty safe to say that we probably have the most active and extensive water pollution cleanup program going on, on the shores of Lake Michigan than has ever been witnessed in this country and very probably in the world.

We are beginning to see that advances and improvements are being made, but in this business of environmental protection you are always faced, as you move along with your program, with new problems which were not anticipated or fully considered when you started.

For example, as many of the people here may know, I have been involved practically day and night and Saturdays and Sundays for the past few months with the problems of mercury pollution -- something we really hadn't thought much about until the last few months -- and hopefully we are beginning to see the outlines of getting that program under control at least from discharges to watercourses.

One of the problems that have faced us here in Lake Michigan is the problem of thermal pollution and heated discharges, and that is what we want to concern ourselves with for this week.

Some people ask, "Why Lake Michigan?" And I

think the reasons for that are fairly clear. We do have an active program in Lake Michigan and we want to see that program succeed. There are investments of literally hundreds of millions of dollars by the cities and industries on the shores of Lake Michigan to prevent it from going the way of some other lakes. We believe we have devised a program which is under way which will save Lake Michigan and Lake Michigan is in the process of being saved, and we want to be sure that we are not going to have an impact from another source of pollution -- whatever it is -- which will destroy this program and have the lake go downhill toward accelerated aging or eutrophication.

Another thing I think we have to keep in mind is, among the Great Lakes -- again, I would like to repeat that the Great Lakes are the single greatest freshwater resource that we have in the free world -- but among the Great Lakes, the only one which is completely an American lake is Lake Michigan, and this is one where we have complete jurisdictional authority, and we also have to share the burden for everything that goes into that lake and it is our responsibility. So I think with the problem of thermal pollution, we do have a landmark situation here in Lake Michigan.

Before we start the meeting, I would like to

indicate how we see this. We today have an investigatory report developed by people within the Federal establishment. We will call upon these representatives first to make statements. Then we will have questions of these people in order to clarify the situation. There will be two statements by Federal people. I have also had an indication, although not this morning yet, that after they have completed, the Federal Power Commission might want to make a statement, and if the representative of the Federal Power Commission is here, I wish he would get in touch with Mrs. Piere -- would you stand up, Mrs. Piere? -- and we will make arrangements to put the Federal Power Commission representative on then. Then we will call upon the power industry to make statements.

We have had a tentative schedule issued for public officials, citizen groups, and other industries later on in the week. The sooner representatives who wish to make statements register their request and indicate the amount of time they will require the sooner we will be able to formulate a definitive schedule and give you a fairly close idea of when each individual can appear.

The way it looks to me now, today and tomorrow will be taken up by statements from the Federal people

and from the power industry.

I would like to call on the representatives of the States to introduce themselves. May we start to our right, Mr. Frangos.

MR. FRANGOS: My name is Thomas Frangos from the Wisconsin Department of Natural Resources.

MR. FETTEROLF: Carlos Fetterolf, Michigan Department of Natural Resources.

MR. PURDY: Ralph Purdy, Michigan Water Resources Commission.

MR. MILLER: Perry Miller, Indiana Stream Pollution Control Board.

MR. POOLE: Blucher Poole, Indiana Stream Pollution Control Board.

MR. STEIN: Mr. Currie.

MR. CURRIE: I am David Currie, Chairman of the Illinois Pollution Control Board.

MR. KLASSEN: Clarence Klassen, Director, Illinois Environmental Protection Agency.

MR. HARTLEY: Robert Hartley, Federal Water Quality Administration, Great Lakes Region.

MR. MAYO: Francis Mayo, Regional Director, Great Lakes Region, Federal Water Quality Administration.

I would like, Mr. Chairman, to advise the

audience that Mr. Hartley is our recently appointed enforcement program director for the Great Lakes Region and I would like to take this opportunity to introduce the new director of our Lake Michigan basin office, Mr. Lee Townsend. If Lee is here, I would like him to stand, please. Thank you.

MR. STEIN: My name is Murray Stein from the Department of the Interior, a representative of Secretary Walter J. Hickel.

May we hear from Mr. Yates Barber of the Department of Interior?

Mr. Barber.

STATEMENT OF YATES M. BARBER, STAFF ASSISTANT, BUREAU OF SPORT FISHERIES AND WILDLIFE, WASHINGTON, D.C.

MR. BARBER: Mr. Chairman, honored conferees, ladies and gentlemen.

Some of you have had questions as to the basis for a position that waste heat should not be added to the waters of Lake Michigan. That position was introduced to you by Federal participants at the Lake Michigan Conference here in Chicago last May.

Y. M. Barber

It is my privilege to summarize for you here a report entitled, "Physical and Ecological Effects of Waste Heat on Lake Michigan," which provides the answers to many of those questions. By now, I am sure that many of you are familiar with the report and its contents.

MR. STEIN: Mr. Barber, do you want that report in its entirety in the record?

MR. BARBER: Yes.

MR. STEIN: Without objection that will be entered into the record as if read.

(The report above referred to follows.)

Supplement *

PHYSICAL AND ECOLOGICAL EFFECTS OF WASTE HEAT ON LAKE MICHIGAN

U.S. Department of the Interior
Fish and Wildlife Service

October 6, 1970

ERRATA

Page 8, Table 1:
Beach water (subzone)
Area (sq mi): for 1,677 read 1,533
Percentage of total area: for 7.5 read 6.8.
Volume (cu mi): for 4.8 read 4.4.

Page 9, Table 2:
Beach zone, Area (sq mi)
Grand Traverse Section: for 378 read 234.
Entire Shoreline: for 1,677 read 1,533.
Beach zone, Volume (cu mi)
Grand Traverse Section: for 1.07 read 0.66.
Entire Shoreline: for 4.76 read 4.36.

Page 10, line 2: delete (except chubs and sculpins).

Page 17, Table 5, line 3: for ruduced read reduced.

Page 33, Table 12:
Area of beach water in zone (sq mi)
Grand Traverse Sector: for 378 read 234.
Total beach zone: for 1,677 read 1,533.
Projected total thermal input in year 2000 per square foot of beach water (Btu/ft^2/hr).
Grand Traverse Sector: for 0.613 read 0.991.
Total beach zone: for 9.21 read 10.08
Percentage of maximum rate of natural heat input.
Grand Traverse Sector: for 0.8 read 1.4.
Total beach zone: for 12.6 read 13.8.

Page 37, last line: for bouyant read buoyant.

Page 39, line 11: delete sentence, "In the entrainment region . . ."

Page 39, lines 18-20: should read, ". . . by evaporation, conduction, and back radiation accounts for a considerable amount--but, since it is in proportion to its differences in temperature above natural or "ambient," the total loss is actually rather small."

Page 40, line 20: for valve read value.

*As submitted after the close of the Conference.

Page 44, line 15: for certerline read centerline.

Page 46: The following statement was read into the record in Chicago by Mr. Yates Barber, Bureau of Sport Fisheries and Wildlife:

"CLARIFICATION STATEMENT FOR USE BY THE CONFEREES, LAKE MICHIGAN ENFORCEMENT CONFERENCE, Chicago, Ill., September 28, 1970.

Some of the conclusions reached on page 46 are in error due to editing problems. There it is inferred that the bulk of the heat discharged to the lake is retained by the lake. In order that a plume of excess heat not grow continuously with time, a balance must exist between the heat added from the source and that lost. The principal cause of loss is by exchange at the air-water interface. It was shown that as the excess temperature approaches ambient (i.e., at about $2^{\circ}F$ and less above ambient) that the process of atmospheric cooling becomes dominant over temperature decreases due to entrainment and turbulent diffusion.

Table 14 and the other examples were simply meant to convey the distinction between a substance which doesn't decay with time (hence, whose concentrations is changed locally by entrainment, advection, and diffusion) and one which does (where the additional process of atmospheric cooling takes place). A non-decaying substance discharged continuously would gradually fill the receiving body of water; a decaying substance, however, can come into equilibrium with the receiving water in the vicinity of the source. However, the area enclosed by, say, the $1^{\circ}F$ excess temperature isotherm will vary widely with local meteorological and limnological conditions.

This does not alter the important conclusion of Subsection 2c (page 46) that under some conditions large percentages of the discharged waste heat are added to the water mass of the lake. Neither are the conclusions of ecological impact in any way altered, since the misinterpretation occurred during the editing phases of report preparation and was not involved in the determination of ecological effects."

Page 46, line 11: for dilution plus mixing read dilution plus cooling.

Page 67, line 20: should read "Although 50 percent of the eggs of yellow perch spawned . . ."

Page 68, line 15: for Recham read Reckahn.

Page 71, line 5: for unpublished data). read personal communication).

Page 79, line 6: for Stoermer and Yand (1969) read Stoermer and Yang (1969).

Page 85, line 4: for only read even.

Page 87, line 20: for shear read sheer.

Page 90, line 6: for only read even.

Physical and Ecological Effects of Waste Heat on Lake Michigan

U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILD LIFE SERVICE
SEPTEMBER 1970

PHYSICAL AND ECOLOGICAL EFFECTS OF WASTE HEAT ON LAKE MICHIGAN

Prepared by

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Bureau of Commercial Fisheries
Ann Arbor, Michigan

in cooperation with

Bureau of Sport Fisheries and Wildlife

Federal Water Quality Administration

UNITED STATES DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

September 1970

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I. INTRODUCTION

There is reason for concern about potential serious ecological damage to Lake Michigan as a result of the discharge of industrial and municipal waste heat. At the predicted rate of increase, the waste heat load rejected to Lake Michigan by year 2000 would be more than 10 times the present load. The source of most of the waste heat will be the power industry. Required power capacity has been doubling each decade and there is no sign that this rate will diminish.

Everyone concerned with the problem agrees that not enough is known about the ecological effects of massive heated effluents and that a great deal of research is needed on this problem. Unfortunately, the information is needed now; since it is not available, however, interim standards must be set for Lake Michigan on the basis of existing knowledge.

The purpose of the present report is to present the available evidence that substantiates this concern. The evidence reasonably demonstrates that heat addition, as presently proposed, is an essentially cumulative problem that would contribute to inshore eutrophication and be intolerable from the fish and wildlife standpoint by year 2000. Therefore, it is in the public interest to stop this process now, rather than attempt the difficult task of correcting or reversing it after it has occurred. On the basis of the evidence presented herein, this Department supports stringent standards for Lake Michigan, and concludes that no significant amounts of waste heat should be discharged into Lake Michigan.

II. DESCRIPTION OF LAKE MICHIGAN

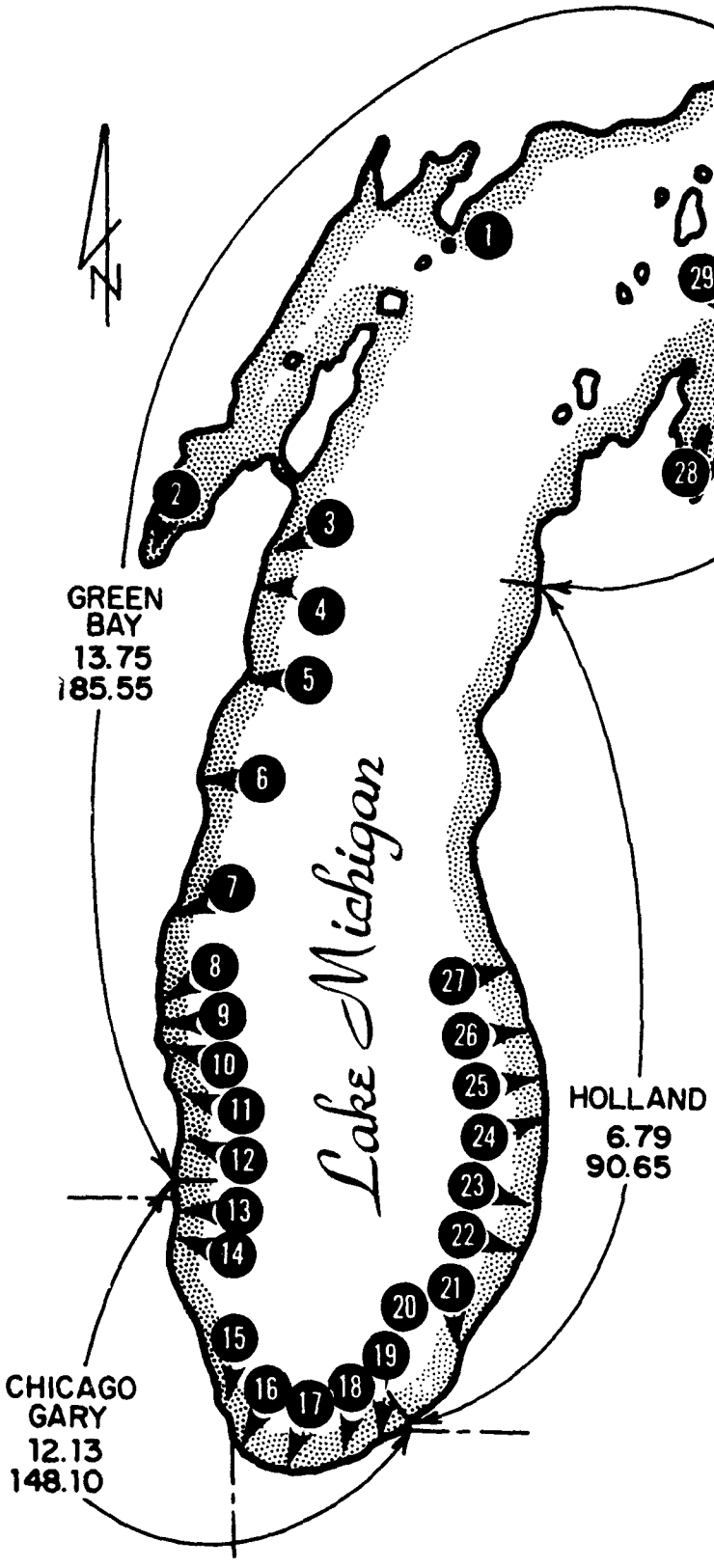
A. OVERVIEW

The following general information is largely from Beeton and Chandler (1963) and United States Department of the Interior (1966).

Lake Michigan, the sixth largest freshwater lake in the world, has an area of 22,400 square miles and a shoreline of 1,661 miles (including Green Bay) (Figure 1). It is bordered by Michigan, Indiana, Illinois, and Wisconsin; most of the 67,860 square-mile drainage area is in Michigan and Wisconsin. Maximum length of the lake is 307 miles, and maximum width is 118 miles in the northern basin (from Little Traverse Bay to Little Bay de Noc) and 75 miles in the southern basin (from Grand Haven to Milwaukee). Maximum depth is 923 feet and mean depth is 276 feet. Lake volume is estimated at 173 trillion cubic feet or 1,170 cubic miles.

The southern two-thirds of the lake is an open water area free of islands. The shoreline is regular and the bottom contours are gentle. The northern one-third of the lake is characterized by more rugged bottom relief and shoreline. Islands and bays are common.

No large tributaries (over 5,000 cfs) flow into Lake Michigan, and it has the smallest discharge of the five Great Lakes--55,000 cfs at the Straits of Mackinac. Lake level is subject to an annual fluctuation of slightly more than 1 foot. Water levels are highest in summer and lowest in late winter or early spring. The average surface elevation of the lake is 578.77 feet above the mean sea level (International Great Lakes 1955 datum).



NO.	NAME	CAPACITY (M.W.)
1.	Escanaba	23
2.	Pulliam	392
3.	Kewaunee	527 NU 1972 -
4.	Point Beach	2x497 NU 1971&72 -
5.	Manitowoc	52
6	Edgewater	129(+330 in 1969)
7	Pt. Washington	411
8.	Valley (Milw.)	280 in 1969
9.	Commerce St. (Milw.)	35
10.	Lake Side	311
11.	Oak Creek	1619
12.	Racine	23
13.	Zion	2x1100 NU 1972&73 -
14.	Waukegan	1066
15.	South Works	105
16.	State Line	923
17.	Mitchell	390(+115 1970) -
18.	Bailly	590
19.	Michigan City	203 1973
20.	(No name yet)	400 1973
21.	D. C. Cook	2x1100 NU 1972&73 -
22	Palisades	811 NU 1970 -
23.	So. Haven	17.5
24.	DeYoung	53.5
25	Campbell	650
26	Grand Haven	23
27.	B. C. Cobb	510
28.	Traverse City	15
29.	Big Rock	75 NU

Figure 1.--Lake Michigan map showing four shoreline sectors described by Acres (1970), and estimate of total waste heat production (billions of BTU's/hr) for 1968 (upper number) and 2000 (lower number). The sites of existing power installations (numbers 1 to 29) are from Krezoski (1969).

Ice is common along the shores of Lake Michigan in winter but the open lake remains ice-free during all but the most severe winters. The open lake surface waters range in temperature from a low of 32 to 35°F in March to a peak of 75°F or greater in August. The lake is stratified in summer and deep waters remain near 39°F throughout the year (Figure 2). A graphic generalized annual temperature cycle, by lake sector, is shown in Figure 3.

Winds over Lake Michigan are primarily westerly; at least 60 percent of all observations at Grand Rapids, Michigan, and Chicago, Illinois, recorded wind from the western half of a north-south line.

The chemical environment of Lake Michigan has changed and is changing at a significant rate. The concentrations of total dissolved solids in Lake Michigan are increasing at a rate of about 2 percent per decade. Typical values were 128 mg per liter in 1880, 142 in 1920, 155 in 1960, and about 158 in 1969. Concentrations of phosphate and nitrate are also presumably increasing, although this increase cannot be demonstrated because measurements in past decades were not reliable.

Dissolved oxygen in Lake Michigan, except in southern Green Bay, is usually above 90 percent of saturation at all depths. A few isolated measurements of 65 to 90 percent of saturation have been reported for the hypolimnion of the southern basin. No values below 90 percent were detected, however, in studies by the Bureau of Commercial Fisheries Great Lakes Fishery Laboratory in 1968.

Although Lake Michigan in 1970, by generally accepted standards (and excluding pesticides), has high water quality and most of the characteristics of an oligotrophic lake, a measurable loss of water quality is taking place and the rate of change has not been altered.

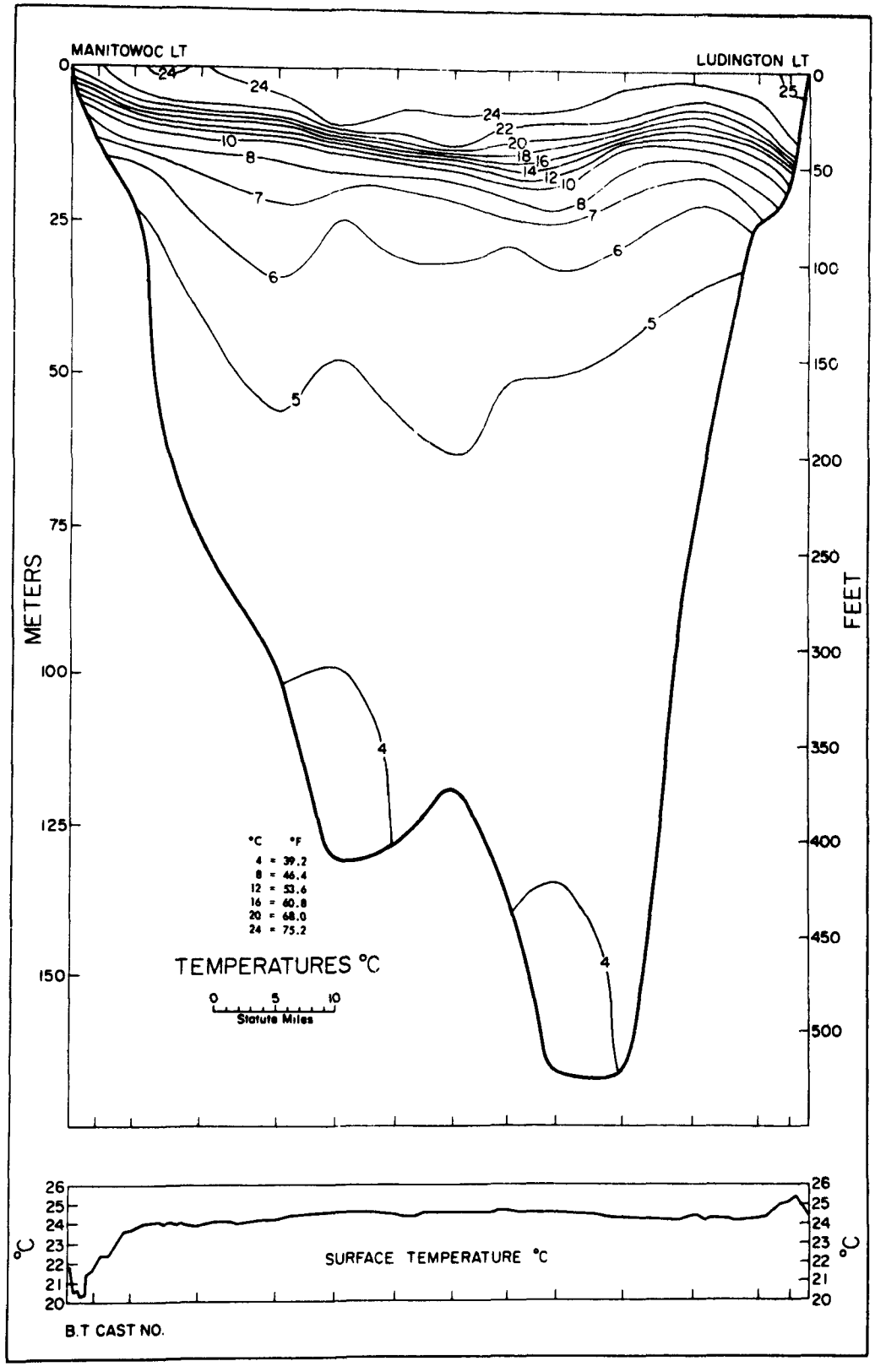


Figure 2.--Typical summer vertical temperature structure of Lake Michigan. Warm waters of 20° to 24°C (68.0-75°F) are in upper 10-20 meters, thermocline or zone of rapid temperature change is at 15-25 meters, and cold water of 4° to 8°C (39-46°F) at greater depths.

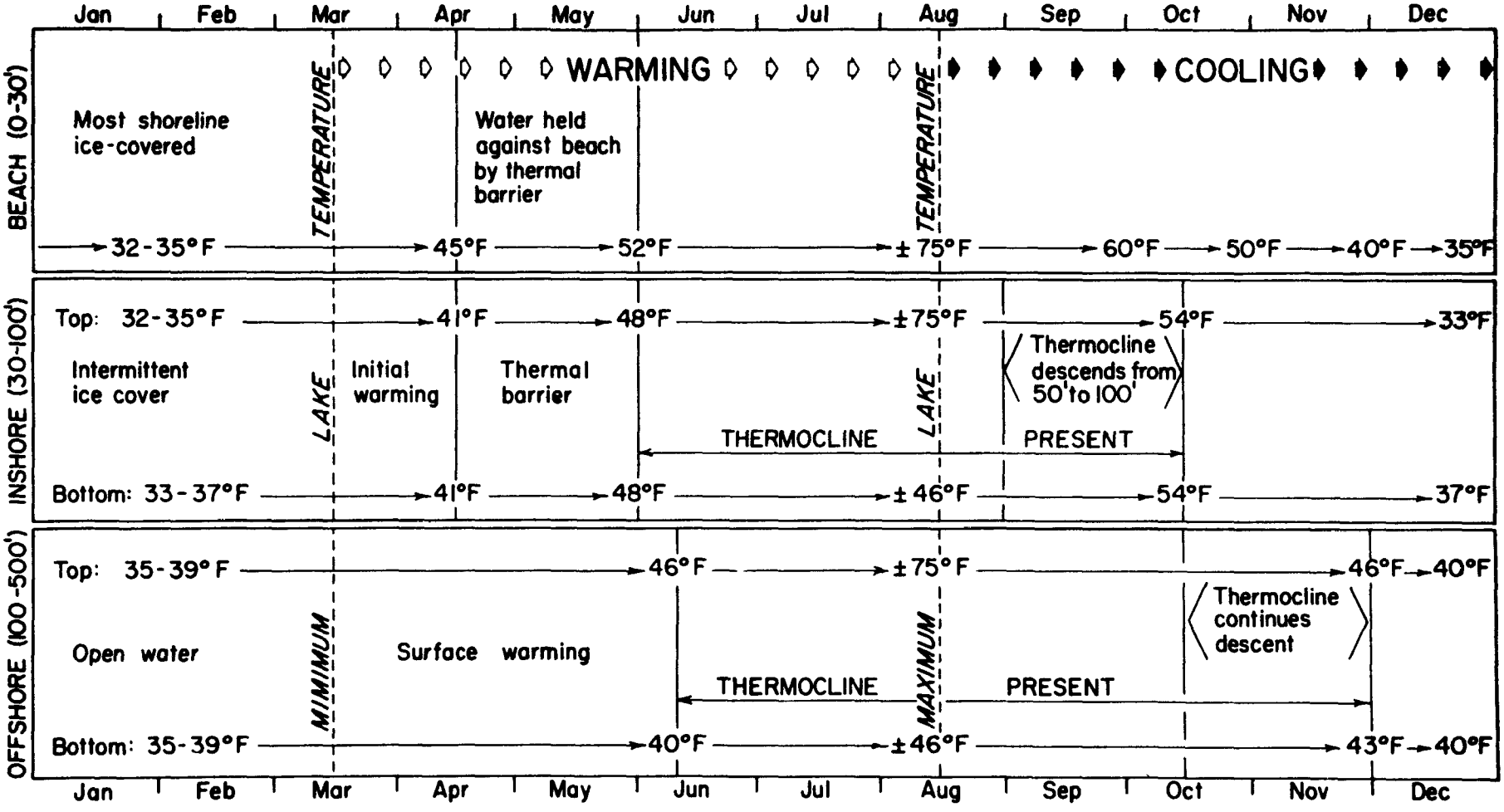


Figure 3.--Generalized annual temperature cycle in Lake Michigan by depth zones, with details of seasonal thermal characteristics.

For later consideration in this report, it is desirable to discuss the lake as two distinct, major zones, the inshore zone and the open lake. The inshore zone is defined as that volume of water which lies between the shoreline and the 100-foot depth contour. Within the inshore zone is the beach water zone, a sub-area that extends from the shoreline out to the 30-foot depth contour. The open lake zone lies beyond the 100-foot contour. Tables 1 and 2 present certain characteristics of these zones.

B. INSHORE WATERS

1. Importance of Inshore Zone

The inshore zone of Lake Michigan is probably the most important portion of the lake from the standpoint of man. Not only is it the zone that is most used by man (for example, as a source of water supply for domestic, industrial, and cooling water and as an area for fishing, boating, and swimming), but it is also the most biologically productive portion of the lake. The fishery productivity of the shallow and inshore waters of Lake Michigan has traditionally been the highest of any area in the lake. For example, within the State of Michigan waters of Lake Michigan, Green Bay constitutes less than 10 percent of the area but has contributed as much as 65 percent of the total annual commercial catch (Hile et al., 1953). Probably one of the basic reasons for the high productivity of the shallow water is the presence there of a substrate within the lighted surface zone where photosynthesis can take place. Also, nutrients are continually recycled from the bottom back into the water column due to strong vertical mixing processes.

Table 1.--Depth and volume characteristics of the major zones of Lake Michigan

Zone	Depth range (ft)	Area (sq mi)	Percentage of total area	Volume (cu mi)	Percentage of total volume
Open Lake	>100	17,360	77.5	1,122.0	95.5
Inshore Water	0 to 100	5,040	22.5	47.6	4.1
Beach water (subzone)	0 to 30	1,677	7.5	4.8	.4
Entire Lake	-	22,400	-	1,174.36	-

Table 2.--Lengths, widths, areas, and volumes of beach and inshore zones for four shoreline sections of Lake Michigan. The sections are analogous to those defined by Acres (1970).

Section of shoreline 1/	Length of shoreline (mi)	Beach zone			Inshore zone		
		Ave. width (mi)	Area (sq mi)	Volume (cu mi)	Ave. width (mi)	Area (sq mi)	Volume (cu mi)
Grand Traverse	327	0.35	378	1.07	1.04	339	3.21
Holland	207	.85	132	0.37	2.55	529	5.01
Chicago-Gary	103	2.05	143	0.41	6.21	640	6.06
Green Bay	1,024	1.06	1,024	2.90	3.45	3,532	33.40
Entire shoreline	1,661	0.96	1,677	4.76	3.03	5,040	47.68

1/ See Figure 2 for locations of sections.

The inshore and surface waters of Lake Michigan also are occupied by all species of fish (except chubs and sculpins) at one time or another during their life cycles. Some species such as yellow perch and catfish spend much of their life in shallow water; other species are present in the shallows only when immature or during migrations.

2. Extent of Inshore Water

The average width of the inshore water zone is 3 miles. The area is 5,040 square miles, or about 22 percent of the total area of the lake and three times the area of the beach water zone. The volume of water is 48 cubic miles--10 times that of the beach water zone but only 4.1 percent of the volume of the entire lake.

In contrast, the beach water zone has an average width of only 0.96 mile although the average is 2.05 miles for the Chicago-Gary sector. Its surface area is 1,677 square miles, or about 7 percent of the lake surface, including Green Bay. The volume is 4.5 cubic miles, or about 0.5 percent of that of the entire lake.

The approach of Acres (1970) has been followed in dividing the inshore zone of Lake Michigan into four sections (Figure 1). The physical dimensions of these segments are described in Table 2.

3. Thermal Trends in Inshore Waters

Seasonally, inshore water temperatures range from 32°F to as high as 82°F. They are lowest from January to mid-March, when the water is usually covered with ice. The initial period of warming generally begins in late March. Because of the high surface-to-volume ratio, the inshore areas warm more rapidly than the open lake.

By mid-April the beach waters are warmed to about 48°F, while the waters of the open lake remain below 38°F. This situation creates a strong temperature gradient between the inshore and open lake waters, and is an effective horizontal mixing barrier, which may persist as long as 6 weeks. During this time, pollutants introduced into inshore waters pose a potentially serious problem, because they are trapped there and progressively increase in concentration.

Inshore surface waters reach maximum temperatures in mid-August; bottom water temperatures are variable, however, due to vertical movements of the thermocline. During the summer, such movements are caused by wind-induced internal waves or seiches and cause bottom temperature changes as much as $\pm$ 18°F in less than 24 hours.

Changes in the wind direction over the lake induce large changes in the temperature of the entire inshore zone, at least several times each season. Wind shifts cause surface waters to be blown away from shore and deep, colder waters to upwell into the inshore zone. Figure 4 shows the vertical temperature structure of the lake during such event, including the very cold water along the eastern shore.

The net natural warming causes the top of the thermocline to descend below the 100-foot depth contour during September to mid-October. Cooling is rapid in the fall and is complete by late December.

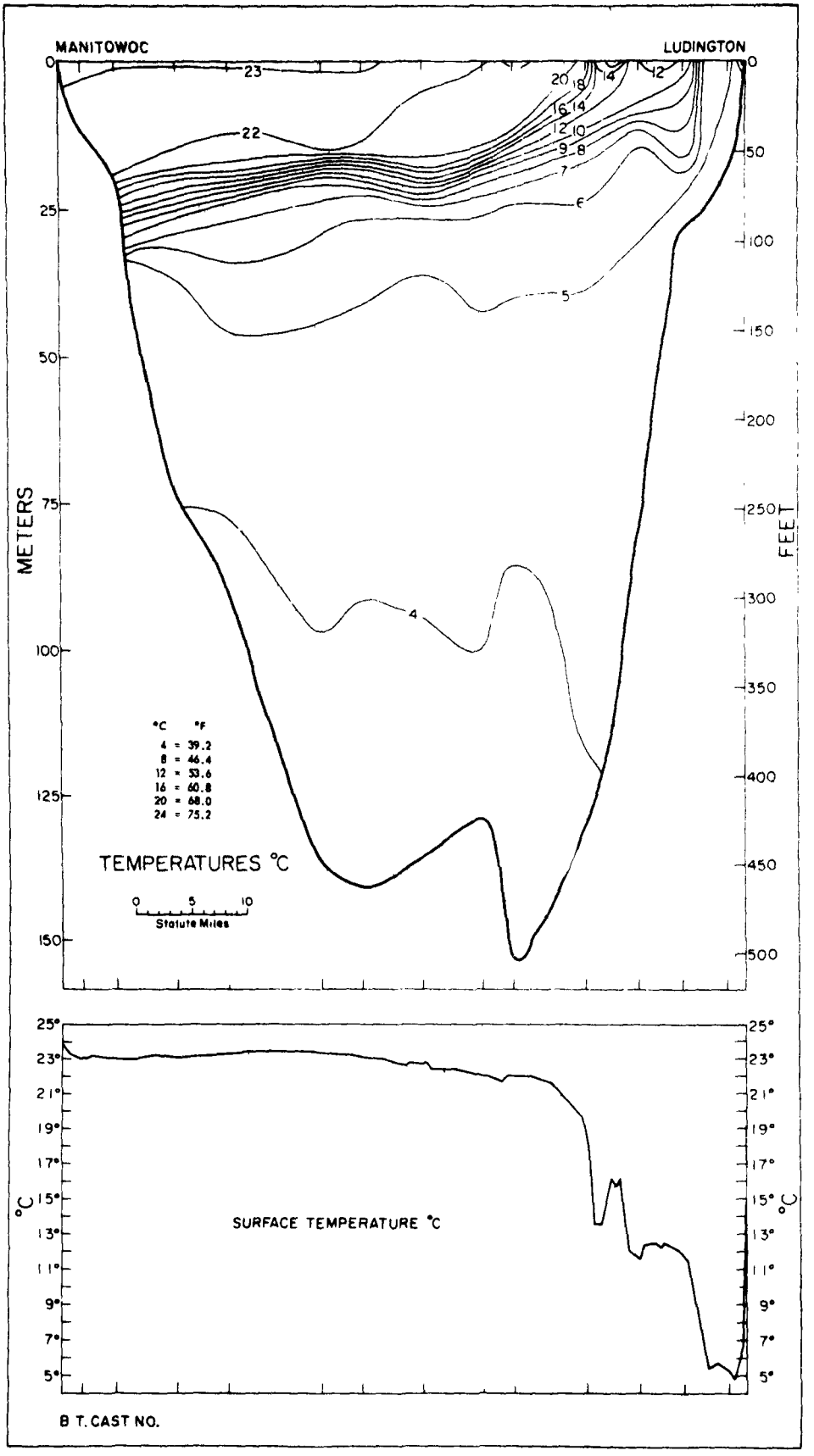


Figure 4.--Lake Michigan vertical temperature profile in mid-August, showing thermocline and a seiche-induced upwelling of cold water along the east shore.

4. Inshore Currents

The currents of the inshore waters are to some extent independent of the general system of lake-wide currents (which are discussed later). Inshore currents move parallel to the shoreline and with the prevailing winds, especially within the 30-foot depth contour (that is, a wind blowing from the north will cause the inshore waters to flow south).

Average current speeds at the 60-foot contour tend to be slower on the western shore of the lake (0.16 to 0.32 ft/sec) than on the eastern shore (0.38 to 0.45 ft/sec). Since winds throughout the region average 11 to 13 miles per hour (17 to 20 ft/sec), the currents average 1 to 3 percent of the wind speed.

5. Inshore Water Chemistry

Generally chemical concentrations are higher and the variation is greater in inshore waters than in the open waters of Lake Michigan (Table 3). The inshore waters receive municipal and industrial discharges and have in many locations been classified as being polluted (FWPCA, 1968).

Ammonia concentrations up to 1.4 mg per liter have been found near Calumet City, Illinois, and soluble phosphorus concentrations up to 1.5 mg per liter near Milwaukee, Wisconsin. Phenols and chlorides, both originating from industrial wastes, have been detected in high concentrations in inshore waters of the lake.

Table 3.--Chemical characteristics measured in inshore waters of Lake Michigan in 1962-63

[Values for average and range are in milligrams per liter unless otherwise indicated; ND - not detectable at sensitivity of test.]

Characteristic	Number of samples	Average	Range
Dissolved oxygen	2,541	10	3.7-16
Saturation (percent)	1,701	102	43-148
BOD	730	1.4	ND-8.6
NH_3-N	1,751	0.13	ND-1.4
NO_3-N	1,654	0.14	ND-0.90
Organic-N	529	0.21	0.01-0.70
Total PO_4	1,382	0.04	ND-5.0
SiO_2	645	1.7	0.4-4.4
Na	400	4.0	1.8-7.5
K	453	1.2	0.5-3.8
Dissolved solids	976	175	86-810
Specific conductance (micromhos per centimeter)	2,452	285	33-1130
pH (pH units)	2,113		6.4-9.3
Alkalinity	2,169	105	70-210
Ca	616	35	17-40
Mg	898	12	7-14
Cl	1,611	7.1	1.5-94
SO_4	1,547	20	10-76
Phenols (micrograms per liter)	1,033	2	ND-32

Dissolved oxygen is sometimes more depleted in the inshore waters than in deeper areas of the lake. Concentrations as low as 3.7 mg per liter (43 percent saturation) have been detected. Measured biochemical oxygen demands (BOD) have been as great as 6.7 mg per liter outside Milwaukee Harbor and 8.6 mg per liter near the mouth of the Grand River (off Grand Haven, Michigan).

Although levels of most chemical substances in the inshore waters are not now high enough to be considered critical for most water uses, they do show evidence of water quality degradation due to the large amounts of pollutants being discharged to Lake Michigan.

Control of these pollutants has been clearly recognized as a matter of great public concern; to date more than $1 billion has been spent by government (at all levels) and industry for sewage treatment facilities along the shore of Lake Michigan. It is estimated that several billion more dollars will be required to complete the job.

6. Fishery Resources

Nearly all of the most valuable and abundant native species of Lake Michigan live in the inshore region, but all of the important native species that lived in this zone have been greatly reduced or are now rare (Tables 4 and 5). All of these native species once migrated into tributary streams and rivers, usually to spawn; except for the runs of common suckers, these migrations have virtually vanished. The whitefish was once the most valuable fish of the lake, and whitefish and lake herring were extremely abundant in shore and tributary areas. Both species vanished from these areas, however, soon after mill dams,

Table 4.--Average annual production (thousands of pounds) of major[1/] species of Lake Michigan

Period	Native species								New species				Other[2/] species	Average
	Sturgeon	Lake trout	Suckers	White-fish	Lake herring	Wall-eye	Yellow perch	Chubs	Carp	Smelt	Alewife	Coho salmon		
1879-1900[3/]	834	7,225	1,810	2,715	16,977	378	3,866	2,061	261	-	-	-	[4/]	35,149
1910-1919[3/]	13	6,763	4,035	1,670	8,642	189	2,411	3,525	247	-	-	-	[4/]	27,059
1920-1929[3/]	7	7,001	2,117	2,111	4,015	88	1,537	2,902	679	-	-	-	[4/]	20,477
1930-1934	[5/]	5,342	2,258	3,730	4,985	111	1,199	4,367	769	425	-	-	354	23,540
1935-1939	[5/]	5,038	2,280	1,201	4,621	78	2,406	5,295	1,605	1,462	-	-	234	24,220
1940-1944	[5/]	6,579	2,125	1,351	1,830	49	2,729	1,971	1,702	2,913	-	-	425	21,674
1945-1949	[5/]	2,675	1,901	3,756	6,044	506	1,446	5,435	1,319	765	-	-	560	24,407
1950-1954	3	14	882	1,436	8,000	605	1,963	10,482	1,170	4,384	-	-	243	29,182
1955-1959	1	[6/]	652	105	3,639	488	3,055	9,947	1,785	6,983	568	-	104	27,327
1960	1	[6/]	767	124	232	118	3,285	12,659	1,416	3,267	2,369	-	73	24,311
1961	2	[6/]	494	395	177	97	4,959	12,133	1,842	2,152	3,199		109	25,559
1962	1	[6/]	263	266	116	67	4,050	11,115	1,206	1,546	4,742	-	103	23,475
1963	3	26	299	285	41	61	4,872	7,460	1,277	1,203	5,396	-	98	21,021
1964	3	[6/]	215	777	34	35	5,835	5,172	1,320	969	11,744	-	97	26,201
1965	2	[6/]	168	995	46	27	1,296	7,440	2,016	927	14,007	-	70	26,994
1966	2	[6/]	404	1,422	49	24	736	7,228	2,714	1,110	29,004	-	71	42,764
1967	[6/]	1	391	875	30	16	1,265	9,089	2,542	1,225	41,396	1,484	137	58,951
1968	2	73	465	893	53	10	631	10,183	2,352	1,789	27,194	1,999	166	45,810

1/ Species that have had an annual production greater than one million pounds.
2/ Includes species for which catches have always been less than one million pounds.
3/ Average for years of record.
4/ Incomplete data.
5/ Fishing prohibited in Michigan 1929-1950 and in other states after 1929.
6/ Less than 500 pounds.

Table 5.--Depth distribution and abundance of Lake Michigan fish in early period (at time of settlement) and recent period (last several decades)

[A = abundant; R = ruduced; VR = very rare]

Species	Inshore						Value and use
	Shallow		Intermediate		Open lake		
	Early	Recent	Early	Recent	Early	Recent	
Native shallow							
Emerald shiner	A	VR					Valuable forage
Lake herring	A	VR	A	VR			Valuable forage and food
Sturgeon	A	VR					Valuable food
Common sucker	A	R					Low value food
Sturgeon sucker			A	VR			Low value food
Yellow perch	A	R					Valuable food and recreation
Walleye	A	VR					Valuable food and recreation
Whitefish	A	VR	A	R			Valuable food
Native deep							
Burbot	A	VR	A	VR	A	VR	Low value food
Chubs (7 species)					A	R	Valuable forage and food
Deepwater sculpin					A	R	Valuable food
Lake trout	A	VR	A	R	A	R	Valuable food and recreation
Exotic							
Alewife		A		A		A	Nuisance, fish meal, valuable forage
Carp		A					Low value food
Coho salmon		A		A		A	Valuable food and recreation
Smelt		A		A			Valuable food and recreation

industrialization, and deforestation blocked movement or caused tributaries and shore areas to become warmer and more turbid. These factors may also have contributed to early elimination or reduction of runs of sturgeon, yellow perch, and walleye in many tributaries or shallow areas.

Populations of the larger native inshore species less affected by warming and turbidity (suckers and walleye) or that persisted at intermediate depths of the inshore region (lake herring and whitefish), were reduced greatly in the late 1940's and the 1950's by sea lamprey predation. The lake herring and remaining abundant inshore species (emerald shiner and yellow perch) were adversely influenced by competition during the explosive increase in dominance of the alewife during the late 1950's and 1960's. Before the alewife invasion, the lake herring was the most abundant species of the lake, and the emerald shiner was extremely abundant in rivers and harbors, where it often clogged water intakes. Both were major forage species for inshore predators such as yellow perch and walleyes.

All exotic species, including coho salmon, are very abundant in inshore areas during part of the year. Carp became abundant in shallow areas in the late 1800's and were particularly favored by the warmer and more turbid tributaries that resulted from forest removal and settlement. Smelt became abundant at the shallower depths during 1930-60 but were reduced substantially when the alewife became extremely abundant. The alewife has become the most conspicuously abundant inshore species because of spring dieoffs, but there is no evidence that its

abundance equals the total of the previously very abundant species that it has replaced. The alewife is now the primary forage species for all major predators of the lake, but its objectionable characteristics have fostered management objectives aimed at reducing its abundance.

Other new inshore species which are not abundant, but which are important features of the present fishery restoration efforts on the Great Lakes, are the steelhead trout, brown trout, kokanee salmon and splake (lake trout-brook trout hybrid). Plantings of steelhead trout and brown trout have been started in Lake Michigan, and early results are promising.

Substantial amounts of money have been and are being spent on Lake Michigan fishery programs. Since 1967 the sea lamprey control program on Lake Michigan has involved an expenditure of $6 million (69 percent U.S., 31 percent Canadian), and the current annual lamprey control budget is $500,000. In addition, 11 million lake trout have been planted since 1965 by Federal and State governments at a cost of about $1 million. The States of Illinois, Indiana, Michigan, and Wisconsin all maintain fishery management programs on their Lake Michigan waters and place very substantial monetary values on the sport fishery, boating, and other recreational uses. Michigan, for example, is carrying a $90,000 management budget in fiscal year 1971 to conduct Lake Michigan fishery sampling and maintain a research station. The cost of the State's 1970 Lake Michigan stocking program--involving principally coho salmon--was $270,000. Michigan fishery statistics indicate that in 1969, 557,000 angler days were

spent fishing for trout and salmon on Michigan waters of the lake, at an estimated expenditure of $16 per day, for a total angler expenditure of $9.5 million (Fish Division, Michigan Department of Natural Resources, personal communication).

C. OPEN LAKE

1. Definition and Extent

The maximum length of the open lake area is 307 miles; the average width is 118 miles. The surface area is 17,360 square miles--approximately 77 percent of the entire lake surface. The volume is 1,122 cubic miles--96 percent of the entire lake volume.

2. Thermal Trends in the Open Lake

Despite its great depth, Lake Michigan undergoes seasonal temperature changes similar to those in most inland lakes of temperate North America. The deep waters of the open lake remain close to 39°F, the temperature of maximum density, throughout the year, whereas surface (and shallow) waters undergo considerable thermal changes seasonally ranging from 32°F to as high as 82°F. (See Figure 3 for a generalized treatment of the temperature cycle in the open lake.)

The open lake remains ice-free except during extremely cold winters. During this period the water cools very slowly to the seasonal minimum in mid-March. Highest temperatures (35-39°F) at this time are in deep offshore waters.

Initial warming begins in late March. Thermal stratification is evident in the open lake by early June, but is not persistent and well established until late June. Depth of the upper limit of the thermocline is then about 50 feet. Surface temperatures rise rapidly over the entire lake until mid-July. Between mid-July and mid-September, surface temperatures remain nearly constant. Maximum lake temperatures usually are in mid-August. The upper limit of the thermocline descends

from a depth of about 50 feet to about 100 feet during September to mid-October; it continues descent in the open lake during November and may reach 250 feet before it disintegrates. By late December, rapid cooling is complete and the lake is again nearly homothermous.

3. Currents in the Open Lake

Winds, water temperatures, bottom shape, rotation of the earth, and other factors all influence the currents of Lake Michigan. Seasonal temperature changes may be the predominant driving forces of net circulation (Huang, 1969). This recent theory contradicts an earlier one that winds are the primary driving force (Ayers et al., 1958). Huang's mathematical evidence demonstrated that net circulation can be maintained in southern Lake Michigan by thermal factors alone. Winds modify net circulation by causing surface-driven movements and by rocking the entire lake back and forth. Huang (1969) distinguished several different types of thermally induced circulations in Lake Michigan. All are based on the fact that fresh water is most dense at about 39°F. Water of higher or lower temperature is lighter and floats on 39°F water. Figure 5 summarizes Huang's theory and shows the annual cycle of water temperature in the lake.

During January to March the entire lake mixes together but as heating begins in April the inshore water heats most rapidly. A "thermal bar" develops and effectively isolates the inshore waters from the rest of the lake. As heating continues the "thermal bar" moves out into the lake and by June the lake becomes thermally stratified into a warm upper layer and a cold deep layer.

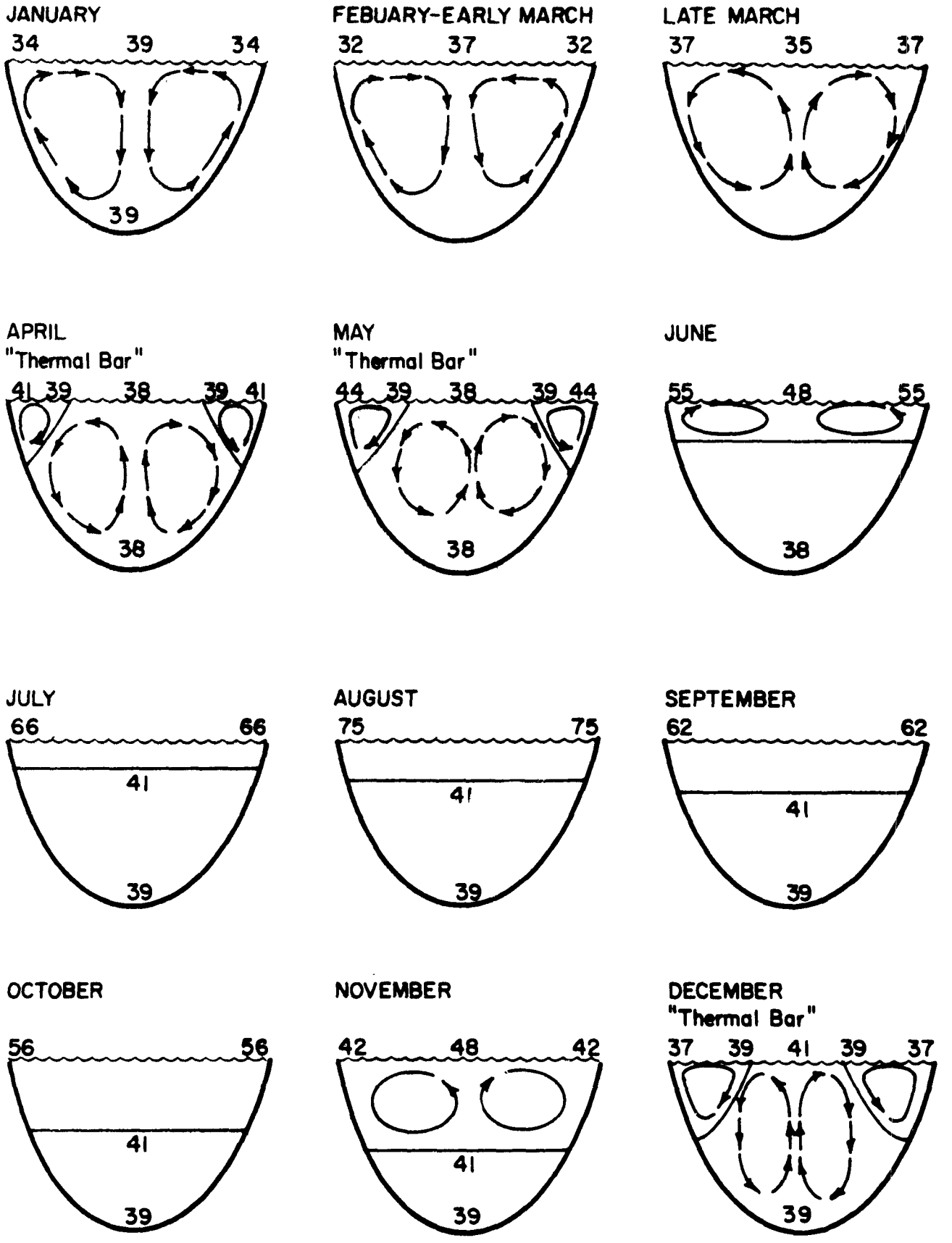


Figure 5.--Seasonal water temperatures and thermally induced circulations in southern Lake Michigan. (Numbers indicate approximate water temperature in °F. Circulation in July through October is primarily wind driven, and seiches are common. Figure adapted from Huang [1969], Rondy [1969], and others.)

After fall cooling, a second but weaker "thermal bar" occurs in December. Normally it is not observed, however, because of the weak temperature differences and the mixing of the strong winter winds.

4. Open Lake Chemistry

The open-lake waters of Lake Michigan are generally typical of oligotrophic lakes. Oxygen is always near saturation and the concentrations of nitrogen and phosphorus are low. Total dissolved solids average 158 mg per liter and the alkalinity is 110 mg per liter (Table 6).

5. Fishery Resources

Few native species have been abundant in the offshore region of Lake Michigan (Table 5). All of these are now reduced or very rare. The deepwater sculpin and seven species of chubs were extremely abundant in deep water where they lived during the entire year. These were the major forage of the two native deepwater predators--the lake trout and burbot. Larger chubs were also valuable food species and the two largest species were heavily exploited by the early fishery and became rare in the early 1900's. All other species of chubs have recently been reduced greatly by the combination of continued heavy exploitation, sea lamprey predation, and alewife competition.

Lake trout and burbot once lived in all depth zones of the lake. The adults were most abundant in deep water, and the young in shallower areas. Reports of the early fishery indicate, however, that adult lake trout were common in inshore areas and the larger rivers, as they were taken by fishermen in shore seines during the mid-1800's.

Table 6.-- Chemical characteristics measured in the open-lake portion of Lake Michigan in 1962-63

[Values for average and range are in milligrams per liter unless otherwise indicated; NS = not sampled; ND = not detectable at sensitivity of test.]

Characteristic	Number of samples	Average	Range
Dissolved oxygen	1,080	12	8.4-17
Saturation (percent)	497	102	73-152
BOD	NS	-	-
NH_3-N	429	0.06	ND-0.50
NO_3-N	595	0.13	ND-0.65
Organic-N	313	0.19	ND-0.52
Total Solids PO_4	388	0.02	ND-0.14
SiO_2	299	2.5	0.6-5.5
Na	321	3.9	2.7-6.5
K	325	1.1	0.4-2.0
Dissolved solids	417	155	100-240
Specific conductance (micromhos per centimeter)	918	260	185-345
pH (pH units)	1,040		7.5-8.9
Alkalinity	858	110	75-130
Ca	395	33	25-40
Mg	318	12	8-16
Cl	607	6.5	3.3-11
SO_4	561	20	12-30
Phenols (micrograms per liter)	NS	-	-

Large burbot may also have been taken in the early inshore fishery but not mentioned because of their low value as food fish. Lake trout and burbot were reduced to near extinction by sea lamprey predation in the late 1940's and early 1950's. Sea lamprey control measures and intensive lake trout stocking in the late 1960's have increased lake trout abundance substantially.

Of the exotic species that have been introduced into or have invaded Lake Michigan, the alewife and coho salmon live in the offshore region of the lake. Chinook salmon are also being stocked in Lake Michigan; their distribution is not clearly understood, although they appear to live in the offshore areas. Young coho salmon and alewives live throughout the lake most of the year and adults of both species live in the offshore area during the winter and much of the summer. Adult alewives concentrate to spawn near shore and in tributary streams in late spring and early summer; in some years they clog water intakes and die in large numbers, causing a major public nuisance. Coho salmon move to shore areas, and into streams to spawn during the fall and early winter. Alewives have become the most abundant fish in the lake and constitute the major forage supply for open-lake predators; all native forage species have been reduced greatly by various factors--including alewife competition.

III. THERMAL LOADING

A. PRESENT LOADING

Projections on thermal loading have been developed primarily from a recent Canadian publication here referred to as the "Acres Report" (Acres, 1970). These projections have the advantage of also providing data on heat discharges from the steel industry and municipalities. Current, but unpublished, Federal Power Commission projections are also available, and do not differ significantly from those in the Acres Report. The FPC projections have been inserted for decades not represented in the Acres Report. Tables 7 to 12 summarize the projections for megawatt capacity of power plants, waste heat from power plants and from other sources, cooling water requirements of power plants, and a breakdown of waste heat input by shoreline sector.

The primary source of Lake Michigan waste heat effluents is the power industry. In 1968 once-through cooling requirements for all Lake Michigan power installations were 6,643 cfs, which introduced an estimated 29.85 billion Btu's/hour of waste heat to the lake. As of early 1970, one nuclear and 23 fossil fuel power plants were operating on the lake, with a total capacity of 8,278 mw. Seven additional plants (five nuclear and two fossil fuel) were under construction and scheduled for operation by 1974, bringing the total on the lake to 31. In aggregate these plants will have a power capacity of 15,626 mw.

Table 7.--Projected 100 percent megawatt capacity for power plants on Lake Michigan, 1968 and 2000, by lake sector. 1/

Type of plant, and sector	Year			
	1968	1980	1990	2000
Fossil fuel plants				
Grand Traverse	72	82	82	82
Holland	1,484	1,484	1,484	1,484
Chicago-Gary	2,854	6,250	14,486	24,500
Green Bay	3,115	3,605	3,500	3,500
Nuclear plants				
Grand Traverse	75	138	286	918
Holland	0	2,046	5,281	12,516
Chicago-Gary	0	2,573	2,807	6,000
Green Bay	0	3,600	10,910	24,500
Combined (fossil fuel & nuclear)				
Grand Traverse	147	220	368	1,000
Holland	1,484	3,530	6,765	14,000
Chicago-Gary	2,854	8,823	17,293	30,500
Green Bay	3,115	7,205	14,410	28,000
Total projected capacity	7,600	19,778	38,836	73,500

1/ Data for 1968 and 2000 abstracted from Appendix J, Acres (1970); those for 1980 and 1990 prepared from unpublished data of the Federal Power Commission.

Table 8.--Projected waste heat addition (billions of Btu's/hr) to different sectors of Lake Michigan from power sources 1/

Type of plant, and sector		Year			
		1968	1980	1990	2000
Fossil fuel plants					
Grand Traverse		0.28	0.32	0.32	0.32
Holland		5.79	5.79	5.79	5.79
Chicago-Gary		11.13	24.38	56.50	95.55
Green Bay		12.15	14.06	13.65	13.65
	Subtotal	29.35	44.55	76.26	115.31
Nuclear plants					
Grand Traverse		.50	.92	1.92	6.15
Holland		-	13.71	25.38	83.86
Chicago-Gary		-	17.24	18.81	40.20
Green Bay		-	24.12	73.10	169.15
	Subtotal	.50	55.99	129.21	299.36
Combined (fossil fuel & nuclear)					
Grand Traverse		.78	1.24	2.24	6.47
Holland		5.79	19.50	41.17	89.65
Chicago-Gary		11.13	41.62	75.31	135.75
Green Bay		12.15	38.18	86.75	182.80
Total projected power industry heat addition		29.85	100.54	205.47	414.67

1/ Although based on power capacity projections from Acres (1970), the Btu figures were derived by assuming 100 percent capacity operation and a 20°F effluent rise. (Btu/hr estimates were obtained by multiplying megawatts of capacity by 0.0039 x 10^9 for fossil fuel and 0.0067 x 10^9 for nuclear fuel). Acres assumed average capacity operation.

Table 9.--Projected heat addition (billions of Btu's/hr) from the steel industry and municipal effluents to different sectors of Lake Michigan. 1/

Source and sector		Year 1968	Year 2000
Steel industry			
Grand Traverse		0.00	-
Holland		0.00	-
Chicago-Gary		6.13	10.95
Green Bay		0.25	0.45
	Subtotal	6.38	11.40
Sewage effluents			
Grand Traverse		0.60	-
Holland		1.00	1.00
Chicago-Gary		1.00	1.40
Green Bay		1.60	2.30
	Subtotal	4.20	4.70
Combined steel and sewage effluent inputs		10.58	16.10

1/ Adapted from Acres (1970).

Table 10.--Principal present and projected waste heat addition (billions of Btu's/hr) to Lake Michigan. 1/

Source	Year	
	1968	2000
Power industry		
Fossil fuel plants	29.35	115.31
Nuclear plants	.50	299.36
Steel industry	6.38	11.40
Municipal effluents	4.20	4.70
Total heat input	40.43	430.77

1/ Although based on power capacity projections from Acres (1970), the Btu figures were derived by assuming 100 percent capacity operation and a 20°F effluent rise. Btu/hr estimates were obtained by multiplying megawatts of capacity by 0.0039×10^9 for fossil fuel and 0.0067×10^9 for nuclear fuel. Acres assumed average capacity operation.

Table 11.--Present and projected cooling water (cubic feet per second) required by the power industry in different sectors of Lake Michigan. 1/

Type of plant, and sector		Year			
		1968	1980	1990	2000
Fossil fuel plants					
Grand Traverse		62	71	71	71
Holland		1,288	1,288	1,288	1,288
Chicago-Gary		2,477	5,425	12,574	21,267
Green Bay		2,704	3,129	3,038	3,038
	Subtotal	6,531	9,913	16,971	25,664
Nuclear plants					
Grand Traverse		112	205	426	1,368
Holland		-	3,051	7,875	18,664
Chicago-Gary		-	3,827	4,186	8,947
Green Bay		-	5,368	16,269	36,536
	Subtotal	112	12,451	28,756	65,515
Combined (fossil fuel & nuclear)					
Grand Traverse		174	276	497	1,439
Holland		1,288	4,339	9,163	19,952
Chicago-Gary		2,477	9,252	16,760	30,214
Green Bay		2,704	8,497	19,307	29,574
Total cooling water requirements		6,643	22,364	45,727	91,179

1/ As opposed to the average capacity requirements of Acres (1970), these estimates were developed by assuming operation at 100 percent capacity.

Table 12.--Calculation of the projected total waste heat input into Lake Michigan, by shore segments, in year 2000, including a comparison of waste heat input as a percentage of the maximum natural rate of heat input (1,750 Btu/ft^2/day) 1/

Sector of lake	Area of beach water in zone (sq mi)	Projected total thermal input in year 2000 (billions of Btu/hr)	Projected total thermal input in year 2000 per square foot of beach water (Btu/ft^2/hr)	Percentage of maximum rate of natural heat input
Grand Traverse	378	6.47	0.613	0.8
Holland	132	90.65	24.63	33.8
Chicago-Gary	143	148.10	37.15	50.9
Green Bay	1,024	185.55	6.49	8.9
Total beach zone	1,677	430.77	9.21	12.6

1/ Although based on power capacity projections from Acres (1970), the Btu figures were derived by assuming 100 percent capacity operation and a 20°F effluent rise. Btu/hr estimates were obtained by multiplying megawatts of capacity by 0.0039 x 10^9 for fossil fuel and 0.0067 x 10^9 for nuclear fuel. Acres assumed average capacity operation.

Although the power industry is the primary source of man-made heat addition to Lake Michigan, it should not be regarded as the only one. Certain industrial and municipal sources are also significant contributors of waste heat. The Acres Report projections indicate, for example, that in 1968 the steel industry contributed 16 percent of the man-made thermal input to Lake Michigan, or 6.38 billion Btu's/hour.

The combined power, steel industry, and municipal waste heat input to Lake Michigan in 1968 is estimated at some 40 billion Btu's/hour.

B. FUTURE LOADING (THROUGH YEAR 2000)

For the past 30 years, the Nation's electric power loads have grown at an average rate of 7 percent per year; consequently a doubling of electric power facilities has been required each decade. Forecasted load growth is the same through 1990 (Anonymous, 1968) and 2000 (Acres, 1970). More nuclear units will be installed in the Northeast and Midwest than in any other section of the United States. Nowhere are these plans for expansion more apparent that on Lake Michigan. Table 7 summarizes projections of growth in capacity.

The doubling of power capacity each decade shows the estimate of Lake Michigan megawatt capacity increasing at a geometric rate. Cooling water requirements will also increase at a similar rate (almost fourteenfold) from 6,643 cfs in 1968 to 91,179 cfs in 2000 (Table 11). Heat addition from steel and municipal sources is expected to increase to 17.30 billion Btu's/hour by 2000 (a 63 percent increase over that

in 1968). In aggregate, it is estimated that waste heat addition to Lake Michigan from these sources will increase from 40 billion Btu's/hour in 1968 to about 431 billion in 2000.

C. WASTE HEAT DISSIPATION

1. Non-technical Overview

To consider both the immediate and eventual fates of waste heat in Lake Michigan, it is necessary to understand the process of addition of effluent heat to the water mass and its dissipation to the air. Recent findings tend to substantiate the theory that under normal conditions the principal amount of waste heat is passed to the water mass, and only a relatively small proportion is dissipated directly from the plume to the atmosphere. Csanady (1970) advanced theoretical conclusions which indicate that heat dissipation is "diffusion-controlled." He concluded (though he did not fully discuss the important topic of atmospheric loss through back radiation) that excess temperature diffuses into the lake, if shoreline currents are normal and the water is moderately deep. He believed that his findings are supported by an empirical study by Palmer (1969). Hoops et al. (1968) concluded, on the basis of work at a Lake Monona (Wisconsin) power plant, that surface heat losses were about 5 percent of the heat discharged by the power plant; the remaining 95 percent was dissipated by dilution with lake water. Sundaram et al. (1969) concluded that the heated discharge of the proposed Bell Nuclear Station on Cayuga Lake (New York) would increase the average surface temperature of this 66.4-square mile lake about 0.7°F.

The size of the area affected by heat addition often can be predicted with some degree of confidence. However, the state of the art is not such that forecasts are completely accurate for any given heat source. The reasons for this deficiency are several, and they must be understood if an appreciation for the prediction is to be gained. It is also necessary to gain insight into the mechanics of heat dissipation in general. An attempt is made here to outline the theory, presupposing no special background in fluid mechanics or thermodynamics.

Heat, like mass, must be accounted for--and it can be accounted for through the idea of its conservation with time. Heat contained in a given parcel of water can be lost in several ways: (1) by absorption at the (lake) bottom, (2) by radiation back to the atmosphere when in contact or near-contact with the air, or (3) by evaporation and conduction to a colder air mass. If a mass of heated water is discharged to a lake and does not decrease in temperature as a result of these processes, it will naturally add its heat to the heat already in the lake. This process cannot, of course, continue indefinitely; it can, however, increase the temperature of the lake receiving water to that of the immediate discharge area if the lake is small enough. After a certain time, the entire lake comes to equilibrium and this equilibrium is maintained by exchange at the air-water interface.

A second process can be envisioned: Instead of following a body of water, consider a volume fixed in space in such a way that movement of water through the volume is allowed. Water of a certain temperature may then entirely displace a colder body of water mechanically. Such a process is due simply to the physical movement, or advection, of water into the volume.

A final process can be envisioned: Assume that half the water in the fixed volume is displaced by water ot a different temperature. If the two bodies of water are allowed to mix completely, the result is a temperature midway between the two initial temperatures. This process can be roughly described as turbulent diffusion.

Thus, there are essentially four means by which a body of water can lose (or gain) heat: (1) by exchange at the air-water interface, (2) by advection, (3) by diffusion, and (4) by any combination of these three means. Analyses that are currently employed to evaluate temperature effects are based on these processes, although some of the mathematical tools that are employed are exceedingly sophisticated and the analyses are sometimes intractable. The intractability results from our lack of knowledge about such matters as lateral and vertical exchange processes (advection and turbulent diffusion), evaluation of background temperatures (or what the temperature would be if no heat sources were present), and hydrodynamics under the influence of bouyant jets.

If a dyed, heated, body of water is steadily discharged from a small orifice at a given velocity into a shallow, non-moving, clear, very large body of water, the dye decreases in intensity with increasing distance from the source and gradually becomes indistinguishable at a certain distance from the source. If the intensity of color down the midstream of the resultant plume could be measured, the intensity could be plotted on graph paper in the form of a simple curve that would describe the intensity-distance relationships. If the shallow receiving water body is replaced by a deep one, the plotted points will not fall on the same line. This simplified description differentiates between two-dimensional situations (i.e., in shallow water, where the dye is uniformly distributed with depth and the two dimensions are in the horizontal direction) and three-dimensional cases (i.e., in deeper water, where the dye distribution drops to zero at depth and has a different vertical distribution with distance from the source). The three-dimensional situation is extremely difficult to analyze theoretically; under field conditions it is even difficult to sample properly. Most engineering evaluations proceed from the two-dimensional case (in technical jargon the 'vertically integrated' assumption is made) to calculate the area which is of a higher temperature because of the heated water discharge.

In the three-dimensional situation, there is a region immediately near the discharge point (which is usually in shallow water) where the dye intensity remains essentially the same as that at the

point of discharge. The surface area of this region may be rather small (a point to remember when considering loss of heat to the atmosphere). Adjacent to this region, "clear" water is brought into the dyed area in conjunction with a certain decrease in velocity; this clear water is said to be "entrained" and its magnitude is described by an "entrainment coefficient." In the entrainment region mixing occurs at the edges of the plume; little mixing takes place very near the source. This process is similar to the perhaps more familiar process of the building up of towering storm clouds. Here the vertical growth is effected by air being brought in from below (entrained) and moving upward. In the entrainment region, mixing occurs at the edge of the plume, whereas little mixing takes place very near the source. Another region can be described where the dye concentration is diminished by diffusion at the edges and loss in a vertical direction; the surface area traced by the edges of this region is relatively large (analogously with the heat loss phenomenon this is the region where loss to the atmosphere by evaporation, conduction and back radiation, accounts for a considerable amount. But, as it is in proportion to its differences in temperature above natural or "ambient," the total loss is actually rather small.)

Three main points evolve from the preceding description: (1) Although heat is lost to the atmosphere near the source because the temperature may substantially exceed the ambient temperature, the total amount lost is small because the surface area of this region

(where losses take place in the absence of mixing) is small. (2) The bulk of the heat in the region near the source is simply added to the receiving water for a longer time. Further losses will occur in the next region, and the magnitude of loss to the atmosphere will depend on the surface area (greater than in the latter region) and the temperature difference between the regions and the ambient (smaller than in the latter regions). (3) In the final dissipative stages, heat is diffused and lost by surface cooling, but here the temperature does not greatly exceed the ambient temperature.

In total, therefore, most of the heat is retained in the volume of water near the discharge site and a rather large area can be expected to become heated.

Ayers et al. (1970), who made field observations near power plants in Michigan City, Indiana, and Waukegan, Illinois, did not list the condenser flows or discharge temperatures, nor give auxiliary data which could be used to make a 'jet release' analysis. They ascribed most of the temperature decrease with distance from the outfall to surface cooling. This explanation can hold, however, only if the discharge volume is small or the width of the discharge orifice is so great as to reduce the velocity of the jet to a small valve. To evaluate properly the heat buildup near an outfall, results from one survey cannot be extrapolated directly to another. Rather, a case-by-case evaluation is required and, at this stage of our knowledge, nothing less will suffice. Information required for the evaluation has been given in earlier paragraphs and includes such data as the dimensions

of the outfall, volume of flow, and background or ambient temperatures. When the ambient temperature is not uniform in relation to distance from the shore, evaluation of what constitutes an "excess" temperature is doubtful at best; such conditions are likely to result periodically and, of course, during "thermal bar" conditions. The analysis by Ayers et al. (1970) is open to criticism because of their choice of ambient temperature; in fact, it is not clear from their illustrations whether an ambient temperature was indeed measured at all.

2. Studies of Model Plumes

Data from two evaluations of model plumes have been selected to provide some physical dimensions to the foregoing discussion. In one that was completed by Benedict (1970) specifically for the present report, the variables used were similar to those that might be expected for a Lake Michigan thermal plume. The assumed discharge volume (731 cfs) and temperature differential (25°F) are on the order of a conventional fossil fuel plant on Lake Michigan. The second evaluation is that of Pritchard-Carpenter Consultants (1970) for the proposed Davis-Besse Nuclear Power Station on Lake Erie. This study provides an example of the heat rejection potential of a Great Lakes nuclear installation of 1,500 cfs. (At least one larger plant is under construction on Lake Michigan--the Donald C. Cook Plant, near Benton Harbor, Michigan, at 3,500 cfs.)

a. Lake Michigan Surface Jet Model

Benedict's shoreline discharge model, which simulates a Lake Michigan discharge on the order of the Campbell Plant (a conventional power plant near Port Sheldon, Michigan), assumes zero lake

currents, an ambient temperature of 65°F, once-through cooling, a 25°F rise over the condensers, an effluent of 731 cfs, and a plume depth of 5 feet. There is no allowance for surface heat loss. Since the theoretical plume, under conditions of no current, would generate symmetrically outward from the discharge, it is possible to examine the thermal characteristics in terms of distance that waste heat isotherms extend (Table 13).

Evaluation of the isotherms was carried to the 0.5°F limit only for illustrative purposes since under normal conditions natural processes would distort the plume shape and diffuse the heat to depths greater than 5 feet. However, under the conditions of the model and at equilibrium, the thermal influence would extend along the plume center line a substantial distance (4.8 miles to the 1.0°F isotherm and 20 miles to the 0.5°F isotherm) and thus cover a rather extensive area.

b. Lake Erie Nuclear Model

Pritchard-Carpenter Consultants (1969, 1970) computed and analyzed plume distributions for the Toledo Edison Compnay, as part of that company's evaluation of the proposed Davis-Besse Nuclear Power Station on Lake Erie.[1] Analyses were carried out for two conditions--no lake current and with shoreline current. Only the shoreline-current condition is discussed here, since it is the more typical in Lake Michigan. In this situation, the plume is bent in the direction

[1]The Toledo Edison Company kindly consented to use of these data in the present report.

Table 13.--Distance (miles) from source of excess temperature isotherms calculated from a Lake Michigan surface jet model.

Waste heat isotherm (°F)	Distance (miles) from plume source at centerline
20	.052
15	.057
10	.062
5	.234
2.5	.717
1.0	4.80
0.5	20.17

of the current. Although the proposed plant is to be situated on Lake Erie, the calculations provide interesting summary statistics on plume dimensions as they apply to the large flows required by nuclear power plants.

In general, an onshore wind causes currents that are parallel to the coast in the nearshore region. When the plume is bent so that it is directed along the coast, entrainment (and thus, dilution) can be effected only on one side of the plume. The result is that the rate of decrease of temperature is less than if the plume had been directed straight out into the lake.

Calculations of the plume dimensions were based on assumptions of an 18°F temperature rise, 1,526 cfs of cooling water, 70°F ambient temperature, a 10 mph wind, and a longshore current directed towards the southeast at a rate of 0.67 fps. Estimates were made of the plume centerline length, width, and area (Table 14).

The 1°F excess temperature isotherms were about 52 and 8 miles from the source for the two conditions of dilution only and dilution plus cooling, respectively, and the respective areas affected were about 374 and 13 square miles.

c. Application of results from Model Studies

The Lake Michigan jet and Lake Erie "dilution only" examples approximate situations in which atmospheric and lake conditions do not permit rapid dissipation of waste heat to the atmosphere. Under conditions when such atmospheric losses would occur, the lake volume

Table 14.--Dimensions (in miles and square miles) of excess temperature isotherms in a bent jet thermal plume discharge from the Davis-Besse Nuclear Power Station for the case of an ambient transverse current of 0.67 ft.sec^{-1}, and a jet discharge velocity of 6.7 ft.sec^{-1}. (Converted from report by Pritchard-Carpenter Consultants, 1970). 1/

Excess temperature isotherm(°F)	Dilution only			Dulution plus cooling		
	Length (mi)	Width (mi)	Area (sq mi)	Length (mi)	Width (mi)	Area (sq mi)
14	0.051	0.018	0.002	0.051	0.019	0.001
12	.095	.036	.003	.095	.036	.003
10	.197	.074	.014	.197	.074	.014
8	.479	.180	.086	.437	.177	.083
6	1.458	.714	1.040	1.184	.679	.807
4	3.276	.941	3.081	2.537	.850	2.155
2	13.125	2.178	28.588	5.946	1.275	7.569
1	52.462	7.083	373.048	8.181	1.555	12.697

1/ Length = length of the area within the specified isotherm along the axis of the thermal plume; width = width of the area within the specified isotherm; area = area contained within the specified isotherms.

affected by waste heat would diminish. However, from the earlier discussion of heat dissipation, it appears that, at best the percentage of the total waste heat rapidly lost to the atmosphere is sufficiently small that the assumption of little or no waste heat loss to the atmosphere is reasonable, at least during a great deal of the annual temperature cycle. It follows that the assumption of moderate or no waste heat loss to the atmosphere is reasonable during a good deal of the annual temperature cycle--recognizing of course that short-term loss to the air occurs and that nearly all of the waste heat will be removed during the fall overturn and winter. The "dilution plus mixing" example of the Davis-Besse plume evaluation appears to be very conservative in describing the actual area and volume of thermal influence; and the "dilution only" assumption of the other two examples is the more applicable. It is concluded that large percentages (at times virtually 100 percent) of the discharged waste heat will be diluted into the water mass and that the heating effect of one plume can cover many areal miles of the lake.

3. Magnitude of Projected Waste Heat Addition

It has been advanced that at times most waste heat would be diffused into the water mass for an ecologically significant time period. Waste heat production is projected to be 431 billion Btu/hr

on Lake Michigan in year 2000; and to assess the potential ecological impact of this waste heat addition, it is desirable to place dimensions on the physical characteristics of waste heat distribution. Existing information on this topic is very limited; the following discussion is intended to provide at least a limited amount of insight into the situation, as projected.

Acres (1970) estimated that 0.52 Btu/ft^2/day of waste heat would be added to Lake Michigan in year 2000--an increase of 0.47 over the 1968 value of 0.05 Btu/ft^2/day (based on estimtates of average power capacity operation and the waste heat additions from other sources). This estimate applies to the entire lake surface, however, and does not allow for the likelihood that the waste heat release would occur in the inshore waters.

Table 12 presents estimates of waste heat inputs to the 1,677 square miles of beachwater zone (0-30 foot depth) by shoreline sector for the entire lake. The last column of the table presents the projected waste heat input, expressed as a percentage of the maximum natural rate of heat input. (The natural input estimate for nearshore waters of Lake Michigan [based on unpublished data of the Bureau of Commercial Fisheries] is supported by estimates for Lake Ontario of 1,735 Btu/ft^2/day [Rodgers, 1968] and for Lake Cayuga of 2,000 Btu/ft^2/day [Sundaram et al., 1969].) This very general statistic indicates that the rate of waste heat input would in the year 2000 approximate 13 percent of the natural maximum heat input (For the Chicago-Gary Sector,

this statistic is 51 percent and for the Holland Sector, 34 percent).

The basis of the statistic is subject to criticism, since some of the waste heat will diffuse beyond the 30-foot contour (average width, 1 mile), some will be lost to the air, and, of course, the concentration of waste heat near the discharges will cause great variability in the actual value of the statistic. However, available studies indicate that Lake Michigan thermal plumes hug the shoreline, and it follows that the principal ecological impact would occur in the shallower waters; and it is this fact that makes the general use of the statistic valid. Furthermore, during certain periods the "thermal bar" lies entirely within the inshore zone, preventing transfer of heat to deeper water.

Substantial refinement of the assumptions is both desirable and needed, and other approaches to the problem can be taken. The existing calculations are sufficient, however, to permit the conclusion that projected waste heat production would add to the beach water sector of Lake Michigan an artificial thermal load that is equal to a significant percentage of the natural rate of heat input. This conclusion has ecological significance in terms of both eutrophication and fishery effects.

IV. EFFECTS OF TEMPERATURE FLUCTUATIONS ON LAKE MICHIGAN FISH

A. INTRODUCTION

Increased demand in recent years for the use of natural surface waters for cooling has caused widespread concern that the addition of artificial heat to these waters will be harmful to aquatic life. As a consequence the effects of temperature on aquatic life are under intensive study and some of the results are now being published. Extensive bibliographies by V. S. Kennedy and J. A. Mihursky (1967) and E. C. Raney and B. W. Menzel (1969) list over 1,200 references that cover the early literature as well as some of the more recent publications. Excellent review articles describing the thermal requirements of fishes were published by J. R. Brett (1956, 1960) and R. E. Burrows (1963). A book edited by P. A. Krenkel and F. L. Parker (1969) and the published Proceedings of the Second Thermal Workshop of the U. S. International Biological Program (J. A. Mihursky and J. B. Pearce, eds; 1969) deal with the biological aspects of thermal pollution for major groups of aquatic plants and animals. Although the present section is limited to a discussion of the effects of temperature changes on fish and other organisms in Lake Michigan, references are made to the published literature when necessary, to describe thermobiological principles and to fill gaps in the knowledge of the specific thermal requirements of Lake Michigan aquatic organisms.

The factors that determine the growth, survival, distribution, and abundance of fishes and other coldblooded aquatic organisms in nature are complex and incompletely known, but the role of temperature

is firmly established as a major one. All available information indicates that each organism has specific thermal tolerances or limits that reflect the thermal requirements for each of the important metabolic functions in the individual; these functions and thermal tolerances vary from life stage to life stage. When the limits are exceeded the organism functions at reduced efficiency, and may ultimately die. The rate at which individuals, populations, or species are lost depends on the degree to which the thermal limits are exceeded, the duration of exposure to thermal stress, and the indirect effects of these thermal conditions (e.g., effects on the abundance of organisms suitable as food).

The temperatures that are rapidly lethal have well defined limits and these have been thoroughly described for many species, including some found in Lake Michigan and the other Great Lakes. Less well known but equally important are the temperature limits for successful survival in other situations where unfavorable temperatures reduce the ability of the organisms to move about, escape predation, compete with other species for food, and otherwise successfully complete all of the vital life processes and stages (including reproduction).

The use of inshore waters of Lake Michigan for waste heat disposal would have a serious impact on fishes that must complete their early life stages (especially egg incubation and early growth) in the inshore and beach water zones. Fishes are least mobile in these life stages and therefore least able to avoid unfavorable thermal conditions. Also affected adversely would be the highly mobile adults that require these shallow-water areas for spawning and the anadromous fishes that

need to pass through the inshore and beach zones to spawn in tributary streams or to enter Lake Michigan as young from the tributary streams to complete the growth phase of their life cycle. Shallow-water organisms other than fishes, many of which are required as food for fishes or are otherwise important to man, would also be affected by the use of inshore lake waters for waste heat disposal.

B. EFFECTS ON ADULTS AND JUVENILES

Most organisms cannot live at temperatures much higher or lower than those to which they are accustomed (Kinne, 1963), and a general relation can be demonstrated between the temperatures that are lethal for adult fishes and the temperatures of the natural environment in which these fishes occur. In natural populations the temperatures that are lethal for adult fishes usually exceed the natural temperature extremes by only 9 to 12°F (Brett, 1969).

The lethal limit for juvenile coho salmon is 77°F (Brett, 1952) and adults die in about 60 minutes at 77°F (Coutant, 1969). Coho salmon must pass through the beach zone waters as juveniles descending to Lake Michigan and as adults ascending tributary streams to spawn. When adult coho salmon concentrate off stream mouths in late summer and early fall before entering these streams to spawn, average bottom water temperatures in the beach zone range from 69°F (August) to 58°F (end of September), and one year in three the temperatures can be as much as 10-11°F higher than the average values (Figure 6). In mid-August of an average year a rise of only 8°F would increase bottom water temperatures in the beach zone beyond the lethal limits, and in one year of three an even smaller increase

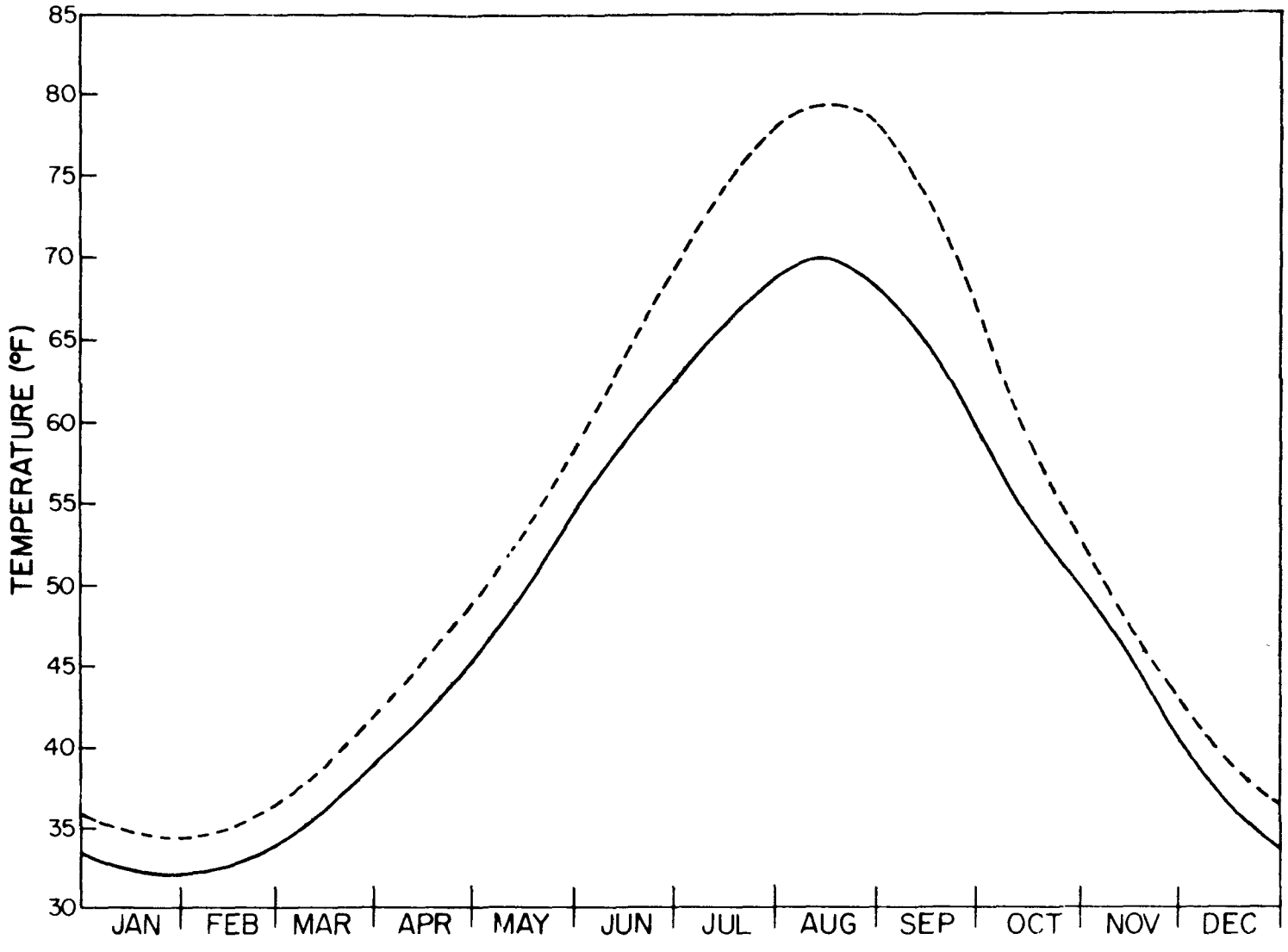


Figure 6.--Average Lake Michigan beach zone water temperatures. Temperatures were measured on the bottom at 18 to 36 feet; dashed line indicates one standard deviation above the average (1/3 of all temperatures fell between the two lines). Data compiled from Church (1941 and 1942), Chicago Municipal Water Treatment Facilities (1966; unpublished records), and the Bureau of Commercial Fisheries (1954, 1955, and 1969; unpublished).

would exceed 77°F. By the end of September a rise of 19°F would exceed the lethal level. Although surface water temperature data are not available for the beach zone, the surface temperatures would be higher than those of the bottom waters used to construct the curve in Figure 6; the migrants must pass through these surface waters to enter the stream mouths.

In addition to fish mortalities that occur when temperatures exceed the upper temperature tolerance limit of fishes, mortalities may also result when fish acclimated to high temperatures are suddenly exposed to sharply dropping temperatures.

Emery (1970) described a mortality that occurred as a result of a natural upwelling of cold offshore bottom water in Georgian Bay, Lake Huron. The upwelling suddenly lowered beach zone bottom water temperatures from 65.3°F to 44.6°F in about 11 hours; recovery was rapid, however, and by the 15th hour bottom water temperatures in the affected area had risen to 64.9°F. The more mobile fishes left the area when the temperature dropped but crawfish and sculpins could not; these ceased feeding and many died.

Low temperature mortalities may also occur in Lake Michigan as a result of the use of lake water for cooling. In a report of a fish kill on Lake Michigan at the Consumers Power Company Campbell Plant at Port Sheldon on August 29, 1968, the Michigan Water Resources Commission concluded that a sharp drop in water temperature (from 71 to 57°F) at the intake of the Port Sheldon installation gave fish in the discharge water a low temperature shock to which they were unable to adjust (Robinson, 1969). Species found dying or in distress at the

time of the investigation were channel catfish, carp, suckers, and gizzard shad--all generally considered to be intolerant of low temperatures or of low temperature shock.

Although the fish kill at Port Sheldon was due in part to the invasion of the shallow beach zone by cold offshore water, the high temperature of the effluent water to which the fish had become acclimated was also a contributing factor. Fish mortalities caused by low temperature shock are also likely to occur in the absence of coldwater upwellings when effluent water temperatures fall--as when a power plant goes "off line" or its level of operation is greatly reduced. Little information is available on the thermal tolerance of the alewife but a recently completed manuscript entitled "Effects of temperature on electrolyte balance and osmoregulation in the alewife (Alosa pseudoharengus) in fresh and sea water" by J. G. Stanley and P. J. Colby, indicates that the alewife is very intolerant of low temperature shock. When alewives acclimated at 62.6°F were subjected to an 18°F temperature decrease in 2 hours, 13 of 21 (62 percent) died. This information suggests that severe mortalities of alewives could be caused in effluent waters by low temperature shock when a power plant reduces its level of operation. The effect would be most severe during the spring when the lake water is cold and alewives concentrate near shore before spawning.

Sublethal temperature shock has also been shown to affect adversely the well being and survival of juvenile salmonids. According to the temperatures of Figure 6 and the lethal temperatures of juvenile coho salmon (Brett, 1952), a temperature rise of 15 to 35°F in the beach

zone waters at stream mouths would be required to kill young downstream migrants. Coutant (1969), however, has shown that heat doses only 25 percent as large as those required to cause loss of equilibrium (the dose required to cause equilibrium loss is less than that required to cause death) measurably increases the susceptibility of juvenile chinook salmon and rainbow trout to predation.

The heat doses required to cause harm to juvenile and adult Lake Michigan fishes are not known but there is little doubt that sub-lethal temperature shock and increased susceptibility of affected fishes to predation would be important consequences of discharging heated effluents into Lake Michigan.

Even more restrictive than the lethal temperature limits are the limits for the efficient function of the complex of vital life processes that ensure the continued successful existence of the individual, population, and species. The temperature requirements for these vital processes are known for only a few species, but the available information indicates that the general form of the relations may be similar for most fishes native to the temperate waters of North America. Among these fishes the swimming ability, feeding rate, food conversion efficiency, and growth rate typically are low at low natural environmental temperatures, rise with rising temperature to some maximum (at the "optimum temperature"), and then decline sharply with further temperature increases as the upper lethal temperature is approached. Figure 7 shows the effect of temperature on the food intake, growth, and conversion efficiency of coho salmon. The curve of Figure 7 marked "ration" describes the voluntary rate of food intake at the various

temperatures. Intake was low at low temperatures, rose with temperature to a maximum at about 59-64°F, and then declined sharply at higher temperatures. Growth followed a trend similar to that of intake. Growth rate was most rapid at 59°F and fell off at higher and lower temperatures. Extension of the ends of the growth curve indicates that growth rate was nil at about 39 and 70°F.

Conversion efficiency which is defined as,

$$100 \times \frac{\text{growth in weight}}{\text{weight of food eaten}}$$

gives the percentage of the food eaten that is converted into growth. When no growth occurs the conversion efficiency cannot exceed zero percent; according to Figure 7 this occurs at about 39°F and at 69-70°F.

Where the problem has been studied intensively (for sockeye salmon; Brett, 1969), the evidence indicated that the successful natural range of the species coincides with areas in which water temperatures do not exceed the "optimum" for food conversion efficiency by more than a few degrees and where food conversion efficiency is not reduced to less than 80 percent of the maximum. According to Figure 7, the food conversion efficiency of coho salmon--a close relative of the sockeye--reached a maximum at about 54.5°F and fell below 80 percent of maximum at 62°F. Temperatures higher than 62°F during the growth phase of the coho salmon can be expected to reduce the population success of this species.

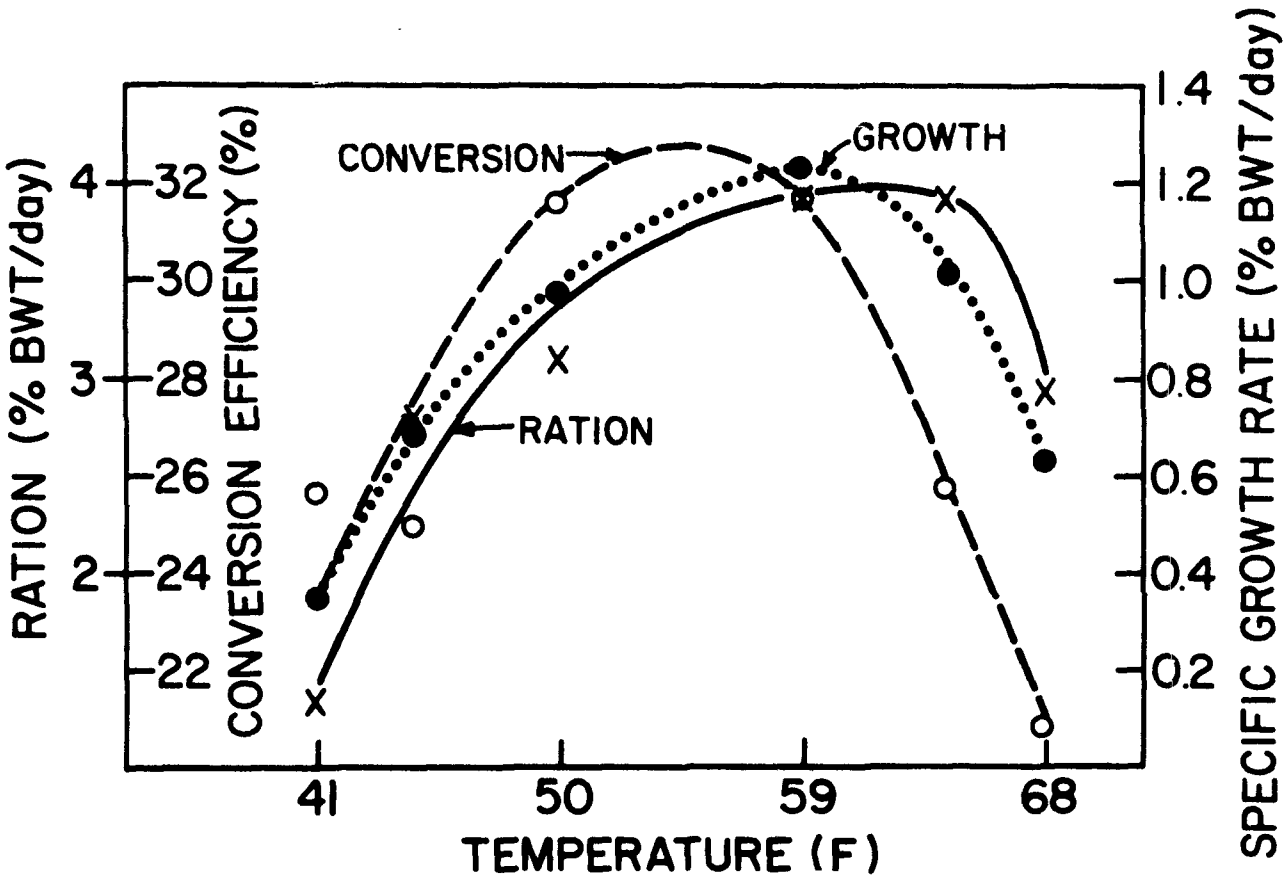


Figure 7.--The effect of temperature on the food intake, growth, and conversion efficiency of juvenile (0.5-pound) coho salmon held in fresh water and fed unrestricted amounts of alewives from Lake Michgian (T. Edsall, unpublished data).

In addition to its effect on the growth, survival, and general well being of fishes, temperature is also important because it directly affects the availability of coho salmon (and other fishes) to the angler. The temperature range for optimum feeding rate of juvenile coho salmon fed unlimited amounts of alewives is 59-64°F; elevation of temperature above 64°F reduces feeding rate (Figure 7). An even lower optimum temperature for feeding in nature (where food availability is restricted) is predicted from data on optimum temperature for growth and conversion efficiency of coho salmon whose food intake was restricted to levels approaching those in nature (T. Edsall, unpublished data)--and indeed the optimum feeding temperature for adult coho salmon in Lake Michigan is about 50-55°F (Borgeson, 1970). When adult coho salmon in Lake Michigan concentrate off stream mouths before ascending the streams to spawn, lake water temperatures average 69 to 56 (August to end of September) and one year in three range from 69 to 79°F in mid-August and from 58 to 69°F at the end of September (Figure 6). According to Figure 7 elevation of inshore water temperatures at this time, when the major portion of the catch of coho salmon is usually made in Michigan waters of Lake Michigan, will sharply lower the feeding rate and consequently reduce angler success.

Elevation of beach zone water temperature may also delay the start of the upstream migration, thereby shortening the duration of the stream fishery for salmon. In 1969 about one-half of the Lake Michigan salmon caught by anglers were taken in tributary streams.

Although temperature data for the beach zone waters at the time of the salmon runs are not available for Lake Michigan, the 1968 run of coho salmon "jacks" (precocious males) in the Chagrin River, a tributary of Lake Erie, did not begin until beach zone water temperatures fell below 65°F, and in 1969 the first run of adult coho salmon seen in Lake Erie entered the Chagrin River on September 13, after the beach zone water temperatures had dropped to 66°F; furthermore, the peak of the 1969 run did not occur until October 24-26 when temperatures were 58-62°F (Russel Scholle, Ohio Division of Wildlife, personal communication).

C. EFFECTS ON MATURATION AND SPAWNING REQUIREMENTS

1. Maturation

The environmental requirements for normal maturation of the sex products within the gonads of adult fishes have been studied for only a few species (see Welch and Wojtalik, 1968, for a review). Most studies show that both temperature and light cycles are important. Recently the FWQA Laboratory, Duluth, Minnesota, has shown that water temperatures must be 43°F or lower for 5 months to ensure normal maturation of the eggs of yellow perch; higher temperatures upset the natural temperature and photoperiod cycles and significantly reduce both the number and viability of the eggs that are spawned. The average water temperature in Lake Michigan drops below 43°F on about November 20 and rises above 43°F again on about April 20--a period of 5 months; any delay in cooling in the fall or acceleration of warming in the spring will shorten the time available for maturation to a period less than that required. Although water colder than 43°F will

still be available to perch, there is evidence that they may not avoid, or may be attracted to, the warmer waters when they are available (Weatherly, 1963; Ferguson, 1958).

2. Spawning

In general, the discharge of heated effluents in shallow water can be expected to have its most serious effects on Lake Michigan fishes during spawning and egg incubation. The available information suggests that most Great Lakes fishes that spawn in shallow water have preferred spawning sites, and that in years of low population abundance these areas are used to the exclusion of other areas. During years of high abundance, however, spawning is much more widespread. Spawning areas of most shallow-water spawners in Lake Michigan are not precisely known, but the distribution of the whitefish fishery during the spawning season, as indicated by past records, indicates that whitefish spawned in the shallow shoreline waters of the entire lake in times of high abundance (S. H. Smith, Bureau of Commercial Fisheries, personal communication). Although populations of whitefish in Lake Michigan are now at an all-time low, and their spawning may be restricted to a few local areas, population increases that should result from current fishery management programs will increase the number of spawning areas used; consequently, all potential spawning sites must be protected. Similar protection may also be required for the inshore spawning areas of yellow perch, smelt, lake herring, and lake trout.

There is mounting evidence supporting the hypothesis that coregonid fishes have narrow temperature limits for spawning. Monti (1929) found that whitefish did not spawn in Italian lakes where winter temperatures remained above 45-46°F. Whitefish in the Great Lakes spawn in November and December when the lake is cooling, and a drop to 42°F is required to stimulate spawning (Louella E. Cable, Bureau of Commercial Fisheries, manuscript in preparation). Temperatures above 42°F will presumably exclude whitefish from their preferred spawning grounds. Lake herring spawn later than whitefish--from mid-November to mid-December, when the temperature drops from 39 to 37°F (Smith, 1956). Several other investigators (Stone, 1938; Washburn, 1944; Brown and Moffett, 1942; P. J. Colby and L. T. Brooke, manuscript in preparation) observed that lake herring spawn when the temperature falls below 39°F. Cahn (1927) found that ripe female lake herring in laboratory tanks would not spawn at 40°F, but would do so only after the temperature had dropped to 38.5°F or lower. John (1956) reported that lake herring will spawn--later than usual--when temperatures are above 39°F during late autumn, but suggested that the delay may reduce egg survival. Pokrovskii (1960), as cited by Lawler (1965), wrote that the temperature of the water at the time of spawning exercises an influence on the abundance of year-classes of certain whitefishes and on their yield; in some years the quantity of fertile eggs reached 80-100 percent, in others it decreased to 30-50 percent, and in one instance only 10 percent of the eggs deposited were fertile. Such low fertility was attributed to long drawn-out

autumns in which the males leave the spawning grounds before the optimum spawning temperature for females is reached.

Yellow perch spawn in the spring during rising temperatures. Optimum spawning temperatures are 46-54°F; at 61°F spawning is reduced and at temperatures above 62°F eggs are aborted without being fertilized (unpublished data, FWQA, Duluth). The spawning season for perch in Lake Michigan begins about May 15 and ends about July 1 (L. Wells, Bureau of Commercial Fisheries, personal communication). Water temperatures average 49°F on May 15 (one year in three this average may be as high as 53°F) and 62°F on July 1 (in one year in three this average may be as high as 69°F; Figure 6). Thus, in one year in three, the addition of heat to the spawning areas at the start of the spawning season (May 15) would cause the optimum temperature for spawning to be exceeded, and the addition of heat towards the end of the spawning season would cause the females to abort their eggs.

Lake Michigan alewives spawn from early June, when temperatures in spawning areas rise above 60°F, through mid-August, if temperatures remain below 82°F (Edsall, 1970). Although most Lake Michigan alewives spawn in flowing water in tributary streams, spawning is common in the sheltered areas of Green Bay in northwestern Lake Michigan, and occurs occasionally along the unprotected shoreline of Lake Michigan proper when the lake water is warm enough. The warming of lake waters by heated effluents will facilitate lake spawning by alewives where spawning now occurs only infrequently.

Any increase in the abundance of alewives that is likely to result from an increase in the spawning areas, however, is contrary to present management objectives (see section on fishery resources) for Lake Michigan.

D. EFFECTS ON INCUBATION REQUIREMENTS

The available evidence suggests that a normal self-sustaining fish population may continue to exist successfully only in areas where temperatures are in the range that permit the production of viable fry from at least 50 percent of the eggs that are spawned (Alderdice and Forrester, 1968). Information on the effects of temperature on survival and development of eggs and fry of Great Lakes coregonid fishes is scanty; published work is limited to only a few studies on the influence of temperature on early survival and development. Lawler (1965) found that year classes of whitefish in Lake Erie were strong only when suitable temperatures prevailed; fall temperatures must drop early to 43°F, the decrease to the optimum temperatures for development must be steady, and spring temperatures must increase slowly and late in the season to provide prolonged incubation near the optimum developmental temperatures. Christie (1963) found production of larger year classes of whitefish in Lake Ontario to be associated with cold Novembers followed by warm Aprils. Price (1940), who incubated whitefish eggs at constant temperatures from 32 to 54°F, found that the optimum hatching temperature was 33°F and at temperatures above 43.2°F the hatch of viable fry fell below 50 percent. Colby and Brooke (1970), who incubated lake herring eggs at constant temperatures ranging from

32 to 54°F, demonstrated that the highest temperature at which 50 percent of the eggs produced viable fry was 44.6°F, and that the optimum temperature was about 42°F. Most of the mortalities occurred during the early stages of development (gastrulation and organogenesis) when the eggs were most sensitive to adverse temperatures. According to the data of Price (1940), Colby and Brooke (1970), and Figure 6, lake temperatures are already at the maximum tolerable for the successful incubation of whitefish and cisco eggs and the addition of heat to the lake in the fall in areas where the eggs of whitefish or ciscoes are incubating will reduce the viable hatch below the 50 percent level.

It is obvious that a 10°F rise over natural maximum tolerable temperatures during spawning (from 42 to 52°F for whitefish and from 39 to 49°F for lake herring) would cause high mortality among eggs during the critical period of early embryo development. A 5°F rise over natural temperatures (to 47°F) would kill whitefish eggs or increase the incidence of abnormalities, and a 3.6°F rise shortens the incubation period of lake herring by at least 29 days (Colby and Brooke, U. S. Bureau of Commercial Fisheries, manuscript in preparation), causing the fish to hatch in a potentially hostile environment in which light may not be of the right intensity, or food may not be of the proper kind (species), size, or density to ensure survival. Braum (1967) reported that Coregonus eggs incubated at 39°F hatched after 65 days. Eggs spawned in December hatched at the end of February, when plankton

is scarce. Modern German hatcheries incubate eggs at 34°F to delay hatching until April, after 120 days of incubation, to take advantage of the larger plankton population than available. Einsele (1966) stated that it is now firmly established that in the Austrian Alpine lakes only 1 to 10 adults will result from 10,000 naturally spawned coregonid eggs. In the laboratory, however, survival can be varied from nearly 100 percent to nil by varying food density and light intensity. Einsele suggested that the feeding conditions for fry improve as the year proceeds from March to the end of April and early May, when the light intensity may rise above 100 lux and the number of copepodites per liter may increase to 20 or more. Fry stocked at this time would most likely have the best chance of survival. He also pointed out that in Alpine lakes the feeding situation for coregonid fry does not improve continuously as the year proceeds, but that there is a turning point towards the end of May when diurnal plankton migration begins and crustacean plankton moves down to 10-20 meters during the daytime. The light intensity for fry may be critical at 5 meters and is certainly too low below 10 meters. Also, at this time the many zooplankters may not be in the appropriate size range for food of fry. Einsele also stated that stocking fry from hatcheries in January and February had little or no effect on the fish population.

Although factors governing egg and fry survival in Lake Michigan have not been studied intensively at the Great Lakes Fishery Laboratory, evidence from a local field study in progress

suggests that shortening the incubation period could be potentially deleterious to the fish stocks.

Preliminary investigations of lake herring feeding habits by the Great Lakes Fishery Laboratory show that they have some specific food requirements. Fry begin feeding about 6 days after hatching, which is well before the yolk-sac is absorbed. The diet is composed primarily of Crustaceans of the order Eucopepoda - suborders Cyclopodia and Calanoida for the first 2 to 3 weeks (or until they reach a total length of 15 mm) at which time species of the suborder Harpacticoida are found in their gut. The range of mean total length of food eaten (to 0.6 mm) by fry 12 to 18 mm long is less than the mean total lengths of the preferred food available (0.6 to 1.mm). Thus fry are selecting food organisms that are small enough for them to ingest or that have swimming speeds or behavior patterns that enable the fry to capture them. In either case the food organisms ingested are not adults but rather juveniles of a stock that has recently reproduced. Evidence from a food selectivity study shows an increase in abundance of cyclopoid juveniles coinciding with the hatching and appearance of lake herring (cisco) fry. At this time the stock of calanoids is increasing in density but decreasing in average size, indicating a younger population. This population is increasingly fed upon by the lake herring fry as the density of cyclopoids drop (P. J. Colby, Bureau of Commerical Fisheries, manuscript in preparation).

The timing of these natural events is no doubt essential for the perpetuation of these fish stocks and has evolved as a result of natural selection, e.g., fish which spawned earlier or later were selected against by the environment. Any heat discharge which would interfere with this natural timing (e.g., cause the fry to hatch when the natural preferred foods are lacking or scarce) would jeopardize the survival of that stock.

Temperatures above 64°F will cause mortality in excess of 50 percent of the eggs of yellow perch during the first 24 hours afte. the eggs are spawned (FWQA, Duluth; unpublished data). According to Figure 6 the average temperatures on May 15 (the start of the spawning season), June 1, and June 15 (the end of the spawning season), were 49, 53, and 58°F respectively; and in one year of three they might be as high as 53, 58, and 64°F. Temperature elevations of 15°F on May 15, 11°F on June 1, and 6°F on June 15 would bring the water temperature to 64°F, the lethal limit. In one year of three temperature rises of 11 and 6°F could bring lake temperatures to 64°F on May 15 and June 1; on June 15 the temperature may already equal the lethal limit.

Although 50 percent of the eggs spawned may hatch at temperatures below 64°F, the most viable fry are produced only from eggs incubated at temperatures below 61°F (FWQA, Duluth, unpublished data). Temperature rises of 12, 8, and 3°F on May 15, June 1, and June 15, respectively, could bring the average water temperature to 61°F (Figure 6). In one year of three temperature rises of only 8°F

on May 15 and 3°F on June 1 might bring the temperature to 61°F, and after June 7 the temperature may already exceed that value.

E. EFFECTS ON FRY REQUIREMENTS

Fry of whitefish, lake herring (cisco), smelt, alewife, and yellow perch occupy inshore waters during at least the early stages of their development; limited evidence suggests that those which move into deeper water later in the fry stage inhabit upper levels.

Hart (1930) found that whitefish in the Bay of Quinte (Lake Ontario) spawned mostly in water 8-15 feet deep, and that the eggs began hatching in about mid-April. The newly hatched fry remained near the surface, and about 2 weeks after hatching began to school and concentrate in water less than 18 inches deep. About 4 weeks after hatching they moved into water 3 or 4 feet deep, but always remained near the surface. Reckan (1970) found whitefish fry in South Bay, Lake Huron, in shallow areas (less than 3 feet deep) in late June and early July. Studies of the early life history of whitefish now being conducted by the University of Wisconsin-Milwaukee in Green Bay and northwestern portions of Lake Michigan have shown that Lake Michigan whitefish also use the inshore areas for egg incubation and nursery grounds; about 90 percent of the larvae were at water depths of 10 feet or less (Walter Hogman, University of Wisconsin, personal communication).

Pritchard (1930) reported that cisco spawning in the Bay of Quinte took place in water 8-10 feet deep, and that the eggs hatched in late April and early May. The fry ranged in shallow water with whitefish fry until they were about 1 month old, when they moved into deeper water. Cisco fry have also been observed in shallow water in Lake Huron (Faber, 1970). The cisco fry were often present in the upper 8 inches of water very near shore (e.g., around docks); small numbers, however, were regularly taken in surface collections over deep water.

Smelt spawn in early spring in tributary streams and along shore in Lake Michigan (as evidenced by the concentrations of sport fishermen during smelt spawning time). How long the fry remain in the shallow water is not known, but Wells (1968) demonstrated that most remain in the warm upper strata until late summer. In eastern Lake Erie young smelt frequent shallow epilimnial waters and at times are heavily concentrated near shore (Ferguson, 1965).

Alewives spawn in late spring and early summer in tributary streams (and along shore in some areas) in Lake Michigan (Edsall, 1970). Soon after hatching, which is primarily in June and July, the young are mostly in the upper few feet of water very near shore, but as they grow older some rapidly disperse into the upper warm levels over deeper areas, and may be found in midlake by late summer (BCF, unpublished data; Wells, 1968).

Yellow perch spawning areas in Lake Michigan are not completely known but most apparently spawn among weeds or on rocky shoals. These

areas provide substrates to which the ribbon-like egg masses can cling. Hatching occurs mostly in June, at least in southeastern Lake Michigan. Largest catches of fry by BCF have been in water about 16 feet deep, and few fry have been caught in water deeper than 33 feet. Sampling has been extremely limited in water shallower than 16 feet, but on the basis of perch fry distribution in other lakes, it seems extremely likely that the fry in Lake Michigan are most abundant in water shallower than that depth.

Although the distribution of the fry of a number of other species is poorly known, some undoubtedly occupy inshore areas of Lake Michigan. The larvae of burbot and deepwater sculpins (both present in Lake Michigan), for example, have been observed in association with whitefish fry in very shallow water in Lake Huron (Faber, 1970). Two common Lake Michigan forage species, trout-perch and spottail shiners, are mostly in water less than 30 feet deep when they are in spawning condition in early summer (Bureau of Commercial Fisheries, unpublished data; Wells, 1968).

Published information on the thermal tolerance of larval fishes, including coregonids, is almost totally lacking. Recent studies in which newly hatched cisco fry acclimated at 38°F were subjected to temperature shock showed that 100 percent of the fry were immobilized in about 700 minutes at 73°F, 55 minutes at 77°F, and 5 minutes at 81°F (T. Edsall, unpublished data). Studies by Coutant (1969) on the effect of acute sublethal temperature shock on juvenile salmonids revealed that heat doses only 25 percent as large as those required to cause loss of equilibrium caused a

significant increase in the susceptibility of the shocked fish to predation. No records were made of the heat doses required to produce loss of equilibrium in cisco fry, but they were considerably lower than those required to produce immobilization (T. Edsall, unpublished data). Although studies of the susceptibility of cisco fry to predation were not made, the available information suggests that cisco fry that hatch in middle to lake April and are subjected to temperatures of less than 10°F above the average for that date (Figure 6) have an increased susceptibility to predation.

F. OTHER EFFECTS

1. Effects on Fish

Historically, there is little doubt that increased temperatures and lower flows in tributary streams following deforestation and settlement were important factors associated with the reduction or elimination of stocks of whitefish, lake herring, and lake trout that spawned in rivers and shallow areas of the Great Lakes. Heavy exploitation, mill dams, and pollution were also suspected of being contributing causes; however, even after these factors were eliminated as influences, the stocks did not recover while the temperature increases persisted (forests were not replanted, and industries and cities that caused aquatic warming grew larger).

Increased temperature is still considered today the most likely cause for the reduction in numbers of whitefish, lake herring, and lake trout from tributaries and shallow areas of all of the Great Lakes, and the virtual elimination of all of these

species from the St. Clair River, Lake St. Clair, the Detroit River, and Lake Erie, where they were once abundant. Lakes St. Clair and Erie recovered to some degree from this loss because they are shallow and thus are favorable for members of the perch family (walleyes, blue pike, saugers, and yellow perch), which can tolerate warmer waters. These species cannot, however, live in the cold, deep water of the other Great Lakes, nor can other species--as is illustrated by Lake Ontario, where all large lake species (including those of the perch family) are greatly reduced or absent. Fish are very scarce in Lake Ontario throughout the offshore region, which includes some 70 or 80 percent of the area of the lake.

Crossman (1969) noted that, although the increase of 2°F in average water temperature in Lake Erie since the period 1918-27 does not seem large, it is actually equivalent to moving the lake 50 miles to the south--and many of the prime species, such as lake trout, whitefish, and ciscoes (lake herring) were already at the southern limit of their temperature tolerance in Lake Erie before settlement. He also stated that, for whitefishes, temperatures only slightly above a critical level during incubation seriously reduce the number of eggs that hatch and the number of young fish that will be added to the population.

Several studies and observations support the hypothesis that temperature is presently limiting the natural distribution of coregonid fishes in the Great Lakes area (Frey, 1955; Lawler, 1965; Colby and Brooke, 1969; Crossman, 1969; Edsall and Colby, 1970).

Some of the potential insidious effects of heated effluents on the spawning grounds in Lake Michigan include the changing of the ecology of this critical habitat. Milner (1874) reported that lake trout in Lake Superior spawn in 7 to 90 feet of water, and James Reckahn (Ontario Department of Lands and Forests, personal communication) has noted that whitefish spawn over water from a few inches to 20 feet deep.

Hart (1930) found whitefish eggs in crevices and under stones. They were observed most commonly at a depth of about 8 feet and none were observed below a depth of about 15 feet. Whitefish and lake trout both spawn over suitable bottom areas where wave action and currents keep the bottom swept clean. The observations of Merriman (1935), Royce (1936), and Royce (1951) show that lake trout spawning areas are restricted to bottoms of clean gravel or rubble, free of sand and mud. Royce (1951) stated: "As the fish make no effort to bury the eggs, the bottom must have crevices into which the eggs can fall, if eggs and larvae are to be protected." Because crevices and interstices are required for protection of eggs of whitefish, lake herring, and lake trout in shallow water, any heat addition that will accelerate production and deposition of organic matter, prolong decomposition reactions and contribute decomposition products to these confined microhabitats will have deleterious effects on egg survival. These subtle changes may already be taking place in the Great Lakes; research on the problem is much needed. It is important that water quality in the bottom-water interface does not

approach conditions described over fiber deposits by Colby and Smith (1967) if fish survival is to be ensured. Anoxic conditions, with associated production of bacteria similar to those over fiber beds, could occur in areas of increased heat in the presence of adequate nutrient sources. Such a situation could result where a sewage treatment plant and a power plant discharge effluents in the same vicinity.

2. Mortality of Water Birds

Multiplication of bacteria is encouraged by increasing summer lake temperatures. One particular organism of concern is Clostridium botulinum type E, the bacterium which has caused dieoffs of fish-eating birds on Lake Michigan and has caused human mortalities. Although this organism readily grows at low temperatures, it has an optimum range of about 68-86°F. Since it becomes most common in areas of high localized temperatures, any increase in temperature within this range will stimulate both multiplication of the organism and production of its toxin.

3. Intake Damage

Although the major share of attention so far has been focused on the thermal effects of cooling water discharges on the metabolism of Lake Michigan fish, several other consequences of using the lake waters for cooling also merit serious consideration.

Thermal shocking of aquatic organisms pulled into a power plant is an important consideration when judging intake damage. Just as important are the physical jarring and smashing to which organisms (adult fish, fish fry, and plankton) are subjected when

they are brought up against the fish screens and internal piping of the intake structures. Assuming a use rate of 91,000 cfs (by the year 2000), about 1.1 percent of the total volume of the water inside the 30-foot depth contour (where the eggs, larvae and juveniles of many important Lake Michigan fishes are most abundant) will be passed through the cooling systems of power generating plants daily; and in one year a water volume equal to several times the entire water mass inside the 30-foot contour would pass through these cooling systems. Available information on the effect of thermal shock on larval fishes (see the section of fry requirements for information on the thermal tolerance of larval lake herring) indicates that the expected temperature rise alone experienced by these fishes while passing through the cooling system would be very injurious or immediately lethal. Similar undesirable effects are anticipated for other important aquatic organisms, including phytoplankton (Morgan and Stross, 1969) that serve as food for Lake Michigan fishes.

4. Discharge Damage

The addition of chemicals to clean cooling systems may also cause damage to Lake Michigan fishes and food organisms. Chlorine is generally used to limit the growth of algae on condenser surfaces. The amount of chlorine used depends on the installation but chlorination to 0.1 mg/liter for about one-half hour, three times daily, is typical. Although the amount of chlorine introduced to the lake will not significantly increase the chloride content of the lake, the

the chlorine will have a bactericidal and algicidal effect on organisms in the treated water. Preliminary data obtained to determine the potential of chlorine for use as a fish toxicant indicate that even short exposures to concentrations of less than 0.1 mg/liter are lethal to young coho salmon in natural Michigan surface waters (L. Allison, Michigan Department of Natural Resources, personal communication). Other toxicants such as chromates and copper sulfate (used to combat algal problems in cooling facilities) may also be present in the discharge water and have a serious effect on the aquatic environment.

Heated effluents from power plant cooling systems will be saturated or supersaturated with dissolved gases and will cause the formation of emboli in fishes that will damage gills, eyes, epidermis and other tissues and may be lethal. Newly hatched whitefish and lake herring larvae are highly susceptible to damage from supersaturation (T. Edsall, Bureau of Commercial Fisheries, personal communication; J. Reckahn, personal communication). Larvae of other Lake Michigan fishes are probably also susceptible.

V. EUTROPHICATION

The general effects of increased water temperature on the phytoplankton and other algae are known, but are not well delineated--particularly with respect to lakes. Patrick (1969) stated: "Blue-green algae will increase due to increased organic load and/or to rise in temperature . . .. In general, the blue-green algae have more species that prefer temperatures from 35°C [95°F] upward, whereas the green algae have a relatively large number of species that grow best in temperatures ranging up to 35°C [95°F] although some can grow at higher temperatures. Most of the diatom species prefer lower temperatures--that is, temperatures below 30°C [86°F]. The natural succession of species which we find is largely due to the fact that species can outcompete each other under varying temperature conditions. Of course, other ecological conditions also control the kinds of species which we find present at various seasons of the year. These conditions are light, nutrients, and so forth." The synergistic effect of increased temperature and increased nutrient concentration suggested by Dr. Patrick may be of particular concern with respect to present and projected conditions in Lake Michigan.

In Lake Erie, the most eutrophic of the Great Lakes, a succession of algal pulses occurs each year. Diatoms appear first in late winter or early spring when temperatures begin to rise above freezing, following the winter period of relatively little algal activity. Diatoms reach their maximum at temperatures of 35°F to

50°F. When the temperature rises above 50°F, green algae become dominant and remain dominant until the temperature nears its maximum of about 75°F. Above 75°F blue-green algae appear, and as the lake begins to cool, very large blooms frequently occur.

The algal succession as described above for Lake Erie has not been generally observed in Lake Michigan, even though temperature ranges are similar. The reason for the difference is that Lake Erie is richer and more variable in nutrient content; algal succession is not due to temperature alone, but is the result of temperature and adequate nutrient supply. The response in Lake Erie to artificial heat rise could be expected to be a change in the time of the algal succession during the warming season. Pulses of diatoms, green algae, and blue-green algae would probably occur earlier than would be expected naturally. In addition, artificial warming would lengthen the period of dominance of blue-green algae by simply sustaining temperatures above 70°F for a longer period.

In Lake Michigan, however, indications are that nutrients in the inshore waters are approaching levels commonly found in the central basin of Lake Erie. Lake Michigan inshore waters receive a substantial and increasing load of nutrients in the form of nitrogen, phosphorus, and other fertilizing agents from domestic effluents and agricultural runoff. Therefore, it can be expected that the inshore waters of Lake Michigan, if nutrients are not sufficiently controlled, will attain conditions of algal production

similar to those in Lake Erie. When these conditions are reached, temperature becomes a very important factor. Dominance of green and blue-green algae will become more frequent and persistent. Blue-green algae, which are especially responsive to higher temperatures, will become more prolific in direct proportion to temperature increase. Stoermer and Yand (1969) reported that, although the dominant phytoplankters in Lake Michigan are still diatoms, the numbers of taxa that are associated with degradation of water quality have increased, and that a number of species which were able to thrive only in the naturally enriched areas near shore and in estuaries are now found in some areas of the open lake. They stated: "Consideration of distribution and relative abundance of the major components of the plankton flora leads one to the conclusion that Lake Michigan is probably at the present time about at the 'break point' between rather moderate and transient algal nuisances, largely confined to the inshore waters, and drastic and most likely irreversible changes in the entire ecosystem." Temperature increases, whatever the amount, will tend to promote these undesirable changes, especially in inshore waters.

C. L. Schelske and Stoermer, in the abstract of a paper entitled "Depletion of Silicon and Accelerated Eutrophication in Lake Michigan," presented at the meetings of the American Society of Limnology and Oceanography in August 1970, have commented further on this. They stated: "During the past 30 years, the relative abundance of diatom species commonly associated with degradation of water quality has

increased. In the summer of 1969, the plankton diatoms comprised less than 10 percent of the phytoplankton in samples from the southern part of the lake, which was a significant deviation from previous years when the diatoms comprised at least 65 percent of the phytoplankton. . . . . The evidence compared with data from Lake Erie and Lake Superior suggests that accelerated eutrophication in Lake Michigan is rapidly approaching the point of a severe environmental change in which the diatom flora will be reduced or replaced by green and blue-green algae." The overall effect of heated discharges will be to reinforce an increase in warmwater algal species at the expense of more desirable coldwater species.

Hawkes (1969) cited the work of Poltoracka-Sosnowska (1967) in which the phytoplankton was compared among three Polish lakes having different temperature ranges:

"Lichen Lake received thermal discharges from the electricity-generating stations at Konin and had a temperature range of 7.4 C [45.3°F] to 27.5°C [81.5°F]. Slesin Lake was not influenced by thermal discharges and had a temperature range of 0.8°C [33.4°F] to 20.7°C [69.3°F]. The third lake was only slightly influenced by thermal water. It was found that Lichen Lake, the warmest lake, supported the richest phytoplankton flora: 285 forms; and Slesin Lake, the least number: 198. In contrast with the other lakes, the phytoplankton flora of Lake Lichen was comparatively constant. It was observed that, as the temperature of Lichen Lake rose, the numbers of phytoplankton species increased. The characteristic dominant forms

in Lichen Lake were the diatom Melosira granulata and the blue-green alga, Microcystis aeroginosa. These two algae are characteristic of eutrophic situations. In the cold water of Lake Slesin, the diatom Stephanodiscus astraea (an oligotrophic form) was dominant.

"Patalas (1967) compared the productivity of Lichen Lake with that of a natural cold-water lake in the same lake system. It was found that the primary productivity of the heated lake (7.3 $g/m^2/d$) was almost twice that of the cold lake, 3.75 $g/m^2/d$. Secondary productivity in the form of phytophagous crustacea and rotifers was 4.5 $g/m^2/d$ in the heated lake, compared with 1.06 $g/m^2/d$ in the unheated lake."

The rate of eutrophication is controlled primarily by nutrient supply and water temperature. Either can be a limiting factor to productivity. Nutrient control measures are being undertaken at municipal and industrial effluent outfalls on a lake-wide basis; however, many diffuse sources of nutrients are not now amenable to control (e.g., agricultural and urban runoff and sediment erosion). Waste heat inputs, on the other hand, are entirely "point" sources and, on an overall basis, can be controlled much more efficiently that can nutrients. Thus, the control of waste heat provides greater assurance that the expensive productivity-limiting objectives of nutrient control will be attained.

VI. ECOLOGICAL RAMIFICATIONS OF THE ADDITION OF WASTE HEAT TO LAKE MICHIGAN

A. INTRODUCTION

Details of the resource, the mechanism and projected magnitude of waste heat input, and pertinent interactions of aquatic life and temperature have been reviewed in earlier sections. It is the purpose of the present section to examine the ecological ramifications of waste heat addition to Lake Michigan. The effects of individual plumes on aquatic life at specific sites are discussed, as well as the broader lake-wide aggregate effects of the projected waste heat rejection that would result from once-through cooling in coming decades.

B. GENERALIZED PLUME IMPACT

Unless a discharge is located sufficiently far from shore and in deep water, waste heat will under normal lake current conditions frequently be carried to the beach water zone, where the ecological impact will be essentially the same as that of a shoreline discharge. For this reason, attention is focused primarily on shoreline point and jet discharges.

A single plume, depending principally on effluent volume and temperature, will exert a thermal influence over a significant lake area. For example, the "dilution only" model study for the Davis-Besse Nuclear Plant indicated that the plume for an 18°F temperature

rise would at equilibrium cover 28 square miles to the 2°F isotherm and 373 square miles to the 1°F isotherm (Table 14). Thus, organisms in substantial areas of the inshore waters would be exposed to the biological influence of the unnaturally warmed water.

A more extensive variation of a single plume ecological effect is the situation where two or more waste heat discharges are close enough to interact. An additive effect will cause the thermal ecological impacts from the interaction to be more intense than if only one heat source existed.

The once-through cooling process will thermally shock and physically jar adult fish, fry, and plankton. Physical damage occurs against fish screens, internal piping, and intake structures. Industrial and power operations also frequently add algicides to cooling water with resultant adverse effects on organisms. It is desirable to relate this once-through cooling damage to the large volume of water required for a single plant. A 600 cfs effluent would require 142 billion gallons of lake water per year and a 3500 cfs effluent, 826 billion gallons. In the course of an operational year, a proportionately large amount of plankton would be destroyed or placed under unnatural stress.

There will frequently be a sector which will exhibit temperatures sufficiently higher than ambient lake temperatures to be lethal or immobilizing to nearly all species in Lake Michigan. The size of the sector so affected depends, among other things, upon the discharge temperature and velocity, lake current velocity, and tolerances of specific organisms. Intolerant organisms of all life stages must

avoid this sector or suffer stress or mortality; thus they are prevented from normal habitation or utilization of this zone.

There will also be a heated sector adjacent to the one nearest the outfall that is not lethal, but from time to time actually attracts certain species of fish. Angling success is reputedly sometimes improved in such sectors. The vicinity of the plant outfall will from time to time be "flushed" by storms and upwellings; the frequency of such occurrences is discussed in section II. The physical dynamics are not clearly understood but the mixing will predictably occur--sometimes with great rapidity and accompanied by sharp drops in temperature in the area of the thermal discharge. At such times, fish attracted by the warm water and acclimated to it are exposed to stress. Such stress can be sufficient to cause fish mortalities, as happened at the Campbell Plant near Port Sheldon, Michigan, in August 1968. It is suspected that a similar stress condition might occur when the heat source is shut off, as when a power plant goes off line.

An unnatural, three-dimensional continuum of temperature decrease extends from the warmest water at the discharge out to where the lake mass exhibits ambient temperatures. Within this continuum of thermal influence of the plume, the waste heat will directly and indirectly influence life processes of fishes, including feeding rate, maturation, growth, spawning, incubation, vulnerability to predation, hatching, and larval development.

Adverse physiological effects will result when optimum thermal limits for a particular life process are exceeded in the plume; these influences will generally increase in subtlety with distance from the discharge. Evidence discussed in section II indicates that only slightly elevated temperatures, properly timed and sufficiently long, can be critical in the various life history stages of Lake Michigan species. The evidence also indicates that adverse thermal limits are already approached by existing water temperature regimes; and that in warmer years, the lake temperatures may for several species already exceed these limits. For example, Lake Michigan temperature regimes may now be at borderline limits for optimum growth, reproduction, and/or survival of yellow perch, whitefish, lake trout, lake herring, alewives, and coho salmon. Thus, it appears that artificial heating would aggravate and intensify existing critical adverse effects and perhaps create new ones. Particularly in warmer years, temperature increases induced by waste heat would detrimentally affect these species or reduce their habitat in the area influenced by the plume.

An extensive zone of thermal influence would affect the species composition of algae and bacteria, in favor of species preferring higher temperature; for example, green and blue-green algae would be favored over diatoms. Such a localized eutrophication effect is particularly important in lake zones where nutrient concentrations are high.

In addition to "flushing" in the actual vicinity of the discharge, the entire area influenced by waste heat will also be purged from time to time with colder lake water. Since the addition of waste heat serves to "inflate" local natural temperatures in the shallow water environment, one resultant net effect is to exaggerate the natural temperature extremes caused by the flushing out process and thereby complicate ecological adjustments to the extremes.

C. POTENTIAL IMPACT OF CUMULATIVE WASTE HEAT

Assuming the once-through cooling technique, the projected year 2000 situation in which 431 billion Btu/hr of waste heat would be discharged to Lake Michigan requires a more general approach to ecological evaluation. The number of discharges under such a situation is unknown, although estimates as high as 100 have been advanced. Several definite impacts are recognizable, if not quantifiable.

It has been demonstrated that waste heat addition in coming decades could significantly raise the temperature in extensive areas of the inshore waters, particularly the beach water zone. Waste heat from individual shore discharges are capable of thermally influencing many miles of lake shore. As the frequency of discharges along the shore increases, many plumes would eventually be so close together that their effects would merge. With the magnitude of projected waste heat, it is not difficult to envision a very sizable proportion of the beach water zone and certain adjacent waters physically affected by artificial temperature increases.

The aggregate influence of waste heat from increasing numbers of plants around the perimeter of the lake would proportionately magnify the unnatural effects on fish and other aquatic organisms caused by a single plume. Where several plants would exist in proximity, ecological problems would be intensified with interaction of their thermal zones of influence.

Under such warmed conditions and in those areas where nutrients are approaching critical levels, changes toward increased eutrophication would be expected. The increased eutrophication would be evidenced by dramatic increases in blue-green algae.

Extensive areas of waste heat influence would also favor species of bacteria tolerant of relatively high temperatures. Under certain conditions, the warming influence would assist in proliferating both the abundance and toxin production of Clostridium botulinum type E during summer and fall, and increase the probability and magnitude of mass dieoffs of shore and water birds.

Finally, projected once-through cooling water requirements of 91,000 cfs for year 2000 would require a volume of lake water equal to roughly 1 percent of the beach water zone daily, or 2.15 trillion gallons per year. On the basis of shear volume of water used, thermal and physical damage to aquatic organisms by once-through cooling could be expected to reach considerable ecological significance.

VII. CONCLUSIONS

(1) The inshore zone is in many respects the most important portion of Lake Michigan. It is the most used by man and is the most biologically productive.

(2) At times very large percentages (up to virtually 100 percent) of the waste heat discharged to the lake are diffused into the beach water zone; and studies of model plumes indicate that the influence of the heated water from a single discharge can cover many areal miles of the lake.

(3) Assuming that once-through cooling water requirements in the year 2000 will result in the discharge on the magnitude of 431 billion Btu/hr of waste heat into Lake Michigan, a significant artificial thermal load would be added to the beach water zone. Since this waste heat load would equal a significant percentage of the natural rate of heat input, it is not difficult to envision resultant physical warming of a large proportion of the beach water zone and certain adjacent waters.

(4) Heated plumes alter the natural habits of fish, exclude them from discrete areas of heated water near shore, and produce the hazard of stress and mortality in the event of rapid cooling. The plumes also create a broad area of thermal influence in inshore waters, which in an unnatural manner influences critical life history stages of fish and other aquatic organisms in the vicinity of the discharge. Evidence indicates that for several fish species,

critical life history stages are adversely affected. Furthermore, during warmer seasons, the waste heat accelerates the eutrophication process over and probably outside the discharge vicinity, which is an undesirable effect in oligotrophic Lake Michigan. The added heat also alters the normal species composition of algae during cooler seasons, and improves conditions for the development of Clostridium botulinum type E bacteria during warmer seasons.

(5) On the basis of available evidence, the practice of once-through cooling, regardless of any temperature standard (except virtually no heat addition), will impart the bulk of waste heat to the lake mass for an ecologically significant period of time. In other words, a 1,000-cfs discharge 5°F above the ambient temperature will transmit essentially the same amount of heat into the lake as a 250-cfs discharge with a 20°F rise, and for essentially the same length of time. It follows that, regardless of any number standard, the magnitude of ecological impact of the heat would be on the same order (disregarding more direct effects, such as fish mortalities near the discharge, which may perhaps be avoided by more thoroughly diluting the effluent).

(6) If the projected amount of waste heat is an amount sufficient to impart ecological damage to the lake, the only available alternative is to restrict the addition of waste heat to that level which will minimize or avoid damage.

(7) The timing of natural events is essential for the perpetuation of Lake Michigan coldwater aquatic life that has evolved as a result of natural selection. Any waste heat influence which would interfere with this natural timing places the survival of this aquatic life in jeopardy. Evidence presented in this report indicates that only slightly elevated temperatures, if properly timed and sufficiently long, can be critical in the life history stages of Lake Michigan species.

(8) Assuming the projected year 2000 cooling water requirement of 91,000 cfs and once-through cooling, an amazing water volume equal to 1.1 percent of the beach water zone volume would be passed through the cooling systems of power generating plants daily (4.4 percent per day for the Chicago-Gary sector). An unquantified, but significant, amount of physical and thermal damage would occur to plankton, eggs, larvae and juvenile fish. Prevention of this damage can be achieved by simply avoiding the technique of once-through cooling. Such an objective can be readily achieved by the use of closed cooling systems.

(9) Rate of eutrophication is controlled primarily by nutrient supply and water temperature, either of which may limit productivity. Since nutrient levels in certain areas of Lake Michigan are now approaching critical levels, a lake-wide shallow water warming influence would contribute to accelerating eutrophication. Therefore, the careful control of waste heat provides greater

assurance that the productivity-limiting objectives of the immensely expensive lake-wide pollution control program will be attained.

(10) Environmental influences in Lake Michigan which are detrimental to the species characteristics of large northern lakes pose a serious threat to the United States-Canadian sea lamprey control program, the State-Federal lake trout restoration program, the coho and chinook salmon sport fisheries, alewife control, and other fishery programs. Potential lake-wide effects of waste heat discussed in this report are considered to constitute such a detrimental environmental influence.

(11) On the basis of the above points, it is concluded for ecological reasons that no significant discharge of waste heat into Lake Michigan should be permitted.

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Y. M. Barber

MR. BARBER: Report preparation has been a cooperative effort of the Bureau of Commercial Fisheries, Bureau of Sport Fisheries and Wildlife, and the Federal Water Quality Administration. The principal scientific input came from the Great Lakes Fishery Research Laboratory at Ann Arbor, Michigan, although specific inputs have come from diverse sources. The Ann Arbor installation is and has been since the early 1920's the Federal Governments principal biological research facility concerned with the Great Lakes. The scientists of this laboratory called attention to the pollution problems of the Great Lakes more than 15 years ago before most of the telltale symptoms were obvious to the public. These men have been increasingly involved in the problems of the lakes and reflect a unique reservoir of knowledge and experience in the ecology of these waters.

Since our principal topic is how waste heat will affect Lake Michigan, I would like to review with you briefly some of the physical dimensions of the lake. Lake Michigan is 307 miles long and has a maximum width of 118 miles in its northern basin and 75 miles in the southern basin. The shoreline is 1661 miles and the surface area is 22,400 square miles or 14,336,000 acres. The maximum depth is 923 feet and mean depth is 267 feet.

Volume of the lake is 1,170 cubic miles.

Of special interest to these discussions are figures related to the shoreline waters of the lake. Two areas have been delineated. The first we call the "inshore zone," which consists of the waters extending from the shore to the 100-foot depth contour. The width of this area ranges from 1.04 miles in the Grand Traverse area to 6.21 miles in the Chicago-Gary area with an average width of 3 miles for the entire lake shore. The surface area of this inshore zone is 5,040 square miles or 22.5 percent of the total lake. The volume is 46.6 cubic miles or 4.1 percent of the total lake volume.

The "beach zone" is that portion of the "inshore zone" which extends from the shore out to the 30-foot depth contour. This zone varies from one-third of a mile wide in the Grand Traverse area to 2 miles in the Chicago-Gary area with an average width of just under 1 mile around the lake. The surface area of the beach zone is 1,677 square miles (1,073,000 acres) or about 7.5 percent of the total lake area. The volume of the beach zone is 4.8 cubic miles, only about 0.40 percent of the total volume of the lake.

In developing the report, present and potential waste heat input was estimated for municipal sewage and

steel manufacturing as well as for power generation. However, the bulk of this waste heat projection is from the latter source and, therefore, it is the prime item of our discussion. For the sake of comparing cooling water discharge volumes, we have converted estimates of B.t.u. per hour into cooling water flows expressed as cubic feet per second at a temperature rise over intake of 20 degrees Fahrenheit.

The estimates of power generating capacity likely to be installed on Lake Michigan now and at various intervals through the year 2000 are in line with the generally accepted rule of thumb that generating capacity will about double each 10 years. The installed capacity in 1968 on Lake Michigan was 7,600 megawatts, all of which was fossil-fueled except one 75 megawatt nuclear plant. In the year 2000 the estimates are 73,500 megawatts capacity of which 43,934 megawatts would be nuclear.

The output of waste heat by these power facilities when operating at 100 percent of capacity is estimated to be 29.85 billion B.t.u. per hour in 1968 and 414.67 billion B.t.u. per hour in the year 2000, an increase of almost 14 times in 32 years. When translated into volumes of cooling water raised 20 degrees Fahrenheit

it equals 6,600 cubic feet per second in 1968 and 91,000 cubic feet per second in the year 2000.

To gain some perspective for the volumes of water and heat that we are talking about, 91,000 c.f.s. is equal to 182,000-acre feet per day or 66 million acre feet per year. The latter figure is comparable to the volume of water in the top 4.6 feet of water over the whole 14.3 million acres of the Lake Michigan surface.

Early in the preparation of this paper it became obvious that there is less than unanimity in the view of engineers, hydrologists, physical limnologists, and others as to the behavior and fate of waste heat discharged to the lake. Some implied an almost immediate loss of most of the waste heat to the atmosphere from the plume area on the lake surface, but others concluded that significant amounts of waste heat would be mixed into the lake waters and retained for some period of time.

Now, ladies and gentlemen, at this point, I would like to interrupt my address to present a statement for the record in order to clarify what has apparently been an editorial error on page 46 of our report. I would like to read this for you.*

"Some of the conclusions reached on page 46 are in error due to editing problems. There it is inferred

*Clarification statement.

that the bulk of the heat discharged to the lake is retained by the lake. In order that a plume of excess heat not grow continuously with time a balance must exist between the heat added from the source and that lost. The principal cause of loss is by exchange at the air-water interface. It was shown that as the excess temperature approaches ambient (i.e., at about 2 degrees Fahrenheit and less above ambient) that the process of atmospheric cooling becomes dominant over temperature decreases due to entrainment and turbulent diffusion.

" Table 14 and the other examples were simply meant to convey the distinction between a substance which doesn't decay with time (hence, whose concentration is changed locally by entrainment, advection and diffusion) and one which does (where the additional process of atmospheric cooling takes place). A nondecaying substance discharged continuously would gradually fill the receiving body of water; a decaying substance, however, can come into equilibrium with the receiving water in the vicinity of the source. However, the area enclosed by, say, the one degree Fahrenheit excess temperature isotherm will vary widely with local meteorological and limnological conditions.

" This does not alter the important conclusion

of subsection 2c that under some conditions large percentages of the discharged waste heat are added to the water mass of the lake. Neither are the conclusions of ecological impact in any way altered since the misinterpretation occurred during the editing phases of report preparation and was not involved in the determination of ecological effects."

I hope that this will clarify what has been expressed as concern at this point.

MR. STEIN: Mr. Barber, can this be supplied to the conferees in writing?

MR. BARBER: Yes. We have copies available. Would you like it now or at the conclusion?

MR. STEIN: It doesn't matter. Why don't you distribute these now to the conferees? (See line 24, page 116.)

MR. BARBER: After some consideration, it was evident that under certain conditions large amounts of heat from discharge waters would become mixed with the lake waters. Under these conditions, discharges involving thousands of second feet of water heated several degrees above receiving water temperatures can be expected to form extensive plumes. Under severe conditions these plumes can extend for miles and their location and extent will vary with the conditions.

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With variations of wind, current, and temperature, individual plumes can be expected to effect significant areas of beach zone water on each side of a shoreline or near shore discharge. Considered collectively, the total number of such discharges would have impact along a major part of Lake Michigan's 1,661 miles of shoreline. More especially, most of the beach zone could be affected at the south end of the lake where it is widest and where the greatest amount of generating capacity is expected to concentrate.

The fishery resources of Lake Michigan have undergone substantial and devastating changes in recent decades. Beginning with the effects of habitat changes and possibly overfishing some species declined. The advent of the sea lamprey and the alewife through man-made navigation projects resulted in a major reduction in the desirable native Lake Michigan species. However, extensive programs are now under way to control the sea lamprey and success is being obtained. Stocking of lake trout, coho salmon, and other species is resulting in development of extensive and much sought after sport fisheries. Continuing management efforts will result in further great improvement of the native species such as lake trout, whitefish, walleye, yellow perch, chubs,

and others, as well as the introduced desirable exotics such as salmon and trout. The continued existence of present fisheries and the further development of the vast potential of Lake Michigan is dependent upon maintaining beach water and inshore areas as well as the open lake in conditions suitable for their healthy existence.

The beach water zone constituting the shallows of the lake are vital areas for fish life. Nearly every important fish species of the lake, both native and exotic, uses the beach water zone at some phase of its life cycle. Most species spawn there, some of them in depths of less than 15 feet. These species include the whitefish, lake trout, yellow perch, lake herring, and others. These areas are also the vital nursery areas for the larvae and juveniles of many species. The eggs of some species of fish have prolonged incubation periods and are present throughout most of the winter on the bottom of the beach water zone.

The recently introduced coho salmon pass through the inshore waters in their natural migrations to ascend rivers. The most important harvest of these fish is the popular sport fishery which take place as the adults converge in the inshore zone for movement into the streams.

Warming of the beach and inshore zones can affect the various fish populations in a variety of ways. It may

exclude the fish from important units of shallow water habitat. It may prevent development of sex products, prevent spawning or prevent hatching when spawning does occur. It may cause hatching of young into a hostile environment when proper food organisms are lacking. Movement into or out of thermal plumes by adults or juveniles, or exposure of less motile forms to shock by wandering plumes, upwellings or cessation of plant operations may cause death by thermal shock or stress which affects coordination, leaving the individual vulnerable to predators.

However, effects upon fish life will not necessarily be manifested in the form of massive numbers of dead fish. Eggs resorbed by a gravid adult as a result of temperature changes, or eggs or larval stages which are destroyed, can be critical for a population, yet such effects are sometimes near impossible to determine in the field and are most clearly shown in the laboratory. Such insidious effects are much more likely than conspicuous kills of adult fish windrowed on the beach.

Some parts of Lake Michigan may already be too warm for some species; further warming would place additional pressures on their survival.

Y. M. Barber

Alewives use both inshore and open lake waters and warming of inshore waters may facilitate its spawning activities. The alewife is particularly vulnerable to thermal shock, especially from sudden drops in temperature. The incidence of alewife dieoff may be increased by the presence of heated plumes within the inshore zone.

With present projections, massive volumes of lake water would pass through generating facilities under once-through cooling in the year 2000. Our data indicate that a volume equal to over 1.1 percent of the beach water zone of the entire lake would be passed through the power plants daily. This statistic rises to an amazing 4.4 percent in the Chicago-Gary sector of the lake. Plankton organisms, as well as eggs and larval stages of fish are present, and damage to these important organisms from thermal shock, as well as from the physical impact of passage through the plant system, can be expected to be of ecological significance.

The recent trend of water quality in Lake Michigan has been one of decline, both from alterations of the watershed and from the discharge of pollutants. While quality of the lake water is high by generally accepted standards (excluding pesticides), there is a significant loss of quality taking place. Concentrations

of total dissolved solids are increasing by about 2 percent per decade and increased from 128 mg/liter in 1880 to 158 mg/l in 1969.

The rate of algal growth -- and here we are largely concerned with the eutrophication process -- is controlled primarily by nutrient supply and temperature. Generally the diatoms reach their greatest abundance at temperatures of 35 degrees Fahrenheit to 50 degrees Fahrenheit. Between 50 degrees Fahrenheit and 75 degrees Fahrenheit the green algae become dominant and above 75 degrees Fahrenheit the blue-greens take over. This process has been quite obvious in Lake Erie where "algal pulses" occur and very large blooms of blue-green algae have appeared as the lake began to cool after exceeding 75 degree Fahrenheit temperatures.

Even though temperature ranges in Lake Michigan are quite similar to those of Lake Erie, these "algal pulses" have been less generally observed. The reason is the lower level of nutrients in Lake Michigan waters. However, indications are that the inshore waters of Lake Michigan are approaching nutrient levels similar to those of Lake Erie.

The addition of waste heat to the waters of Lake Michigan will contribute to and accelerate the

eutrophication process, beginning first in the inshore waters but extending as well to the open waters if nutrient levels and temperatures are increased. Even relatively small increase in inshore temperatures can be expected to alter algal composition in favor of the undesirable blue-green algae. At the expense of the more desirable cold-water species, the periods of dominance by the undesirable forms will be lengthened.

An additional possible effect of warming of lake waters, especially in shallow waters of high nutrient content, is the increase of bacterial growth. Almost every year some loss of bird life is suffered from botulism on Lake Michigan. Under certain conditions, a warming influence would assist in proliferating both the abundance and toxin production of Clostridium botulinum type E during summer and fall, and increase the probability and magnitude of mass dieoffs of shore and water birds.

In summary, the inshore zone is in many respects the most important portion of Lake Michigan and is the most used by man. At times large percentages of waste heat discharges are diffused into the beach water zone of the lake. Available information indicates the heated water plumes may cover many square miles. Present projections indicate that the 1968 power generating

cooling water requirements of 6,643 c.f.s. would by the year 2000 be increased to 91,000 c.f.s. The rate of waste heat discharges from the major sources would be increased from 40.43 billion B.t.u. per hour to 430 billion B.t.u. per hour, an increase of nearly eleven times.

Much of this waste heat would be introduced to the important inshore waters. This waste heat load would on both an individual plume basis and as a total of many plumes affect extensive areas of the beach and inshore zones. Critical life history stages of many species of fish would be adversely affected to a serious degree.

The eutrophication process would be accelerated by the warming trends, especially where nutrients are approaching the critical level.

Even slightly elevated temperatures, when of sufficient duration and coincident with critical life history stages of Lake Michigan organisms,can have devastating ecological impact.

We, therefore, conclude that for ecological reasons no significant discharges of waste heat into Lake Michigan should be permitted.

MR. STEIN: Thank you, Mr. Barber.

I understand you have some people here with you

who can answer questions.

MR. BARBER: Yes, we do.

MR. STEIN: Are there any comments or questions from the conferees on Mr. Barber's statement?

Mr. Currie.

MR. CURRIE: Yes. First of all, Mr. Chairman, I would like to request that questions from the public be permitted as well as from the conferees. We do this in our proceedings before the Illinois Board and we find it can be extremely helpful.

MR. STEIN: We indicated that questions from the public would be permitted before we called this meeting, and if you want to reiterate that as a request, of course that is fine. But we are going to do it.

MR. CURRIE: Thank you.

I would like to ask Mr. Barber if he can give us some explanation of the meaning of the phrase "no significant discharges."

MR. BARBER: I think we have to say ecologically significant. As we have indicated in our report, the lake is already getting too warm for many of our species. Any warmer water is likely to result in increased eutrophication. Therefore, I think when we say "significant", we have to mean that which would be detectable away from the point

of discharge.

MR. CURRIE: Detectable by a thermometer in terms of eutrophication?

MR. BARBER: I think by a thermometer, since as a matter of a standard it has to be measurable for administration purposes.

MR. CURRIE: So that no significant discharge means no detectable discharge?

MR. BARBER: Well, I think the standard has to be written to clarify these points and spell out exactly what we mean as far as our report goes. We refer to heat which is detectable away from the point of discharge. I don't mean a mile away, but as was originally stated with one degree at the end of the pipe.

MR. CURRIE: So that when you say "significant", you do not mean, then, that it is necessary to prove in every case that the heat discharge in question causes significant harm to the ecology of the lake?

MR. BARBER: That is right, sir.

MR. CURRIE: Now, in our hearings last week, several witnesses for utility companies suggested that the limited time that any given water molecule would remain in an elevated temperature would severely minimize the

effect of waste heat on Lake Michigan. Could you comment on that, please?

MR. BARBER: If I may, I would like to refer that question to one of our specialists who is here for the purpose of answering that. Mr. Richard Callaway from the National Thermal Pollution Laboratory.

MR. CALLAWAY: I think the time that they came up with at that conference would have been a 10-day half life for the life of the plume, which means if the plume exists and then the discharge stops, about 10 days would be required for the disappearance of that plume.

MR. CURRIE: I think it was a slightly different point that was being made, because if you don't have a small plume but a very large one you are constantly putting heat in it.

MR. STEIN: I suggest we speak a little more slowly.

MR. CURRIE: I shall try.

Any given molecule of water will pass rather quickly through the plant back into the water and will lose its heat to other particles of water so that although there is a constant heating of water, the different molecules of water that are heated so that any single molecule of water retains its heat for a relatively short

period of time, and the time is a few hours, as I recollect.

MR. CALLAWAY: I don't think so. If you are talking about heating that molecule -- if you can heat a molecule -- as the molecule is discharged from the pipe -- I think the figures in that report, I am not positive -- said there is a 10-day decay time for that particular plume. Now, this could vary from one day to 10 or 15 days.

I think the meaning is: If a plume exists, enclosing a certain area above ambient temperature, and the discharge of heated water is terminated, then this plume is going to approach the ambient temperature -- the natural lake water temperature, and it is going to take something up to 5 or 10 days to approach it.

MR. CURRIE: One more, Mr. Stein.

Mr. Barber, I notice the main thrust of the report seems to me to be that heat in sufficient quantities can cause harm -- and possibly everyone will agree with that -- and what bothers me is the absence of quantification. How much heat causes how much harm? We are being asked, I think, to adopt standards that forbid any significant increase of heat to the lake, rather strictly defined as you have defined it, on the basis of a statement that too much heat can cause harm.

Y. M. Barber

How do we know how much heat is going to be significant in terms of the ecology of the lake?

MR. BARBER: Well, we have to recognize that Lake Michigan is a rather unique lake. It has an enormously complicated biota, and the impact of heat on this is, of course, our greatest concern.

I would like to ask Dr. Colby if he could give us comments on that. Dr. Colby is from our Ann Arbor laboratory.

MR. STEIN: When you people come up, Mr. Barber, I wish they would identify themselves with their full name at least the first time.

DR. COLBY: My name is Peter J. Colby from the Great Lakes District Laboratory at Ann Arbor, Michigan.

Would you repeat the question?

MR. CURRIE: The question was essentially: How do we know how much harm is done by how much heat?

DR. COLBY: All right. You realize it is very difficult to tell you how much is significant. If I can give you some idea by illustration, it depends on what the ambient temperature is and how far this temperature is from a critical temperature. Any excess heat which causes 50 percent mortality is certainly critical.

Y. M. Barber

If you are in the critical area then one degree can be very important as far as incubation. If you are going to exceed the mortality of 50 percent or 60 percent, that may be critical. If you are talking about two degrees centigrade over ambient for the duration of an incubation period of lake herring or whitefish, you could reduce the incubation period by as much as a month.

Fish that would normally hatch in April would now be hatching in March. We think they would hatch in a very hostile environment at that time of year.

MR. CURRIE: Is this what the factual situation is around here? Are these the existing temperatures and are these the existing types of fish so that you are prepared to say that that consequence will take place from a given amount of heat in Lake Michigan?

DR. COLBY: Yes, right. These are native species. We have not studied plumes. This is not our line of business. But we know what effect temperature has on the incubation of the egg. We know where they lay their eggs. We don't know exactly all of the spawning grounds, but we assume, for instance, in Lake Michigan, that the whitefish are found all over the lake, and that they use inshore areas. If you increase

the temperature of most inshore areas -- this depends on how much area we are going to cover, if we are covering 10 miles, 5 miles up and down and we have 30 plants around the lake, then we have covered a third of the inshore areas of the lake -- I would say this would be significant.

MR. CURRIE: Thank you.

MR. STEIN: Thank you.

Are there any other comments or questions?

MR. PURDY: I would like to pursue that.

MR. STEIN: Before we go on, may I again make a suggestion?

I think we are getting some very valuable meterial in colloquies here. Probably one of the most important things we are producing is the record. I would ask you all to remember this is going to be a long hard week, particularly for Mrs. Hall, who is taking this down. Please try to speak clearly and slowly.

Mr. Purdy.

MR. PURDY: Yes, again, I think that we recognize that heat can cause these problems, but I am not sure that we have the answer that Mr. Currie was seeking -- at least not to the extent that it helps me form a plan of implementation within the State of Michigan.

Y. M. Barber

Yes, when you exceed these critical temperatures, we agree that these things will take place, but how will any heat input cause these temperatures to be exceeded, if any? Because this is what we seem to be saying: This one degree at the end of the pipe -- you know the exhaust of an outboard motor is going to be one degree warmer than the water taken in. Are we going to ban outboard motors used on Lake Michigan?

MR. STEIN: Mr. Mayo.

MR. MAYO: I would like to speak to that point, Mr. Chairman.

I think I understand the conferee from Michigan's point in raising that issue, but I would hope that the potential impact or the discussion of the potential impact of vessel operation on Lake Michigan would not become really a serious point of discussion because I think it can be dismissed as not being a significant issue, and I would refer the conferees to the recent Federal regulations with respect to the control of oil spills from vessels. In those regulations, they specifically exempt the operation of vessels in the navigable waters coming under the jurisdiction of the regulations from the controlling points of the regulations.

Y. M. Barber

And I would like to suggest that the conferees take a look at that specific regulation and the exemptions applied to vessels and see if we can't draw a parallel to the heat discharge issue from vessels in this Lake Michigan situation.

MR. STEIN: Are there any other comments on this?

I would like to suggest that this is a problem that has come up in the discussion of thermal pollution in other areas of the country and, of course, I think it has to be met, but I am not sure that it may not lead us down a false path.

Particularly this issue came up from developing the water pollution control standards for the State of Kansas where they raised such questions as: What is going to happen with pollution from an outboard motor? What is going to happen in a town that is discharging a little sewage effluent or a lot of sewage effluent? What is going to happen to a town in the winter that takes its water from wells and discharges the water as waste into surface waters when the intake water is of a higher temperature than the discharge waters? And I think we can spin these out again, and again, and again.

Now, it seems to me that without making a

judgment as to what any degree in temperature rise should be or if we should restrict it at all, that if we are going to have any meaningful control or program for control of temperature rises in our waters, that we have to make some reasonable classifications, and some of these sources, I think, have to be omitted from the consideration. Otherwise, as we try to formulate a program, if you are going to assume that by that formulation you are going to make that apply to every possible source, I think you can be led into thickets where it is not going to be very easy to get out.

MR. PURDY: Well, I can agree with you to a certain point, Mr. Stein, but I think that this is the real heart of the issue is to determine some number of B.t.u.'s per hour that can be considered a significant discharge so that we could make a judgment factor of those discharges that we can exclude.

MR. STEIN: I think you are right. In other words, in your usual precise engineering fashion you said what I said very shortly.

I think you are talking in terms of making a classification, and handling the smaller discharges possibly a different way than you would do massive discharges.

Y. M. Barber

MR. PURDY: So far I haven't been able to get my finger on that exclusive figure, and I am reasonably certain that if we adopted a standard in Michigan that said no significant heat discharge, I am not positive that this would be received well by the Department of Interior and approved, so we need to get more specific on it.

MR. STEIN: Let me again try to do this. I don't think we are going to leave here -- I guess we know each other well enough -- I don't think we will leave here or come up with a recommendation of anything that vague. Obviously we are looking for a figure.

Now, I think, again, maybe we can put this directly to Mr. Barber.

Mr. Barber, in your opinion, what kind of heat rise would you allow at the pipe for significantly large heat discharges into Lake Michigan?

MR. BARBER: Significantly large -- I assume, Murray, that you mean moving into the area of large facilities such as power plants.

MR. STEIN: Such as power plants, that is correct.

MR. BARBER: Well, I think our report indicates that the one degree can be damaging in spawning areas of fish; in critical circumstances, one degree could contribute

to the eutrophication process. I think one degree at the end of the pipe isn't a bad place to start.

MR. STEIN: Are there any other comments or questions?

MR. PURDY: I have some other questions.

MR. STEIN: Certainly.

MR. PURDY: Mr. Barber, in the report, and in your summary you have directed most of your remarks to the inshore and the beach waters. I can foresee now the proposal being placed before my commission that the discharge would be into the offshore waters. Do you have some comments now with respect to that?

MR. BARBER: We have given this a considerable amount of thought. We have not treated it at any length in the report. There are several reasons for this. An important one is that there are economic impacts that would be considered therein.

But leaving this aside, we viewed discharges to offshore waters as having considerable serious effects as well. To begin with, let's say we only get 3 or 4 miles offshore with an offshore discharge. I believe that all of our studies indicate that under some conditions this plume could come back on shore, and we would expect essentially the same effects from this plume coming back

to shore -- into the shore zone -- as the outer edges of the thermal plume discharged to the inshore waters. If the offshore discharge is made subsurface, then it will likely result in nearly all and maybe all of the heat being added to the total heat budget of the lake.

We think that heating in local areas could be a serious eutrophication matter. You understand, sir, that in looking at all of these things we are faced with, some very large facilities are coming, and there may be a great many of them.

MR. PURDY: Well, I would also like your opinion with respect to, say, the immediate danger from existing facilities.

MR. BARBER: There is reason to believe that the existing facilities are capable or may have already caused many of these effects we are talking about. Some of them being long-term existing facilities, it is a little late to go back and determine what their impact has been when we do not know what was there before.

I would ask Mr. John Carr of our Great Lakes Laboratory if he would like to comment on this at this point. Can you comment for us on this, John?

MR. CARR: I don't have anything further to add.

MR. PURDY: I didn't hear that.

Y. M. Barber

MR. BARBER: He said that he didn't think he would have anything to add to what I have already said.

MR. PURDY: Well, in your summary, you point out that the warming of the beach and inshore waters can affect the various fish populations and may exclude the fish from a number of -- well, from important units of shallow water habitat, that may prevent development of sex products -- it may do this and a number of other things.

There are some existing thermal plumes. Have you made studies and have you observed these effects from those plumes in Lake Michigan?

MR. BARBER: Let me again ask John: Have we had any studies of these?

MR. CARR: No.

MR. BARBER: No, sir, we have not.

MR. PURDY: I feel, again, this is an important problem that we need to direct ourselves to because we do have some studies under way on the immediately proposed new plant -- that is the pre-operational studies and post-operational studies -- that would give valuable information if there is not an immediate danger from those particular plumes.

If there is an immediate danger and some

additional restrictions must be placed upon their operation, why then I question whether there is a need to go on with the pre- and post-operational studies.

MR. BARBER: I think the pre- and post-operational studies of these areas are extremely valuable records which we do need, and we are going to need more and more in the future.

One of our problems now is that we do not have sufficient data almost anywhere you go. The problems of making biological investigations of natural bodies of water far exceeds those relating to anything we can dream up in engineering, because frequently they require essentially 365-day-a-year attention to these specific areas: and, therefore, we simply lack techniques for some of the studies that we would like to have in these waters. But we certainly agree with you that we do need an acceleration of research in all of these areas.

MR. PURDY: What I am saying, though, is that if we need immediate restrictions on those, the whole program will change and whether the pre- and post-operational studies will be continued by the waste discharger, I don't know, because a part of it now is to meet an order of my commission that states that they must demonstrate that they are not causing any injury, and if we place

restrictions now upon that discharge, and require cooling facilities, I am not sure that the studies will continue.

MR. BARBER: This may be true.

MR. STEIN: Well, that may be true, but I think this is probably the limit we have in this business, and I think this is a real difference. We had a thermal case and still have one in Florida, as you probably know. The contention was made by the Federal people that temperatures above 90 degrees would cause damage to the aquatic life down there.

Some people at the University of Miami began talking in terms of the studies to be done. Now, as I understand, the people of Miami have completed their studies and are in full agreement with the Federal investigators, but the construction has gone on so far that we are faced with a real awkward problem on what do you do when you need power.

Now, I think the real issue we have here is: Are we going to go ahead with pre- and post-operative studies and in effect use the lake as the laboratory to see what effect the condition of the heat is on the lake, or are we going to make a judgment in advance, take possibly a more cautious view on the basis of opinion, and not use projected laboratory results to see that

that happens. In both cases, I think you will have -- you should have pre- and post-operative studies, but I really do believe, Mr. Purdy, that if we adopt the second course and exercise these restrictions, the pre- and post-operative studies will probably have to be done by the governmental agencies.

MR. PURDY: I think so, and I think there is a third aspect, and that is certainly you cannot continue the program forever of pre- and post-operational studies without making a decision, and whether we could consider, say, the presently existing plants and those that are under construction in one area, and then new facilities that might be proposed in the future in a different area.

MR. STEIN: Well, that is something that I think the conferees are going to have to -- one of the issues we are going to have to grapple with.

I guess this is, again, going to be a difficult problem because I think some of the people sitting at the table, particularly Mr. Klassen and Mr. Poole, have been around at least as long as I have; and one of the big changes we have wrought, I think in our day, in changing the procedure and the law, is eliminating the grandfather clauses which were existing in many of the State regulations and exempted the existing polluters from that.

Y. M. Barber

But if we have to meet that, I guess that is something we will have to take up.

MR. PURDY: One other question with respect to temperature of Lake Michigan.

Mr. Barber, in your summary you indicated that it had warmed. It was my understanding from a report by John Ayers in 1965 on the climatology of Lake Michigan that the temperature of Lake Michigan has dropped in recent years.

MR. BARBER: May I refer that to our specialist Mr. Carr, in the audience, please?

MR. STEIN: He knew you would finally get a question, Ralph, that would get Mr. Carr up.

MR. CARR: The name is John Carr. I am with the Great Lakes Fishery Lab at Ann Arbor.

Dr. Ayers' report did show that the temperature of Lake Michigan is a little colder. Whether it is statistically significant or not I am not sure. But with respect to what we are talking about, if you have heard Stan Smith's discussion on the changes in fish species in the Great Lakes, you have got some background. The streams tributary to the lake are definitely warmer than they have been, and these streams in the area around the mouths of these streams are nc longer usable by the

species that were there because of temperature, among other things. So we are not talking about the entire lake being warmer; we are talking about certain specific areas used by certain specific species near the mouths of these streams.

MR. PURDY: Thank you.

MR. STEIN: Thank you.

Are there any other comments or questions?

MR. CURRIE: One more, Mr. Chairman.

MR. STEIN: Mr. Currie.

MR. CURRIE: You mentioned, Mr. Barber, that the Interior Department has not made studies of existing thermal plumes in Lake Michigan to determine their effect on the lake's ecology.

There are some studies of that nature that have been made by others, and I wonder if you are familiar with and could comment on the study made by Doctors Pipes and Beer for the Commonwealth Edison Company.

MR. BARBER: I am not personally familiar with it.

Ken, do we have someone here who is -- could you review this one, or was it available to you?

MR. ROBERTS: Yes, it was available.

MR. BARBER: Would you like to comment on it,

Y. M. Barber

please? This is Mr. Kenneth Roberts of the Bureau of Commercial Fisheries in Washington.

MR. ROBERTS: My name is Kenneth R. Roberts. I am the Resource Management Officer with the U. S. Bureau of Commercial Fisheries, Arlington, Virginia.

The studies by Doctors Beer and Pipes have been quoted quite a lot, as we have gone down the road of hot water in Lake Michigan, and I am afraid that I can only offer an opinion based upon my personal experience. I believe that this particular study was rather short-term in nature, and I believe that it lacks the depth required to reach the assumptions and the conclusions that some people have attached to it.

MR. STEIN: Thank you.

Are there any other comments or questions?

Thank you very much, Mr. Roberts.

Any other comments from the panel?

MR. FRANGOS: Mr. Chairman.

MR. STEIN: Mr. Frangos.

MR. FRANGOS: Frangos from Wisconsin.

I would like to ask Mr. Barber: There was some information presented at one of the recent reconvened sessions of this conference -- information provided by the Bureau of Commercial Fisheries, I believe -- that suggested perhaps that we ought to go about the procedure of

identifying spawning areas or those areas around the perimeter of the lake that were significant for fishery purposes and others, and this bit of information at least suggested the idea that maybe there are some areas in the lake that are extremely sensitive, and that you ought to exclude all kinds of discharges into those areas. At the same time, there may be some areas that are biologically inactive to date because of natural conditions, at the bottom -- the storm conditions that rile up the lake, etc.

I am wondering, on the basis of your report and some of the comments that we have had this morning, whether you have rejected this type of a proposal?

MR. BARBER: We, of course, considered, I think, all of these points. The fact that a particular area may not be biologically productive as, for example, for spawning, does not preclude the fact that it may be used at some other time by migrating fish moving around the lake, and this can be quite important.

Frequently young fish, small fish, can use an area and escape detection reasonably well unless there is a very close continuous prolonged monitoring of that area to determine what extent juveniles enter the region.

One of the problems you get into with a thermal plume is that it becomes a 365-day-a-year fact of life

for that particular point. Therefore, it is automatically waiting to invoke its impact at any time on the natural activities in the lake. Admittedly, we may not always determine these or have opportunity to, but we did consider them very seriously in reaching our decisions in the report.

MR. FRANGOS: In other words, you believe we cannot operate in this kind of a fashion in terms of a site?

MR. BARBER: I thank that, yes, sir.

MR. STEIN: Are there any other comments or questions from the panel memebers?

If not, we will entertain questions from the audience now.

I would suggest that anyone who wants to speak come on up to the microphone and ask your question.

MRS. BOTTS: I am Mrs. Lee Botts. I am on the staff of the Open Lands Project, a private conservation organization, which has recently organized a federation of conservationist civic groups in all four States around the lake.

As a member of the public, I do not understand the concern with quantification that Mr. Currie has expressed, nor why the thermal pollution question is so

much more difficult than, say, the question of air pollution from sulphur dioxide. Had we known when we began to use coal in the quantity that we have used it what the effects on our air quality would be, I cannot believe we would not have taken steps to prevent it.

But we are in a different situation with heat. We know the heat and we know that heat, especially in massive quantities, has an effect. We are not talking about a slight increase in the amount of heat put into Lake Michigan; we are talking about eleven times as much heat going into Lake Michigan, and I don't understand why it is so difficult to take an action to prevent that heat from being added to Lake Michigan, and then -- as has been done with sewage and waste disposal under actions that this conference has taken in the past -- then proceed gradually as you can to eliminate other possible sources of heat.

And I would like to ask: Why the question of prevention of thermal pollution is not being considered here?

MR. STEIN: Does anyone want to make a comment on that? I guess you are asking the power companies and us on the panel to adopt the same objective to generate more light than heat.

Y. M. Barber

Mr. Currie.

MR. CURRIE: I think that the conferees are certainly concerned with the question of prevention of thermal pollution, and I think we all realize we have an opportunity to get in before serious damage is done, as we did not do in many other comparable cases.

I think the purpose of my question was that it is costly to prevent heat from being discharged into Lake Michigan, and that before we require people to spend substantial amounts of money to do this, we have to be reasonably confident that there is at least a substantial possibility of significant damage from the quantities of heat with which we are concerned.

I am interested in getting as much information on both the cost and the benefits of prevention of thermal pollution as is possible.

MRS. BOTTS: Well, if I can amplify a little further: You have been concerned with air pollution, and we have been concerned here in Illinois. When we set standards for sulphur dioxide, for example, and then sought to eliminate the sources of sulphur dioxide, we went after the biggest sources first, and I think that the analogy applies to the thermal standards, and we are talking about adding tremendous sources of heat. So that

Y. M. Barber

I am suggesting that the logical thing to do is to avoid having to deal with those sources in the future.

MR. STEIN: Are there any comments or questions?

Mr. Currie, you raised an interesting point, but I think the conferees are going to have to grapple with this, and the point is this: that this is expensive.

We have to consider whether there is going to be a damage before we require it. Let me just pose a question, because I think this is what the conferees are going to have to decide. They must make the judgment -- and this isn't the regulatory agency -- if anyone is using a natural resource or a public resource such as a public lake, and he is going to change it and heat it, it is incumbent upon him to show that he is not going to cause any damage. This goes with any change in the environment.

Now, I think this is the type question that must be handled by the conferees. I am not sure that this is all one-sided on the part of the regulatory agencies to demonstrate that there is a damage before we can prevent it. I would hope the industry, when it appears, might have taken some of that responsibility upon itself and will indicate the effects of the changes that it intends

to create.

MR. CURRIE: I think another way to put what I have been saying is that I hope the utility companies and the others who do put or wish to put heat in the lake will present evidence which attempts to show that there is no significant harm to be done by the quantities of heat with which we are concerned, and I would like to have some evidence on the other side if it exists.

MR. STEIN: I think we are in agreement.

Are there any other questions from the audience?

MR. FELDMAN: Mr. Stein, I am from the audience.

Dan Feldman. I am a lawyer and I represent the Commonwealth Edison Company.

We have had some difficulty with the Department of Interior publication and I wonder if I could just take a minute or two to try to get some clarification on what is meant in part of the "white paper."

I think I can ask some questions of Mr. Barber that will go further along in trying to understand where we may differ.

MR. STEIN: Go right ahead.

MR. FELDMAN: Mr. Barber, at page 47 of the paper, there is a figure for --

MR. BARBER: May I get my copy? I have it and

it is marked.

MR. FELDMAN: At page 47, there is a figure of 1,735 B.t.u.'s per square foot for input into the lake; and on page 48, there are some fairly strong figures about the percentage of input by utilities -- about the amount of input by utilities as that will compare with the 1,735 B.t.u.'s per square foot which is a natural input figure.

Do you have the place I am referring to?

MR. BARBER: Yes, I do, sir.

MR. FELDMAN: Have we been correct in assuming that the figure of 1,735 B.t.u.'s per square foot is solar radiation alone and does not include longwave radiation to the lake?

MR. BARBER: Excuse me one second.

Ken, who developed this figure, please? Can you respond?

MR. ROBERTS: My name is Kenneth Roberts.

The figure was brought out by Doug McLain Douglas McLain -- formerly with our Ann Arbor Laboratory. He based this estimate upon estimates from other lakes -- two other lakes -- and one unpublished estimate that he had developed while at the Great Lakes lab.

MR. FELDMAN: My question really was: Insofar

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as we have been able to check the sources, the figure seems to represent only one of the two kinds of radiation which the lake receives, that is solar rather than longwave; and since longwave is several times solar radiation, it made the percentage figure on page 48 three times as large as it ought to be.

MR. BARBER: Sure.

Ken, do you know what he used as the basis for this figure?

MR. ROBERTS: I do not know what his basis was. As he translated it to me, I understood it to mean the total maximum natural daily heat input per square foot to Lake Michigan.

MR. STEIN: Mr. McLain isn't here now, is he?

MR. ROBERTS: That was my interpretation of his basis.

MR. STEIN: Do you think you have the scope of the question? Perhaps you could get in touch with McLain and give us this information probably later today or tomorrow morning.

MR. ROBERTS: Yes, sir.

MR. STEIN: Why don't you try that? Thank you.

MR. FELDMAN: Mr. Barber, a few minutes ago, in answer to another question with respect to the discharges which are located far offshore and which have some velocity,

ADDRESS ONLY THE DIRECTOR,
BUREAU OF SPORT FISHERIES
AND WILDLIFE

153-A

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
WASHINGTON, D.C. 20240

JAN 18 197

Mr. Murray Stein
Assistant Commissioner -
Enforcement and Standards Compliance
Environmental Protection Agency
Water Quality Office
Washington, D.C. 20242

Dear Mr. Stein:

During the September 28 morning session of the 1970 Lake Michigan Pollution Enforcement Conference, a utility representative requested clarification of the meaning of the term "maximum natural rate of heat input" to Lake Michigan, as discussed on page 47 of the Department of Interior report, Physical and Ecological Effects of Waste Heat on Lake Michigan. The question focused upon whether the cited values of "maximum natural rate of heat input" considered all five natural components of lake surface heat transfer. At that time you requested that we provide information for the record to answer this question.

We have contacted Mr. Douglas McLain of the National Marine Fisheries Service, who researched and provided these estimates for the paper. He has indicated that the unpublished Lake Michigan estimate of 1,750 Btu/ft.^{2}/day (occurring in late June or early July) was developed from a technique by:

Johnson, Flittner and Kline. 1965. Automatic Data Processing of Marine Weather Reports in the Pacific Ocean, Special Scientific Report--Fisheries #503, U.S. Fish and Wildlife Service.

The estimate does include the five components of solar radiation, reflected radiation, effective back radiation, evaporation, and sensible heat, and thus represents a net value of maximum natural heat input. Further, Mr. McLain has indicated the corroboratory estimates for Lake Ontario (1,735 Btu/ft.^{2}/day from Rogers, 1968) and Cayuga Lake (2,000 Btu/ft.^{2}/day from Sundaram et al., 1969) cited on page 47 also represent net values of the five heat transfer components.

We hope that this information is sufficient to clarify the matter and would like to have it included in the conference proceedings.

Sincerely yours,

Paul E Thompson

Paul E. Thompson
Acting Assistant
Director - Research

you indicated that your studies tended to show that plumes from those discharges would part of the time be driven back to the shoreline so that you would still have some shoreline impact. And I just wondered if the studies included any quantification of that so that we knew whether it was going to come back to the shoreline once a week or once a month or once a year or any figure at all.

MR. BARBER: We did not run model studies on that. That is right, is it not, Dr. Benedict?

DR. BENEDICT: That is correct.

MR. BARBER: We did not.

However, let me say this: We recognize that if you got out completely in the middle of the lake, maybe it would not come ashore. We are assuming that within the realm of economic feasibility or building such outfalls that this would be a factor to be considered.

MR. FELDMAN: I also thought that when you were answering that question you indicated that if you used a discharge far off the lake -- far off the shoreline, and that it was a subsurface discharge, that the effect of that would be to tend to add all of the heat to the lake, and I wasn't sure whether that statement, if I understood you correctly, had any relationship with the editorial change with which you interrupted your statement this

morning, because that editorial change seemed to me to modify in some substantial part the conclusions at pages 44 and 45 of the paper with respect to how much heat is going to stay in inshore areas.

MR. BARBER: All right, now, as far as my statement that if it was subsurface all that heat might go into the lake, that doesn't mean stay in there forever, but I mean for today it is there, and this I realize depends upon the points of discharges that are involved and the type of discharge that is involved.

Now, as for the extent to which our change modifies pages 44 and 45, may I call on Mr. Callaway for a response, please?

MR. CALLAWAY: I am not sure what I am supposed to respond to.

MR. STEIN: Let me ask: Do your editorial changes change your conclusions in the report? Can you answer that?

MR. BARBER: As was stated in that statement, at the conclusion we said, "This does not alter the important conclusion of subsection 2c that under some conditions larger percentages of the discharged waste heat are added to the water mass of the lake." Neither are the conclusions of ecological impact in any way altered since

the misinterpretation occurred during the editing phases of report preparation and was not involved in the determination of ecological effects."

MR. STEIN: Let me go off the record in this procedure for a moment.

(Discussion off the record.)

MR. FELDMAN: Maybe I can put that question to you in a little more coherent form.

MR. BARBER: All right, sir.

MR. FELDMAN: Assume with me for a second that in the Chicago-Gary section of the lake, 10 miles of coastline, there are ten offshore discharges. Each of these is a high velocity discharge, so that the 2-degree isotherm from each of those discharges occupies an area of 99 acres. That would give us 1,000 acres within the 143 square miles of what the paper defines as the Chicago-Gary beach area.

Assume further that the transit time for any molecule of water in each of those plumes is one and a half hours, so that if you are at the point of discharge you will be out of the plume and back to ambient in one and a half hours.

Now, on those assumptions, would you expect there to be ecological damage to the lake?

Y. M. Barber

MR. BARBER: What is the volume of your discharge?

MR. FELDMAN: You have got ten plants of 1,000 megawatts in terms comparative to those used in your report.

MR. BARBER: Total of a thousand?

MR. FELDMAN: Yes. And I am assuming for this that they are operating at 100 percent of capacity all day every day.

MR. BARBER: In other words, you are asking what would we expect the ecological impact from --

MR. FELDMAN: You have made some assumptions about the year 2000 capacity and I was changing the shape of the discharge and reducing the number of plants to something less than, I think, 12 percent of your 2000 assumption and asking you if the conclusions still held.

MR. BARBER: Yes, I think they would.

Discharges of waste heat in that zone are going to have a warming effect on portions of the area, and these can and probably will contribute to eutrophication in that area particularly if dissolved solids are increased, and they can constitute areas of trouble for fish, yes.

MR. FELDMAN: I tried to as a slightly different question.--I tried to ask not are we going to have a localized problem, but if the area defined by the 2-degree

isotherm on all of these 10,000 megawatt plants includes only 1,000 acres out of the 143 square feet in the Chicago-Gary area, then do you find ecological damage?

MR. BARBER: All right.

To begin with, I don't know how you can really confine it to 1,000 acres. Let me say this: This is based on an average, is it not? Is that average plume size or what? In other words --

MR. FELDMAN: I have asked you to assume that each plume reaches a 2-degree isotherm, that the area within the 2-degree isotherm for each plume is 99 acres, so that my ten plants aggregate roughly 1,000 acres.

MR. BARBER: Well, frankly, let me go back. I don't see how you are going to achieve that because under varying weather conditions, how are you going to hold it to 99 acres? This is the problem.

MR. FELDMAN: If we can solve that problem, do you still see ecological damage?

MR. BARBER: Yes, I think we will, if you are putting out as much heat as a 1,000 megawatt plant does. If you put it in the air, that is another matter, but if you put it into the lake, we have got problems.

MR. STEIN: Thank you, Mr. Feldman. I appreciate those clarification questions. I would like to be around --

if that is clarifying -- when you cross-examine sometime.

Are there any other questions or comments from the audience?

If not, thank you very much, Mr. Barber.

MR. PURDY: Mr. Stein, I have one that I skipped.

MR. STEIN: Yes, Mr. Purdy.

MR. PURDY: In the first part of the report you use the term "cumulative." I am wondering what your terms of reference are for this. Are you saying that if it accumulates from one year to the next -- are you speaking about the additive effect of new and additional plants through the years?

MR. BARBER: No, we are not assuming accumulation from year to year. We are assuming that cumulative effect is where we might have one or several plants. It might or might not affect each other's discharge.

MR. PURDY: I think this is an important discussion, because when you use the term "cumulative," this might mean you put heat in there this year, it will stay there and you will add to it, and eventually it is going to boil the lake.

MR. BARBER: Thank you for asking that question, because I think this is basic to many of the arguments related to the report.

Y. M. Barber

Actually we have assumed that the year-to-year accumulation would be negligible if at all and our concern is for within season accumulations of heat.

MR. STEIN: Thank you.

Do you want to ask a question? Come on up. Mr. Barber, don't leave yet. Your popularity is increasing.

MR. LINCOLN: I will try to be very brief. My name is Lincoln. I am from the Outboard Marine Corporation.

MR. STEIN: May we have your full name?

MR. LINCOLN: Richard Lincoln from the Outboard Marine Corporation in Milwaukee.

I would like to ask for a clarification, sir, of your statement and Mr. Purdy's statement that possibly power plants other than the large fixed power plants should be excluded from this discussion, if you will, and probably from the Federal regulations that will eventually result. Was that the intent of your remarks?

MR. STEIN: No, I didn't say that, and I don't think Mr. Purdy said that.

The question we have is a clarification of -- one of heat sources.

MR. LINCOLN: Yes, sir.

MR. STEIN: And let's take a big power plant on

one side and an outboard motor on the other. I can give you my view in one second right now. I would exclude the motor boats.

Now, the question that Mr. Purdy proposes: In dealing with this problem, when we have a complete spectrum of, say, power plants, big industrial plants, such as steel mills, municipalities, large ones, small ones, various other things, that it might be possible in order to protect the lake, in order to draw lines somewhere, and include some and exclude others, that does not mean we have made a conclusion whether we are going to draw such a line or not, or that we are going to certainly draw a line and split existing power plants and new ones.

Mr. Purdy just raised this as a possibility for our consideration.

Mr. Purdy.

MR. PURDY: I agree.

MR. STEIN: Thank you.

MR. PURDY: Thank you, Mr. Stein.

MR. STEIN: Are there any other comments or questions? If not, again, thank you, Mr. Barber. I think that was a very excellent report. The colloquies were excellent in attempting to lay out the problem and try to get at, I think, what all of you by now recognize as one of our most difficult ones to try to work our way

through this and come up with equitable solutions.

May we have Dr. Bruce Tichenor?

STATEMENT OF BRUCE A. TICHENOR, CHIEF, HYDROGRAPHIC BRANCH, NATIONAL THERMAL POLLUTION RESEARCH PROGRAM, PACIFIC NORTHWEST WATER LABORATORY, CORVALLIS, OREGON

DR. TICHENOR: Mr. Chairman, conferees, ladies and gentlemen. My name is Bruce Tichenor. I am with the Department of Interior. I work at the Corvallis Laboratory. I am with the National Thermal Pollution Research Program, and I am going to make a short presentation on the Department of Interior report, "Feasibility of Alternative Means of Cooling for Thermal Power Plants Near Lake Michigan." I understand there has been some distribution of this report and I am sure some of you in the audience have seen it.

A study was conducted to determine both the technical and economic feasibility of closed cycle cooling systems for thermal power plants near Lake Michigan.

MR. STEIN: By the way, do you want this full report to be put into the record as if read?

DR. TICHENOR: Yes, sir.

MR. STEIN: It will be done so without objection.

(The document above referred to follows in its entirety.)

FEASIBILITY OF ALTERNATIVE MEANS OF COOLING FOR THERMAL POWER PLANTS NEAR LAKE MICHIGAN

U. S. DEPARTMENT OF THE INTERIOR • SEPTEMBER 1970

FEASIBILITY OF ALTERNATIVE MEANS OF COOLING FOR THERMAL POWER PLANTS NEAR LAKE MICHIGAN

Prepared by:

National Thermal Pollution Research Program
Pacific Northwest Water Laboratory

and

Great Lakes Regional Office

U. S. Department of the Interior
Federal Water Quality Administration

August 1970

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I. INTRODUCTION

Scope

This report presents an evaluation of various methods of dissipating waste heat from thermal power plants near Lake Michigan. The feasibility of the cooling methods are considered from both an engineering and economic standpoint.

It must be emphasized at the outset that the following analyses are directed towards determining the feasibility of various cooling methods; no attempt is made to optimize any particular plant or site.

In addition to determining the engineering and economic feasibility of cooling devices, the effect of their operation on the environment is examined.

Waste Heat Load

The engineering calculations on the various cooling devices are made on the basis of a "typical" 1000 MWe fossil-fueled power plant with a nominal thermal efficiency of 40 percent. With in-plant and stack losses of 15 percent of the total heat input, such a plant will discharge 3.84×10^9 Btu/hr to the condenser cooling water. This same waste heat load would be created by a 600 MWe nuclear power plant with a boiling water or pressurized water reactor, assuming a nominal thermal efficiency of 33 percent and 5 percent in-plant losses. Other combinations of plant size and thermal efficiency which result in 3.84×10^9 Btu/hr waste heat to cooling water are shown in Figure I-1 for both 5 percent and 15 percent in-plant losses. For example, a 750 MWe fossil-fueled plant (15 percent in-plant losses) with a thermal efficiency of 34 percent has a waste heat load equivalent to the "base" 1000 MWe, 40 percent efficient plant.

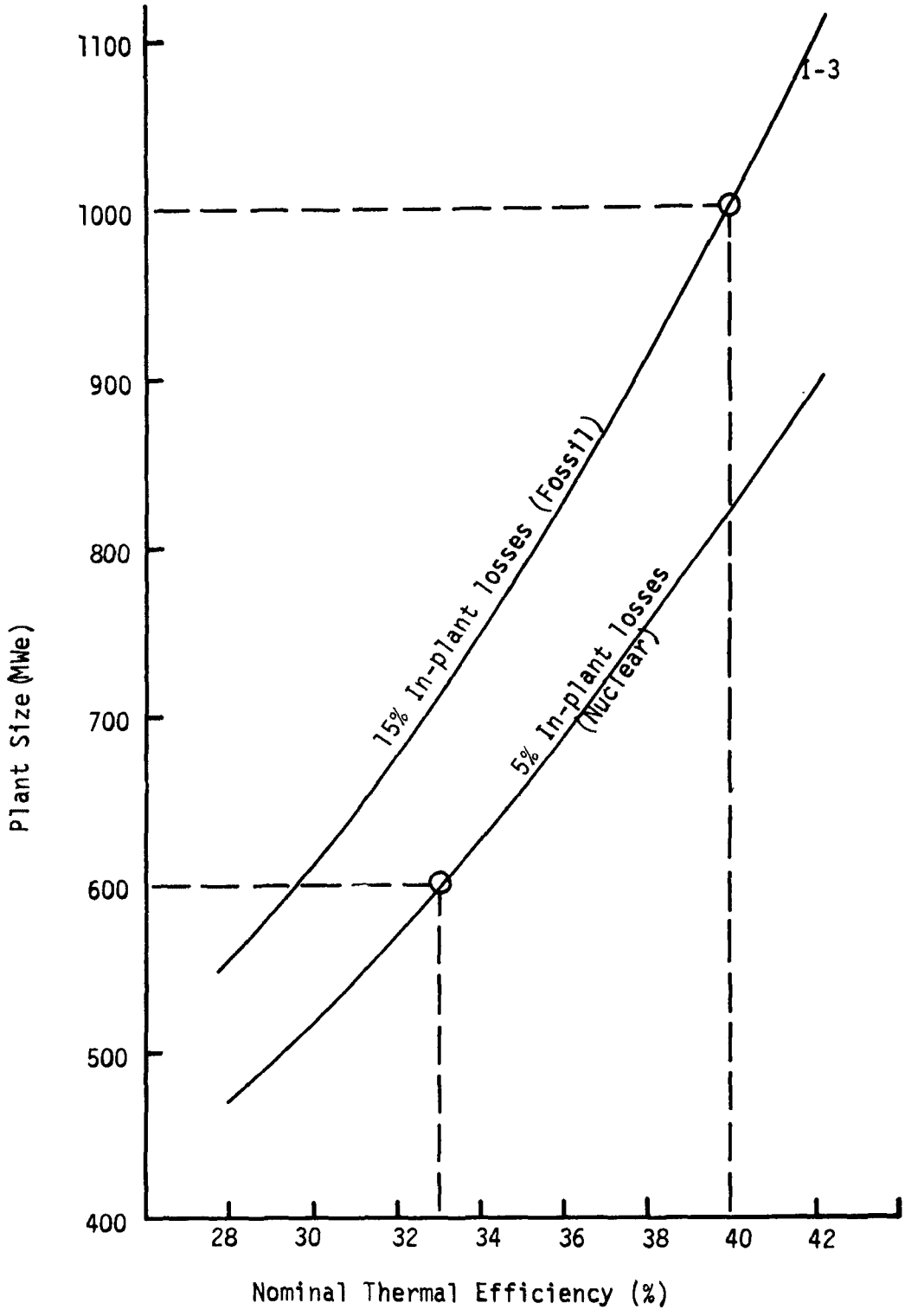

Figure I-1: Equation of Plant Size and Thermal Efficiency for Waste Heat to Cooling Water of 3.84×10^9 Btu/hr.

Cooling Methods

A wide variety of cooling methods are available for dissipating waste heat from thermal power plants. The feasibility of the following cooling devices are evaluated:

1) Evaporative cooling towers
    a) Mechanical draft
    b) Natural draft
2) Cooling ponds
3) Spray cooling canals
4) Dry cooling towers (Heller System)
    a) Mechanical draft
    b) Natural draft

A cooling system employing each of the above devices is sized for a closed-cycle, recirculating configuration using design meteorological data representative of critical summertime conditions. The annual operating characteristics and costs of the selected systems are evaluated using long-term seasonal average weather conditions.

Regional Considerations

In order to account for regional variations in climatic conditions, the Lake Michigan area is divided into four geographical sections. Figure I-2 shows these four sections: NW, NE, SE, and SW. Personnel at the Weather Bureau Office in Chicago agreed that the four sections are representative of the climatic areas around Lake Michigan. As can be seen from Figure I-2, the NW section is bounded by the Mackinac Straits in the north and Sheboygan, Wisconsin in the south; the SW section extends from Sheboygan to Gary, Indiana; the SE section lies between Gary and Pentwater, Michigan; and the NE section extends from Pentwater to the Mackinac Straits.

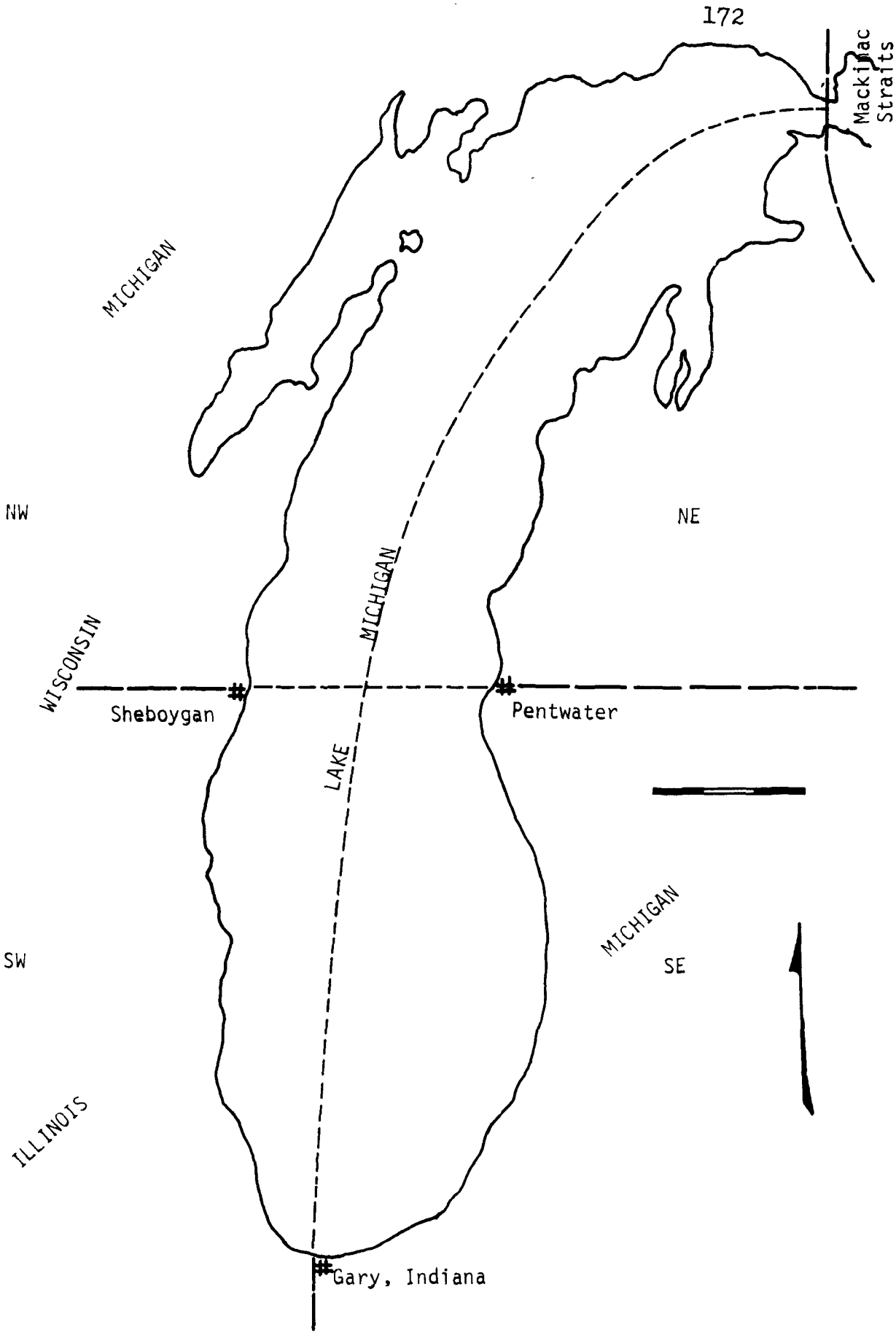

Figure I-2: Climatic Sections -- Lake Michigan

II. METEOROLOGY

Data Requirements

The operation of the devices used to dissipate waste heat is primarily a function of the weather. Therefore, an evaluation of their feasibility requires an accurate set of meteorological data. Significant variations in the design climatic factors with respect to season and location must be accounted for.

The nature of the heat transfer phenomena which a particular cooling device uses to dissipate heat to the atmosphere determines the meteorological data requirements for the device. A compilation of the heat transfer mechanisms and associated meteorological data requirements for the alternative heat dissipation methods is given in Table II-1.

In addition to the weather data requirements shown in Table II-1, information on lake temperatures is needed to compare once-through cooling systems with the alternative cooling systems.

Seasonal Considerations

Four seasons are selected to represent a full annual cycle:

Winter - December, January, February

Spring - March, April, May

Summer - June, July, August

Fall - September, October, November

TABLE II-1

METEOROLOGIC DATA REQUIREMENTS

Cooling Method	Heat Transfer Mechanism	Meteorologic Data Required
Evaporative Cooling Towers	Convection Evaporation	Dry-bulb Temperature Relative Humidity*
Cooling Ponds	Radiation Convection Evaporation	Solar Radiation Dry-Bulb Temperature Relative Humidity* Wind Speed Cloud Cover
Spray Cooling Canals	Evaporation Convection	Dry-bulb Temperature Relative Humidity* Wind Speed
Dry Cooling Towers	Convection	Dry-bulb Temperature

*Wet-bulb or dew point temperature can also be used.

Meteorological Data Summary

Table II-2 presents a summary of average meteorological data for each of the four seasons and geographical sections. The major data source used to compile this table was the Climatic Atlas of the United States (Reference II-7) prepared by ESSA in 1968. This publication presents a wide variety of weather data on maps with isolines for the specified meteorological parameter.

Data for the parameters shown in Table II-2 were obtained as follows:

(1) Dry-bulb Air Temperature

Average monthly temperatures were compiled for each of the four seasons for the four sections from maps on pages 1-23 of the Atlas. These data are shown in Table II-3.

(2) Relative Humidity

Average monthly relative humidities were compiled from maps on pages 61 and 62 of the Atlas. While seasonal variations were detected from these maps, it was difficult to obtain enough detail to show variations in relative humidity between the four sections around Lake Michigan. These data are given in Table II-4.

(3) Wet-bulb Air Temperature

These data were calculated from the dry-bulb temperature and the relative humidity using tables relating wet-bulb depression (i.e., dry-bulb minus wet-bulb temperature) versus relative humidity (Reference II-15).

TABLE II-2

METEOROLOGICAL DATA SUMMARY — AVERAGE CONDITIONS

		(1)	(2)	(3)	(4)	(5)	(6)
Section	Season	Dry-bulb Air Temperature (°F)	Relative Humidity (%)	Wet-bulb Air Temperature (°F)	Cloud Cover (1/10's)	Wind Speed (mph)	Solar Radiation (ly/day)
NW	Winter	21	80	20	8	11.0	160
	Spring	42	70	38	6	11.4	400
	Summer	67	70	61	5	8.8	510
	Fall	49	75	45	7	10.4	230
SW	Winter	25	80	23	8	11.0	160
	Spring	45	70	41	6	11.4	400
	Summer	70	70	64	5	8.8	510
	Fall	52	75	48	7	10.4	230
SE	Winter	27	80	25	8	11.0	160
	Spring	46	70	42	6	11.4	400
	Summer	70	70	64	5	8.8	510
	Fall	52	75	48	7	10.4	230
NE	Winter	23	80	22	8	11.0	160
	Spring	41	70	37	6	11.4	400
	Summer	66	70	60	5	8.8	510
	Fall	49	75	45	7	10.4	230

TABLE II-3

AVERAGE MONTHLY DRY-BULB TEMPERATURES (°F)
(Reference II-7)

Month	Season	Section			
		NW	SW	SE	NE
December		24	27	30	27
January		20	23	26	21
February		20	24	25	21
	Winter	21	25	27	23
March		30	34	35	30
April		42	45	46	42
May		55	56	56	52
	Spring	42	45	46	41
June		63	66	67	62
July		69	72	72	68
August		68	71	71	67
	Summer	67	70	70	66
September		61	64	64	61
October		50	53	52	50
November		36	38	40	36
	Fall	49	52	52	49

TABLE II-4

AVERAGE MONTHLY WEATHER DATA

Month	Season	Relative Humidity (%)	Cloud Cover (1/10's)	Solar Radiation (ly/day)
December		80	8	120
January		80	8	125
February		80	7	225
	Winter	80	8	160
March		70	7	325
April		70	6	400
May		70	6	475
	Spring	70	6	400
June		70	6	525
July		70	5	525
August		70	5	475
	Summer	70	5	510
September		75	6	350
October		75	6	225
November		75	8	125
	Fall	75	7	230

(4) Cloud Cover

Maps on pages 71 and 72 of the Atlas were used to obtain cloud cover data. As with relative humidity, sectional variations were difficult to determine. Table II-4 contains the monthly and seasonal data.

(5) Wind Speed

The wind data were obtained from Asbury (Reference II-1), where average monthly wind speeds from Chicago, South Bend, Escanaba, Muskegon, Sault Ste. Marie, Green Bay, and Milwaukee were compiled for the years 1952, 1953, 1954, 1955, 1960, and 1962 and plotted in a curve showing wind speed versus month for a complete annual cycle (Figure 7 of Reference II-1).

(6) Solar Radiation

Data for mean daily solar radiation were obtained from the Atlas using maps on pages 69 and 70 and are presented in Table II-4. Again, variations between the four sections were difficult to detect.

Design Meteorological Data

While the weather information presented in Tables II-2, II-3, and II-4 is useful in evaluating the performance of a particular cooling device over a complete annual cycle, it is not appropriate for designing the device. Cooling systems must be designed to assure adequate performance under all conditions, not just under "average" conditions. Therefore, one usually selects a set of design data which represents a severe condition from the standpoint of operating the cooling device.

Severe summertime weather conditions represent the "design" case for thermal power plant cooling systems operating in the vicinity of Lake Michigan. This is true for two reasons:

(1) The efficiency with which the cooling device dissipates heat to the atmosphere is lowest during the summer.

(2) The demand for electric power and hence the requirement for full load operation of the plant is highest during the summer for the majority of electrical consumers in the area.

Table II-5 shows the design conditions selected for the four sections.

TABLE II-5

DESIGN METEOROLOGICAL DATA

Section	(1) Dry-bulb Temperature (°F)	(3) Wet-bulb Temperature (°F)	(4) Cloud Cover (1/10's)	(5) Wind Speed (mph)	(6) Solar Radiation (ly/day)	(7) Equilibrium Temperature (°F)
NW	82	70	0	8.8	750	85
SW	86	74	0	8.8	750	87
SE	85	73	0	8.8	750	86
NE	83	71	0	8.8	750	85

The data in Table II-5 were selected as follows:

(1) and (3) Dry- and Wet-bulb Temperatures

The Marley Company, one of the nation's largest manufacturers of cooling towers, states in Cooling Tower Fundamentals and Application Principles (Reference II-14, page 8):

> "Performance analyses have shown that most industrial installations based upon wet-bulb temperatures which are exceeded by no more than 5% during a normal summer have given satisfactory results. The hours that the wet-bulb temperature exceeds the average maximum by 5% need not be consecutive hours and may occur in periods of relatively short duration."

On the basis of this recommendation, as well as others (Reference II-13, page 157), wet- and dry-bulb temperatures not exceeded more than 5 percent of the time during the months of June through September were selected as design conditions. The Marley Company has tabulated these data for a large number of U. S. and foreign cities (Reference II-14) and Table II-6 gives these data for various locations around Lake Michigan with averages for each of the four selected sections.

(4) Cloud Cover

Zero cloud cover was selected as the design condition to coincide with the occurrence of maximum solar radiation.

TABLE II-6

DESIGN DRY- AND WET-BULB TEMPERATURES (°F)
(Reference II-14)

City	State	Section	Dry-bulb	Wet-bulb
Oshkosh	Wisconsin	NW	85	72
Green Bay	Wisconsin	NW	82	72
Manitowoc	Wisconsin	NW	82	72
Iron Mtn.	Michigan	NW	83	68
Marquette	Michigan	NW	78	68
		Ave. NW	82	70
Chicago	Illinois	SW	89	75
Milwaukee	Wisconsin	SW	84	73
Burlington	Wisconsin	SW	85	73
Aurora	Illinois	SW	88	75
		Ave. SW	86	74
Muskegon	Michigan	SE	82	73
Grand Rapids	Michigan	SE	85	73
Benton Harbor	Michigan	SE	84	73
Michigan City	Indiana	SE	87	74
Gary	Indiana	SE	86	74
		Ave. SE	85	73
Traverse City	Michigan	NE	83	72
Charlevoix	Michigan	NE	84	71
Manistee	Michigan	NE	83	72
Glen Arbor	Michigan	NE	82	71
		Ave. NE	83	71

(5) Wind

The selection of a design wind speed is made difficult by the lack of data on the temporal distribution of wind velocity in the Lake Michigan area. Available U. S. Weather Bureau data do not provide adequate information of this type. Therefore, the average summer wind speed data from Asbury (Reference II-1) is applicable as the design case, since it does represent the wind condition concurrent with the other design meteorological variables. Also, only cooling ponds have wind speed as a major design variable, and the large retention time in ponds makes the average wind speed an appropriate design variable.

(6) Solar Radiation

One of the most complete summaries of meteorological data for the Lake Michigan region was prepared by Moses and Bogner from data collected at the Argonne National Laboratory Weather Station (Reference II-19). This summary includes a complete compilation of solar radiation data for September 1950 through December 1964. Figure 46 on page 244 of Moses and Bogner (Reference II-19) gives a percentile distribution of daily total solar radiation. A value of 750 langleys/day represents the June-July conditions at the 95 percent level (i.e., exceeded not more than 5 percent of the time). Therefore, this value was selected as the design condition.

(7) Equilibrium Temperature

The equilibrium temperature of a body of water is reached when the net exchange of energy at the water surface equals zero. In other words, it is the temperature reached by a body of water exposed to a given set of climatic conditions for an infinite period of time (i.e., until equilibrium is reached).

Column 7 of Table II-5 shows the equilibrium temperature for each geographical section for the design meteorological conditions in Columns 1, 3, 4, 5, and 6. The computations were made using a computer program (Reference II-9) according to methodology described by Edinger and Geyer (Reference II-8).

Theoretical Limitations of Cooling Devices

Each of the cooling devices discussed previously have theoretical limits on their ability to cool water. These limits are as follows:

Wet Tower -- Wet-bulb temperature

Cooling Pond -- Equilibrium temperature

Spray Cooling Canal -- Wet-bulb temperature

Dry Tower -- Dry-bulb temperature

The data in Table II-5 can be used to determine the theoretical lower limit of cooling for each device in each of the four geographical sections. It should be emphasized, however, that engineering and economic considerations require the outlet temperatures from the cooling devices to exceed these theoretical lower limits.

Lake Temperatures

Numerous publications (References II-1-6; 10-12; 16-18; 20-22) contain information on the temperature of Lake Michigan. However, no available compilation of data adequately describes the temporal distribution of temperatures in the nearshore areas where power plants would obtain cooling water. Good sources of data for the nearshore zone are municipal water intakes and existing power plant intakes. Table II-7 presents values for average water temperature determined from these records for each of the four geographical sections.

The following sources were used to compute the data in Table II-7:

SW - Gary, Indiana and Milwaukee, Wisconsin water intakes; average depth = 38 feet; average distance from shore = 6500 feet; time period: 1959-1969. These stations are part of the National Water Quality Network; the data are contained in FWQA's "STORET" Information System.

SE - St. Joseph, Benton Harbor, Holland, Grand Rapids, and Muskegon, Michigan water intakes; average depth = 40 feet; average distance from shore = 4500 feet. These values were developed from Michigan Water Resources Commission data for maximum, minimum, and 90 percentile temperatures (Reference II-16). The SW region data and surface water data (References II-4,10,16) were used as aids in establishing specific values.

TABLE II-7

AVERAGE LAKE TEMPERATURES (°F)

Month	Season	Section			
		NW	SW	SE	NE
December		34	39	40	35
January		34	35	34	34
February		33	34	34	34
	Winter	34	36	36	34
March		34	36	36	35
April		36	41	41	37
May		43	46	47	44
	Spring	38	41	41	39
June		49	51	52	50
July		53	55	57	54
August		54	56	58	55
	Summer	52	54	56	53
September		60	61	61	60
October		52	55	55	53
November		42	47	47	44
	Fall	51	54	54	52

NE - Ludington and Big Rock, Michigan water intakes; average depth = 30 feet; average distance from shore = 2200 feet. These data were also developed from Michigan Water Resources Commission data. SW region data and surface water data were again used as aids in establishing specific values.

NW - Escanaba, Michigan steam station water inlet temperatures; shoreline intake. These data are not very representative of the NW region, however, data from the NE and SW regions were used to establish values along with BT data (Reference II-10). It is a common rule of thumb that the Wisconsin side of the lake is slightly cooler than the Michigan side in summer and roughly the same at other times.

In addition, a design lake water temperature is needed to size a plant's once-through condenser system for comparison with the alternative cooling systems. The above sources were used to establish temperatures at the 95 percentile level. Averages of the 95 percentile values for the three summer months are shown in Table II-8 and used as design temperatures for the four geographical sections.

TABLE II-8

DESIGN LAKE TEMPERATURES (°F)
(95 Percentile)

Month	Section			
	NW	SW	SE	NE
June	60	64	65	60
July	67	71	72	68
August	69	72	73	70
Summer	65	69	70	66

It should be recognized that the temperatures in Tables II-7 and II-8 refer to points in the main body of the lake at about a mile from shore and at depth. Surface and beach water tend to follow air temperature more closely and display more daily and yearly variation; similar remarks apply to Green Bay, Traverse Bay and the southern tip of Lake Michigan. As an example, data from several municipal water intakes between Chicago and Gary, Indiana indicate 95 percentile temperatures as much as 4 degrees warmer than shown for the SW section in Table II-8.

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III ECONOMIC CONSIDERATIONS

General Cost Factors

The cost of power generation, i.e. the busbar cost, is expressed in Mills/KWH and is usually broken down into fixed and variable cost components. Fixed charges are those which are unaffected by plant output and include interest on money, amortization of the plant capital cost, interim replacements, insurance, and taxes. Although income taxes vary somewhat with plant use, they are usually included in fixed charges because they are reasonably predictable and the courts have held that the return which a utility is entitled to earn must be computed after allowance for such taxes (Reference III-4). The annual fixed charge rate is expressed as a percentage of plant capital cost. It is the sum of the charges alloted to each contributing item noted above. In determining the fixed cost contribution to total busbar cost, the annual cost is calculated in dollars and then converted to Mills/KWH in accordance with plant operation time.

Variable costs, also called operating costs or production costs, are those associated with the amount of generation and include fuel, payroll labor, and other operating and maintenance expenses. Each of these items is expressed in terms of Mills/KWH.

Both fixed and variable costs are influenced by the heat dissipation system of a plant. The opposite is also true, because general cost factors play a major roll in the optimal design of a plant-cooling system combination. Hence, it is important to establish economic criteria in the early stages of this study.

The sum of charges noted above make up the busbar cost of power from a given plant without regard to its location. For an overall optimization of power costs at the load center in a large system, the location of a new plant must also be assessed in terms of transmission and distribution costs. These costs may outweigh additional costs involved in off-stream cooling devices. Battelle Northwest (Reference III-2) cites a cost of about 0.3 Mills/KWH per 100 miles of transmission. This figure is substantiated by the analysis of Hauser (Reference III-6) who concludes that the additional cost of wet cooling towers, about 0.2 Mills/KWH, is equivalent to a transmission distance of about 80 miles. In a discussion of evaporative cooling systems related to costs of nuclear plants at numerous locations throughout the United States, Kempf and Fletcher (Reference III-7) state that "...the use of a costlier evaporative system at a site situated favorably with respect to load centers may be economically preferable to the transmission of power from sites which can use once-through cooling but are remote from load centers."

Study Approach

The economic analysis is directed toward the effect of cooling system choice on the total busbar cost of generating power. An economic life of 30 years is assumed for all plants and systems considered.

Initially, an attempt was made to determine the representative capital and operating costs for the "Typical" 1000 MW fossil fuel plant which could be studied at a number of general sites around Lake Michigan. Such a single plant approach was found to be unreasonable because of the wide variation in capital costs and operating costs, including fuel, for existing plants adjacent to the Lake. Federal Power Commission data (Reference III-5) for ten such plants built since 1960 reflect capital costs ranging from $105 to $186/KW. For the same plants, operating costs (i.e., fuel, operation and maintenance) ranged from 2.20 to 3.53*Mills/KWH. Such variations of over 60 percent indicate the potential inaccuracy in assuming a single set of cost values to be representative throughout the study area. This is particularly true when assessing additional costs of alternative cooling systems since the busbar cost increase for alternative systems, other than dry cooling, will be less than 5% (Reference III-6).

In order to provide a meaningful interpretation of plant economics for a number of sets of cost factors, three rate values are used for each cost component which might vary from one situation to another. Values were grouped in "Low", "Normal," and "High" sets in an attempt to bracket cost conditions which will be encountered within the study area (Table III-1). The combination of factors called "Normal", Case II, is the most representative of an overall average of current costs; the "Low" and "High" combinations, Cases I and III, respectively, are included to represent reasonable extremes.

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* Information as of 1968.

TABLE III-1

COST FACTORS

Case		Plant Capital Cost ($/KW)	Fixed Charge Rate (%)	Fuel Cost (¢/10^6Btu)	Land Cost ($/acre)
I	(Low)	110	11	25	250
II	(Normal)	135	14	30	500
III	(High)	160	17	35	1000
IV	(Normal-High Capital Cost)	160	14	30	500
V	(Normal-High Fixed Charge)	135	17	30	500
VI	(Normal-High Fuel Cost)	135	14	35	500
VII	(Normal-High Land Cost)	135	14	30	1000

Four additional sets of cost factors were used to show the effect of variation in individual factors as opposed to the combined effect of changing all factors from case to case. (See Table III-1, Cases IV-VII). In these cases, the "Normal" level of cost factors was used as a base except that one value from the "High" level was substituted in each of the four cases.

Information on cost components was obtained from numerous surveys, indexes and general references. Table III-2 presents sources and cost data by component category.

With this background, we can compute the basic plant cost for the seven combinations of economic factors cited in Table III-1. This information is presented in Table III-3 which gives the capital cost in dollars per KW and busbar cost in Mills per KWH. The busbar cost was calculated by summing up a constant operation and maintenance cost of .75 Mills/KWH with the fuel and fixed charge costs.

Differences in busbar costs between Cases I, II and III are brought about by changes in all of the first three cost factors (land costs are included for cooling pond analysis only -- the cost of land for the plant itself is included in the plant capital cost). As shown in Table III-4, Cases IV-VI are used to determine the busbar cost differences due to changes in individual cost factors. These data provide the basis for a later comparison of the added cost of specific cooling systems to other economic factors influencing generation cost.

TABLE III-2

COSTS AND REFERENCES

Source	Cost Data			
	Plant (Fossil) ($/KW)	Fixed Charge (%)	Fuel (¢/10⁶ Btu)	Land ($/acre)
Short (III-10)	117	11-13		
Electrical World (III-1)	118	14	25	
Federal Power Commission (III-4,5)	105-186[a]	104%[b]	26.1	
Federal Power Commission (III-5)			28.9[c]	
R. W. Beck (III-9)			30[a]	
U. S. Dept. of Commerce (III-12)				206-1238[a]
Edison Electric Institute (III-3)	97%[b]		25.5[a]	
Kempf & Fletcher (III-7)				200-6000
Swengel (III-11)	126	13.55	24.2	
National Coal Assoc. (III-8)			25.5[a]	
WRC Advisory Committee (III-13)			26.4[a]	

a/ Specific to States around Lake Michigan.
b/ States around Lake Michigan compared to U.S. average -- based on index values.
c/ Based on 10 plants currently using Lake Michigan for cooling.

TABLE III-3

BASIC PLANT COSTS
(Once-Through Cooling)

Case	Fixed Charges[a] (Mills/KWH)	Operating Costs		Total Capital Cost ($/KW)	Busbar Cost (Mills/KWH)
		Fuel[b] (Mills/KWH)	O & M[c] (Mills/KWH)		
I	1.69	2.13	0.75	110	4.57
II	2.63	2.56	0.75	135	5.94
III	3.79	2.99	0.75	160	7.53
IV	3.12	2.56	0.75	160	6.43
V	3.20	2.56	0.75	135	6.51
VI	2.63	2.99	0.75	135	6.37
VII	2.63	2.56	0.75	135	5.94

[a] Based on 82 percent plant factor.

[b] Based on 40 percent nominal plant efficiency.

[c] Based on U. S. average (Reference III-5)

TABLE III-4

INFLUENCE OF INDIVIDUAL COST FACTORS ON BUSBAR COST

Cost Factor Item	Case No.	Difference from Case II (Normal)	Resulting Change in Busbar Cost, Mills/KWH
Plant Capital Cost	IV	$25/KW	0.49
Fixed Charge Rate	V	3%	0.57
Fuel Cost	VI	5¢/10^6 Btu	0.43

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IV. ENGINEERING CONSIDERATIONS

Introduction

The initial requirements for approximating the size and performance of alternative cooling systems are the design meteorological and lake temperature data for the four geographical sections (Tables II-5 and 8). Based on these data and generalized cost estimates for system components and operation, component sizes and performance characteristics are determined via digital computer programs.

The procedure for designing each cooling device varied according to the sources of the computer programs. A computer program developed by the Dynatech Corporation was used as a primary means for analyzing wet cooling towers, cooling ponds and once-through systems (Reference IV-5). The Ceramic Cooling Tower Company provided computer runs for the design of power spray modules for cooling canal systems (Reference IV-2). Advanced design and cost data on mechanical and natural draft dry (Heller) cooling systems were obtained from R. W. Beck and Associates (Reference IV-9).

The Dynatech and R. W. Beck computer programs are the results of FWQA research contract efforts. Back-up data from in-house sources were provided on natural draft wet towers and cooling ponds. Supplementary cost data on wet towers were obtained from The Marley Company (Reference IV-3) and Research-Cottrell, Inc. (Reference IV-10). Dynatech's program also had some design data on dry systems. Cross-referencing and spot checks between Dynatech, R. W. Beck and in-house calculations were made to assure consistency and reasonable agreement of the results despite the varied approaches used in system design.

Descriptions of the analytical techniques used in calculating the sizes and performance of the cooling devices are not presented in this report. The reader is urged to consult appropriate references on the subject (References IV-1, 4-5, 7-8, 12).

General Optimization Procedure

All cooling systems perform most effectively at elevated water temperatures. Reduced pumping and fan power, shorter tower packing, and smaller pond surface areas can be achieved by increasing the inlet water temperature to the cooling system. The same temperature increase, however, adversely affects the efficiency of the power plant as it results in condensing the steam at a higher turbine backpressure, and thus increases the turbine heat rate. An economic optimization therefore involves the analysis of the two competing factors for the selection of the condensing steam temperature.

Another important factor in determining the size and cost of a cooling system (i.e., cooling device and condenser) is the approach temperature. For a wet cooling tower and spray canal, the approach is equal to the difference between the cold water temperature and the ambient wet-bulb temperature. The approach temperature for a cooling pond is equal to the difference between the outlet cold water temperature and the equilibrium pond temperature; and for a dry tower, it is equal to the difference between the outlet water and dry-bulb temperatures. The smaller the approach, the larger the cooling device's heat exchange surface and consequently the cost. The magnitude of the approach temperature also affects the operation of the power generation system. The smaller the approach, the more efficient the power generation because of the lower sink temperature.

Dynatech Program

In designing a particular cooling system, Dynatech's computer program (Reference IV-5) optimizes with respect to both the approach and the condenser temperature. The calculations start with a minimum allowable condenser temperature. System costs are then calculated for all allowable approaches in increments of 1°F. This process is repeated for all allowable condenser temperatures, increasing the latter in each trial by 1°F. In this manner, the costs for all combinations of approach and condenser temperatures are calculated. The minimum cost that is found in this process gives rise to the "optimum" combination of approach and condenser temperatures for the design meteorological conditions.

In addition to size and performance data, the computer program provides capital system cost and total operating cost for the design conditions. An adjusted total operating cost estimate based on the off-design ambient meteorologic data (i.e., annual operation) and various plant capacities is also given. All seven combinations of economic factors presented in Table III-1 were used in the analysis for this report.

Dynatech's computer program has two options for specifying the plant capacity factor. One is a straight 100 percent capacity factor implying full-load year-round operation of the plant, and the other is a variable capacity operation over an annual cycle. The latter option was used here with an average yearly capacity factor of 82%. The selected capacity distribution throughout an annual cycle is as follows:

Capacity	1.00	.80	.60	.25	0
Hours/year	5150	1750	800	700	360

These data are needed for determining the yearly operating cost of the selected cooling system.

Another important system cost factor is the turbine heat rate and its variation with capacity factor and the condenser operating temperature. Data for a typical GE turbine of a 1000 MW capacity were used with the Dynatech program. Turbine heat rates at several capacity factors were obtained from the manufacturer's heat rate tables (Reference IV-6). At 1" Hg turbine backpressure and a capacity factor of 100 percent, the turbine heat rate is 7415 Btu/KWH; at 25 percent capacity it is 8807 Btu/KWH. (Note that the above are heat rates for a specific turbine and should not be equated to an overall plant heat rate). The Dynatech program has an interpolating routine that evaluates the heat rate at the plant capacity factor for the baseline design conditions*. Other heat rates are needed for the off-design* operating conditions, since it is necessary to calculate the total heat rejected at various capacities. From the heat rejection data and the percent of time the plant operates at off-design conditions, an estimate of the cooling system operating cost and the associated fuel savings can be made.

The off-design spring, summer, fall, and winter conditions were matched with the power plant capacity to allow maximum plant output during the summer and winter peaks. Table IV-1 shows the percent of time the cooling systems operate for various plant capacities.

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*The baseline design weather conditions and lake temperatures are given in Tables II-5 & II-8, respectively. Off-design conditions are given in Tables II-2 and II-7.

TABLE IV-1

PERCENT OF COOLING SYSTEMS TIME AT OFF-DESIGN CONDITIONS

Plant Capacity, %	Spring	Summer	Fall	Winter
100	10	40	10	40
80	15	35	15	35
60	35	15	35	15
25	40	10	40	10
0	0	0	100	0

These data are used in conjunction with the seasonal weather data (Tables II-2 and II-7) to compute annual operating costs for the chosen cooling system. The effect of more favorable off-design weather conditions gives average operating costs (in Mills/KWH) substantially lower than the operating costs under design conditions.

In the course of the present studies, it was found that during extremely cold winter conditions, the cooling system did not receive adequate heat to prevent it from freezing. In practice, the flow rate can be changed to prevent this, or, in the case of cooling towers, ice rings for natural draft or fan reversal for mechanical draft towers can be used. It may even be advantageous to burn more fuel and generate greater quantities of electric power. No such provisions were made in Dynatech's program. For this reason, the cost data based on the variable ambient conditions may be too high. The 5 percent summer design data imposed severe operating conditions for tower design with the result that the cooling systems were "too good" during the winter off-design conditions.

For mechanical draft wet tower cooling systems the capital cost data developed by the Dynatech program agrees reasonably with 1970 published and unpublished information available from The Marley Company (Reference IV-3) and Fluor Corporation (Reference IV-11), two major tower manufacturers in the United States.

The total system cost for the natural draft towers presented in the following section of this report may not be minimal. Research-Cottrell (Reference IV-10) supplied current capital cost data, which checked favorably with that published by The Marley Company (Reference IV-3). However, this capital cost, which was inserted into the program, is based on a tower height of 500 feet and a tower diameter of 400 feet.

Thus, the optimization process became somewhat artificial. In particular, the approach temperature had to be fixed so that the tower size would be appropriate for the capital cost provided by Research-Cottrell. Hence, the operating cost portion of the total system cost may be inflated.

In determining the capital cost of a cooling pond, the Dynatech program simply multiplies the pond size (acres) by the land cost ($/acre). Thus, no land preparation or construction costs are included.

Ceramic Cooling Tower Program*

For this study, design data for spray cooling canals using Power Spray Modules (PSM) were supplied by the Ceramic Cooling Tower Company*. The output from the Ceramic program includes the number of Power Spray Modules, the minimum canal dimensions, and module cost.

As a part of the input data required for Ceramic Cooling Tower's computer program, the heat load, the water flow, the cooling range, and the outlet water temperature are all specified. These data were obtained from a cooling pond cooling system designed by the Dynatech program. Additional input data requirements include dry- and wet-bulb temperature, wind velocity, and barometric pressure.

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*The use of this program does not imply endorsement of the product by FWQA.

Other assumptions for complete cost evaluation of spray canals follow:

1. The condenser system cost was obtained as calculated from the Dynatech cooling pond system optimization.

2. The capital cost of the cooling canal system includes 15 percent of the material cost for installation and electrical work. The cost of the land and canal preparation was assumed at 12 percent of the material cost. The land cost was less than 1 percent, a very small cost item compared to cooling ponds.

3. The operating cost was based on the baseline design conditions with adjustments made for cooler temperatures. An adjustment factor of 0.62 was calculated based on the number of units in operation during spring, summer, and fall conditions. A maintenance cost equal to 1 percent of the operating cost was added, consistent with Dynatech's calculations.

4. The sum of the condenser system cost, the amortized capital cost and O & M cost made up the total system cost. No differential fuel cost was included, because it was assumed that the differential heat rate of a plant with a PSM system could be minimized by operating adequate number of units as the ambient conditions change.

R. W. Beck Program

R. W. Beck's computer program optimizes the dry system based on four major cost items -- capital cost, auxiliary power cost, cost due to loss of capacity, and fuel cost. Parametric study of all cost items are considered for initial temperature differences (ITD) between the inlet dry-bulb air and the inlet hot water temperatures ranging from 30°F to 80°F. At large initial temperature differences, the cooling system is highly efficient and thus compact and relatively inexpensive. The auxiliary power requirements are also relatively small. On the other hand, the loss of power and the resulting fuel cost are great. Thus, the last two cost items compete for the low ITD while the first two compete for the high ITD. The optimal ITD for a given region is consequently dictated by the combined effects of all cost factors.

R. W. Beck's program was run for four sites around Lake Michigan in order to show the effects of weather variations. These sites were Chicago, Green Bay, Milwaukee, and Grand Rapids. A total of 7500 hours per year of operation was assumed. One-half of this time was at 100 percent capacity and the other half at 75 percent capacity. The remaining 1260 hours per year were for shutdown.

The fuel cost and the fixed charge rates from Table III-1 were used. Whenever there occurred a loss of capacity of 10 hours per year or more at full throttle, gas turbine peaking units were used to make up for this loss. The loss of capacity at full throttle is due to high backpressure that may occur at peak demands. The cost of gas turbine peaking unit was assumed at $100/KW.

Both natural and mechanical draft dry towers were considered for all regions. The optimum tower dimensions and all cost items were output from the program.

References

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IV-3. Dickey, Joe Ben and Robert E. Kates. "Thermal Pollution and the Water Cooling Tower." Presented April 2, 1970 in San Francisco at the meeting of the National Pollution Control Conference and Exposition.

IV-4. Edinger, Dr. John E. and Dr. John C. Geyer. Heat Exchange in the Environment. Cooling Water Studies for Edison Electric Institute, Research Project RP-49, The Johns Hopkins University, Baltimore, Maryland. June 1, 1965.

IV-5. Fuller, W. D. A Survey and Economic Analysis of Alternate Methods for Cooling Condenser Discharge Water in Thermal Power Plants, Phase II-Task I Report: System Selection, Design, and Optimization. Dynatech Report No. 921, Prepared for the Federal Water Quality Administration. July 8, 1970.

IV-6. General Electric. Heat Rates for General Electric Steam Turbine-Generators...100,000 KW and Larger. GET-2050B. (No date).

IV-7. McKelvey, K. K. and Maxey Brooke. The Industrial Cooling Tower. Elsevier Publishing Company. 1959.

IV-8. The Marley Company. Cooling Tower Fundamentals and Application Principles. Kansas City, Missouri 64114. 1967.

IV-9. R. W. Beck & Associates. Personal Communication. 1970.

IV-10. Research-Cottrell, Inc. Personal Communication. 1970.

IV-11. Weis, Edward. Fluor Products Co., Inc. "Tower Selection." Industrial Water Engineering. Volume 7, Number 5, pp. 25-29. May 1970.

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V. RESULTS

Performance data for the various alternative cooling systems are presented in Section A below. Cooling system cost includes the cost of condenser, pumps, piping, and controls, as well as the specified heat dissipation device. Comparative capital and busbar costs for the complete power plant using these alternative cooling systems are examined in Section B.

A. Cooling Systems

Introduction

For each cooling system, engineering performance data and capital and total system cost data are presented in tabular form. Since most of the data are self-explanatory, only limited descriptions of the tables are given.

Wet Cooling Towers

Performance Data

Mechanical Draft

A complete set of performance data for the mechanical draft wet cooling tower operating under design conditions is given in Table V-1 for each case and for the four sections of the Lake Michigan area. There appears to be little sectional variation.

All temperature values are rounded to within one degree. For this reason, one cannot expect to exactly recalculate the heat rejected by multiplying the range by the condenser flow.

TABLE V-1

PERFORMANCE DATA FOR A MECHANICAL DRAFT WET COOLING TOWER SYSTEM
AT DESIGN CONDITIONS

Case*	Section	Fan Power 10^3 hp	Cond. Flow 10^8 lb/hr	cfs	Q_{REJ} 10^9 Btu/hr	H_2O Evap cfs	Air Flow 10^8 lb/hr	Range °F	Approach °F	Cond. Temp. °F
I	NE	2.20	2.26	1010	4.24	15.9	1.39	19	16	111
	SE	2.25	2.27	1010	4.25	16.1	1.40	19	15	112
	SW	2.13	2.28	1020	4.27	16.2	1.37	19	15	113
	NW	1.75	2.39	1060	4.24	15.8	1.32	18	18	111
	AVERAGE	2.08	2.30	1020	4.25	16.0	1.37	19	16	112
II	NE	2.23	2.16	962	4.25	16.0	1.36	20	16	112
	SE	1.96	2.28	1020	4.27	16.1	1.33	19	16	113
	SW	2.16	2.17	966	4.28	16.3	1.34	20	15	114
	NW	1.79	2.27	1010	4.25	15.9	1.29	19	18	112
	AVERAGE	2.04	2.22	988	4.26	16.1	1.33	20	16	113
III	NE	1.95	2.16	962	4.27	16.0	1.29	20	17	113
	SE	1.99	2.17	966	4.28	16.2	1.30	20	16	114
	SW	1.88	2.18	971	4.30	16.3	1.27	20	16	115
	NW	1.82	2.16	962	4.27	15.9	1.26	20	18	113
	AVERAGE	1.91	2.17	966	4.28	16.1	1.28	20	17	114
IV	NE	1.95	2.16	962	4.27	16.0	1.29	20	17	113
	SE	1.99	2.17	966	4.28	16.2	1.30	20	16	114
	SW	2.16	2.17	966	4.28	16.3	1.34	20	15	114
	NW	1.79	2.27	1010	4.25	15.9	1.29	19	18	112
	AVERAGE	1.97	2.19	975	4.27	16.1	1.31	20	17	113
V	NE	1.72	2.17	966	4.28	16.0	1.23	20	18	114
	SE	2.01	2.07	922	4.30	16.2	1.27	21	16	115
	SW	1.90	2.08	926	4.31	16.3	1.24	21	16	116
	NW	1.84	2.07	922	4.28	16.0	1.23	21	18	114
	AVERAGE	1.87	2.10	935	4.29	16.1	1.24	21	17	115

* See Table III-1

TABLE V-1 (Cont.)

PERFORMANCE DATA FOR A MECHANICAL DRAFT WET COOLING TOWER SYSTEM
AT DESIGN CONDITIONS

Case*	Section	Fan Power 10^3 hp	Cond. Flow 10^8 lb/hr	cfs	Q_{REJ} 10^9 Btu/hr	H_2O Evap cfs	Air Flow 10^8 lb/hr	Range °F	Approach °F	Cond. Temp. °F
	NE	2.20	2.26	1010	4.24	15.9	1.39	19	16	111
	SE	2.25	2.27	1010	4.25	16.1	1.40	19	15	112
VI	SW	2.46	2.27	1010	4.25	16.2	1.44	19	14	112
	NW	2.32	2.26	1010	4.22	15.8	1.42	19	16	110
	AVERAGE	2.31	2.27	1010	4.24	16.0	1.41	19	15	111
	NE	2.23	2.16	962	4.25	16.0	1.36	20	16	112
	SE	1.96	2.28	1020	4.27	16.1	1.33	19	16	113
VII	SW	2.16	2.17	966	4.28	16.3	1.34	20	15	114
	NW	1.79	2.27	1010	4.25	15.9	1.29	19	18	112
	AVERAGE	2.04	2.22	988	4.26	16.1	1.33	20	15	113

* See Table III-1

Natural Draft

Table V-2 presents the performance data for wet natural draft towers operating under design conditions. Little variation between the four geographical sections was found, so the data are averaged over all sections.

System Cost

Mechanical Draft

Table V-3 presents the total capital cost and average cooling system cost rate for the wet mechanical draft towers described in Table V-1.

Natural Draft

Table V-4 presents the total capital cost and average cooling system cost rate for the wet natural draft cooling towers described in Table V-2. As mentioned previously, a tower capital cost of $6.50/KW is assumed for all cases. It should be specifically noted again that fixing the approach on the one hand and the tower cost on the other hand severely limits the cost optimization process. Thus, the total cooling system operating cost given is probably not minimal. This point is particularly stressed here for the comparison with the smaller costs for wet mechanical tower cooling systems.

TABLE V-2

PERFORMANCE DATA FOR NATURAL DRAFT WET COOLING TOWER
AT DESIGN CONDITIONS

Case *	Tower Height ** Ft.	Condenser Flow 10^8 lb/hr	cfs	$Q_{Rejected}$ 10^9 Btu/hr	Water Evaporated cfs	Air Flow 10^8 lb/hr	Range °F	Approach °F	Condenser Temp., °F
I	536	1.91	850	4.24	16.1	1.54	23	12	112
II	523	1.83	815	4.26	16.1	1.50	24	12	113
III	511	1.77	788	4.28	16.2	1.47	25	12	114
IV	511	1.77	788	4.28	16.2	1.47	25	12	114
V	502	1.72	766	4.29	16.2	1.44	25	12	114
VI	536	1.91	850	4.25	16.1	1.54	23	12	112
VII	523	1.83	815	4.26	16.1	1.50	24	12	113

* See table III-1

** Base diameter ≈ (Height/1.25)

TABLE V-3

COST DATA FOR MECHANICAL DRAFT WET COOLING TOWER SYSTEMS

Case*	Section	Condenser & Pump Cost, $/KW	Capital Cost of Tower, $/KW	Total System Capital Cost, $/KW	Total System Cost Mills/KWH
I	NE	5.87	2.85	8.72	0.178
	SE	5.89	2.94	8.83	0.179
	SW	5.91	2.89	8.80	0.179
	NW	6.03	2.55	8.58	0.177
	AVERAGE	5.93	2.81	8.74	0.178
II	NE	5.74	2.83	8.57	0.221
	SE	5.91	2.76	8.67	0.225
	SW	5.78	2.86	8.64	0.223
	NW	5.89	2.54	8.43	0.221
	AVERAGE	5.83	2.75	8.58	0.223
III	NE	5.76	2.66	8.42	0.271
	SE	5.78	2.73	8.51	0.273
	SW	5.80	2.69	8.49	0.274
	NW	5.76	2.53	8.29	0.269
	AVERAGE	5.78	2.65	8.43	0.272
IV	NE	5.76	2.66	8.42	0.225
	SE	5.78	2.73	8.51	0.227
	SW	5.78	2.86	8.64	0.228
	NW	5.89	2.54	8.43	0.226
	AVERAGE	5.80	2.70	8.50	0.227
V	NE	5.78	2.49	8.27	0.260
	SE	5.66	2.71	8.37	0.260
	SW	5.68	2.67	8.35	0.261
	NW	5.64	2.52	8.16	0.256
	AVERAGE	5.69	2.60	8.29	0.259

* See Table III-1

Continued

TABLE V-3 (Cont.)

COST DATA FOR MECHANICAL DRAFT WET COOLING TOWER SYSTEMS

Case*	Section	Condenser & Pump Cost, $/KW	Capital Cost of Tower, $/KW	Total System Capital Cost, $/KW	Total System Cost Mills/KWH
VI	NE	5.87	2.85	8.72	0.234
	SE	5.89	2.94	8.83	0.235
	SW	5.89	3.07	8.96	0.237
	NW	5.86	2.91	8.77	0.232
	AVERAGE	5.88	2.94	8.82	0.235
VII	NE	5.74	2.83	8.57	0.221
	SE	5.91	2.76	8.67	0.225
	SW	5.78	2.86	8.64	0.223
	NW	5.89	2.54	8.43	0.221
	AVERAGE	5.83	2.75	8.58	0.223

* See Table III-1

TABLE V-4

COST DATA FOR NATURAL DRAFT
COOLING TOWER SYSTEMS

Case*	Condenser & Pump Capital Cost,$/KW	Total System Capital Cost, $/KW	Total System Cost Mills/KWH
I	5.40	11.90	0.241
II	5.31	11.81	0.306
III	5.21	11.71	0.373
IV	5.21	11.71	0.310
V	5.14	11.64	0.358
VI	5.40	11.90	0.314
VII	5.30	11.80	0.306

* See Table III-1

Cooling Ponds

Only flow-through ponds are examined in detail. Mixed pond sizes were not determined, however it is estimated that with proper selection, their areas would be about two to three times greater than the flow through ponds.

Performance Data

Flow-through cooling pond sizes and other parameters vary little from one section of the lake to another because of the small variations in the design ambient conditions. For example, there is less than 4 percent variation among the sizes in the four sections corresponding to Case I. Therefore, Table V-5 presents the average performance data for the four geographical sections. Optimum pond size is strongly influenced by the land cost as indicated in Table V-5. It varies from 2030 acres for a land cost of $500 per acre in Case II to 1490 acres for a land cost of $1000 per acre in Case VII.

System Cost

Table V-6 gives the total capital and average cooling system cost rates for flow-through cooling ponds. Variations in the cost of the cooling system between the four geographical sections are also shown.

TABLE V-5

COOLING POND PERFORMANCE DATA AT DESIGN CONDITIONS

Case*	Pond Size, Acres	Water Evap. cfs	Q_{REJ} 10^9 Btu/hr	Equilibrium Temp., °F	Hot Water Temp., °F	Range °F	Condenser Flow cfs
I	2140	40.8	4.21	86	104	17	1090
II	2030	39.3	4.23	86	106	19	1010
III	1470	32.2	4.26	86	108	19	1000
IV	2030	39.3	4.23	86	106	19	1010
V	1740	35.7	4.26	86	108	20	950
VI	2100	40.3	4.22	86	105	18	1060
VII	1490	32.5	4.25	86	107	19	1030

* See Table III-1

TABLE V-6

COST DATA FOR COOLING POND SYSTEMS

Case*	Section	Condenser & Pump Cost $/KW	Pond Capital Cost, $/KW	Total System Capital Cost $/KW	Total System Cost, Mills/KWH
I	NE	6.02	0.53	6.55	0.110
	SE	6.08	0.53	6.61	0.111
	SW	6.19	0.53	6.72	0.113
	NW	6.06	0.55	6.61	0.111
	AVERAGE	6.09	0.54	6.63	0.111
II	NE	5.88	1.03	6.91	0.148
	SE	5.94	1.02	6.96	0.149
	SW	5.90	1.00	6.90	0.148
	NW	5.78	1.02	6.80	0.145
	AVERAGE	5.88	1.02	6.90	0.148
III	NE	5.91	1.38	7.29	0.193
	SE	5.82	1.55	7.37	0.194
	SW	5.92	1.57	7.49	0.197
	NW	5.82	1.37	7.19	0.190
		5.87	1.47	7.34	0.194
IV	NE	5.88	1.03	6.91	0.150
	SE	5.94	1.02	6.96	0.151
	SW	5.90	1.00	6.90	0.150
	NW	5.78	1.02	6.80	0.147
	AVERAGE	5.88	1.02	6.90	0.150

* See Table III-1

Continue

TABLE V-6 (Cont.)

COST DATA FOR COOLING POND SYSTEMS

Case*	Section	Condenser & Pump Cost $/KW	Pond Capital Cost, $/KW	Total System Capital Cost $/KW	Total System Cost, Mills/KWH
V	NE	5.76	0.79	6.55	0.171
	SE	5.68	0.96	6.64	0.172
	SW	5.77	0.96	6.73	0.175
	NW	5.67	0.78	6.45	0.168
	AVERAGE	5.72	0.87	6.59	0.172
VI	NE	6.02	1.07	7.09	0.153
	SE	6.08	1.05	7.13	0.154
	SW	6.04	1.03	7.07	0.152
	NW	5.92	1.05	6.97	0.150
	AVERAGE	6.02	1.05	7.07	0.152
VII	NE	5.91	1.38	7.29	0.157
	SE	5.96	1.60	7.56	0.162
	SW	5.92	1.57	7.49	0.161
	NW	5.95	1.41	7.36	0.159
	AVERAGE	5.94	1.49	7.43	0.160

* See Table III-1

Spray Cooling Canals

Performance Data

Performance data for spray cooling canals using Ceramic Cooling Tower Company's Power Spray Module are given in Table V-7. The input data were selected from the cooling pond design information given in Table V-5. As indicated in Table V-7, the PSM's are arranged in rows of four units across the canal, with from 28 to 32 rows spread along the canal's length. Thus, water flowing down the canal will be cooled as it passes through consecutive rows of PSM units.

System Cost

The average total material cost for the spray cooling canals described in Table V-7 is $1.83/KW. Further additional costs, as described previously in Section IV - "Engineering Considerations" - increase the total capital cost (exclusive of condenser system) to $2.30/KW. Table V-8 presents the spray cooling canal cost data.

Dry Cooling Towers (Heller System)

Performance Data

The optimal initial temperature difference (ITD) for all sites examined ranged from 57 to 62°F. For these ITD's, the optimal water cooling range is on the order of 50 percent of the corresponding ITD.

TABLE V-7

SPRAY COOLING CANAL PERFORMANCE DATA AT DESIGN CONDITIONS

Parameter	Section NW	SW	SE	NE
Approach, ^{o}F	20	16	17	19
Range, ^{o}F	20	20	20	20
Cold Water Temp., ^{o}F	90	90	90	90
Condenser Flow, cfs	960	960	960	960
Heat rejected, 10^{9} Btu/hr	4.3	4.3	4.3	4.3
Total number of PSM-4-10-75	112	128	124	116
Number of units per row	4	4	4	4
Number of rows	28	32	31	29
Total Horsepower	8400	9600	9300	8700
Minimum channel width, ft.	160	160	160	160
Minimum channel length, ft.	4480	5120	4960	4640

TABLE V-8

COST DATA FOR SPRAY CANAL COOLING SYSTEMS

Case*	Condenser & Pump $/KW	Spray Canal $/KW	Total Capital Cost, $/KW	Total System Cost, Mills/KWH
I	6.09	2.30	8.39	0.148
II	5.88	2.30	8.18	0.185
III	5.87	2.30	8.17	0.225
IV	5.88	2.30	8.18	0.185
V	5.72	2.30	8.02	0.216
VI	6.02	2.30	8.32	0.189
VII	5.95	2.30	8.25	0.185

* See Table III-1

The land requirement for a mechanical draft tower at ITD = 57°F is 8.7 acres and at ITD = 62°F is 7.8 acres.

The size of a natural draft tower varies with the initial temperature difference, being smaller when the ITD is large. The height, base diameter, and the top diameter date at the two extreme ITD's are listed in Table V-9 below:

TABLE V-9

DIMENSIONS OF NATURAL DRAFT COOLING TOWER IN FEET

Dimension	ITD = 57°F	ITD = 62°F
Height	487	455
Base diameter	593	547
Top diameter	398	383

Cooling System Cost

Capital Cost

The range of capital cost for a mechanical draft dry cooling tower system for Chicago is listed below:

ITD °F	58-59
Cost without peaking, $/KW	16.8 - 17.1
Cost with peaking, $/KW	24.0 - 24.1

The capital cost of a natural draft dry tower depends on the size of the tower. Additional cost for peaking units is included whenever a substantial loss in capacity occurs. Gas turbine peaking units were chosen at an assumed cost of $100/KW. The total capital cost is the sum of these two items. The range of capital costs of natural draft cooling towers for the sites examined are listed in Table V-10 as a function of optimal ITD's.

TABLE V-10

COOLING SYSTEM CAPITAL COST ($/KW) OF NATURAL DRAFT DRY COOLING TOWER

Site	ITD °F	Cost without Peaking ($/KW)	Cost with Peaking ($/KW)
Chicago	57-58	18.8 - 19.1	25.8 - 25.8
Grand Rapids	57-58	18.8 - 18.4	25.1 - 25.2
Milwaukee	58	19.7	26.8
Green Bay	58-62	18.5 - 19.7	25.4 - 25.5

System Cost

The total cost of the cooling system with mechanical draft dry cooling towers for the four sites examined are listed in Table V-11.

TABLE V-11

TOTAL SYSTEM COST DATA FOR MECHANICAL
DRAFT DRY COOLING TOWER SYSTEMS (MILLS/KWH)

Case*	Chicago	Green Bay	Milwaukee	Grand Rapids	Average
I	0.57	0.55	0.58	0.55	0.56
II	0.72	0.69	0.72	0.69	0.71
III	0.87	0.82	0.87	0.82	0.85
IV	0.72	0.69	0.72	0.69	0.71
V	0.85	0.82	0.84	0.81	0.83
VI	0.74	0.70	0.74	0.70	0.72
VII	0.72	0.69	0.72	0.69	0.71

* See Table III-1

The total costs of the cooling system with natural draft dry cooling towers for the four sites examined are listed in Table V-12.

TABLE V-12

TOTAL SYSTEM COST DATA FOR NATURAL
DRAFT DRY COOLING TOWER SYSTEMS (MILLS/KWH)

Case *	Chicago	Green Bay	Milwaukee	Grand Rapids	Average
I	0.54	0.52	0.54	0.51	0.53
II	0.67	0.64	0.68	0.64	0.66
III	0.80	0.77	0.82	0.77	0.79
IV	0.67	0.64	0.68	0.64	0.66
V	0.79	0.76	0.81	0.76	0.78
VI	0.68	0.65	0.69	0.65	0.67
VII	0.67	0.64	0.68	0.64	0.66

* See Table III-1

B. Economics of Cooling Systems and Total Plants

Total costs are presented which account for all components included in each cooling system. For the sake of comparing costs of alternate cooling systems, however, the cost in excess of the minimum requirement is most meaningful. The minimum cooling system requirement for this analysis is the once-through cooling system described earlier in Section III. Table V-13 shows the cost differential in capital cost ($/KW) and busbar cost (Mills/KWH) for the cooling systems designed for the various economic conditions defined by Cases I through VII.

The effect of cooling system choice on the total cost of producing power is shown in Table V-14 which summarizes total busbar costs for all plant-cooling system combinations studied. The busbar costs in Table V-14 include all fixed and variable cost components which are involved in the cost of the basic plant with once-through cooling, Table III-3, and the differential cooling system costs, Table V-13.

TABLE V-13

CAPITAL COST AND BUSBAR COST DIFFERENTIAL
(In Excess of Once-Through System)
($/KW and Mills/KWH)

Case*	Mechanical Draft Wet Tower		Natural Draft Wet Tower		Cooling Pond		Spray Canal		Mechanical Draft Dry Tower		Natural Draft Dry Tower	
	$/KW	Mills/KWH	$/KW	Mills/KWH	$/KW	Mills/KWH	$/KW	Mills/KWH	$/KW	Mills/KWH	$/KW	Mills/KWH
I	3.76	0.079	6.92	0.142	1.65	0.012	3.41	0.049	19.07	0.46	20.82	0.43
II	3.64	0.096	6.87	0.179	1.96	0.021	3.24	0.058	19.11	0.58	20.86	0.53
III	3.54	0.117	6.82	0.218	2.45	0.039	3.28	0.070	19.16	0.70	20.91	0.64
IV	3.61	0.099	6.82	0.182	2.01	0.022	3.29	0.057	19.16	0.58	20.91	0.53
V	3.49	0.108	6.84	0.207	1.79	0.021	3.22	0.065	19.25	0.68	21.00	0.63
VI	3.79	0.106	6.87	0.185	2.04	0.023	3.29	0.060	19.02	0.59	20.77	0.54
VII	3.64	0.096	6.86	0.179	2.49	0.033	3.31	0.058	19.11	0.58	20.86	0.53

*See Table II-1

TABLE V-14

TOTAL BUSBAR COSTS FOR STANDARD POWER PLANT* USING COOLING SYSTEM SPECIFIED
Mills/KWH

Case**	Once-Through	Mechanical Draft Wet Tower	Natural Draft Wet Tower	Cooling Pond	Spray Canals	Mechanical Draft Dry Tower	Natural Dra Dry Tower
I	4.57	4.65	4.71	4.58	4.62	5.03	5.00
II	5.94	6.04	6.12	5.96	6.00	6.52	6.47
III	7.53	7.65	7.75	7.57	7.60	8.23	8.17
IV	6.43	6.53	6.61	6.45	6.49	7.01	6.96
V	6.51	6.62	6.72	6.53	6.58	7.19	7.14
VI	6.37	6.48	6.56	6.39	6.43	6.96	6.91
VII	5.94	6.04	6.12	5.97	6.00	6.52	6.47

*Fossil-fueled,1000 MW electrical output, 40% nominal efficiency, 82% plant capacity factor (As defined in Section I).

** See Table III-1

VI. ENVIRONMENTAL EFFECTS OF COOLING DEVICES

Introduction

The areas of environmental concern associated with heat dissipation methods can be separated into four general categories:

1) Fog potential
2) Consumptive water loss by evaporation
3) Drift
4) Blowdown

A fifth category, "Effect on Local Weather," can also be considered, but this effect is closely related to number 1 above.

In terms of the alternative methods of heat dissipation discussed in this report, the above concerns may be associated with specific cooling devices as shown in Table VI-1.

It is apparent from Table VI-1 that dry cooling devices should have no adverse affect on the environment. In fact, it has been suggested by Stewart (Reference VI-23) that the heat from dry towers could be used beneficially to dissipate fog at airports.

TABLE VI-1

ENVIRONMENTAL EFFECTS OF COOLING DEVICES

Cooling Method	Environmental Effects			
	Potential Fog	Evaporation	Blowdown	Drift
Wet Towers	Yes	Yes	Yes	Yes
Ponds	Yes	Yes	No	No
Spray Canals	Yes	Yes	Yes	Yes
Dry Towers	No	No	No	No

Fog Potential

Definition of the Problem

Essentially, fog is a cloud at ground level and can be described as a collection of very small liquid water droplets (e.g., <50 micron diameter) suspended in the air. Fog exists only when the air is saturated with water vapor. Since cold air becomes saturated at a much lower water content than warm air, cold climates present a greater potential for fog. Thus, one need not worry about fog formation except under climatic conditions of high humidity and low temperature.

Wet cooling devices discharge water vapor to the atmosphere as a direct result of their primary heat exchange mechanism - evaporation. Under normal circumstances, this discharge of moisture-laden air is dissipated rapidly in the ambient air. However, under severe climatic conditions (i.e., high humidity and low temperature) the moisture could produce a fog condition if the moisture were trapped in the lower levels of the atmosphere, such as during a period of high atmospheric stability (i.e., an inversion).

Cooling towers do produce visible plumes. However, plumes are not a problem unless they reach the ground, thus causing fog. In fact, only when the fog occurs over inhabited areas would it be considered a problem. Special concern should be directed towards a fog which may cause obstruction of vision on highways or near airports. Downwash of the plume from an oil refinery's mechanical draft cooling tower caused such a problem on an adjacent highway during the winter of 1959 (Reference VI-11, see paper by Hall). The problem was solved by installing heaters in the tower stack, thus increasing the ability of the air to hold water vapor and prevent saturation conditions. This technique is described by Buss (Reference VI-5). Such problems should normally be prevented by siting a cooling tower as far from highways and airports as possible. Also, the tower should be located so it is downwind from the point of interest during periods of low temperature and high humidity.

Under normal conditions, cooling tower plumes rise due to their initial velocity and buoyancy and rarely intersect the ground before they are dissipated. The plumes also have the ability to penetrate through

an inversion. Visual observations at the Keystone Plant near Shelocta, Pennsylvania, indicate that even under conditions of severe local ground fog, the plumes from the plant's cooling towers penetrated through the ground fog and were dissipated in the upper air.

Several publications are available (References VI-2-5, 11, 14, 20, 23, and 24) which deal with the fog potential of wet cooling towers. While it is generally agreed that cooling towers are potential fog producers, it is also generally agreed that they are not probable fog producers. Most authorities agree that low profile mechanical draft towers are more likely to produce a fog condition than tall, natural draft towers. However, at least one source (Reference VI-14) indicates that the initial height of the vapor emission is not important, but rather the concentration of the heat and water vapor in a single point (i.e., natural draft tower) rather than in a line source (i.e., mechanical draft towers) tends to provide greater opportunity for the plume to rise.

Very little information is available on the fog potential of cooling ponds. Decker (Reference VI-11) contends that "Pond cooling should provide the greatest change of fog formation at the surface," however, experience to date (Reference VI-20) indicates that this cold weather "steam fog" stays over the surface of the pond and does not create local fog problems. Winter icing can occur near the edges of the pond. Actually, one would not expect the fog conditions over a cooling pond to differ much from those over a once-through discharge area of a lake or river.

Environmental Studies

At least two reports (References VI-4 and 20) deal with site visits to large U. S. power plants which utilize wet towers. One report was prepared by a utility (Reference VI-4), the other by State and Federal pollution control agencies (Reference VI-20). Both study teams visited plants in the coal mining region of the Appalachian Mountains, i.e., Keystone, Fort Martin, Big Sandy, and Clinch River. The pollution control agency team also visited the Mt. Storm plant which uses a cooling pond. The general conclusions of both reports are the same -- fog from the towers (and pond) was not considered a problem by the plant operators or by the local residents. A similar study conducted in Europe resulted in the same conclusion (Reference VI-11).

Of course, visits to sites and discussions with plant personnel can only give qualitative information as to the fog potential of cooling towers. A rigorous, scientific investigation is needed to provide firmer evidence. Such a study is being conducted at the Keystone plant by IIT Research Institute. The study's principal investigator, Dr. Eric Ansley, reports in a recent issue of Electrical World (Reference VI-2):

> "There is some apprehension today that cooling-tower emissions may produce undesirable environmental effects. Inadvertent weather effects, including local fogging and icing, cloud formation, and increased precipitation, are often cited as possibilities. Initial results from ground and aerial studies being conducted by IIT Research Institute of Chicago at the Keystone Generating Station indicate that no immediate problems appear to exist."

Thus, it appears that much of the talk about fog from cooling towers is not based upon what actually happens with existing installations. Of course, the fact that major problems have not yet come to light should not make us complacent as to the potential problem. Decker (Reference VI-11) concludes "...that except for extremely poorly-located cooling towers, the operators should encounter very little, if any, liability because of nuisance to neighbors." Therefore, detailed meteorological surveys should be made at the sites of all future large cooling tower installations where fog could be a potential problem.

Potential in Lake Michigan Area

E G & G has prepared a map, reproduced in Figure VI-1, showing the distribution of fog potential for the United States (Reference VI-14, page 38). According to E G & G, the "qualitative classification for the potential for adverse cooling tower affects" was made using the following criteria (Reference VI-14, page 36):

a) High Potential: Regions where naturally occurring heavy fog is observed over 45 days per year, where during October through March the maximum mixing depths are low (400-600m), and the frequency of low-level inversions is at least 20-30%.

b) Moderate Potential: Regions where naturally occurring heavy fog is observed over 20 days per year, where during October through March the maximum mixing depths are less than 600m, and the frequency of low-level inversions is at least 20-30%.

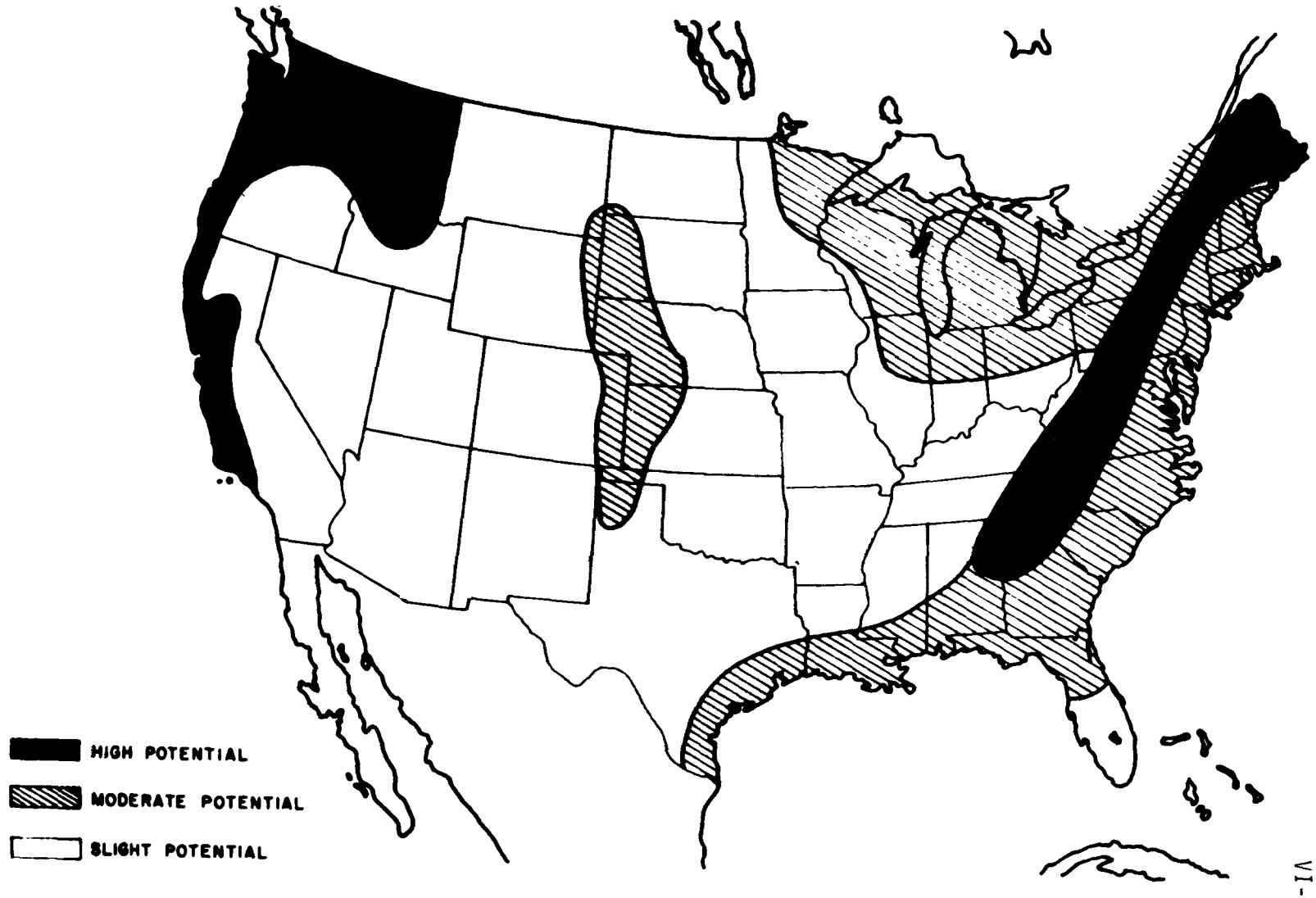

FIGURE VI-1 GEOGRAPHICAL DISTRIBUTION OF POTENTIAL ADVERSE EFFECTS FROM COOLING TOWERS, BASED ON FOG, LOW-LEVEL INVERSION AND LOW MIXING DEPTH FREQUENCY.

c) Low Potential: Regions where naturally occurring heavy fog is observed less than 20 days per year, and where October through March the maximum mixing depths are moderate to high (generally >600m).

As shown in Figure VI-1, Lake Michigan is located in an area of "moderate potential." Thus, some concern over potential fogging in this area seems justified. It must be emphasized, however, that the classifications of "high," "moderate," and "low" potential are relative rather than absolute descriptors. Thus, a cooling tower located in an area of "high potential" would be more likely to cause a fogging problem than one located in an area of "moderate" or "low potential," but whether or not the tower ever produced a fog problem would depend on specific site and climatic conditions. For example, the plants visited by the study teams mentioned previously were located predominantly in the "high potential" region of Figure VI-1 and no fogging problems were reported.

A study conducted by Travelers Research Corporation (Reference VI-24) to evaluate the climatic effects of a natural draft cooling tower for the proposed Davis-Besse Nuclear Plant at Locust Point on Lake Erie concluded that the visible plume will touch the ground only 2 percent of the time on an annual basis and that localized icing could occur at ground level approximately 3 percent of the time. No problems due to precipitation were anticipated. The results of this study, while specific to the Lake Erie site, give some indication that towers near Lake Michigan may have similar minor environmental effects due to similar weather conditions and because both areas lie in the same region of "moderate potential" indicated in Figure VI-1. This study is of special interest since Toledo Edison recently announced plans to use a natural draft wet tower at the Davis-Besse facility.

Calculations of Fog Potential

Two simplified methods are presented below for evaluating the fog potential of cooling towers in the vicinity of Lake Michigan.

Method 1

Fog is formed when the local humidity is raised to saturation. Thus, when cooling towers add water vapor to the atmosphere in quantities sufficient to cause saturation of the ambient air, fog will be produced.

The criterion for fog can be expressed as (Reference VI-14):

$$q_s - q_a \leq \Delta q$$

where,

q_s = Liquid-water content at saturation, g/m^3

q_a = Liquid-water content of ambient air, g/m^3

Δq = Liquid-water added by cooling towers, g/m^3

E G & G (Reference VI-14) states that Δq is normally between 0.1 and 0.5 g/m^3 one or more kilometers downwind from the tower. Thus, any time $(q_s - q_a)$ is less than 0.1 to 0.5 g/m^3, there is a potential for fog conditions within one or two miles of the cooling tower.

Figure VI-2 presents plots of $(q_s - q_a)$ equal to 0.1 g/m^3 and 0.5 g/m^3 for various combinations of relative humidity and air temperature. Any combination of relative humidity and temperature falling in Zone C (i.e., $(q_s - q_a) > 0.5$ g/m^3) indicates weather conditions very unlikely to produce a cooling tower fog. This is true simply because the ambient air is able to assimilate more than 0.5 g/m^3 of water vapor without becoming saturated. Weather exhibiting temperatures and relative humidities in Zone B (i.e., 0.1 $g/m^3 < (q_s - q_a) < 0.5$ g/m^3) has a low probability of producing a cooling tower fog, while a temperature-relative humidity combination falling in Zone A (i.e., $(q_s - q_a) < 0.1$ g/m^3) has a high probability of causing a fog condition when combined with a cooling tower air-water vapor effluent.

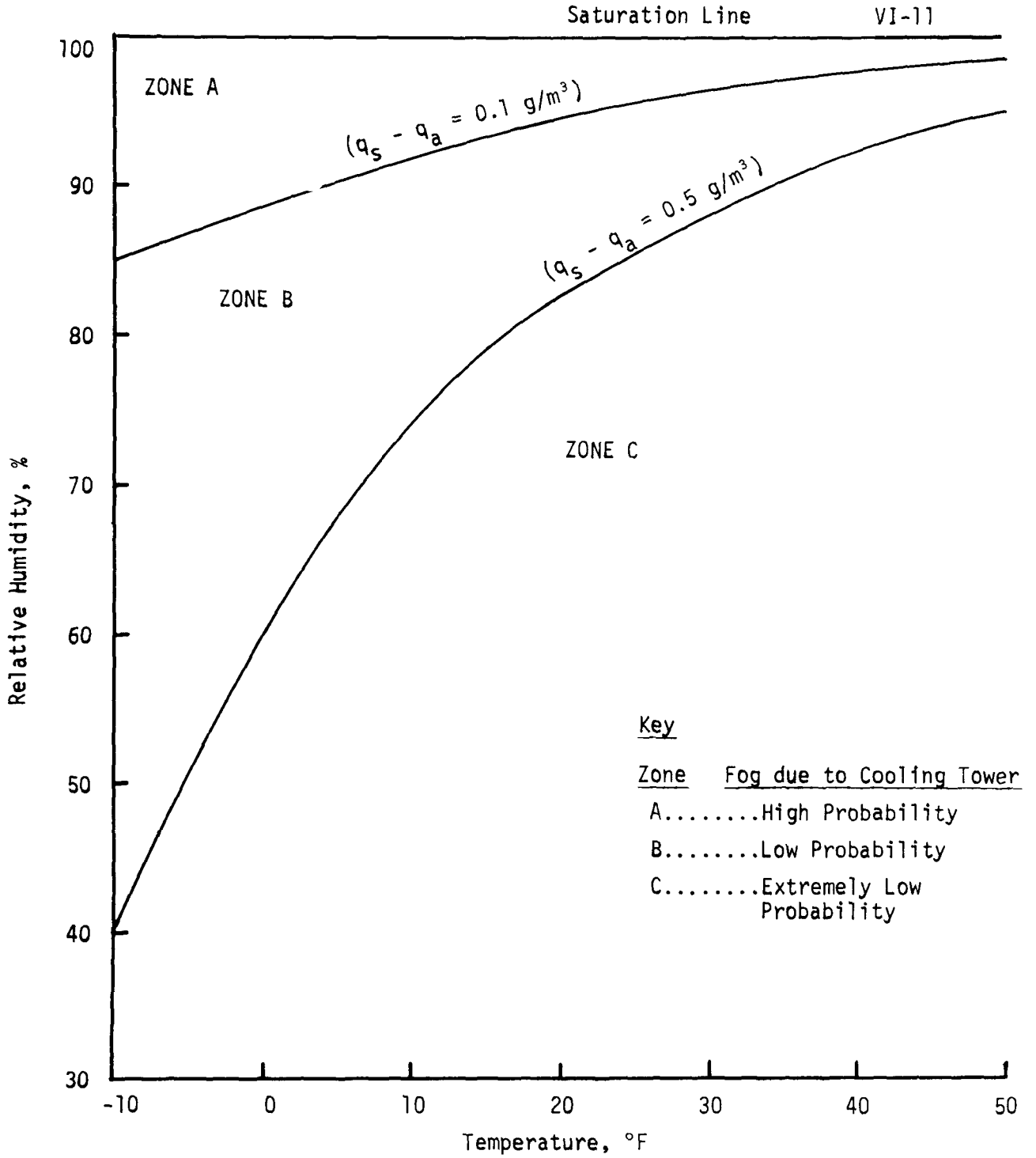

Figure VI-2: Plots of $(q_s - q_a) = 0.1$ and $0.5\ g/m^3$ for Relative Humidity versus Temperature

In order to determine the potential for cooling tower fog in a particular location, one should determine the total percent of time the weather conditions shown in the three zones of Figure VI-2 occur. Two stations in the Lake Michigan area are selected for such an analysis. Green Bay, Wisconsin is representative of the cold northern area and Chicago, Illinois is chosen to represent the more moderate climate of the south end of the Lake. Appropriate data were obtained from the U. S. Weather Bureau summaries of hourly observations (References VI-8 and 10).

Table VI-2 gives a breakdown of the percent of time over an annual cycle when the conditions in the three zones of Figure VI-2 occurred for four ranges of wind speed:

TABLE VI-2

PERCENTAGE OF TIME WEATHER CONDITIONS OCCURRED FOR ZONES A, B, AND C OF FIGURE VI-2

	Green Bay (North)			Chicago (South)		
Wind	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
<5 mph	0.2%	2.5%	97.3%	0.02%	0.6%	99.4%
<15 mph	0.7%	9.6%	89.7%	0.09%	3.3%	96.6%
<25 mph	0.8%	12.1%	87.1%	0.11%	4.1%	95.8%
All winds	0.9%	12.3%	86.8%	0.11%	4.2%	95.7%

Further separation of meteorological conditions by wind speed is included in Table VI-2 because high winds are more likely to provide ventilation to sweep fog away if it does form.

Weather data from Grand Rapids, Michigan (Reference VI-9) on the east side of the lake were also examined. Fog probabilities were found to be intermediate between those at Chicago and Green Bay.

Method 2

The necessity of assuming a value for Δq in the foregoing analytical method can be overcome by computing the dilution of a cooling tower plume with the ambient air. A simplified method of approximating the dilution of a cooling tower plume by the ambient atmosphere can be developed from standard methods of evaluating smoke plumes from a point source.

Turner (Reference VI-25) gives values of vertical and horizontal dispersion coefficients (σ_z, σ_y) for plumes as a function of downwind distance for several atmospheric stability categories. These coefficients can be used to estimate plume spread in the two cross-sectional dimensions of the plume, and thus the dilution of the plume with the ambient atmosphere is indicated.

Assuming no dilution for the first 100 meters downwind (this should be a very conservative assumption), one can estimate plume spread and plume dilution for values of x greater than 100 meters by the following equations:

$$\text{Vertical spread at } x_2 = \frac{\sigma_{z2}}{\sigma_{z1}}$$

$$\text{Horizontal spread at } x_2 = \frac{\sigma_{y2}}{\sigma_{y1}}$$

$$\text{Plume Dilution} = \frac{\sigma_{z2}\ \sigma_{y2}}{\sigma_{z1}\ \sigma_{y1}}$$

where,

x = Downwind distance

σ_{z1}, σ_{y1} = Dispersion coefficients at x = 100 meters

σ_{z2}, σ_{y2} = Dispersion coefficients at x_2

Tables VI-3,4 and 5 summarize the pertinent data from Reference VI-25. Note that stability classes A-F are indicated. Class A represents the most unstable condition where dilution and plume rise would be maximized. Stability increases from A to F, where Class F represents the most stable atmospheric conditions were dilution and plume rise would be minimal.

TABLE VI-3

DATA FROM FIGURES 3-2, 3-3, 4-1 IN TURNER (VI-25)

Downwind Distance (x) meters	Atmospheric Stability Class	Horizontal Dispersion (σ_y) meters	Vertical Dispersion (σ_y) meters	Cross-section Dispersion (σ_y, σ_z) square meters
100	A	27	10.4	400
	B	19	10.1	210
	C	12	7.4	94
	D	8	4.7	40
	E	6	3.5	22
	F	4	2.3	9
1000	A	210	450	100,000
	B	150	110	17,000
	C	105	60	6,200
	D	69	32	2,100
	E	50	22	1,100
	F	33	14	500
10,000	A	1050	>10,000	>2,000,000
	B	1020	1030	>1,000,000
	C	820	500	400,000
	D	560	130	82,000
	E	410	80	33,000
	F	270	46	12,500

TABLE VI-4

DILUTION RATIOS

X_2	Stability Class	Dilution Ratios
1,000 m	A	250
	B	81
	C	67
	D	53
	E	50
	F	56
10,000 m*	A	>5,000
	B	>4,700
	C	4,250
	D	2,050
	E	1,500
	F	1,390

*A somewhat more accurate estimate of the dilution rates at 10,000 m can be obtained by using the ratio of $\sigma_{y1}\ \sigma_{z1}/\sigma_{y2}\ \sigma_{z2}$, where x_1 = 1000 m and x_2 = 10,000 m and multiplying the ratio by the dilution rate at x = 100 m. These are shown in Table VI-5.

TABLE VI-5

DILUTION RATIOS

X	Stability	Dilution Ratios
10,000 m	A	>8,000
	B	>12,000
	C	6,060
	D	1,560
	E	660
	F	225

To evaluate the amount of dilution required to prevent a cooling tower fog, one must have information on the ambient air temperature and relative humidity as well as the initial temperature of the tower plume which is assumed to be saturated.

Two cases are illustrated below:

Case 1 - High Fog Potential

Air Temperature = 0°F

Relative Humidity = 95%

Plume Temperature = 50°F (estimated)

Plume moisture = 9.4 g/m^3

Ambient air moisture = 1.21 g/m^3

Moisture in saturated 0°F air = 1.27 g/m^3

$\therefore$ Dilution (D) required:

$$9.4\ g/m^3 + 1.21\ g/m^3\ (D) = (1 + D)\ 1.27\ g/m^3$$

$$D = 136$$

Therefore, one part tower effluent to more than 136 parts ambient air will not produce saturation. From Table VI-4, it is seen that at a downwind distance of 1000 meters insufficient dilution (i.e., D < 136) is obtained for stability Classes B, C, D, E, and F. These classes would produce a visible plume at that distance, and fog would be possible if the plume reached the ground, however, normally the plume would rise. The most unstable condition (e.g., Stability Class A) would provide adequate dilution. This trend corresponds to Reference VI-14 where it is concluded that more stable conditions provide greater fog potential. Table VI-5 indicates that at 10,000 meters dilution sufficient to prevent fog is present for all stability categories.

Case 2 - Low Fog Potential

Air Temperature = 50°F

Relative Humidity = 95%

Plume Temperature = 80°F (estimated)

Plume moisture = 25.3 g/m^3

Ambient air moisture = 8.9 g/m^3

Moisture in saturated 50°F air = 9.4 g/m^3

$\therefore$ Dilution required:

$$25.3\ g/m^3 + 8.9\ g/m^3(D) = (1 + D)\ 9.4\ g/m^3$$

$$D = 32$$

Since Table VI-4 indicates dilution rates in excess of 32 for all stability classes, a visible plume at 1000 meters downwind would not exist and fog would not be possible.

It should be emphasized that the above analyses (i.e., Methods 1 and 2) are very general and unsophisticated. However, they do indicate that weather conditions in the Lake Michigan area are seldom severe enough to cause extensive fog conditions in the vicinity of wet cooling devices.

A more sophisticated approach to analyzing the potential for adverse weather effects due to cooling towers was developed by E G & G under an FWQA contract (Reference VI-14). However, the mathematical model constructed by E G & G is only useful in analyzing specific sites with specific meteorological data. It would be impractical to generalize the model to run cases applicable to this Lake Michigan study. It should be emphasized, therefore, that for proposed specific power plant sites, adequate meteorological data should be collected during the site selection phase so that accurate predictions of the fog potential of cooling towers at these sites can be made.

Consumptive Water Loss by Evaporation

Heat transfer by evaporation is one of the principal mechanisms by which wet cooling systems dissipate waste heat to the atmosphere. Thus, transfer of mass occurs and is a factor in the Lake Michigan water budget.

The present average water budget is approximately characterized by precipitation of 50,000 cfs, tributary inflow of 39,000 cfs, evaporation of 40,000 cfs, diversion at Chicago of 3,400 cfs, and discharge at the Straits of Mackinac of 46,000 cfs (References VI-1 and 17).

Hauser and Oleson (Reference VI-15) compared the evaporation losses of several wet cooling systems. They (Figure 2 of Reference VI-15) estimated evaporation rates as reflected in Table VI-6 given the following meteorological and design conditions:

Wet bulb temperature	=	70°F
Relative humidity	=	60%
Cloud cover	=	7/10
Wind speed	=	8 mph
Cooling range	=	20°F

It must be emphasized that the data in Table VI-6 are representative of specific meteorological and plant operating conditions and thus they cannot be applied to the cooling system designs presented here for Lake Michigan. However, the data in Table VI-6 do give order of magnitude estimates useful in determining the relationship between the evaporation rates for various cooling methods.

TABLE VI-6

BASED ON DATA FROM HAUSER AND OLESON (REFERENCE VI-15)

Cooling System	Evaporation cfs[1]
Cooling Pond (2 acres/MW)	20.0
Cooling Pond (1 acre/MW)	16.0
Mechanical Draft Tower	13.0
Spray Pond	12.7
Natural Draft Tower	12.0
Natural Lake or River	9.4

[1]For a 1000 MWe fossil fueled plant at 82 percent capacity factor average annual evaporation (assume constant meteorological conditions).

Data on rates of evaporation loss for the various wet cooling devices at summertime design meteorological conditions are presented in Section V, "Results," in Tables V-1, V-2, and V-5. To obtain data meaningful in terms of the annual water budget, one must adjust these values to reflect 1) lower evaporation rates during the off-design conditions, and 2) plant operation at less than 100 percent capacity.

The average annual evaporation rate for the wet towers and spray canals are approximated by multiplying the rate under design conditions by the plant capacity factor (0.82) and by 0.8 to reflect an average decrease in evaporation rate of 20 percent during the off-design period.

Cooling ponds experience a much more pronounced drop in evaporation during the off-design period (i.e., annual cycle) because of a large decrease in the incoming long and short wave radiation. For example, the design incoming radiation equals 5580 Btu/ft^2 day, while for the normal annual cycle it averages 3070 Btu/ft^2 day. Thus, during off-design conditions averaged over the year the pond dissipates approximately 2500 Btu/ft^2 day less energy. In terms of evaporative loss this is equivalent to 10 cfs per 1000 acres of pond surface. This factor along with the plant capacity factor (0.82) is used to calculate annual evaporation rates from design condition evaporation rates.

Table VI-7 presents the evaporation rates for both the design case and average annual conditions for the appropriate cooling devices. The data given in Table VI-7 represent the evaporation rates averaged over the four geographic sections since little variation was found between these sections. The average evaporation rates for all seven cases is also given.

In evaluating the consumptive water loss for cooling ponds, the natural evapo-transpiration losses of the area should be considered. The Lake Michigan region has an average annual precipitation rate of 30-inches per year (Reference VI-7) and an average annual runoff rate of 10-inches per year (Reference VI-18), giving an average annual natural evapo-transpiration rate of 20-inches per year. For land areas corresponding to cooling pond sizes, the average evapo-transpiration rates in cfs are given as:

Land Area	Evapo-transpiration
1500 acres	3.5 cfs
1750 acres	4.0 cfs
2000 acres	4.6 cfs

TABLE VI-7

EVAPORATION RATES (cfs) - WET COOLING DEVICES

Case*	Mechanical Draft Tower		Natural Draft Tower		Cooling Pond (Flow-Through)		Spray Cooling Canal		Once-Through Cooling
	Design Condition	Average Annual	Design Condition	Average Annual	Design Condition	Average Annual	Design Condition	Average Annual	Average Annual
I	16.0	10.5	16.1	10.6	40.8	15.9	-	-	-
II	16.1	10.6	16.1	10.6	39.3	15.6	-	-	-
III	16.1	10.6	16.2	10.6	32.2	14.3	-	-	-
IV	16.1	10.6	16.2	10.6	39.3	15.6	-	-	-
V	16.1	10.6	16.2	10.6	35.7	15.0	-	-	-
VI	16.0	10.5	16.1	10.6	40.3	15.8	-	-	-
VII	16.1	10.6	16.1	10.6	32.5	14.4	-	-	-
Ave.	16.1	10.6	16.1	10.6	37.1	15.2	16.1[1]	10.6[1]	8.2[2]

*See Table III-1.

[1]Values approximated as equal to towers.

[2]Asbury (Reference VI-1), see following text.

These natural evapo-transpiration rates should be subtracted from the pond evaporation rates to give the net consumptive water loss due to the cooling ponds. When this is done, the consumptive water loss for the cooling ponds is less than one cfs greater than the evaporation losses from wet cooling towers.

Any discussion of the consumptive water loss due to wet cooling devices must also consider the increase in natural levels of evaporation caused by once-through cooling. For example, Asbury (Reference VI-1) estimates the increase of evaporation in Lake Michigan due to thermal discharges from power plants with once-through cooling to be 9 cfs for each 1000 MW_t (thermal) of waste heat discharged. A 1000 MWe fossil fueled plant wastes about 3800 Btu/KWH to the cooling water as compared to an electrical output of 3413 Btu/KWH. Thus, a 1000 MWe fossil plant with once-through cooling will increase natural lake evaporation by about (3800/3413)(9) = 10 cfs.

By using the plant capacity factor of 0.82 to adjust the 10 cfs figure, an average annual evaporation rate of 8.2 cfs is obtained for the once-through system. The relationship between this value and those given in Table VI-7 for the various cooling systems corresponds to the relationship proposed by Hauser and Oleson (Reference VI-15) and presented in Table VI-6. Therefore, when one compares the evaporation rates for wet towers and spray canals with the evaporation rate for once-through cooling, a difference of only (10.6 cfs minus 8.2 cfs =) 2.4 cfs exists. For cooling ponds, the difference is less than 3.4 cfs, when natural levels of evapo-transpiration are considered.

Drift

Drift is entrained water that is carried out of the top of a wet cooling tower or from a spray canal in liquid droplets rather than vapor. Drift can produce undesirable effects.

Waselkow (Reference VI-26) points out that "flash-over" of transmission lines was caused by excessive drift. This problem was solved by relocating the transmission lines. Waselkow recommends a 500-foot separation between cooling towers and transmission lines.

Recent surveys of existing power plant facilities (References VI-4, 6, 20, and 22) have uncovered only minor problems involving drift from freshwater towers. Drift is more likely to result from mechanical draft than from natural draft towers. However, in situations where drift has been noted, the area affected was limited to the immediate vicinity of the tower installation.

The typical drift guarantee of 0.2 percent of the circulating water flow is far in excess of current engineering capability and practicality for large towers. Drift can be almost completely eliminated by control of air velocity and design of drift eliminators. Mechanical draft towers can be purchased today with certification of drift elimination to the 0.02 percent level. Current developmental work by cooling tower manufacturers is expected to enable further reduction of drift.

Blowdown

As water is lost by evaporation from the cooling water supply of wet cooling devices, non-evaporating substances are concentrated in the remaining cooling water. There is a practical limit of concentration of the substances if scale corrosion and general deterioration of the cooling structures are to be prevented. To avoid such problems, a certain amount of the cooling water customarily is drained off the system for disposal. This water, termed blowdown, is replaced by fresh makeup water.

Blowdown, as it comes from the tower, contains concentrated solids and dissolved salts and minerals present in the original makeup water; it may contain special chemicals used to prevent scale and corrosion of condenser tubes and deterioration of wood structures; it may contain special algicides and fungicides; and, it is generally at a higher temperature than ambient lake or stream water. Hence, blowdown is an industrial waste in every sense of the word, subject to control under water quality standards.

The relationship between concentration of non-volatile, "conservative" constituents and design and operation of the cooling devices is:

$$C = \frac{E + D + B}{D + B}$$

where,

C = The multiple of concentrations of makeup water
E = Evaporative loss
D = Drift
B = Blowdown

Evaporation, drift, and blowdown are conventionally expressed as percent of circulating flow rate.

The volume of blowdown discharged to a receiving water is strongly influenced by the concentration multiple, but the temperature of the blowdown is independent of this factor. Therefore, the thermal pollution of Lake Michigan can be minimized practically to the point of extinction by increasing the concentration multiple.

The effect of concentration multiples on volume of blowdown from wet towers and spray canals for our typical 1000 MWe plant is demonstrated in Table VI-8. In these example computations evaporative losses are established from Table VI-7 and a figure of 0.05 percent is used for drift. With this figure for drift and assuming no leakage, the maximum concentration multiple that could be reached with no blowdown is 35:1. If drift is taken as 0.2 percent, the maximum concentration multiple is 9.5:1.

The concentration of dissolved solids in the Lake Michigan is very low. Hence, even with no blowdown the salt concentration of the circulating flow would not be at all unique to power plant operation in the United States.

TABLE VI-8

BLOWDOWN FROM WET TOWERS AND SPRAY CANALS

Concentration Multiple (C)	Evaporation Losses (E)	Blowdown (B)	
		%	cfs
1:1	1.7%	1.75	17
5:1	1.7%	0.38	4
10:1	1.7%	0.14	1
25:1	1.7%	0.02	0.2
35:1*	1.7%	0	0

*Maximum concentration multiple.

A 5:1 concentration multiple is frequently used as a generalization (Reference VI-13), but a survey of several power plants by FWQA reveals a very wide range in actual practice. DeFlon (Reference VI-12) and Southern Nuclear Engineering (Reference VI-22) cite concentrations of circulating flow in cooling towers up to 100,000 ppm total dissolved solids. The mechanical draft towers at the Mohave power plant in the arid southwest are designed for zero blowdown to receiving waters.

Table VI-9 shows average chemical concentrations found on two transects of Lake Michigan in 1962-63 (Reference VI-21). The southernmost transect (41°30'-41°45') is in the Chicago area and could be expected to have the most pollutants. The other transect (43°30'-43°45') runs from Pentwater, Michigan to Sheboygan, Wisconsin and was chosen because there are few streams or major waste inputs in the area. Included are potential concentrations in blowdown water, calculated at a ratio of 5:1. These concentrations compared to those permissible for public water supplies, do not appear to be high enough to cause concern. It also is obvious from Table VI-9 that treatment of blowdown to reduce hardness (Ca and Mg alkalinity) and heavy metal concentrations would allow much higher concentration multiples than 5:1.

TABLE VI-9

CHEMICAL CONSTITUENTS OF LAKE MICHIGAN WATER

Lake Michigan Water Chemistry; Averages in 1962-63 and at Concentration of 5:1*					Permissible Surface Water Criteria For Public Water Supplies**
Latitude	41°30'-41°45'		43°30'-43°45'		
Parameter	Avg. mg/l	At Conc. of 5×	Avg. mg/l	At Conc. of 5×	mg/l
NH_3-N	0.16		0.07		
NO_3-N	0.12	0.60	0.19	0.95	10 (as N)
Total PO_4	0.06	0.30	0.02	0.10	
Alkalinity	105	525	110	550	400-500
Specific conductance as Micromhos/cm	280	1400	220	1100	
K	1.0	5.0	1.0	5.0	
Ca	34	170	33	165	
Mg	12	60	12	60	
SiO_2	1.7	8.5	2.9	14.5	
SO_4	22	110	21	105	250
ABS	0.04	0.20	0.05	0.25	
Cl^-	8.0	40.0	6.6	33.0	250
Phenols as µg/l	2.0		0.5		
Oil & Grease	7.5	37.5	-	-	Virtually absent

TABLE VI-9 (Cont.)

CHEMICAL CONSTITUENTS OF LAKE MICHIGAN WATER

Lake Michigan Water Chemistry; Averages in 1962-63 and at Concentration of 5:1*					Permissible Surface Water Criteria For Public Water Supplies**
Latitude	41°30'-41°45'		43°30'-43°45'		
Parameter	Avg. mg/l	At Conc. of 5×	Avg. mg/l	At Conc. of 5×	mg/l
Turbidity in mg/SiO_2	2.7	13.5	0.9	4.5	
Cu	<0.005	<0.025	<0.005	<0.025	1.0
Cadmium	<0.005	<0.025	<0.005	<0.025	0.01
Chromium	<0.005	<0.025	<0.005	<0.025	0.05 (as Cr^6)
Pb	<0.005	<0.025	<0.005	<0.025	0.05
Ni	<0.005	<0.025	<0.005	<0.025	
Zn	<0.005	<0.025	<0.005	<0.025	5

*Risley and Fuller, 1965 (Reference VI-21)

**Interior, U. S. Department of, FWPCA, 1968, page 20 (Reference VI-16)

Table VI-10 shows the relationships of temperature of blowdown from wet cooling devices at design meteorological conditions and design summer lake temperature. Although these relationships would vary seasonally and with operating practices, the increase above ambient would be appreciable in all cases. However, the effects of blowdown temperatures on Lake Michigan cannot be projected out of context from the volumes of blowdown discharged. See Table VI-8.

If makeup water is taken from Lake Michigan (or similarly dilute sources) blowdown can be reduced to almost any level without hazard from salt discharged to the atmosphere by drift. As shown in Table VI-9 Lake Michigan water is non-corrosive and the chloride concentration is very low.

Blowdown may also contain chemicals which are added to the cooling water for special control purposes (See Table VI-11). Many of these are toxic and may have to be treated to comply with water quality standards, a task which Donahue (Reference VI-13) claims can be accomplished economically.

Toxicants in blowdown can be controlled by careful choice of treatment chemicals to ensure use of those which will do the job with the least effect on the environment. For example, chlorine used for prevention of fouling is lost in the tower through evaporation and residual chlorine in blowdown can be very low. But, other anti-fouling agents, such as mercuric compounds,are very toxic and should be avoided.

TABLE VI-10

TEMPERATURE OF BLOWDOWN AT DESIGN CONDITIONS

Wet Cooling Device	Blowdown Temperature (°F)	Lake Temperature (°F)	Temperature Difference (°F)
Mechanical Draft Tower	88	68	20
Natural Draft Tower	84	68	16
Spray Canal	90	68	22

TABLE VI-11

SUMMARY OF CHEMICAL TREATMENTS*

Potential Problem	Factors	Causative Agents	Corrective Treatments
Wood Deterioration	Microbiological Chemical	Cellulolytic fungi Chlorine Sodium Carbonate	Fungicides Acid
Biological Growths	Temperature Nutrients pH Innoculants Deposits	Bacteria Fungi Algae	Chlorine Chlorine Donors Organic Sulfurs Quatenary ammonia
General Fouling	Suspended Solids Water Velocity Temperature Contaminants Metal Oxides	Silt Oil	Polyelectrolytes Polyacrylates Lignosulfonates Polyphosphates
Corrosion	Aeration pH Temperature Dissolved Solids Galvanic Couples	Oxygen Carbon dioxide Chloride	Chromate Zinc Polyphosphate Tannins Lignins Synthetic Organics

TABLE VI-11 (Cont.)

SUMMARY OF CHEMICAL TREATMENTS*

Potential Problem	Factors	Causative Agents	Corrective Treatments
Scaling	Calcium Alkalinity Temperature pH	Calcium Carbonate Calcium Sulfate Magnesium Silicate Ferric Hydroxide	Phosphonates Polyphosphates Acid Polyelectrolytes

*From: Donahue, page 37 (Reference VI-13)

If high concentrations of toxicants are necessary in the cooling system, they require treatment before release. For example, toxicant hexavalent chromates can be reduced by reaction with sulfides and the excess sulfides removed by aeration; chromium and copper salts may be reduced by contact with lime and copper ash (Reference VI-19).

In summary, blowdown composition will vary with plant design and operation and with intake water quality. Adverse effects can be minimized by trade-offs in plant and tower design or by chemical treatment of outlet water.

Summary

While cooling devices do have the potential for producing undesirable environmental effects, such effects do not seem to be a problem for the Lake Michigan area. Careful pre-site selection surveys should eliminate sites which have a high potential for fog or drift problems, and blowdown treatment can be provided, if necessary. Site by site evaluation of the potential for consumptive water loss by evaporation may be necessary.

Lake Michigan temperature standards can be met by (1) design and operation of wet cooling systems with no, or essentially no, blowdown, (2) dilution of any residual blowdown with Lake Michigan water, (3) dry cooling towers, or (4) construction of closed cycle systems at sites independent of Lake Michigan as source of water supply or sump for blowdown.

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VII. CONCLUSIONS

Based on the results presented in this report, it is concluded that any of the six cooling systems evaluated are feasible alternatives to once-through cooling for thermal power plants around Lake Michigan. The absolute magnitude of the numbers derived in the analysis cannot be applied to specific plants because of unique site differences, but the numbers do indicate feasibility.

Meteorologic conditions throughout the study area do not impose restraints that are beyond present-day capabilities in terms of engineering design and continuous operation of the alternative cooling systems.

The impact of alternative cooling systems on the environment appears to be minor. Potential problems can be avoided or alleviated through proper site selection and engineering design.

The maximum economic penalty for each type of cooling system in terms of the approximate percent increase in power generation (busbar) cost above that involving a once-through system is:

Wet mechanical draft tower.....1½%
Wet natural draft tower.....3%
Cooling pond.....<1%
Spray canals.....1%
Dry mechanical draft tower.....10%
Dry natural draft tower.....9%

As indicated, the maximum economic penalty among all wet cooling systems is about 3 percent. The magnitude of this penalty (about 0.2 Mills/KWH) is roughly equivalent to any one of the following:

a) A $10/KW difference in plant capital cost,

b) A 1 percent difference in fixed charge rate,

c) A 2¢/10^6 Btu difference in fuel cost, or

d) An 80-mile difference in power transmission distance.

When a closed-cycle cooling system is chosen for a new plant, more latitude in plant siting is gained because large volumes of cooling water are no longer a site prerequisite. According to the Geological Survey Water-Supply Paper 1800, the area around Lake Michigan is generally one of moderate to high surface water runoff and groundwater availability. Therefore, make-up water acquisition should not pose problems at selected inland plant sites.

B. A. Tichenor

DR. TICHENOR: The purpose of this presentation is to highlight the results of this study described in the report dated September 1970. I will briefly discuss the scope of the study, including data requirements. Results of the economic analyses will be given, and potential environmental effects of cooling devices will be evaluated.

Several cooling devices applicable to closed cycle cooling systems for large thermal power plants were evaluated, including wet cooling towers (both mechanical and natural draft), cooling ponds, spray cooling canals, and dry cooling towers (both mechanical and natural draft). Heller type dry towers were analyzed, since direct air condensers are limited to power plant sizes of about 200 MWe.

The base plant selected for the analyses was a 1000 MWe fossil fueled plant. The waste heat load to be dissipated was computed on the basis of turbine heat rates for a GE turbine rated at 1000 MWe for 1.5" Hg back pressure. The appropriate data were taken from the manufacturer's heat rate tables.

Meteorological data used to design and evaluate each of the cooling devices were collected for the Lake Michigan area. In order to account for regional variations in weather, the area was divided into four geographical

sections. Design data representing conditions exceeded no more than 5 percent of an average summer were selected for each section. The use of the 5 percent limit is conventional with the cooling tower industry. Average climatic data were compiled by season for use in evaluating the year-round costs of operation of the cooling systems.

The economic data used in the analyses were also selected to be representative of the Lake Michigan area. Four basic economic factors were considered: capital cost, fixed charge rate, fuel cost, and land cost. These factors were grouped in "Low," "Normal," and "High" sets in an attempt to bracket cost conditions which will be encountered.

I have a few transparencies here which I will use as I go along.

The first one, please.

... Slide ...

This first table shows these three cases. This may be difficult to read. This is essentially a duplication of Table III in the report. (See P. 285a)

Case II is the most representative of current costs, while Cases I and III represent reasonable extremes of low and high costs, respectively.

ECONOMIC FACTORS

(Fossil Fueled Plants)

CASE	PLANT CAPITAL COST ($/KW)	FIXED CHARGE RATE (%)	FUEL COST (¢/10^6 Btu)	LAND COST ($/Acre)
I	110	11	25	250
II	135	14	30	500
III	160	17	35	1000

Table 1

Each of the six cooling systems were evaluated for seven economic cases (the three just discussed plus four others) and four sets of climatic data, thus giving a total of 168 separate analyses. In order to provide comprehensive coverage, computer analysis was necessary. Three computer programs were used to design and evaluate the economics of the various cooling systems. It should be pointed out that the design calculations provide sizes and basic costs, not detailed engineering specifications.

The economic analysis for each cooling system had two basic parts. First, the capital cost of the system was provided by the design calculations. Secondly, the operating cost of the system was evaluated on the basis of off-design conditions, representing operation over a full annual cycle. Thus, the benefits of weather cooler than the summertime design conditions were reflected in lower turbine back pressures and reduced fuel costs.

The results of our analyses showed that each of the six closed cycle cooling systems is technically feasible. Cooling device sizes, heat rejection rates, condensing temperatures, etc. all fall within reasonable limits. Regional differences in weather are not major factors.

The economic feasibility of the various systems

is best evaluated by determining the effect of cooling system choice on the cost of producing electricity. Specifically, one should compare the cost of electricity produced by a plant with a once-through cooling system to the higher cost incurred when an alternative closed cycle cooling system is used.

... Slide ...

This next table shows the information for the three economic cases. Again, the information for this table was extrapolated from Table V13 and Table V14 of the report. (See P. 288)

The busbar costs shown on this table were computed on the basis of the economic factors for each case. As you can see from this table, cooling ponds are the least expensive alternative and dry towers the most expensive. The table also shows that the use of the most expensive wet system (wet natural draft cooling towers) would increase busbar cost by only about 3 percent. Again, it should be emphasized that the data shown here represent reasonable limits of low (Case I), normal (Case II), and high (Case III) costs. Thus, one could expect the cooling system costs for the majority of plants designed for closed cycle cooling near Lake Michigan to fall within the values delimited by Cases I and III.

Analyses were also conducted for nuclear power

INCREASE IN BUSBAR COST OVER ONCE-THROUGH DESIGN

(Fossil Fueled Plants)

CASE	BUSBAR COST ONCE-THROUGH (Mills/KWH)	COST INCREASES (Mills/KWH)					
		Wet Mech. Draft	Wet Nat. Draft	Cooling Pond	Spray Canal	Dry Mech. Draft	Dry Nat. Draft
I	4.57	0.079	0.142	0.012	0.049	0.46	0.43
II	5.94	0.096	0.179	0.021	0.058	0.58	0.53
III	7.53	0.117	0.218	0.039	0.070	0.70	0.64

Table 2

plants. While nuclear power plants discharge about 60 percent more waste heat, it doesn't necessarily follow that the cost of cooling per kw.-hr. will be 60 percent higher. Factors such as different turbines, higher capital costs, and lower fuel costs for nuclear plants make it difficult to compare the costs of cooling for nuclear versus fossil fueled plants.

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This next table, Table 3 presents three combinations of economic factors for nuclear plants in the Lake Michigan area. As with the three cases for the fossil fueled plants, Cases I and III indicate reasonable limits for the low and high costs, respectively. (See P. 290)

... Slide ...

Table 4 provides data on busbar cost increases for three closed-cycle-cooling systems. You will notice the only three systems that we presented here are the wet towers plus cooling ponds. Again, the cost data for Cases I and III bracket the cooling system costs which would be incurred by a majority of nuclear plants designed for closed cycle cooling near Lake Michigan. (See P. 291)

We left out spray canals and we also left out dry towers. There is no technical reason why those units cannot be used on nuclear power plants.

In discussing the environmental effects of

ECONOMIC FACTORS
(Nuclear Plants)

CASE	PLANT CAPITAL COST ($/KW)	FIXED CHARGE RATE (%)	FUEL COST (¢/10^6 Btu)	LAND COST ($/Acre)
I - N	135	11	15	250
II - N	160	14	19	500
III - N	185	17	24	1000

Table 3

INCREASE IN BUSBAR COST OVER ONCE-THROUGH DESIGN

(Nuclear Plants)

CASE	BUSBAR COST ONCE-THROUGH (Mills/KWH)	COST INCREASES (Mills/KWH)		
		WET MECH. DRAFT	WET NAT. DRAFT	COOLING POND
I - N	4.37	0.085	0.138	0.021
II - N	5.83	0.108	0.177	0.033
III - N	7.60	0.135	0.219	0.061

Table 4

cooling towers there are four areas of concern that should be considered for any closed cycle system near Lake Michigan: fog, consumptive water loss, drift, and blowdown.

1) Fog from wet cooling devices should not be a major concern. Analysis of climatic data from the region indicates that severe weather conditions conducive to fog formation occur very infrequently. For example, a high potential for fog occurs only about 1 percent of the time in Green Bay, Wisconsin. In addition, dilution of the water vapor plume appears to be adequate under almost all weather conditions. In cases where the fog potential appears to be high, intensive collection of appropriate climatic data should be accomplished so more specific evaluations can be made. Also, consideration should be given to locating the cooling device so that it is not immediately upwind of a highway or airport.

2) Consumptive use (evaporation) of water by wet cooling devices was evaluated. Average annual evaporation rates were computed for each wet device and compared to the consumptive loss due to once-through cooling. For a 1,000 MW fossil plant, wet cooling towers and spray canals can be expected to consume about 2 1/2 c.f.s. more than a once-through system; when natural levels of evapo-transpiration are considered, cooling

ponds consume about 3 1/2 c.f.s. more. To put these values in perspective once-through systems consume about 8 c.f.s.

3) Drift from wet cooling devices near Lake Michigan should not produce adverse effects, since freshwater will be used. In addition, modern cooling towers employ drift eliminators which reduce the drift to far below the often-quoted value of 0.2 percent of the circulating water flow.

4) Blowdown can be minimized, in fact eliminated, by increasing the concentration multiple of the makeup water. Even with a drift as low as 0.05 percent, zero blowdown can be achieved with a concentration multiple of 35 to 1. Since the concentration of dissolved solids in Lake Michigan is very low, a concentration multiple of 35 should not provide operational difficulties within the cooling system.

Based on the results of the study, it is concluded that all of the six cooling systems evaluated are technically feasible alternatives to once-through cooling for thermal power plants near Lake Michigan.

The impact of closed cycle cooling systems on the environment appears to be minor. Potential problems can be avoided or alleviated through proper site selection and engineering design.

B. A. Tichenor

The maximum increase in busbar (power production) cost for a closed cycle system using a wet cooling device is about 3 percent. While the absolute magnitude of the costs presented should not be applied to specific plants, the range of costs given by Cases I and III should bracket closed-cycle cooling costs for future power plants near Lake Michigan.

Finally, if the economic effect of selecting a closed cycle cooling system is evaluated in terms of cost to the consumer, a true picture of the real cost burden is achieved.

We put together a chart which is probably difficult for most of you to read which explains this a little fuller. And I will tell you about the numbers this chart shows. (See P. 297)

The first line is the base cost. The base cost of $9.44 per month for electricity generated by a once-through plant was obtained by analyzing data from the Federal Power Commission and the Edison Electric Institute for the States bordering Lake Michigan. These data also indicated an average monthly consumption of 500 kw.-hr. per residential unit. So this base cost of $9.44 per month is the average paid by the average resident for 500 kw.-hr. of electricity.

B. A. Tichenor

The increase in consumer cost due to using a closed cycle cooling system over a once-through system was obtained by assuming that all of the additional busbar cost as represented by Case II of our analysis was passed on to our consumer.

I am sure you can't see, but at the end of each one of these blue bars which indicates the base cost we have added a red bar indicating the additional cost for each system.

I will just go through the numbers: Mechanical draft added 5 cents, natural wet draft added 9 cents, cooling ponds added 1 cent, spray canals added 3 cents, mechanical draft dry towers added 29 cents, and natural draft dry towers added 27 cents.

That is the conclusion of my statement.

MR. STEIN: Before I throw this open, let's see if I understand that because it seems to me kind of important.

On the assumption that -- and I assume you have read Mr. Barber's report -- the power plants be permitted to raise the temperature just 1 degree at the pipe, you say the most this will cost the consumer is 30 cents a month extra on the bill -- it may cost them a lot less.

DR. TICHENOR: This is true. This assumes that the plant was designed at the outset with a closed cycle cooling system being considered.

MR. STEIN: Right.

Are there any comments or questions?

Mr. Frangos.

MR. FRANGOS: Mr. Chairman, could we have a copy of that graph?

MR. STEIN: Do you have a copy of that graph in your main report?

DR. TICHENOR: No, sir.

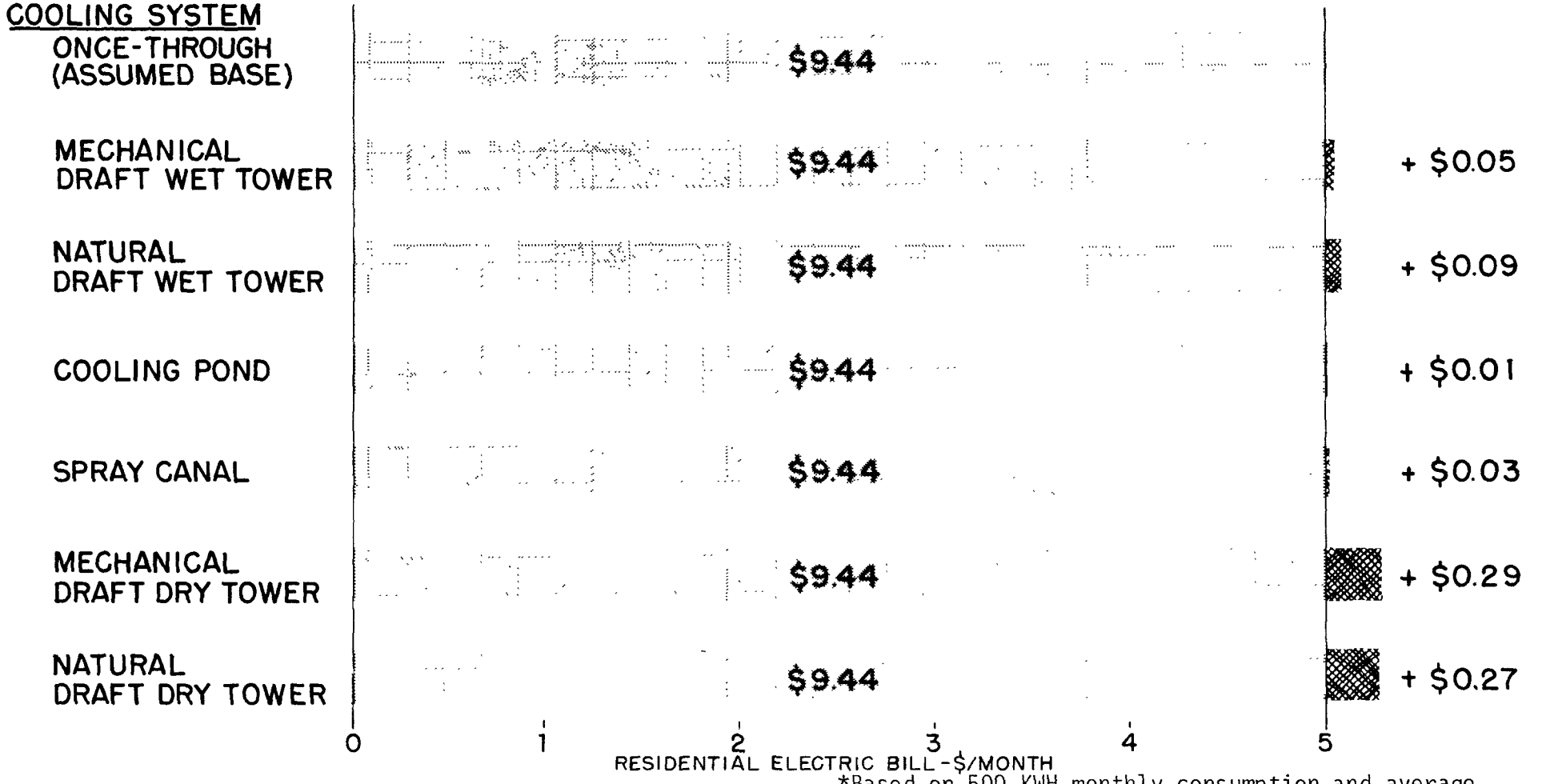
MR. STEIN: Well, let's see if we can make a picture of that and get it for the conferees. I think that is a fairly important document, and I would like to have that for the record, too, when we get it. Maybe we can do that while we are here; take a picture and reduce it and get it. Do you think that could be done?

MR. MAYO: No problem. The Regional Office will take care of that.

MR. STEIN: Thank you. Are there any other comments or questions?

(The chart above referred to follows.)

EFFECT OF COOLING SYSTEM COST ON AVERAGE RESIDENTIAL MONTHLY ELECTRIC BILLS *



*Based on 500 KWH monthly consumption and average monthly cost of $9.44 for each residential unit in Michigan, Illinois, Indiana, and Wisconsin. Data from FPC publication R-75, "Typical Electric Bill," 1969, and "EEI Statistical Year Book of the Electric Utility Industry for 1968."

B. A. Tichenor

MR. FRANGOS: Mr. Chairman, I am wondering if you could tell us if you went through any calculations with the economics with the facilities that are installed.

DR. TICHENOR: Yes, we did some computations. We made some rather basic assumptions when we did these calculations.

MR. FRANGOS: Do we have those results? Are they available? There is a question of existing and new facilities obviously.

DR. TICHENOR: I think the best way to discuss this problem rather than in terms of specific plants is to talk about what sort of problems there are in what is called "back fitting" a powerplant. As you read in the report, the temperature rises through the condenser for a plant with closed cycle cooling systems are much in excess of those temperature differences that you get for the once-through plants. This is to optimize the design of the cooling device. You can make a smaller cooling device by using a higher temperature.

Now, the problem with taking a plant that is either in operation or about to begin operation is that your condenser is designed to provide a much lower temperature increase on the order of 20 degrees as opposed to possibly 35 degrees.

B. A. Tichenor

The problems you get into here are not just the fact that your cooling device becomes larger due to the fact that it is operating at a lower temperature, but you get increased back pressure such that your fuel differential costs go up. It costs you more money to produce the power since your efficiencies are lower in terms of costs.

We did run some analyses. The data we had was sometimes insufficient to make these analyses conclusive. However, in terms of increased production cost, increased busbar cost, I believe our data showed that for mechanical draft towers the increase was on the order of .2 mills per kilowatt hour, for natural draft towers on the order of .3 mills per kilowatt hour, and for cooling ponds, it varied quite drastically due to variations in land costs in certain instances.

MR. FRANGOS: Thank you.

MR. STEIN: Thank you.

Are there any other comments or questions?

MR. CURRIE: Yes, Mr. Chairman.

You conclude that all of the six cooling systems evaluated are technically feasible alternatives and that, I take it, means that you disagree with the statement that was made in evidence before our board last week. The statement is as follows: "Dissipation of large quantities of heat directed to the atmosphere without water

evaporation presently is not technologically or economically feasible."

Do you disagree with that statement?

DR. TICHENOR: Was this applied to existing plants or a new facility?

MR. CURRIE: It was a general statement which I think was meant to apply to both.

DR. TICHENOR: Yes, I disagree. If that applies to a plant which is in the design process, I would have to disagree.

We have a research contract with R. W. Beck & Associates which is a consulting engineering outfit, and they are doing feasibility studies for us on dry cooling systems, and most of the data in this report are a result of their computations. It should be recognized that dry towers are not presently being used at the scale we are talking about, however this doesn't discount their feasibility. They are being used in the order of 200 and 300 MW in Europe. There is a facility being built in South Africa on the order of 500 or 600 MW, and there are designs for 700 to 800 MW on the drawing board. So these are feasible.

I am talking about the Heller type system rather than the direct air condenser.

B. A. Tichenor

MR. STEIN: Are there any other comments or questions from the panel?

Any from anyone in the audience? Yes, would you come up, please?

MR. WARREN: Mr. Chairman, I am Frederick Warren from the Federal Power Commission, and since we are on the subject of costs, I would like to ask two questions concerning your recent statements.

First, you indicated you used 1968 data from the Federal Power Commission. Inasmuch as a number of the elements of power costs have been changing quite rapidly in the current period, and because we are looking to costs in the future as they will affect the consumer, I wonder if you have projected these costs forward to, say, 1978 when, if the trends of the moment or at least the costs of the moment were applicable, fuel costs would be higher, capital costs would be higher, and net service costs would be higher.

Do you have any comments on what those costs would be?

DR. TICHENOR: I would like to refer you to Case III of our economic analysis which does deal with high capital costs, high fixed charge rates, and high fuel costs.

B. A. Tichenor

MR. WARREN: How does it compare with the supplemental cost you referred to just earlier, say 27 cents a year, 27 cents a month addition? I mean, would it be twice as high or three times or what?

DR. TICHENOR: For which particular cooling device?

MR. WARREN: Well, pick out one that is significant. Wet cooling tower and dry cooling tower.

DR. TICHENOR: Okay. The wet cooling tower for our Case III appears to be about 20 percent higher than Case II for both mechanical and natural.

MR. WARREN: And the dry cooling tower?

DR. TICHENOR: For the dry cooling tower, it must be 30 percent higher.

MR. WARREN: You mean higher than the numbers that you quoted or higher than the average billing?

DR. TICHENOR: Higher than these.

MR. WARREN: The additional cost on the --

MR. STEIN: Pardon. Would you speak into the microphone?

DR. TICHENOR: The mechanical draft, dry.

MR. WARREN: My other question was relevant to the question of the back fitting which you were discussing. In calculating these costs, have you made assumption of

a -- you know, a shorter average amortization period for such plants assuming they have a present average lifetime of maybe 15 years or 20 years, what is the period of amortization over which you would expect those costs to be written off at the numbers that you have used?

DR. TICHENOR: I think we assumed the same amortization period.

MR. WARREN: You mean 25 or 30 years?

DR. TICHENOR: I believe so, yes. It is in the report.

MR. WARREN: Well, I have to question the realism of that assumption, at any rate. I think this is an important consideration which I expect to refer to, and I am not here, gentlemen, suggesting that costs are the only factors to consider. We just happen to be on this subject at the moment.

But I think with respect to the back fitting of units, once you consider that, obviously the customer would have to pay them over a shorter period.

DR. TICHENOR: If we are talking about back fitting auxiliary cooling to existing plants, you can only afford to pay for those over the existing life, over the remaining life.

MR. WARREN: This would not apply to a plant

that is ready to go on line with the back fitting?

MR. STEIN: In other words, with an existing plant, if you make an improvement, you would have to have a shorter amortization period to make it reasonable or feasible than for a new plant.

DR. TICHENOR: That is the point.

MR. STEIN: I think that is clear.

Again, I hear these figures, and even with the outside assumption, it is going to push up the bill 40¢ a month maximum.

DR. TICHENOR: That is by far the most expensive--the dry system.

MR. STEIN: The most expensive system in adding on an extra 30 percent.

MR. WARREN: I think that would depend on whether his Case III figures the future cost numbers for the decades ahead.

MR. STEIN: I think this is his statement that we want to get in now. This is what he is saying.

DR. TICHENOR: Yes, this is for Case III, and I think the point is that Case III may not represent the maximum of all of these factors. We did not attempt to project these costs into the future.

MR. STEIN: Thank you.

B. A. Tichenor

Do we have any other comments or questions?

Yes, would you come up, please?

MR. PATTERSON: My name is R. W. Patterson of the engineering consulting firm of Sargent and Lundy. I have two questions. One is: Does the Department have any information on the experience that the dry towers have had in Europe and South Africa?

DR. TICHENOR: Yes, we do. We have just received our preliminary copy of the final report from the R. W. Beck Company and they have an extensive section on the experience of this.

MR. PATTERSON: Have they been good or bad?

DR. TICHENOR: They have been both. They have had some corrosion problems in terms of operating problems. They have had some problems, yes, but they have also had some good experiences.

MR. PATTERSON: Would these experiences lead you to believe that the costs would actually be higher for a system that would operate well, or were they based on the costs of towers which have had problems?

DR. TICHENOR: The costs, I don't believe, were extrapolated from the European experience and the reason for this is that some of the towers that were initially built in Europe were not optimized.

B. A. Tichenor

For example, at the Rugely plant, cost data were quite high because this tower was put in more as an experiment. R. W. Beck & Assoc. determined more reasonable costs for U. S. considerations.

One thing I should point out right now, that is stated in the report but I didn't say, is that these additional costs include some gas turbine peaking units for the low generation capacity due to high back pressure.

MR. PATTERSON: Was this with some of the tower manufacturers -- in conjunction with them?

DR. TICHENOR: Yes.

MR. PATTERSON: The other question is of a different nature. The fuel costs that were included in the various alternatives, as I understand it, were based on two or three or four basic fuel costs in order to get a spectrum of fuel costs. But in comparing once-through cooling and cooling tower alternatives, was consideration given to the fact that the cooling facilities will operate at a poorer efficiency than operating with Lake Michigan and that therefore there will be higher fuel costs?

DR. TICHENOR: Yes. What we did is we gave a standard once-through design, put ambient lake temperatures in, operated the once-through plant over the full year to determine the fuel costs and did

the same thing for each of the cooling devices depending on what their temperature was and the back pressure was, so that the difference in the effect of operating with off-design conditions was considered.

MR. PATTERSON: What about referring to the capability charges? The cooling towers by being less efficient and in some cases requiring fans or other mechanical equipment will give a lower output to the system in kilowatts and therefore this kilowatt capacity must be replaced at another plant somewhere or by building another plant to increase the capability of the entire system.

DR. TICHENOR: Basically what we did is we assumed that we could factor that out under the fuel consumption. Although I would say that the amount -- we certainly included the cost of fuel for providing pumping and for providing fan horsepower.

MR. PATTERSON: Those are all of the questions I have.

MR. STEIN: Thank you very much.

Please clarify a question for me, Dr. Tichenor, because I suspect that we may be getting comparisons with the highest possible courses put in here around Lake Michigan all of the time.

Is it your judgment that -- I assume the dry

cooling tower costs the most.

DR. TICHENOR: Of the alternatives.

MR. STEIN: Is it your judgment that the dry cooling tower is going to be universally used around Lake Michigan or will some of the plants be able to take a less expensive system?

DR. TICHENOR: I would think the environmental effects of the wet devices could be satisfactorily solved. There would be no reason why we could not continue to go the wet systems.

MR. STEIN: Are there any other comments or questions?

MR. POOLE: I hate to expose my ignorance, but I haven't been able to tie in the data you showed over here with the report. Is it in the report?

DR. TICHENOR: The first two tables I showed over here are in the report. The ones pertaining to the nuclear plant are not in the report.

MR. POOLE: Could you, not necessarily today, but could you supply us with all these tables?

MR. STEIN: Do you have copies?

DR. TICHENOR: Yes.

MR. STEIN: We can get those supplied by this afternoon or tomorrow morning and duplicated.

B. A. Tichenor

MR. MILLER: Mr. Chairman.

MR. STEIN: Yes, Mr. Miller.

MR. MILLER: I have a question concerning your statement on blowdown. If I understand what you are saying, you say zero blowdown. With all of the cooling towers that I am familiar with, even in this area, with drift, we still have to have blowdown on them. How do you keep the concentration of the solids down?

DR. TICHENOR: How do you keep the concentration of the solids down with zero blowdown? The way you hit zero blowdown is to increase the concentration of the solid until you reach some equilibrium, and the report showed, depending on the amount of water you lost through drift, that the concentration multiple varies from 9.5 to 35 with zero blowdown. If you blow down you get various concentration multiples for various blowdown discharges.

I believe one of the tables in the report gives both volumes of blowdown and concentration multiples. Table VI8 on page VI30 indicates the various concentration multiples assuming evaporation loss of 1.78 percent. And a drift of 0.05 percent.

MR. STEIN: Does that satisfy you, Mr. Miller?

MR. MILLER: I have never seen one operate

this way even with buildup of solids. You either have equipment problems or you have blowdown out of it.

DR. TICHENOR: We recently saw a paper that was delivered by -- I can't remember the gentleman's name -- from the Black and Veatch engineering firm, that was delivered at a Cooling Tower Institute meeting which indicated that they have some data on towers operating with zero blowdown.

MR. ASCHOFF: My name is A. F. Aschoff of Sargent and Lundy Engineers.

I think that you had better examine your Lake Michigan water chemistry, because you cannot run Lake Michigan water at 35 concentration; you will get precipitation of calcium carbonate much below that.

DR. TICHENOR: That is possible. We did not examine that problem.

MR. ASCHOFF: Your other reference in the paper had to do with the salt water tower rather than one operated on lake water where you mixed 100,000 parts per million.

DR. TICHENOR: That is true.

MR. ASCHOFF: I don't think that is relevant to the discussion on Lake Michigan.

DR. TICHENOR: I might mention that we have

data from several power plants operating not on salt water but on freshwater systems, and their dissolved solids -- some of them -- are quite high, but the chemistry may not be the same.

MR. ASCHOFF: You get precipitation of calcium carbonate at about 33 p.p.m., and if you run it on calcium sulphate it comes out about 1,200.

DR. TICHENOR: What would happen if you ran a concentration multiple of 9.5?

MR. ASCHOFF: You might run 5 to 10 on Lake Michigan water on feeding sulphuric acid. That is about the maximum.

MR. STEIN: Thank you.

Are there any other comments or questions? If not, thank you very much, Dr. Tichenor.

May we have Mr. Frederick Warren of the Federal Power Commission?

MR. STEIN: How long is this statement going to be?

MR. WARREN: I would think it would take about 20 minutes, Mr. Stein, to present, and I don't know if you want to have questions afterward or not. Do you have any preference of doing it now or after lunch? It is agreeable with me either way.

MR. STEIN: Why don't you go ahead?

MR. WARREN: All right.

FEDERAL POWER COMMISSION

OFFICE OF THE ADVISOR ON ENVIRONMENTAL QUALITY

September 25, 1970

Commissioner David D. Dominick
Federal Water Quality Administration

Dear Commissioner Dominick:

Herewith three copies of my statement for the Chicago conference to be held September 28, which I called earlier this week to discuss with you.

Frederick H. Warren
Advisor on Environmental Quality

Enclosures

STATEMENT OF
FREDERICK H. WARREN
ADVISOR ON ENVIRONMENTAL QUALITY
FEDERAL POWER COMMISSION

FOR THE
FEDERAL-STATE ENFORCEMENT CONFERENCE
ON POLLUTION OF LAKE MICHIGAN
SEPTEMBER 28, 1970, CHICAGO, ILLINOIS

Since the public announcement in May 1970 of the proposal by the Federal Water Quality Administration to limit the thermal rise of waters discharged into Lake Michigan to 1°F, the Federal Power Commission has been interested to know and to understand the environmental factors which form the technical basis for this proposal and has been concerned with determining the effect such limitations might have on electric power facilities presently using Lake Michigan for water cooling purposes as well as those in construction or planned for building in the future. Just a week ago, the Commission received copies of the reports of the Department of the Interior entitled "Physical and Ecological Effects of Waste Heat on Lake Michigan" and "Feasibility of Alternative Means of Cooling for Thermal Power Plants Near Lake Michigan." We have therefore had only a brief opportunity to

review and analyze their contents. In the meantime, we have explored the extent of other studies on this subject and the status of the electric power situation.

The purpose of this statement is to summarize the nature of the present and prospective electric power situation as related to thermal discharge limitations for Lake Michigan and to provide pertinent comments and conclusions which we believe should receive full consideration in any determination by the responsible environmental agencies as to appropriate thermal standards for Lake Michigan.

The Federal Power Commission is charged by law with responsibilities and duties to promote and encourage the voluntary interconnection and coordination of electric power systems of the Nation in the interest of "assuring an abundant supply of electric energy throughout the United States with the greatest possible economy and with regard to the proper utilization and conservation of natural resources." Reliability and adequacy of electric power supplies are basic to the accomplishment of these goals.

This statement, therefore, sets forth the needs and projected supplies of electric power in the Lake Michigan area, indicates the possible effects of proposed thermal criteria for Lake Michigan on the reliability and cost of power supplies, and urges that these matters be fully considered in the balancing of objectives that will be necessary in adopting final thermal standards for Lake Michigan waters.

Currently, there are 23 electric utility steam-electric plants located on Lake Michigan and utilizing Lake water for condenser cooling on a once-through basis. All except one small nuclear plant are fossil fueled. As shown in Table 1, the total capacity of these plants is 8,393 megawatts.

These 23 existing steam-electric plants are operated by six privately owned and five publicly owned electric utility systems. As shown in Table 2, the plants obtaining cooling water from Lake Michigan provide from 18 to 100 percent of the capacities of these systems and account for 41 percent of the combined system capacities.

Table 1
Existing Utility Steam-Electric Plants
Obtaining Cooling Water From Lake Michigan

Utility System	Plant Name	Fossil or Nuclear	Installed Capacity, MW
Commonwealth Edison Co.	Waukegan	F	1,047
	State Line	F	944
Consumers Power Co.	Big Rock Point	N	75
	Campbell	F	650
	Cobb	F	511
Northern Indiana Public Service Co.	Bailly	F	616
	Michigan City	F	211
	Mitchell	F	529
Wisconsin Electric Power Co.	Commerce St.	F	35
	Lakeside	F	311
	North Oak Cr.	F	500
	Port-Washington	F	400
	South Oak Cr.	F	1,170
	Valley	F	275
	East Wells	F	15
Wisconsin Power and Light Co.	Edgewater	F	459[1/]
Wisconsin Public Service Corp.	Manitowoc	F	10
	Pulliam	F	393
Winnetka Municipal	Winnetka	F	26
Escanaba Municipal	Escanaba	F	23
Holland Municipal	DeYoung	F	83
Traverse City Municipal	Traverse City	F	35
Manitowoc Municipal	Manitowoc	F	75
		Total	8,393

1/ Wisconsin Public Service Company owns 32% of the second unit (330).

Table 2
Utility Systems with Steam-Electric Plants
Obtaining Cooling Water From Lake Michigan

Utility System	Total System Capacity, MW	Steam-Electric Capacity With Lake Michigan Cooling, MW	Percent of System Capacity with Lake Michigan Cooling
Commonwealth Edison Company	10,877	1,991	18
Consumers Power Company	3,411	1,236	36
Northern Indiana Public Service Co.	1,460	1,356	93
Wisconsin Electric Power Company	2,706	2,706	100
Wisconsin Power and Light Company	908	459	51
Wisconsin Public Service Corporation	733	403	55
Holland Board of Public Works	83	83	100
Traverse City Elec. Light & Pwr. Dept.	35	35	100
City of Escanaba	23	23	100
Village of Winnetka	26	26	100
Manitowoc Public Utilities	75	75	100
Total	20,337	8,393	41

To meet the growing utility loads in the area, additional capacity is being installed at one existing fossil fueled plant and five new nuclear plants are being constructed. As shown in Table 3, the total additional capacity being provided amounts to 7,043 megawatts. As planned, the new plants and plant additions would also utilize Lake water on a once-through basis. Thus, with completion of these additions, 28 plants with a total capacity of 15,436 megawatts would be using Lake Michigan for the dissipation of waste heat.

Of the six utilities listed in Table 3, the Indiana-Michigan Electric Company, which is constructing the Cook nuclear plant, is part of a larger system with most of its load extending far from Lake Michigan. Table 4 shows for the other five systems operating in the Lake Michigan area the projected load-supply situation in 1973 when all plants under construction are scheduled for completion.

Table 3
Utility Steam-Electric Plants Under Construction
With Planned Use of Lake Michigan Water for Cooling

Utility System	Plant and Unit	Fossil or Nuclear	Installed Capacity, MW	Scheduled In-Service Date
Commonwealth Edison Co.	Zion No. 1	N	1,000	4/72
	Zion No. 2	N	1,000	5/73
Consumers Power Co.	Palisades	N	812	12/70
Northern Ind. Pub. Serv. Co.	Michigan City (Add.)	F	500	6/73
Wisconsin Elec. Power Co.	Point Beach No. 1	N	502	12/70
	Point Beach No. 2	N	502	9/70
Wisconsin Pub. Serv. Corp.	Kewaunee	N	527 1/	6/72
Ind.-Mich. Electric Co.	Cook No. 1	N	1,100	9/72
	Cook No. 2	N	1,100	6/73
	Total		7,043	

1/ Jointly owned with Wisconsin Power and Light Co. and Madison Gas and Electric Co.

Table 4

Load-Supply Situation for Summer 1973
Selected Utilities Adjacent to Lake Michigan

	Megawatts
Dependable Capacity, June 1970	20,428
Capacity Additions near Lake Michigan by June 1973	4,843
Other Net Capacity Additions by June 1973	3,929
Dependable Capacity, June 1973	29,200
Load, Summer 1973	23,081
Reserves	6,119
	or 26.2%

Table 4 indicates that these five utilities in the Lake Michigan area have adequate reserves for the summer of 1973. However, the figures do not take account of firm purchases and firm sales, both of which could have a significant effect on the reserve margin. The figures are also based on the assumption that all capacity additions listed in Table 3 would be completed without delays. The Zion No. 1 nuclear unit and Michigan City fossil plant addition are scheduled for operation in May 1973 and June 1973, respectively. Should these units be delayed, the reserve for the summer of 1973 would be reduced by 1,500 megawatts to 20 percent. The summer 1970 reserve margins for for these utilities, exclusive of firm purchases and firm sales, was 13.0 percent.

The Commission considers that a reasonable reserve margin for utility systems served predominantly by thermal plants is about 20 percent. It is clear, therefore, that the capacity additions under way provide needed reserve margins and that any significant delays in plant completions would reduce the reserves below margins of safety for reliable service.

The electric utilities serving the areas surrounding Lake Michigan are located in four power supply areas as defined by the Federal Power Commission. Power supply area 11 consists primarily of the Lower Peninsula of Michigan. Power supply area 12 consists primarily of the State of Indiana. The eastern half of Wisconsin and the Upper Peninsula make up power supply area 13. Approximately the northern one-fourth of Illinois, including the Chicago area, comprises power supply area 14.

As shown in Table 5, the energy requirements and the peak loads of these areas are both projected to increase in 1990 to approximately three and one-half times the 1970 amounts.

Table 5
Projected Electric Utility Energy Requirements and Peak Loads
for Power Supply Areas Surrounding Lake Michigan
(Energy in Million kWh; Peaks in Thousand kW)

Power Supply Area	1970		1980		1990	
	Energy	Peak	Energy	Peak	Energy	Peak
11	56,210	9,990	102,000	17,600	181,000	30,600
12	63,120	11,500	123,000	22,000	233,200	41,400
13	27,400	4,660	50,500	8,150	91,300	15,290
14	52,300	10,070	105,000	19,810	195,000	39,020
Total	199,030	36,130	380,500	67,920	700,500	124,310

It should be noted that a large part of the load in power supply area 11 is and will be centered around the Detroit area. However, projections are that a substantial amount of load growth will occur in western Michigan on the eastern shore of Lake Michigan. The majority of the load growth expected for power supply area 12 will be in the middle and southern portions of Indiana, but a significant amount will be in the northern section around Gary, Indiana. Almost all of the loads projected for power supply areas 13 and 14 will be on or near Lake Michigan.

As shown in Table 6, the annual rates of growth for power supply areas 11 and 13 are projected to be slightly lower than the total rate for the four power supply areas considered. This is true for both decades and for both energy requirements and peak loads. The rate of growth for the 1980-1990 period is less than for the 1970-1980 period. Comparing the power supply areas 11, 12, 13, and 14 to the whole United States, the rate of growth is lower in these power supply areas in every instance.

Table 6
Annual Compounded Percent Increase of Projected Electric Utility Energy Requirements and Peak Loads for Power Supply Areas Surrounding Lake Michigan

Power Supply Area	1970-1980 Energy	1970-1980 Peak	1980-1990 Energy	1980-1990 Peak
11	6.1	5.9	5.9	5.7
12	6.9	6.7	6.6	6.5
13	6.3	6.2	6.1	6.0
14	7.2	7.0	6.4	6.5
Total - 4 Areas	6.7	6.5	6.3	6.2
Total - U. S.	7.3	7.2	6.6	6.6

To meet the projected loads in 1990, substantial amounts of generating capacity in addition to that existing and under construction will need to be installed in the Lake Michigan area. Estimates made in connection with updating the National Power Survey indicate that approximately 4,000 megawatts of new fossil fueled capacity and 20,000 megawatts of new nuclear capacity would be constructed on or near Lake Michigan. Thus, by 1990 nearly 40,000 megawatts of steam-electric capacity could be located so as to use Lake Michigan waters for cooling.

Should the projected 24,000 megawatts of thermal capacity not now existing or under construction be required to have auxiliary cooling facilities rather than once-through systems,

the additional plant costs would be an estimated $130 million, using about $10/kW for nuclear and $7/kW for fossil plants. The added consumptive use of water would be approximately 300 cubic feet per second.

If all of the 15,000 megawatts of capacity existing and under construction required conversion from once-through cooling to the use of auxiliary cooling facilities, the required investment, exclusive of sunk costs in constructed facilities, could be of the order of $150 million, using somewhat higher unit costs than for new plants. This would not make allowance for the unavailability of capacities during conversion periods. The increase in consumptive use of water resulting from the alterations would be about 190 cubic feet per second.

Before stating our conclusions, it is in order to make a few comments concerning the principal report of the Department of the Interior dated September 1970 (referred to above), which provides some of the basic background for this conference.

First, the report presents no newly defined proposal with respect to a thermal rise limitation for the Lake and therefore we have had to assume that the proposal of $1^{o}F$ maximum rise still stands.

Second, the "Introduction" of the report, which contains the conclusion "that no significant amounts of waste heat should be discharged into Lake Michigan," appears to rest on certain major assumptions presented in that report. One of the principal assumptions is that the waste heat discharged from power plants into Lake Michigan by the year 2000 will increase approximately tenfold from the present 40 billion Btu's/hour in 1968 to about 431 billion Btu's/hour in the year 2000. This presumes no change whatever in the technology of cooling power plants in this region in the next thirty years, and therefore reflects a straight arithmetic increase of heat load by the projected increases in power capacity. Thus even though about 80 percent of the postulated direct heat load would accrue from units not coming on stream until the 1980's and 1990's, the Department is advocating immediate imposition of the proposed 1°F limit.

Third, in the development of the foregoing estimates of heat loading, the report assumes 100 percent plant factor for the power facilities, which is roughly double the average normal experience of the industry and therefore doubles the postulated heat load estimate.

Fourth, while the report deals extensively with significant changes in the ecology of the Lake resulting from negative factors imposed on various species of fish and plant life, it does not, so far as we have learned, present data evidencing specific harmful effects from operations of the number of power facilities now discharging heated effluents into the Lake.

Fifth, the report refers to a number of factors contributing to degradation of the quality of Lake waters and its biota. These include not only thermal loading but also industrial pollutants, human and agricultural nutrients, and past inadequate management of fisheries. The proposed thermal limitations can hardly be expected to achieve their intended purpose unless these other factors are correspondingly improved.

Sixth, the studies emphasize the critical importance of the inshore portions constituting only 6 percent of the Lake's surface and its biologically most productive area. No consideration appears to be given to the possibility that some of the fringes of the other 94 percent of the Lake might support enhanced productivity if they shared some of the heat from inshore, perhaps promoting bottom upwelling, as the Department

of the Interior has suggested elsewhere. Considerations such as these prompt us to say that the function of regulation is not to dictate engineering choices but rather to set environmental objectives to be achieved and leave to biological/engineering the design of individual solutions suited to particular situations.

These comments do not invalidate the substantial amount of valuable ecological data, analyses, and opinion contained in the report. We are equally as concerned as other participants in this conference with finding and applying protective principles which will not only preserve but improve the ecological condition of this splendid Lake. The present situation, however, in our opinion leaves a number of matters open to question and leads us to state the conclusions which are summarized hereafter.

Conclusions

1. The Commission's responsibilities stated at the introduction of this paper with respect to adequate and reliable supply of electricity together with regard for conservation of natural resources emphasizes that any standards to be implemented on specific thermal rise limits should take account of any potential impact on the power supply situation as well as the

environmental conditions which they are intended to protect. We believe it is apparent that the major quantities of electric power capacity summarized in previous portions of this paper are of such importance to the health and well-being of inhabitants of this area and their economic situation that it would be unacceptable to curtail the scheduled power projects unless it were clearly demonstrated that failure to do so would seriously jeopardize human health and safety or major ecological systems. In consequence, any adoption of new thermal standards should be applied in specific situations in a manner designed to avoid jeopardy of electric power supply schedules.

2. As previously noted, the Commission staff and other conference participants have had merely a few days to consider the technical findings of the Department of the Interior with respect to potential effects of thermal discharges into Lake Michigan. Meanwhile, a significant number of studies on thermal environmental aspects of the Lake have been conducted and many are still under way as summarized in Attachment A to this statement. Since so many studies are still in progress, it is not yet possible to assess the import of their conclusions along

with the data contained in the Department's report. We see evidence of potential for damage but not evidence of an imminent crisis in the condition of the Lake. In our opinion, it would be desirable to consider carefully the results of all these studies as well as examining more fully the implications of the Department's report before instituting major actions which might impair the electric supply situation or have other significant environmental consequences. These factors should be weighed in comparison with the reported potential environmental effects which will not change very greatly in a matter of months.

3. While not contending that dollar costs of power facilities and power generation should control decisions in this matter, it is believed that balanced decisions in the interest of the public as both environmental trustees and power consumers require that cost factors be weighed along with appraisal of related environmental consequences.

4. There is a reasonable opportunity to consider the merits of design changes in plants not yet committed to construction in order to handle thermal discharges by various techniques in addition to present once-through cooling systems.

The same time and cost factors are not applicable if such regulations are imposed on existing power plants or those which are far advanced in construction. We therefore urge the conferees and the environmental agencies involved to consider with more care:

a) Other possible designs for cooling systems of power plants situated in different Lake shore siting situations developed around a set of environmental protection principles.

b) A transition program for any proposed auxiliary cooling requirements applied to plants already designed and in construction; and

c) Individual consideration of the merits, the time schedules, and the economic consequences of applying similar standards to existing plants which are generally of smaller capacity and have more limited life for cost amortization.

5. In view of the responsibilities and concerns expressed herewith on behalf of the Federal Power Commission, and the important impact which any decisions here have on the power

programs we have cited, it is requested that the Federal Power Commission have the opportunity to review any proposed revised thermal effects standards for Lake Michigan and plans for their implementation before such plans are adopted.

Attachment A

LAKE MICHIGAN THERMAL EFFECTS STUDIES

	Title or Subject of Study	Area Investigated	Study Performed By	Study Dates
		A. Studies Completed		
1.	Great Lakes basin study	Lake dynamics-biological, physical, chemical	FWQA	1964
2.	Thermal pollution study	Thermal plume-Waukegan	FWQA	1968
3.	Waukegan-Zion study	Thermal plume-Waukegan	Dr. W. O. Pipes	1968
4.	Waukegan-Zion field sampling	Bottom organisms and temperature measurements	FWQA	1969
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9.	Preoperational study at Kewaunee plant	Biological and Lake temperature survey	Univ. of Wisc. (Dr. Grunwald)	-
10.	Preoperational study at Point Beach plant	Biological and Lake temperature survey	Univ. of Wisc. (Dr. Grunwald)	-
11.	All Wisc. Elec. Power Co. plants	Infra red aerial survey of thermal plumes	Texas Instrument Co.	-
12.	Study of Campbell plant	Survey of thermal plume	Consumers Pwr. Co.	-
13.	Study of Traverse City plant	Measurement of thermal plume	Mich. Water Res. Comm.	1968
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16.	Study of Campbell and Big Rock plants	Infra red aerial survey of thermal plumes	Consumers Pwr. Co.	1969

B. Studies Under Way

1.	Continuous monitoring at Waukegan plant	Measure changes in temperature and oxygen	Ind. Bio-Test (Dr. W. O. Pipes)	1970-71
2.	Phytoplankton studies at Waukegan plant	Evaluate thermal shock at algae in condenser	Ind. Bio-Test (Dr. W. O. Pipes)	1970-71
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5.	Lake dynamics at Waukegan and Zion	Continuously monitor current, water temperature, meteorology	Ind. Bio-Test (Dr. W. O. Pipes)	1970-2
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STATEMENT OF FREDERICK H. WARREN,
ADVISOR ON ENVIRONMENTAL QUALITY,
FEDERAL POWER COMMISSION,
WASHINGTON, D.C.

MR. WARREN: Mr. Chairman, I appreciate the opportunity to appear before you and the conferees here today and to speak to this audience. I am Frederick H. Warren, Advisor on Environmental Quality for the Federal Power Commission.

Since the public announcement in May 1970, of the proposal by the Federal Water Quality Administration to limit the thermal rise of waters discharged into Lake Michigan to 1 degree Fahrenheit, the Federal Power Commission has been interested to know and to understand the environmental factors which form the technical basis for this proposal -- I expect others here have been curious along with me about the same matter -- and has been concerned with determining the effect such limitations might have on electric power facilities presently using Lake Michigan for water cooling purposes as well as those in construction or planned for building in the future. Just a week ago, the Commission received copies of the

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reports of the Department of the Interior entitled "Physical and Ecological Effects of Waste Heat on Lake Michigan" and "Feasibility of Alternative Means of Cooling for Thermal Power Plants Near Lake Michigan." We have therefore had only a brief opportunity to review and analyze their contents. I hope I may be permitted a mild skepticism about the objectivity of the report, the conclusion of which was announced 4 months before its release.

In the meantime, we have explored the extent of other studies on this subject and the status of the electric power situation.

The purpose of this statement is to summarize the nature of the present and prospective electric power situation as related to thermal discharge limitations for Lake Michigan and to provide pertinent comments and conclusions which we believe should receive full consideration in any determination by the responsible environmental agencies as to appropriate thermal standards for Lake Michigan.

The Federal Power Commission is charged by law with responsibilities and duties to promote and encourage the voluntary interconnection and coordination of electric power systems of the Nation in the interest of "assuring an

abundant supply of electric energy throughout the United States with the greatest possible economy and with regard to the proper utilization and conservation of natural resources." This is quoted from the Federal Power Act. Reliability and adequacy of electric power supplies are basic to the accomplishment of these goals.

This statement, therefore, sets forth the needs and projected supplies of electric power in the Lake Michigan area, indicates the possible effects of proposed thermal criteria for Lake Michigan on the reliability and cost of power supplies, and urges that these matters be fully considered in the balancing of objectives that will be necessary in adopting final thermal standards for Lake Michigan waters.

Currently there are 23 electric utility steam-electric plants located on Lake Michigan and utilizing lake water for condenser cooling on a once-through basis. All except one small nuclear plant are fossil fueled. As shown in Table 1 of this report the total capacity of these plants is 8,393 MW.

(The above referred to chart follows.)

Table 1
Existing Utility Steam-Electric Plants
Obtaining Cooling Water From Lake Michigan

Utility System	Plant Name	Fossil or Nuclear	Installed Capacity, MW
Commonwealth Edison Co.	Waukegan	F	1,047
	State Line	F	944
Consumers Power Co.	Big Rock Point	N	75
	Campbell	F	650
	Cobb	F	511
Northern Indiana Public Service Co.	Bailly	F	616
	Michigan City	F	211
	Mitchell	F	529
Wisconsin Electric Power Co.	Commerce St.	F	35
	Lakeside	F	311
	North Oak Cr.	F	500
	Port-Washington	F	400
	South Oak Cr.	F	1,170
	Valley	F	275
	East Wells	F	15
Wisconsin Power and Light Co.	Edgewater	F	459[1/]
Wisconsin Public Service Corp.	Manitowoc	F	10
	Pulliam	F	393
Winnetka Municipal	Winnetka	F	26
Escanaba Municipal	Escanaba	F	23
Holland Municipal	DeYoung	F	83
Traverse City Municipal	Traverse City	F	35
Manitowoc Municipal	Manitowoc	F	75
		Total	8,393

1/ Wisconsin Public Service Company owns 32% of the second unit (330).

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MR. WARREN: These 23 existing steam-electric plants are operated by six privately owned and five publicly owned electric utility systems. As shown in Table 2 of the report, the plants obtaining cooling water from Lake Michigan provide from 18 to 100 percent of the capacities of these systems and account for 41 percent of the combined system capacities.

(The above referred to chart follows.)

Table 2
Utility Systems with Steam-Electric Plants
Obtaining Cooling Water From Lake Michigan

Utility System	Total System Capacity, MW	Steam-Electric Capacity With Lake Michigan Cooling, MW	Percent of System Capacity with Lake Michigan Cooling
Commonwealth Edison Company	10,877	1,991	18
Consumers Power Company	3,411	1,236	36
Northern Indiana Public Service Co.	1,460	1,356	93
Wisconsin Electric Power Company	2,706	2,706	100
Wisconsin Power and Light Company	908	459	51
Wisconsin Public Service Corporation	733	403	55
Holland Board of Public Works	83	83	100
Traverse City Elec. Light & Pwr. Dept.	35	35	100
City of Escanaba	23	23	100
Village of Winnetka	26	26	100
Manitowoc Public Utilities	75	75	100
Total	20,337	8,393	41

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MR. WARREN: To meet the growing utility loads in the area, additional capacity is being installed at one existing fossil fueled plant and five new nuclear plants are being constructed. As shown in Table 3, the total additional capacity being provided amounts to 7,043 MW.

(The above referred to chart follows.)

Table 3
Utility Steam-Electric Plants Under Construction
With Planned Use of Lake Michigan Water for Cooling

Utility System	Plant and Unit	Fossil or Nuclear	Installed Capacity, MW	Scheduled In-Service Date
Commonwealth Edison Co.	Zion No. 1	N	1,000	4/72
	Zion No. 2	N	1,000	5/73
Consumers Power Co.	Palisades	N	812	12/70
Northern Ind. Pub. Serv. Co.	Michigan City (Add.)	F	500	6/73
Wisconsin Elec. Power Co.	Point Beach No. 1	N	502	12/70
	Point Beach No. 2	N	502	9/70
Wisconsin Pub. Serv. Corp.	Kewaunee	N	527 1/	6/72
Ind.-Mich. Electric Co.	Cook No. 1	N	1,100	9/72
	Cook No. 2	N	1,100	6/73
	Total		7,043	

1/ Jointly owned with Wisconsin Power and Light Co. and Madison Gas and Electric Co.

As planned, the new plants and plant additions would also utilize lake water on a once-through basis. Thus, with completion of these additions, 28 plants with a total capacity of 15,436 MW would be using Lake Michigan for the dissipation of waste heat.

Of the six utilities listed in Table 3, the Indiana-Michigan Electric Company, which is constructing the Cook nuclear plant, is part of a larger system with most of its load extending far from Lake Michigan. Table 4 shows for the other five systems operating in the Lake Michigan area the projected load-supply situation in 1973 when all plants under construction are scheduled for completion.

Table 4

Load-Supply Situation for Summer 1973
Selected Utilities Adjacent to Lake Michigan

	Megawatts
Dependable Capacity, June 1970	20,428
Capacity Additions near Lake Michigan by June 1973	4,843
Other Net Capacity Additions by June 1973	3,929
Dependable Capacity, June 1973	29,200
Load, Summer 1973	23,081
Reserves	6,119 or 26.2%

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Table 4 indicates that these five utilities in the Lake Michigan area have adequate reserves for the summer of 1973. However, the figures do not take account of firm purchases and firm sales, both of which could have a significant effect on the reserve margin. The figures are also based on the assumption that all capacity additions listed in Table 3 would be completed without delays. The Zion No. 1 nuclear unit and Michigan City fossil plant addition are scheduled for operation in May 1973 and June 1973, respectively. Should these units be delayed, the reserve for the summer of 1973 would be reduced by 1,500 MW to 20 percent. The summer 1970 reserve margins for these utilities, exclusive of firm purchases and firm sales, was 13.0 percent -- not a very healthy margin.

The Commission considers that a reasonable reserve margin for utility systems served predominantly by thermal plants is about 20 percent. It is clear, therefore, that the capacity additions under way provide needed reserve margins and that any significant delays in plant completions would reduce the reserves below margins of safety for reliable service.

The electric utilities serving the areas surrounding Lake Michigan are located in four power

supply areas as defined by the Federal Power Commission. I won't review the detail in those areas. I don't think it is critical, but as shown in Table 5 power supply area 11 consists primarily of the Lower Peninsula of Michigan. Power supply area 12 consists primarily of the State of Indiana. The eastern half of Wisconsin and the Upper Peninsula make up power supply area 13. Approximately the northern one-fourth of Illinois, including the Chicago area, comprises power supply area 14.

(The above referred to chart follows.)

Table 5
Projected Electric Utility Energy Requirements and Peak Loads
for Power Supply Areas Surrounding Lake Michigan
(Energy in Million kWh; Peaks in Thousand kW)

Power Supply Area	1970		1980		1990	
	Energy	Peak	Energy	Peak	Energy	Peak
11	56,210	9,990	102,000	17,600	181,000	30,600
12	63,120	11,500	123,000	22,000	233,200	41,400
13	27,400	4,660	50,500	8,150	91,300	15,290
14	52,300	10,070	105,000	19,810	195,000	39,020
Total	199,030	36,130	380,500	67,920	700,500	124,310

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MR. WARREN: As shown in Table 5, the energy requirements and the peak loads of these areas are both projected to increase in 1990 to approximately three and one-half times the 1970 amounts.

It should be noted that a large part of the load in power supply area 11 is and will be centered around the Detroit area. However, projections are that a substantial amount of load growth will occur in western Michigan on the eastern shore of Lake Michigan. The majority of the load growth expected for power supply area 12 will be in the middle and southern portions of Indiana, but a significant amount will be in the northern section around Gary, Indiana. Almost all of the loads projected for power supply areas 13 and 14 will be on or near Lake Michigan.

As shown in Table 6, the annual rates of growth for power supply areas 11 and 13 are projected to be slightly lower than the total rate for the four power supply areas considered.

(The above referred to chart follows.)

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Table 6

Annual Compounded Percent Increase of Projected Electric Utility Energy Requirements and Peak Loads for Power Supply Areas Surrounding Lake Michigan

Power Supply Area	1970-1980 Energy	1970-1980 Peak	1980-1990 Energy	1980-1990 Peak
11	6.1	5.9	5.9	5.7
12	6.9	6.7	6.6	6.5
13	6.3	6.2	6.1	6.0
14	7.2	7.0	6.4	6.5
Total - 4 Areas	6.7	6.5	6.3	6.2
Total - U.S.	7.3	7.2	6.6	6.6

I am going to draw some just general numbers from this table, but let me interpolate one moment: The Federal Power Commission has not extended its projections forward to the year 2000 which was used by the Department of Interior in its study and we certainly have not projected our rates forward to the year 2000 for the same heat projection rates which are prevalent in the year 1970.

But in our discussion in Table 6 of the percentages of increase of projected loads in these supply areas around Lake Michigan, the average for the four areas of annual increase in energy capacity is 6.7 as compared with the total U.S. average of about 7.3. That is the

decade 1970-1980. The decade 1980 to 1990, the projection is about 6.3 percent as compared with the projection of the country as a whole of 6.6.

To meet the projected loads in 1990, substantial amounts of generating capacity in addition to that existing and under construction will need to be installed in the Lake Michigan area. Estimates made in connection with updating the National Power Survey indicate that approximately 4,000 MW of new fossil fueled capacity and 20,000 MW of new nuclear capacity would be constructed on or near Lake Michigan. Thus, by 1990 nearly 40,000 MW of steam-electric capacity could be located so as to use Lake Michigan waters for cooling.

Should the projected 24,000 MW of thermal capacity not now existing or under construction be required to have auxiliary cooling facilities rather than once-through systems, the additional plant costs would be an estimated $130 million, using for auxiliary facilities about $10/kw. for nuclear and $7/kw. for fossil plants. The added consumptive use of water would be approximately 300 cubic feet per second.

If all of the 15,000 MW of capacity existing and under construction required conversion from once-through cooling to the use of auxiliary cooling facilities, the

required investment, exclusive of sunk costs in constructed facilities, could be of the order of $150 million, using somewhat higher unit costs than for the supplemental additions to new plants. This would not make allowance for the unavailability of capacities during conversion periods. The increase in consumptive use of water resulting from the alterations would be about 190 cubic feet per second.

Before stating our conclusions, it is in order to make a few comments concerning the principal report of the Department of the Interior dated September 1970 (referred to above), which provides some of the basic background for this conference.

First, the report presents no newly defined proposal with respect to a thermal rise limitation for the lake and therefore we have had to assume that the proposal of 1 degree Fahrenheit rise still stands and I gather that is the Department's proposal.

Second, the introduction of the report, which contains the conclusion "that no significant amounts of waste heat should be discharged into Lake Michigan," appears to rest on certain major assumptions presented in that report. One of the principal assumptions is that the waste heat discharged from power plants into Lake Michigan

by the year 2000 will increase approximately tenfold from the present 40 billion B.t.u.'s/hour in 1968 to about 431 billion B.t.u.'s/hour in the year 2000. This presumes no change whatever in the technology of cooling power plants in this region in the next 30 years, and therefore reflects a straight arithmetic increase of heat load by the projected increases in power capacity. Thus, even though about 80 percent of the postulated direct heat load would accrue from units not coming onstream until the 1980's and 1990's, the Department is advocating immediate imposition of the proposed 1 degree Fahrenheit limit.

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contributing to degradation of the quality of lake waters and its biota. These include not only thermal loading but also industrial pollutants, human and agricultural nutrients, and past inadequate management of fisheries. The proposed thermal limitations can hardly be expected to achieve their intended purpose unless these other factors are correspondingly improved.

In a quick review, as my earlier question indicated, we felt that some of the basic cost assumptions as to capital cost, fuel cost, cost of net service, are probably not realistic for the period we are looking at.

Sixth, the studies emphasize the critical importance of the inshore portions constituting only 6 percent of the lake's volume and its biologically most productive area. No consideration appears to be given to the possibility that some of the fringes of the other 94 percent of the lake might support enhanced productivity if they shared some of the heat from inshore, perhaps promoting bottom upwelling, as the Department of the Interior has suggested elsewhere. Considerations such as these prompt us to say that the function of regulation is not to dictate engineering choices but rather to set environmental objectives to be achieved and leave to biological/engineering the design of individual solutions

suited to particular situations.

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failure to do so would seriously jeopardize human health and safety or major ecological systems. In consequence, any adoption of new thermal standards should be applied in specific situations in a manner designed to avoid jeopardy of electric power supply schedules.

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with the reported potential environmental effects which will not change very greatly in a matter of months.

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c) Individual consideration of the merits, the time schedules, and the economic consequences of applying similar standards to existing plants which are generally of smaller capacity and have more limited life for cost amortization.

5) In view of the responsibilities and concerns expressed herewith on behalf of the Federal Power Commission, and the important impact which any decisions here have on the power programs we have cited, it is requested that the Federal Power Commission have the opportunity to review any proposed revised thermal effects standards for Lake Michigan and plans for their implementation before such plans are adopted.

Thank you for the opportunity of making a statement.

(The following attachment was presented for inclusion in the record by Mr. Warren.)

Attachment 1.

LAKE MICHIGAN THERMAL EFFECTS STUDIES

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13.	Ecological studies at Cook plant	Pre and post operational ecological studies	Univ. of Mich. (Dr. J. C. Ayers)	1969-

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MR. STEIN: Thank you, Mr. Warren.

I would like to clarify one thing before we throw this open for questioning.

The recommendations here are recommendations of an investigatory group, and I thought we have tried to make that clear many times. The equating of this with the Department of Interior position would preclude the need for a workshop such as this. We are trying to arrive at one.

MR. WARREN: I am not sure I understood your comments, Mr. Chairman.

MR. STEIN: The comment was: You keep referring to a Department of Interior position. We are here to try to see if we can get the information for a Department of Interior position. We have a recommendation of an investigatory group or several investigatory groups within our Department.

MR. WARREN: We were not quite clear, sir, at the opening of the meeting what your position was.

MR. STEIN: We certainly appreciate the information we have here, but there is one thing that seems to me to be lacking. With all of the information that the Federal Power Commission has, can we get information on how much these plants are going to raise the temperature. We

keep talking about the 1-degree spectrum on one side, or substantially no degree rise, but it seems to me I have heard that some of these plants intend to raise the water 18 degrees or something for the amount of water that they are taking in when they put it out.

It is possible that the Federal Power Commission knows how much temperature rise we are going to get from the plants that are on the drawing boards now.

MR. WARREN: Mr. Stein, I am quite satisfied that the information with respect to the thermal differential planned by all of the plants now under construction could be brought forward at any time. I am sure this is available.

MR. STEIN: I think this would be important.

MR. WARREN: And I certainly think this is very much the kind of information which the conferees would want to analyze.

MR. STEIN: That is right.

Now, I run into some problems here. Maybe some of these are philosophical but I don't think so.

You say on page 17, "Since so many studies are still in progress, it is not yet possible to assess the import of their conclusions along with the data contained in the Department's report. We see evidence of potential

for damage,but not evidence of an imminent crisis in the condition of the lake. In our opinion, it would be desirable to consider carefully the results of all these studies, and so forth, before we institute major actions."

Well, the problem that I have with that, Mr. Warren is: This is the argument I have been hearing for 30 years about pollution action—that we have all these studies and we should continue in them and it is not conclusive, and we really don't have a crisis. That is why we have the crises now.

Do you really think in this day and age that this is the attitude that we should adopt?

MR. WARREN: Mr. Stein, I don't think that is a fair interpretation of my suggestion. We are saying that because this issue has been raised and focused particularly in the last year or two, that there have been initiated a number of studies and the Department's report takes the account only of certain studies and not of all -- including some of the studies referred to this morning which are pertinent to the subject. There are others which are in progress, and there are still other opportunities we would prefer for considering alternate means of cooling and what their effects would be on the thermal condition of Lake Michigan.

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We are certainly not in any sense advocating indefinite postponement of decisions. Far from it. We believe that the conferees would want to arrive at a focal decision within a very reasonably short period of time, but it should take into account all information which is reasonably pertinent.

MR. STEIN: We agree with that, but the point is: As you know, we are proceeding in some places with what is apparent to be power shortages and the need for more power, and as you delay these decisions you are faced with that Hopkins choice of either taking the choice of the environment or having a brownout.

Now, I think we have let this go so long that I am not sure how much time we have to further study this before we make a determination. If we are going to achieve the desires certainly of the power industry and the Power Commission and certainly of me, that is to have enough power on the line when the people need it, it seems to me that we have to make these choices fairly rapidly.

MR. WARREN: No question but what they should be made in a timely fashion to ensure that the condition of the lake does not degrade further; in fact, is on the way to further improvement. We think there is opportunity for doing that.

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We are concerned with legislating only certain types of cooling solutions to be open for consideration. We do think that it would be desirable to permit engineering ingenuity to come into play and, as a very mild thought, some of these plumes may, in fact, even be considered biologically useful devices. That may be a far-out thought, but I wouldn't want to see it deflected completely out of hand when we are looking into a period of 30 years into the future.

We are asking the conferees to consider dealing with ecological principles rather than specifying engineering solutions.

MR. STEIN: Well, that is another point I wanted to get at.

What do you mean by "ecological principles"? Do you mean a water quality standard rather than an effluent requirement?

MR. WARREN: What I mean there is: The purpose, I believe, of all of the water quality standards is to protect the biosphere; is to protect the natural conditions, and to try and preserve as well as one can while still permitting man's services and needs to be provided for, to protect the biosphere and to improve it. And that is the whole purpose of the regulations.

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MR. STEIN: I understand it, but let me see if I understand you. Do you object -- whatever the amount is -- to setting an absolute temperature amount, or setting the degree rise at the effluent pipe? Do you object to that kind of approach?

MR. WARREN: No, not so long as it is expressed in a way which does permit people to satisfy the protection of the environment by a variety of different techniques if they are applicable. If the degree limit at the pipe is that one-tenth of one degree, I suspect it doesn't permit any alternates at all to be considered. I am not sure that one degree does either. But the purpose is to prevent degradation of the fisheries, the aquatic forms in the lake.

MR. STEIN: But you have no objection, as I understand --

MR. WARREN: Yes.

MR. STEIN: -- if we set a limitation of the heat coming out of a pipe?

MR. WARREN: I am not here to design a regulation with you at this moment.

MR. STEIN: No, I want to understand what your prohibition is. Does your prohibition speak against this in your paper?

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MR. WARREN: Well, my impression, Mr. Stein, is that 1-degree limit leads directly to saying that the only techniques of cooling to be considered are in effect cooling towers or cooling ponds. That is the practical result of it.

MR. STEIN: Let me go back to the question. Let's forget this 1-degree limit for a moment. Let's talk in terms of setting a degree rise -- whatever is considered to be reasonable -- or a maximum temperature at the pipe.

You don't object to that in principle, do you?

MR. WARREN: No, I don't think so. I don't think so. And there would also be the question of whether you are going to permit any mixing zone situations whatever --

MR. STEIN: Well --

MR. WARREN: -- if you had some differential on the pipe.

MR. STEIN: Now, fine. Let me just throw this out, I know a lot of members of the industry are here, and at least I think I have a conviction that I have no problem with either one. But let me suggest that even if you have to go up a little more at the pipe, it might be easier for the regulatory agency and the industry to

consider the point of regulation as the point. I am just putting this out for all of you to consider. This is the one area that the industry can control, and it is all within the scope of its operation. It is also the area that the regulatory agency and both parties can go to and check the temperatures. Otherwise, if you go to mixing zones, here is the problem: I find if you set a mixing zone, you have to go along with a general principle. You adjust it as you get in the lake, as you get on the river, as you have the impact with another plant that also has a mixing zone which might overlap yours, etc. They may be different in all cases.

Then you have the additional problem of both the industry's and the regulatory agency's seeing if you are complying. You are dealing with a tongue of heat which may go out of a mixing zone at a variety of levels for an hour, 2 hours, 3 hours, and come back and forth. And you may get into interminable discussions, interminable arguments on places where you are cited for violations which you don't think are reasonable -- say for violations caused by climatic or hydrologic conditions which may be beyond the control of the company, and which were not fully understood when this was set up.

When we design any kind of a treatment plant we

have a theory of what is going to happen when we design it. So, I would suggest that if we had a theoretical mixing zone, as we do in other places, then we can place your requirement at the place where the industry can control it, and the regulatory agency can measure it, and if the industry meets that requirement, that is fine. If we made no judgment on the effect of the water quality, which I don't think we do very frequently, but if we ever then go back and reevaluate it -- but this is a key point that I really would like the industry and the Federal Power Commission members to think about because I think if we can arrive at an agreement on this, I would hope that we can get together on our method of relating it, at least from the standpoint of methodology, whatever that might be.

MR. WARREN: Let me respond off of the top of my head, Mr. Stein.

I think you are moving in the direction which is quite constructive, particularly if you would couple it with something which was mentioned earlier. I am not sure whether it was rejected or accepted.

That is, I think such end-of-the-pipe attempts to implement a code with pre-operative and post-operative biological monitoring, would begin to develop the kind of data -- not only develop the data but provide a guidance

program and a monitoring program which will assure everybody that we are getting somewhere in terms of environmental protection.

I think it is quite important that this be carried forward and be carried forward very extensively with maximum cooperation hopefully between the Government and the people at the operating facilities.

MR. STEIN: I think we agree, but let me again frame the question.

We are all agreed on pre- and post-operative monitoring. The question is: How much are you going to take a chance with a river or a lake to let that be used as an experimental guinea pig, so to speak, and how much are you going to be restrictive before you start? This is really the key question.

I don't think that anyone disagrees that we should check the water before and after and determine exactly what has happened. But I think the problem we have to face is: What do we think is reasonable prudence in requiring environmental protection before the plant goes into operation, rather than to see how much damage, if any, it does?

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MR. WARREN: I think the solution obviously is that the objects have to be tailored to the individual choice, and there are some parts of the inshore area that I am sure are ecologically extremely sensitive and critical; there are others which I feel sure are not so critical; there is the potentiality for the areas beyond the inshore area where possibly economics may say you can carry out discharges or maybe you cannot. But I think those possibilities should be entertained and I don't advocate that this great lake be used as an indepth test bed, but it has essentially been used as a test bed by men up to the present time.

Now, we are saying, "let's do this far more closely, more intelligently, and be prepared to spend whatever money it is reasonably necessary to improve the protection of the ecology in the future."

MR. STEIN: Right. Now, there is one other point, on page 17. I have two. Let me try this one first. You say, "It is apparent that ... electric power (is) ... of such importance to the health and well being of inhabitants of this area and their economic situation that it would be unacceptable to curtail the scheduled power projects unless it were clearly demonstrated that failure to do so would seriously jeopardize human health

and safety or major ecological systems."

Could you say the same thing, I guess, for steel? Could you say the same thing for oil? And the point is: If you are going to say that what you are doing is of such importance that you cannot interfere with the scheduling that that industry puts out itself, that unless we can clearly demonstrate that failure to do so would seriously jeopardize human health and safety or major ecological systems, I wonder if we are not going to set a precedence for the other basic industries in the country?

MR. WARREN: Mr. Stein, I think this is a reasonable statement of the kind of balance that has to be worked out with respect to the treatment of facilities in operation and scheduled to go into operation.

I don't think that one can find in this report the clear demonstration that human health and safety are threatened or that major ecological systems within this decade are going to be wiped out, destroyed, or anything of that sort.

If this were there, one couldn't say that you should leave these schedules inviolate.

MR. STEIN: Sir, what you are saying sounds like what we have heard over the past quarter century. If you cannot demonstrate that human health or safety is going

to be concerned and clearly demonstrate it, we go ahead with the project. We have done that over and over and over again, and look at the condition of our waters.

Let me make the suggestion here that I think will cut through this: If the industry using this would come forward and indicate that its use of this water, and heating of this water will not endanger health, safety or ecological systems -- and I don't know that I would buy that adjective "major" -- major ecological systems, I think we can get around it.

MR. WARREN: Significant.

MR. STEIN: But I think the industry using this has the same job we have. Now, we have worked this out I think with other industries, and really to the power people here I say: I hope we can do the same thing with this industry.

For example, the packing house industry, the pulp and paper industry, the steel industry, the chemical industry, each comes forward and in building its projects, takes upon itself the responsibility to show that its facilities will not produce any undesirable ecological effects. I hope we can get the same kind of cooperation from the power industry. I look forward to that.

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MR. WARREN: I think you should expect the power industry to deal fully with the biological assessments related to their discharges.

MR. STEIN: There is just one last point that I would like to make. You say, "The report refers to a number of factors contributing to degradation of the quality of lake waters and its biota." This is on page 15. "These include not only thermal loading but also industrial pollutants, human and agricultural nutrients, and past inadequate management of fisheries. The proposed thermal limitations can hardly be expected to achieve their intended purpose unless these other factors are correspondingly improved." And I agree with that statement thoroughly.

But the way I look at it, it may go the other way around. We have been out here since 1965 and we have the people spend hundreds of millions of dollars correcting the industrial pollutants, the human and agricultural nutrients. We have a very severe phosphate restriction on the management of the fisheries.

In other words, if these people are embarked on the program, you can hardly expect them to spend all that money and not expect the power industry to bear its share of protecting the water quality and keeping the heat

within limits which will protect the ecology.

MR. WARREN: I agree with you thoroughly. It should be a balanced program.

MR. STEIN: Right. Thank you.

Are there any other comments or questions?

If not, are there any people in the audience who wish to come up?

MRS. BOTTS: Mrs. Lee Botts of the Open Lands Project. I am going to presume to ask questions of a representative of the Federal Power Commission because I was invited by the Energy Policy Staff of the Office of Science and Technology to represent the Great Lakes area in a study of power plant siting problems, and attend meetings in Washington in connection with this study.

I have two questions which I think are pertinent in the context of the current discussion. One is: Is the power industry trying to meet a need that is being generated by the public, or is it generating a need, so that it could meet it? I say that because we are all familiar with the ads promoting the use of electricity and promoting the use of electricity over the use of other sources of energy. This advertising continued this past summer with assurances from Commonwealth Edison, which is the utility in this area, that it could meet the power

need at that same time that it was being forced to cut back some of its voltages. That led me to the second question.

MR. STEIN: Well, I don't know if it is appropriate for Mr. Warren to answer the question. He is not the industry, he is the Federal Power Commission.

MRS. BOTTS: I understand, but he has been speaking on behalf of the industry and the Federal Power Commission. (Applause)

And the Federal Power Commission is intimately involved in the question of whether the power need which the industry has defined should be met.

MR. WARREN: I would like to respond to the lady's question. Let me first say I am speaking on behalf of the staff of the Federal Power Commission and I am not speaking on behalf of the electric utility industry. I am expressing in the most thoughtful and sincere way the views that derive from the information and background that we have with respect to this picture overall.

Now, this question which you speak of with respect to electrical demand and whether or not the industry is sort of carrying out a self-fulfilling prophesy -- I have heard this term used -- the industry

goes out and prophesies 7 percent per annum rate and then goes out to build plants to meet it, and then goes out to sell that power to the customers. That is the theory which is advanced in support of this particular label.

As a business man -- and I have been a business man -- I think there is no such thing as that kind of a self-fulfilling prophecy.

At any rate, more to the point: When one looks quite seriously at what is the demand for electric power and how it relates to the demands in the household, the vote for that power is the turning on of a switch or the buying of electrical appliances. The other things are conversions in industry to electrified processes as a substitute for other things.

When one looks at the question of whether or not you have been curtailed in the demand by some monitoring or enforcement program, you cannot escape the fact you are really talking about managing the economy of this country, and it is not something which is being managed by the advertising program in the electric industry, in the opinion of this individual, it is something which is intimately woven into the population growth, the household expansion, and the industrial problems -- industrial activity in the country. This

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is a very exhaustive subject.

My opinion is -- and you can only accept it as mine, I am sure -- is that the demand rate is something which is written right into the way this country is growing today.

MR. STEIN: I am not sure that that is what Mrs. Botts is asking.

Let me try to rephrase it because this might help. The other day, as I was sitting sweltering back in Virginia -- as I guess you may have been -- and reading about the brownout and having to shut the lights off in my office in the afternoon because they said all offices with windows had to turn their lights off -- and I guess I am fortunate enough to have a window -- and after I got home, and then I had TV on and a TV commercial came on and it said, "These are the smart people." And it showed a bunch of people walking around who had electricity for their whole home, not other means of power, and I think this is really the issue Mrs. Botts was referring to. We all recognize that we have this question of the expansion. And the question is, as I understand it: Is the industry promoting something and selling power in the face of shortages?

Again, Mr. Warren, I am not sure you are the

man to answer that question.

MR. WARREN: I will make three quick comments. One, I am not here to defend the industry's position on that subject. Two, there are some industries, some power companies which have actually cut out promotional programs because they are not sure, at least in a given period of time, that it is a useful thing. There is, however, a school of thought within the industry that such promotion is desirable to help balance out the loads during different seasons of the year, and thereby in effect keep the total cost at a more reasonable level. Whether these are all definable, defensible arguments I am not here to really support them.

MRS. BOTTS: Well, I had a second question.

MR. STEIN: Fine.

MRS. BOTTS: And that is: Are more production facilities needed in the magnitude that has been described this morning, or do we need other changes in the system of producing power such as changes in the rate structure?

At the present time, the rate structure encourages the large use of electricity by making it cheaper at a per unit rate, so that right here in Chicago, for example, we have many large office buildings that never

turn off their lights because it is cheaper to buy more electricity than to pay somebody to turn the lights off.

At O'Hare Field, the lights in the parking area around O'Hare are left burning 24 hours a day, 365 days a year, and I submit that it is not worth taking chances on losing the life of Lake Michigan in order to keep the lights on at O'Hare Field 24 hours a day.

MR. STEIN: Do you care to respond to that?

MR. WARREN: Well, there are some assumptions in your question, Mrs. Botts, and I can't readily accept them. The two aren't directly equated.

With respect to the matter of rates -- let me just deal with that because that is a more substantive point, I think. The fact is that one can readily expect that the costs of protection such as were being discussed earlier this morning need to be reflected in electrical rates, and these probably will amount to somewhat more than was indicated by the observations here, and these will be felt by the customers both residential and industrial, and these may have some influences themselves on the rate and the manner in which they may be used realistically. That is a very little thing, and I think that we will agree that is how it is reflected.

MRS. BOTTS: I would say finally that in a meeting

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in which I participated last spring, Joseph J. DeDinunno of the Atomic Energy Commission stated that there was not much hope for conservation in reducing the power need by encouraging individual home consumers to lower their rate of usage because 70 percent of the electricity we produce on the shores of Lake Michigan would be used for industry.

Would you say that this electricity is to be produced (of which 70 percent will go to industries) for industry that will be located in this region, or is Lake Michigan going to be used as a resource to encourage other location of industry on the shores of Lake Michigan -- in which case that might be another environmental by-product of permitting the unrestricted use of the water for cooling -- or is Lake Michigan going to be used to support industrial activity in other regions through transmission of electricity to other locations?

I think for the public which has to, in the end, make the final decision, these are factors which need to be elucidated and understood as well.

MR. WARREN: You have presented like a half a dozen questions in one, and it is that kind of a question.

I would like to be sure I know your name, too.

MRS. BOTTS: I am Mrs. Lee Botts, and I am Executive Secretary of the Lake Michigan Federation, which

is sponsored by the Open Lands Project. Thanks for the free plug.

MR. WARREN: Very happy to do it, and I appreciate very much what you and your colleagues have contributed to the power plant siting survey that you spoke of in Washington, and I am quite familiar with it, and we are hopeful that this study will be very helpful when it is available to deal with some of the points that you have raised.

But without going further on that point, the question of whether or not household consumers, for example, have any influence on electrical use within spheres of demand, there are real ways probably in which they can: by not setting the air conditioner higher, deciding not to have a frost-free refrigerator but a more conventional refrigerator which only uses about half as much electricity, or have a black and white TV set instead of a colored TV set -- it takes about half as much electricity -- all of those choices will be available to the individual. They are available now and they will be available in the future.

The industrial demand is not like 70 percent; it is probably like 40 percent of the total demand in the area. It is roughly, I think, 30 percent residential

customers, 25 or 30 percent commercial, and the other 40 percent industrial is about the way it breaks down.

Now, this thought about Lake Michigan being used, let's say, as a national cooling pond from which electricity will be generated to power many other regions around the country -- I don't think that is a realistic situation. This reserve number, which I referred to earlier, indicates that the amount of power that is being generated here is about reasonably related to what are the local demands in this area. And let me urge you and others to recognize that you cannot go too far in this thought of: "I didn't want the power plant here because I don't need electricity here, it is for a fellow over there"-- if we did this with respect to all of your industrial needs -- some guy doesn't want an automobile plant here because he would rather walk; some guy doesn't want a shoe plant here because he can go barefooted. I am not expressing this too well, but we have an industrialized economy in which we are interdependent with each other, and that is what the power situation reflects, too.

In answer to your question, I don't think the picture, if examined in detail, would show that Lake Michigan is being used just for somebody else's power rather than for this region.

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MRS. BOTTS: Well, I guess I will have to go back to the Atomic Energy Commission and find out the source of their failures, and I agree with you that there may be some other factors that will enter into the question. David Freeman, who is the Director of the Energy Policy Staff, for example, feels that -- and has so stated in public -- that the large user of electricity should pay correspondingly more rather than less. That is not a question before this conference, but because economics were brought up, I wanted to get into the record the fact that in considering the total picture, we might consider trying to partly solve the problem in some other ways than using the waters of Lake Michigan. Thank you very much.

MR. STEIN: Thank you, Mrs. Botts.

Would you come up?

MRS. GURLOCHER: My name is Irene Gurlocher of Munster, Indiana. I am speaking as an individual.

Mr. Warren talked about not enough evidence of crisis and before that he mentioned we will leave this to the biological engineering, and he mentioned $300 million would be required for cooling towers for both new equipment and conversion.

Do you have any idea of how much it will cost after there is a crisis; if you have enough evidence of

crises, how much it will cost for biological engineers to bring Lake Michigan back to the condition it is now? Would it cost more than $300 million that the cooling towers will cost?

MR. WARREN: There is no figure existant.

MRS. GURLOCHER: Don't you think that is part of your point?

MR. WARREN: My responsibility and that of these conferees -- particularly of these conferees -- is to consider a program that prevents that crisis from ever arriving or ever having to go to a corrective program.

I thoroughly agree with that philosophy and I am not suggesting that we push beyond the crisis point and fight our way back.

MRS. GURLOCHER: In the responsibility of the Federal Power Commission you mentioned abundant supply of power and conservation of natural resources. How is that weighted by the Federal Power Commission? How much attention is given to the conservation of natural resources in their decision-making? Five percent; 2 percent?

MR. WARREN: Do you know, Mrs. Gurlocher, it is impossible to quantify it? That is the very essential difficulty of the problem. But let me say since the 1920's when the Federal Power Commission was initially charged, it

has had to decide this kind of question. It has to consider in the building of hydroelectric plants what is the need for this power and the effect of this dam, and how could they minimize the impact of this on a stream by maintaining stream flow and assuring preservation of fisheries, use of the lake for recreational means, and how do you equate a recreational facility versus so many kilowatts of power. It is imponderable, in a quantitative sense, but it can be done on the best judgment of men. That is all.

MRS. GURLOCHER: We know the mess we are in, but I think maybe more weight should be given to the conservation of natural resources.

I have another question. You talk about power plants far advanced in construction. There is a power plant in Indiana that has $1 million spent without a permit yet from the Army Corps of Engineers; would you consider that far advanced in construction?

MR. WARREN: I don't know. I would have to look at the specific plant.

MRS. GURLOCHER: The Michigan City plant.

MR. WARREN: I am not even saying that one cannot consider in a given design and construction situation whether or not auxiliary cooling can be added

to it, I am suggesting simply that in developing regulations and their means of implementation that one take account of the special situation in plants in construction and not eliminate the potential kilowatts that they may generate from the time they start up by the need to deal with a cooling situation. If they need auxiliary cooling, it can be provided, but it doesn't need to prevent you and the other people from getting the power they need.

MRS. GURLOCHER: What if they don't get a permit and they have to move their plant? What about that million dollars that they have already spent there? I don't know that I should have to pay that as a consumer if it is poor planning.

MR. WARREN: Let me say, in the broad sense -- and I am very much concerned with this question, and we are very much involved with this question which is a proper power plant siting procedure, the advanced review of the plans for power plants, and transmission facilities, and all the rest of it -- this should involve the proper solution for the views of citizens like yourself and others, the view of public individuals. This is all part of the process which should be improved and which we hope will be improved.

MRS. GURLOCHER: Before or after all these plants

are built on the lake?

MR. WARREN: Oh, in the process of building them.

MR. STEIN: Let me ask you one question, Mr. Warren.

Is the Federal Power Commission involved in the licensing and the regulation of any of the plants on Lake Michigan? I don't think so.

MR. WARREN: Well, not directly, Mr. Stein. The answer is we do not have licensing responsibility with respect --

MR. STEIN: In other words, to promote and encourage the industry in that capacity.

MR. WARREN: That is right. We are, as you know, under the Environmental Policy Act of 1969, required to comment on the agencies that may have licensing responsibility, but not with respect to the environmental factors there.

MR. STEIN: I don't want to cut anybody off, but I think we should recess for lunch. We will stand recessed for lunch until a quarter after 2:00.

(Noon recess.)

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R. W. Purdy

AFTERNOON SESSION

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MR. STEIN: Let's reconvene. Let's hear from Mr. Purdy first.

Mr. Purdy.

MR. PURDY: Mr. Chairman and conferees, I would like to place in the record a letter dated September 12, 1970, addressed to Mr. Klassen, Mr. Poole, Mr. Frangos, and Mr. Mayo, the four other conferees:

"Gentlemen:

"Our Governor's Advisory Council for Environmental Quality discussed the issues involved in the discharges of heated water to the Great Lakes and to Lake Michigan at its August 4, 1970, meeting. One recommendation adopted suggested that the Michigan conferee present at the next meeting of the Lake Michigan Enforcement Conference, a specific recommendation on temperature requirements that should be observed for the protection of the water environment. In addition, the Michigan Water Resources Commission at its July 23-24, 1970, meeting directed its staff to prepare a new proposed set of temperature standards for interstate waters, based on testimony received at a March 1970 public hearing and information subsequently obtained.

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"We have enclosed for your information and review the staff's report in response to the Commission's directive. It will be presented to the Water Resources Commission for its review at the Commission's regular monthly meeting on September 18, 1970. We hope that the Commission will, with such revisions as it deems necessary, endorse the report as a working document to be used for discussion purposes at the next session of the Lake Michigan Enforcement Conference and with all other States where we share common interstate waters.

"We would appreciate receiving your comments on the proposed temperature standards."

Signed by Ralph W. Purdy.

The Commission did consider the staff's recommendations at its September 18 meeting, and it did endorse the report as a working document for further discussions here at this conference or at any subsequent meeting of these conferees, and also for the staff to discuss with other States where we share interstate waters.

Since this may be referred to later on in the conference by some of the other people presenting statements, we thought it desirable to mention it at this point in time.

MR. STEIN: Thank you, Mr. Purdy.

Opening Remarks - Murray Stein

Before we start this afternoon, I think we should really refer to what we have here as an historic occasion. I recall reading recently about a story in Scotland where the Scotch were inveterate fishermen for salmon, and they asked who caught the biggest fish, and they said one guy went out who had never fished before. He decided just to cast his hook over and he brought in a salmon about 65 pounds.

Maybe some of you people have never been at these sessions before, but you have indeed witnessed an historic occasion because some of us who have been around for 25 years have never seen this before. We have gone a complete morning and Mr. Clarence Klassen hasn't said one word.

MR. KLASSEN: I share the honors with Mr. Poole.

MR. STEIN: No, Mr. Poole did say something.

MR. KLASSEN: No, he didn't.

MR. STEIN: Yes, he did. He asked a question.

MR. KLASSEN: No, he didn't.

MR. STEIN: No, I have been checking it off on my list.

MR. KLASSEN: I accept the honor.

MR. STEIN: I hoped you wouldn't be that reluctant, Mr. Klassen.

MR. KLASSEN: I came here, Mr. Chairman, today

with my mind open and my mouth closed, to set an example. (Laughter and applause)

MR. STEIN: You know, we once had an old doctor, whom many of you knew, in the Public Health Service, Dr. Cronin, who was in charge of the Hill-Burton program -- the hospital program when it came out. I was on the elevator of the old building that we occupied in the Public Health Service years ago, and we ran into a Public Health educator who is very famous. By the way, Dr. Cronin, in addition to that was an excellent diagnostician and an excellent physician, as any of you people who knew Dr. Cronin know. He said, "You know, I ran into a Public Health educator, and I knew he was dead."

And this guy, Bentley, said, "How did you know that?"

And he said, "His mouth was closed." (Laughter)

We will call on the power industry now, and we are going to let them manage their time.

Let me indicate the way we are going to work this. The first two representatives will have to leave. We will permit full questioning by the conferees and the audience of these first two. After that, we will let the power industry run all of the way through and then we will only have the conferees questioning, and the citizen

questioning or the audience questioning will be reserved until the end.

Mr. O. K. Petersen will handle the time for the power industry.

Mr. Petersen.

MR. PETERSEN: Thank you very much, Mr. Chairman.

I would emphasize that in getting together for the purposes of time, we have not been together for purposes of our statements, and each company's statement is independent.

Mr. J. H. Young, Secretary of the Edison Electric Institute will speak.

H. J. Young

STATEMENT OF HERRICK J. YOUNG,
ASSISTANT TO THE MANAGING DIRECTOR
AND SECRETARY, EDISON ELECTRIC INSTITUTE
NEW YORK CITY, NEW YORK

MR. YOUNG: My name is Herrick J. Young. I am Assistant to the Managing Director and Secretary of the Edison Electric Institute, which is the national trade association of electric light and power companies in this country. I also serve as Secretary of the Institute's Committee on Environment, a committee made up of chief executives of EEI member companies which gives special attention to the relationship of the electric utility industry and the physical environment.

The member companies of the Edison Electric Institute are concerned that decisions made by the Federal Water Quality Administration regarding thermal discharges into Lake Michigan will not only adversely affect utility operation in the Great Lakes region, but will also have implications in other parts of the nation. Over the years, considerable knowledge has been gained of the effects of thermal discharges, growing out of research sponsored by EEI and its member companies. For this

reason, the Institute has requested time at this proceeding to present comments by two scientists who are involved in a project that began some 8 years ago and we appreciate having this opportunity.

In 1962, Edison Electric Institute initiated research on thermal discharges at The Johns Hopkins University. Those who initiated this work, which we refer to as RP49, realized that thermal discharges from electric power plants were having relatively little effect on receiving waters at that time. They could see, however, that power plants were becoming larger, that the quantities of cooling water being passed through condensers were increasing, and that better understanding of the potential effects of thermal discharges was needed so that future power plants could be designed in such a way as to have minimum adverse effect on the environment.

The work at Johns Hopkins, which incorporates research at a number of field sites around the nation, has continued and developed since that date. It has increased in sophistication and evolved in response to growing understanding by scientists and utility company engineers of the problems involved in discharging cooling water into natural water bodies.

Individual electric utility companies and groups

of companies have sponsored environmental research at plant sites for many years. We have collected data on much of this research, and I have a catalog of studies which we have passed to the conferees. It indicates that some 120 companies have recently completed 190 environmental water studies, that 166 more are under way, and that as of the spring of 1970, 50 more studies were being planned.

(The document above referred to follows in its entirety.)

A SUMMARY OF ENVIRONMENTAL STUDIES ON WATER PROBLEMS

By investor-owned electric utility companies recently completed, under way, and proposed.

Edison Electric Institute

June 1969

INTRODUCTION

In September, 1968, the Water Problems Task Force of the Edison Electric Institute's Committee on Environment undertook a survey of environmental studies made by electric utility companies in recent years in connection with water problems. Ninety-seven investor-owned electric utility companies responded to the survey, indicating studies that had been recently completed, studies that were underway, and studies that were being proposed. The results showed that electric utility companies have gathered a wealth of information concerning the effects of cooling water discharges from electric generating plants on temperatures and on forms of aquatic life.

The work summarized on the following pages represents field studies at plant sites on lakes, rivers, reservoirs, estuaries, oceans, and other bodies of water. In general, the studies were made to help utility company engineers design electric power plants so that they would have a minimal effect on the environment. As a result of these studies, plant designs have been adjusted, and where necessary cooling towers, cooling ponds, spray ponds and even separate cooling lakes have been constructed.

The studies indicated on the following pages do not represent a full picture of environmental water studies made by electric utility companies. Additional studies are known to be underway by companies which did not respond to the survey, and by other power supply agencies. The survey does give an indication, however, of the depth and breadth of interest in environmental water problems which electric utility companies continue to show throughout the nation.

SUMMARY

ENVIRONMENTAL STUDIES ON WATER PROBLEMS

BY FPC REGION

REGION	COMPLETED STUDIES	STUDIES UNDER WAY	STUDIES PROPOSED
I	58	36	12
II	14	15	3
III	17	12	6
IV	17	10	9
V	17	28	6
VI	6	3	-
VII	4	2	1
VIII	19	7	4
OTHER	1	-	-
	153	113	41

NOTE: 97 Investor-Owned Electric Utility Companies Responded to this Survey. Additional studies are known to be completed and under way by other companies and agencies.

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ENVIRONMENTAL STUDIES ON WATER PROBLEMS
BY TYPE OF STUDY

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REGION I - NORTHEAST

Completed Studies

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
1	5	Feb 1966	Dr John E Edinger Dr John C Geyer Staff	Tidal Estuary	Analysis of water temperature near plant
2	12	Aug 1966	Staff	River	Temperature survey river below discharge
3	35	Continuing	Staff	Estuary	Continuous temperature measurement One Location
4	35	Sept 1963	Pritchard-Carpenter, Cons Johns Hopkins University	Estuary	Concentration distribution for material discharged into bay
5	35	Sept 1965	Dr Charles B Wurtz, Cons LaSalle College	Estuary	Biological study of bay, river and creek in vicinity of plant
6	35	Sept 1966	Burns and Roe, Inc	Estuary	Plant intake fish protection facilities
7	39	Aug 1965	Ebasco Services, Inc	Salt Water	Water temperature studies to determine the effect of two stations on the temperature of the adjoining water bodies
8	43	1960	Pennsylvania Electric Assn Subcommittee on water utiliz	Rivers	Heated discharges - their effect on streams
9	43	1961	Generating Station	River	River temperature. Survey #1

NOTE: "Staff" indicates studies made by biologists, ecologists, or other specialists employed as members of the staffs of the sponsoring companies.

REGION I - NORTHEAST
Completed Studies (Cont'd)

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
10	43	1962	Generating Station	River	River temperature. Survey #2
11	43	1962	Generating Station	River	River temperature. Survey #3
12	43	1966	Generating Station	River	River temperature. Survey #4
13	43	1966	Dept of Interior, Pa, New York, Maryland	River	Suitability of the river for restoration of Shad
14	43	1967	Dr Charles B Wurtz, Cons	River	Biological survey of river
15	48	July 1967	Pritchard-Carpenter Assoc	Coastal	Pre-operational Tracer Study Dye tracer to develop probable thermal distribution of CW discharge from plant unit I
16	48	Nov 1964	Stone & Webster Eng Corp	Estuary	River Temp Survey - 1964
17	48	Jan 1966	Stone & Webster	Estuary	River Temp Survey - 1965
18	48	Oct 1964	Stone & Webster	Estuary	Design Memorandum investigate effects of plant on river
19	48	Sept 1968	Traveler's Research Center	Estuary	Thermal measurements to establish distribution of CW discharge in vicinity of plant
20	48	Dec 1968	Raytheon	Estuary	Survey of the thermal distribution patterns from an existing fossil fuel plant to establish a basis for predicting thermal patterns after addition of new unit
21*	54	1961	Subcommittee Penn Electric Assoc	Various	Evaluations of effects of electric power industry of streams
22**	55	1967	Dr Charles B Wurtz, Cons	River	Biological survey of river

NOTE: * Same as Study #8
** Same as Study #14

REGION I - NORTHEAST
Completed Studies (Cont'd)

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
23	55	1959	Staff & Lehigh U	River	Research project of effects of condenser discharge water on aquatic life
24	55	1967	Staff	River	Temperature distribution in river at particular point
25	55	1965	Staff & Dr Charles B Wurtz	River	Effect of station's condenser discharge on the aquatic life in the river
26	56	1959	Dr Charles B Wurtz	River	Study of the Effects of Increased temperatures on biochemical Oxygen demand
27	56	1960	Dr Charles B Wurtz	River	Biological method used in the evaluation of effects of thermal discharge in the river
28	56	1969	Dr E C Raney - Staff	All	"Heated Effluents and Effects on Aquatic Life with Emphasis on Fishes," a bibliography
29	56	1969	Hydro-Research Science	Reservoir	Hydraulic Model Study Circulating Water Screen Structure and Intake Basin
30	56	1969	Dr E C Raney - Staff	Reservoir	Study of stream temperatures and effects on aquatic life at a nuclear power plant
31	58	Oct 1968	St Anselm's College	River	An in-depth study of the physical, chemical, and biological effects of circulating water discharge on river
32	60	Dec 1954	Staff	Connecting water between bays	Water temperature survey
33	60	Sept 1959	Staff	River	Water temp survey above and below station
34	60	Sept 1960	Staff	River	Water temp survey above and below station
35	60	Sept 1961	Staff	River	Water temp survey above and below station

REGION I - NORTHEAST
Completed Studies (Cont'd)

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
36	60	Dec 1966	Sheppard T Powell Assoc	River	Comprehensive investigation to establish capacity of river to assimilate thermal loads from existing and future generating stations
37	60	Sept 1966	Staff	Connecting water between bays	Station heat rejection and temp data. Tidal flow, water analysis, etc
38	60	Aug 1966	Staff	Connecting water between bays	Water temperature survey above and below station
39	60	Oct 1966	Staff	River	Surface water temperature survey of river to establish dispersion pattern of heated discharged water
40	60	Mar 1968	Pritchard-Carpenter	River & Estuary	Dispersion and cooling of waste heat released into river estuary
41	63	Oct 1965	Pritchard-Carpenter	Lake	Drift and dispersion characteristics of lake near shore waters - dye studies
42	75	Dec 1966	U S Dept of Interior; Fish & Wildlife Service	River	Shad Study
43	78	Apr 1967	Webster-Martin	River	The Fishes of the river Drainage Basin of Vt & N H
44	78	Dec 1967	Webster-Martin	River	Water quality
45	84	Mar 1967	Quirk, Lawler & Matusky	Estuary	Salt Water intrusion and pollutant study
46	84	Oct 1966	Northeastern Biologists, Inc	Estuary	Striped Bass egg and larvae studies
47	84	Jan 1967	Quirk, Lawler & Matusky	Estuary	River and river basin water supply study

REGION I - NORTHEAST
Completed Studies (Cont'd)

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
48	84	Nov 1966	Prof Milo C Bell	Estuary	Design of fish protection facilities
49	84	Oct 1967	Dr Alfred Perlmutter	Estuary	Fishery study of effects of pressure on fish
50	84	Sept 1966	Dr G W Prescott	Estuary	Effects of plant operation on river algae
51	84	Apr 1968	Quirk, Lawler & Matusky	Estuary	Effect of nuclear plant cooling water discharge on river temp distribution
52	84	Feb 1969	Quirk, Lawler & Matusky	Estuary	Effect of nuclear plant cooling water discharge on river temp distribution
53	84	Apr 1967	Northeastern Biologists, Inc	Estuary	River temp survey in the vicinity of nuclear plant
54	84	Oct 1968	Texas Instruments, Inc	Estuary	Aerial infra-red studies of temp distributions in river near nuclear plant
55	84	Nov 1968	Dr Alfred Perlmutter	Estuary	River fishery survey at nuclear plant site
56	85	Aug 1968	Camp Dressert McKee	River	Report on comprehensive plant for domestic and industrial waste water disposal
57	90	Sept 1964	Staff - Dr John Storr University of Buffalo	Lake	Limnology Section of Safety Analyses Reports Submitted to AEC for Nuclear Station
58	90	Feb 1967	Staff - Stone & Webster Engrg Corp	River	Flow characteristics and thermal capability of river in particular vicinity

REGION I - NORTHEAST

Studies Under Way

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
59	5	Dec 1968	Sheppard T Powell Assoc	Tidal Estuary	Description of thermal discharge effects at five operating plants
60	5	Dec 1968	Alden Research Lab	Tidal Estuary	Hydraulic model
61	5	Dec 1968	Sheppard T Powell Assoc	Tidal Estuary	Field data for developing and adjusting hydraulic model of Study 2
62	5	Dec 1972	Academy of Natural Sciences of Philadelphia	Tidal Estuary	Marine ecology investigation
63	35	1969	Rutgers University	Estuary	Lethal limits and temperature preference ranges for fish and animal life in and ~~on the water~~ of the bay and study of marine life living in and on bottom of bay
64	39	Undetermined	W Vanderborgh & Son (Oyster Growers)	Salt Water	Study of the operation of an experimental oyster nursery in the discharge basin
65	39	1975	Dr A Perlmutter	Salt Water	Ecological survey - determine extent of any marine biological changes due to operation of nuclear station
66	43	1968	Dr Charles B Wurtz	River	A biological survey of the river
67	43	1971	Staff and Consultant	River & Wells	Background radiation - soil, vegetation, fish, water and river silt
68	43	Undetermined	Consultant & GAI	-	Meteorological study - effect of cooling tower plume

REGION I - NORTHEAST
Studies Under Way (Cont'd)

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
69	48	Dec 1972	Dr Daniel Merriman & Staff	Estuary	River study - of biological, chemical, and physical characteristics before and after operation on the ecology of the river
70	48	-	Combustion Engrg Inc	Estuary	Environmental monitoring program - a preoperational and postoperational study of environmental radiation levels
71	48	Apr 1973	Battelle-Duxbury	Coastal	Survey of key ecological indicators to determine effect of thermal discharge from nuclear station
72	48	-	Tracerlab	Coastal	Survey of radiation levels in the marine environment to establish background and detect any change resulting from the operation of plant
73	48	-	Battelle-Duxbury	Estuary	Study to determine the effect of increased plant capacity on the ecology and aquatic life of the river
74	55	-	Staff	River	River water quality survey
75	55	-	Staff	River	Effect of operation of station on ice formation
76*	55	1968	Dr Charles B Wurtz	River	A biological survey of the river
77	56	1972	Alden Research Lab	Reservoir	Model study to determine temperature effects of heated effluent from two 1000 mw BWR units
78	56	1975	Dr Edward C Raney	Reservoir	A study of the fishes and plankton of reservoir
79	56	1969	Corps of Engineers, Dr Leslie J Hooper	Estuary	Model study to determine thermal capabilities

NOTE: * Same as Study #66

REGION I - NORTHEAST
Studies Under Way (Cont'd)

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
80	56	1970	Dr Ruth Patrick	Estuary	Study of the biological effects of heated discharges
81	58	Oct 1968	Webster-Martin	Estuary	A preliminary study to determine tidal flows, dispersion, salinity and temp for a proposed nuclear plant site
82	60	Sept 1969	Dr Ruth Patrick	River	Effects of heat and temperature changes on ecology of rivers including effects of chlorination on marine life
83	60	Mar 1969	Pritchard-Carpenter	Rivers & Estuaries	Experimental studies of waste heat dispersal, dispersion and transfer to atmosphere of condensing water effluent at present and future electric generating stations
84	63	June 1973	John F Storr	Lake	Ecological survey - fish population, rate of growth, bottom ecological survey
85	75	No Completion	Commonwealth of Penn	River	Automatic water quality monitoring
86	75	-	P.E.A. - Special committee on Acid Mine Drainage	River	Evaluate progress reports on research
87	78	Dec 1968	Webster-Martin	River	Water quality and biological data
88	84	-	Northeastern Biologists, Inc	Estuary	River Fisheries Study
89	84	-	Alden Research Lab	Estuary	Hydraulic models
90	84	-	Alden Research Lab	Estuary	Hydraulic models for thermal studies at nuclear plant sites
91	84	-	NYU Institute of Environmental Medicine	Estuary	Comprehensive ecological study of river near nuclear plant site

REGION I - NORTHEAST
Studies Under Way (Cont'd)

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
92	84	-	N Y State Atomic And Space Development Authority	Estuary	Aerial infra-red thermal studies of water areas adjacent to existing and proposed generating plants.
93	87	Dec 1969	Staff	Estuary	Water temp and current study
94	90	Continuing	Staff - Dr John Storr University of Buffalo	Lake	Effects on Aquatic Life in Lake

REGION I - NORTHEAST

Studies Proposed

Study No.	Company No.	Proposed Date	Conducted By	Type of Water	Title or Brief Description
95	8	-	-	River	Effect of heated water discharge
96	43	Jan 1969	Staff	River	Background radiation, soil, vegetation, fish, well water, river silt
97	48	1970	-	Coastal	Postoperational survey of thermal distribution of CW Discharge
98	55	1968-69	Staff	Rivers	Temperature distribution
99	63	1969	S T Powell & Assoc	River	Temperature profile mapping
100	63	1969	Staff	Lake	Temperature profile mapping
101	63	1969-70	Dr J Carpenter	Lake	Temperature profile mapping - high momentum discharge
102	78	1969	Webster-Martin	River	Water quality and biological data
103	84	May 1969	Contractor to be selected	Estuary	Hydrological study of sound with emphasis on a particular area
104	84	-	-	Estuary	Model study to determine temp distribution in the sound waters adjacent to Island
105	84	May 1969	Contractor to be selected	Estuary	Ecological study of the lower river
106	84	July 1969	Contractor to be selected	Estuary	Ecological study of the sound waters adjacent to Island

REGION II - EAST CENTRAL

Completed Studies

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
107*	2	1961	Penna Sanitary Water Bd	River	Heated discharges their effect on streams
108	17	Fall 1967	Staff	River	Water temperatures in mixing zone
109	17	Fall 1967	Staff	Lake	Water temperatures in mixing zone
110	17	Fall 1968	Staff	Creek & Lake	Water temperatures in mixing zone
111	19	Oct 1962	Staff	River	Flow, temperatures, dissolved oxygen, BoD, air temp, weather, 12 mile stretch of river
112	19	Oct 1954	Prof T J Velz University of Michigan	River	Define waste assimilation capacity of two rivers under natural drought stream flow; and, under regulated flow to serve as a basis for determining reservoir capacity requirements under present and future pollution loads.
113	21	May 1968	Steve L Pernick, Norm Kerman Member companies	River	"Heat Disposal Requirements - Future Generating Facilities." This was a study to determine the amount of heat presently discharged to the rivers, and an attempt to forecast the heat rejection of future units through the year 1990
114	31	May 1964	Staff	River	Effects of power plants & weather conditions on river temperatures
115	31	Mar 1966	Staff	River	Adequacy of river as a source of condensing and cooling water
116	31	May 1967	Pioneer Serv & Engr Co	River	Circulating Water System Study. (Necessity of added cooling towers at existing plants)

NOTE: * Same as Study #8

REGION II - EAST CENTRAL
Completed Studies (Cont'd)

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
117	61	Sept 1966	Staff	River	Downstream temperature measurements
118	61	Sept 1967	Staff	River	Downstream temperature measurements
119	86	Jan 1962	Staff	River	Investigation of the effects of plants on the temperature of river
120	86	Oct 1966	Staff	River	Investigation of plant cooling

REGION II - EAST CENTRAL

Studies Under Way

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
121	2	-	Staff	River	Circulating water temp effect
122	2	-	Staff	River	Circulating water temp effect
123	2	-	Staff	River	Circulating water temp effect
124	17	Fall 1970	Staff	Lake	Temperature in mixing zone
125	17	Fall 1972	Beak Consultants, Inc	Lake	Ecological study
126	17	Oct 1968	Beak Consultants, Inc	Lake	Ecological study
127	17	Oct 1968	Staff	Lake	Temperature study
128	19	Dec 1968	Miami Conservancy District Ohio	River	"Regional Water Quality Management Program"
129	21	Dec 1968	Steve L Pernick, Norm Kerman	River	"Compliance with Water Pollution Control Criteria" - entails a study at each plant to determine our status of compliance with Article 301 of the State Water Pollution Control Rules and Regulations
130	31	May 1971	Indiana Univ Water Resources Research Found	River	Study of Biologic Effects of Heated Water Discharge - before and after addition of generating units
131*	37	-	EEI & Johns Hopkins Univ	River	Cooling water study
132	61	1970	DePauw University	River	Aquatic Life Survey
133	61	1973	DePauw University	River	Aquatic Life Survey

NOTE: * Cooperating utility and field site. EEI and Johns Hopkins University -- cooling water studies RP-49.

REGION II - EAST CENTRAL
Studies Under Way (Cont'd)

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
134	61	Sept 1968	Staff	River	Downstream temperature measurements
135	74	Oct 1969	University of Michigan	Lake	About 9 sq mi of lake immediately adjacent to plant site are being studied for the ecology and hydrology of the lake. Hope to determine a dispersion pattern of discharge water and possible adverse effects on aquatic life

REGION II - EAST CENTRAL

Studies Proposed

Study No.	Company No.	Proposed Date	Conducted By	Type of Water	Title or Brief Description
136	31	Summer 1969	U S Geological Survey	River	Possible study to determine effects of atmospheric conditions on downstream river temperatures with constant plant load
137	49	Summer 1969	Staff	Lake	Thermal increase in lake due to plant discharge
138	86	-	-	Lake	Cooling water discharge dispersion research - 5 year biological survey of lake in vicinity of plant site

REGION III - SOUTHEAST

Completed Studies

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
139	1	Sept 1960	Staff and T Jaffe Auburn University	River	Pre-impoundment water quality study
140	1	Sept 1965	Staff and Dr J V Walters University of Alabama	Lake	Water quality study of company reservoirs
141	1	Sept 1966	Staff	Lake	Water quality study of company reservoirs
142	1	Summer 1966	Staff	River	Water quality at intake of paper mill - Comparison of summers of 1965 and 1966
143	1	Apr 1967	Staff	Reservoir	Study of water quality above and below powerhouse during summer 1966
144	1	July 1966	Staff	River	Survey of water quality through river improvements
145	1	Aug 1966	Staff	Reservoir	Survey of water quality in reservoir
146	1	Summer 1966	Staff	Reservoir	Study of water quality in reservoir
147	1	Sept 1967	Staff	Lake	Water quality study of company reservoirs
148	1	Sept 1968	Staff	Lake & River	Temperature study of water at company steam plant sites and continuing study of company reservoirs
149	20	1960	Staff and Dr Charles M Weiss, University of North Carolina	Lake	Preliminary - Influence of hydroelectric reservoirs upon water quality of river
150	25	1968	Gilbert Assoc & Staff	Gulf (salt)	Thermal effects on the marine environment

REGION III - SOUTHEAST
Completed Studies (Cont'd)

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
151	26	-	-	River	Investigations of condenser cooling water discharges, at certain steam plants to determine distribution of warm water and distance required for mixing under various plant loading conditions and river flows
152	65	Nov 1967	Stone & Webster Eng Corp	River	Thermal effects on river
153	79	-	Staff	River	River water temperatures
154	79	-	Staff	River	River water temperatures
155	79	-	Staff	River	River water temperatures

REGION III - SOUTHEAST

Studies Under Way

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
156	1	End 1968	Staff	River & Lake	Analysis of data from steam plants
157	7	June 1969	North Carolina State University	Estuary	Effects of heated water effluents on river and estuaries
158	7	Oct 1968	Dr Carpenter Johns Hopkins University	Estuary	Estuary hydrological study to determine effects on heated water discharge on estuary temperature
159	7	Aug 1969	North Carolina State University	Estuary	Study of effect of heated water discharge on marine biology in estuary
160*	20	1971	Johns Hopkins University Staff	Lake	EEI Cooling Water Discharge Project RP-49, Physical
161*	20	1971	Johns Hopkins University	Lake	EEI RP-49, Biological
162	20	1971	North Carolina Dept of Inland Fisheries	Lake	Thermal effects on lake fishes
163	20	Continuing	Staff, Dr Charles M Weiss, University of North Carolina	Lake	Influence of hydroelectric reservoirs upon water quality on river
164	25	1974	Staff	Gulf	Temperature monitoring
165*	26	Fall 1968	EEI Johns Hopkins University	River	EEI RP-49
166	79	Dec 1972	Johns Hopkins University Staff	River	Study of the ecology of river before and after installation of a 690 Mw unit
167	79	Oct 1969	Staff	Lake	Temperature distribution in a cooling lake serving two 550 Mw units

NOTE: * Cooperating utility and field site. EEI and Johns Hopkins University - Cooling Water Studies RP-49.

REGION III - SOUTHEAST

Studies Proposed

Study No.	Company No.	Proposed Date	Conducted By	Type of Water	Title or Brief Description
168	1	Sept 1973	Staff	Lake	Evaluation of effects of powerhouse on downstream water quality
169	20	Oct 1968-?	FWPCA, South Carolina Water Pollution Control Authority Staff	Lake	Eutrophication
170	20	1968-69	U S Geological Survey	River	Thermal loading
171	25	1969	State Board of Conservation	Gulf	Quantitative marine ecology measuring program
172	26	-	Staff, consultants, Emory University	Rivers	Biological, radiological and marine life surveys
173	79	1968-72	Virginia Institute of Marine Science	Estuary	Ecological study of the lower river estuary before and after installation of two 815 Mw nuclear reactors

REGION IV - NORTH CENTRAL

Completed Studies

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
174*	9	1968	EEI and Johns Hopkins University	River	EEI Cooling Water Discharge Project RP-49
175	14	June 1968	Dr L P Beer - Staff Dr W O Pipes Northwestern University	Lake	Environmental effects of condenser water discharge
176	14	-	G E Stigall NUS Corp	Lake	Effects of nuclear power station liquid waste discharges
177	14	-	E R Smith NUS Corp	Lake	Evaluation of potential contamination by effluent from particular station
178	14	Oct 1968	Dr L P Beer - Staff Dr W O Pipes Northwestern University	River	Effects of discharge of condenser water into river
179	41	1968	University of Wisconsin Professor Hoopes	Lake	Temperature & Circulation
180	50	Sept 1964	Staff	River	River temperature study - effects of condenser cooling
181	50	Aug 1965	University of Minnesota	Lake	Effects of condenser cooling water discharge on water temperatures in lake including model study
182	50	Sept 1966	University of Minnesota	River	Model study of the cooling water outlet channel
183	82	Sept 1967	Paul M Kronberg Staff	Various	Survey of water conditions near power plants

NOTE: * Cooperating utility and field site. EEI and Johns Hopkins University - Cooling Water Studies RP-49.

REGION IV - NORTH CENTRAL
Completed Studies (Cont'd)

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
184	83	Dec 1957	River Survey	River	Dissolved oxygen and temperatures above and below plant
185	83	Dec 1957	Staff	River	Dissolved oxygen on inlet and outlet of circulating water
186	83	Dec 1961	Staff	River	Dissolved oxygen and temperatures above and below plant
187	83	Jan 1966	Staff	River	Temperature increase in western circulating water
188	83	Mar 1968	Staff and Water Dept	River	River heat rejection over 30 miles of industrial use
189	97	May 1968	Texas Instruments Inc	Lake	Airborne infra-red imagery of power plant cooling water discharges
190	97	July 1967	MIT	River	A model study of thermal stratification produced by condenser water discharge

REGION IV - NORTH CENTRAL

Studies Under Way

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
191	9	-	Staff	River	Cooling water discharge data
192	14	Nov 1968	Dr L P Beer-Staff Dr W O Pipes Northwestern University	River	Effect of condenser waters on river aquatic environment
193	32	Undetermined	Staff	River	Thermal effect
194*	41	1970	University of Wisconsin Professor Magnusson	Lake	Limnology
195	50	Jan 1971	Staff and consultants	River	Environmental monitoring program
196	50	May 1973	Dr A J Hopwood St Cloud State College	River	Ecological study
197	50	June 1973	Dr A J Brook University of Minnesota	River	Algal study
198	50	Continuing	Staff and Dept of Health	River	Radiation monitoring program
199	88	1975	Staff	River - Lake	Cooling water survey -- sample temp, turbidity, dissolved O2 and pH weekly at 18 points in river-lake used for cooling water at two steam electric stations
200	97	1970	University of Wisconsin	Lake	Preoperational study of ecology at site of nuclear plant initial work will establish present status of marine population. Post-operation work will study change in biota and effect of circulating water discharges on life cycle

NOTE: * This program is being undertaken jointly by the investor-owned electric utilities in the state.

REGION IV - NORTH CENTRAL

Studies Proposed

Study No.	Company No.	Proposed Date	Conducted By	Type of Water	Title or Brief Description
201*	14	1970-74	Staff	Lake	Long-term environmental effects of heated effluents and radioactive liquid discharges on lake
202	22	1969	State of Illinois	River	Installation of monitoring station by state for six items including pH, temp, conductivity, total solids, hardness, sulfates
203	50	Sept 1968 Sept 1970	FWPCA National Quality Lab	River	Effect of heated discharges on fish productivity - constant temperature regime
204	50	1970	FWPCA National Quality Lab	River	Thermal tolerance of fish and fish food organisms - natural regime
205	50	1970-77	College Professor	River	Ecological study near nuclear plant
206	50	1970-77	College Professor	River	Algal study near nuclear plant
207	50	1970-Continuing	Department of Health	River	Radiation monitoring program
208	76	1969	Undetermined	River	Temperature studies - vertical and horizontal at one or two large plants
209	88	Dec 1968	Staff	River-Lake	Sample BOD in river-lake used for cooling water at 3 steam electric stations

NOTE: * Five other utilities which are constructing nuclear plants on the lake are also preparing to undertake an intensive survey of the lake and its ability to provide cooling water requirements for nuclear power plants.

REGION V - SOUTH CENTRAL

Completed Studies

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
210*	10	Aug 1968	Johns Hopkins University EEI	Lake	EEI Cooling Water Discharge Project RP-49
211	11	Aug 1967	Marine Science Institute University of Texas Dr E W Behrens	Estuary	Ecology of surpulid worms (life cycle)
212	18	Continuing	Staff	Reservoirs	Temperature surveys, temperature dispersion and capabilities for supporting additional generation. Studies include operating data and isotherm plottings of the reservoir
213	29	Sept 1968	Pyburn & Odum and Stone & Webster	River	Thermal effects of additional unit on river
214	30	1966	Southwest Research Ins	Estuary	Temperature effects in lake and bay
215	30	1967	Southwest Research Ins	Estuary	Oxygen balance of generating station cooling water canal
216	30	1967	Southwest Research Ins	Estuary	Temperature distribution in lake
217	30	1967	R H Hand, Jr	Estuary	Water quality
218	44	1951	Burns & McDonnell Eng Co	Pond	Surface cooling and study of water requirements
219	44	1965	Gilbert Assoc	River	Temperature rise
220	51	Oct 1964	Staff	Lake & Cooling tower	Cooling water for generating station

NOTE: * Cooperating utility and field site. EEI and Johns Hopkins University - Cooling Water Studies RP-49.

REGION V - SOUTH CENTRAL
Completed Studies (Cont'd)

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
221	70	1968	Staff	Sewage disposal plant effluent	Use of waste water for cooling tower makeup
222	73	Oct 1955	U S Geological Survey	Lake	Effect of the addition of heat from a power plant on the thermal structure and evaporation of lake
223	73	Oct 1960	U S Geological Survey	Lake	Effect of an increased heat load on the thermal structure and evaporation of lake
224	73	1968	Staff	Lakes	Miscellaneous lake temperature studies
225	73	1965	Staff	All	A projection of per capita water use for electric power generation in state - report for water commission
226	73	1968	Staff	All	"Cooling Water Requirements for Steam Electric Plants" - a report for the ASCE conference on research needs for power

REGION V - SOUTH CENTRAL

Studies Under Way

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
227	3	Feb 1969	Hydro Science Co	River impoundment	Model study of lower portion of reservoir to study flow patterns to be expected with installation of nuclear station
228	3	1978	Little Rock University	River impoundment	Background survey to obtain biological chemical and radiation information before and after operation of nuclear unit
229	10	May 1972	Gulf South Research Inst	Lake & Estuary	Quantitative studies on fish populations and thier food-web structure in thermally stressed areas, to be conducted in state waters
230	11	Continuing	Marine Science Institute University of Texas Dr E W Behrens	Estuary	"Ecology of Surpulid Worms" cont study
231	11	June 1968	Texas A&M University	Estuary & Lake	"Effects on Fishes and Commercial Invertebrates at Heated Water Discharge Into an Estuary and Three Reservoirs"
232	18	1970	Texas A&M University	Lake & Estuary	"The Effects on Fishes of Heated water Discharge Into Selected Estuaries and Impounded Waters." This 3-1/2 year study is sponsored by a group of electric utilities and industries in Texas to determine the effect of condenser circulating water on aquatic life in Texas lakes and bays
233*	29	June 1970	Texas A&M University	Lake & Estuary	Effects of heated water discharges on fishes

NOTE: * Same as Study #232

REGION V - SOUTH CENTRAL
Studies Under Way (Cont'd)

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
234	29	-	Staff	River	Effect of salt water barrier on salt water intrusion on river
235	29	Continuing	Staff	Estuary	Temp surveys on generation station discharges
236***	29	May 1972	Gulf South Research Inst	Lake & Estuary	Quantitative studies of fish population and their food-web structure in thermally stressed areas, to be conducted in state waters
237*	30	1970	Texas A&M University	Estuary	Effects on fishes and Commercial Invertebrates of Heated Water Discharge into an Estuary and three Reservoirs
238	30	1973	Texas A&M University	Estuary	Numbers and survival rates of economically important organisms passing through generating station
239**	30	1969	Johns Hopkins University EEI	Lake	Cooling water discharge project RP-49
240	30	1969	Southwest Research Inst	Estuary	Heat Distribution Patterns in Bay
241	30	1969	Southwest Research Inst	Lake	Performance of Lake as a source of cooling water for generating station
242***	40	May 1972	Gulf South Research Inst	Lake & Estuary	Quantitative studies of fish populations and their food-web structure in thermally stressed areas, to be conducted in state waters
243***	47	May 1972	Gulf South Research Inst	Lake & Estuary	Quantitative studies of fish populations and their food-web structure in thermally stressed areas, to be conducted in state waters

NOTES: * Same as Study #232
** Cooperating utility and field site. EEI and Johns Hopkins University - Cooling Water Studies RP-49
*** Same as study #229

REGION V - SOUTH CENTRAL
Studies Under Way (Cont'd)

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
244	51	Oct 1973	U S Geological Survey, Water Board, Staff	River	River flow study
245	51	-	Staff	River	River water quality
246*	68	1969	Texas A&M University	Lake	Effect of heat and Effluence on Fish
247**	68	1969	Johns Hopkins University EEI	Lake-river-bay	Cooling water discharge project RP-49
248	68	Undetermined	State Parks & Wildlife Dept	Lake	Lake fisheries survey
249	72	Summer 1971	Staff	Lake	Temperature survey
250*	72	1971	Texas A&M University	Lakes & Estuary	The effects on fishes and commercial invertebrates of heated water discharge into an estuary and three reservoirs
251*	73	Aug 1970	Texas A&M University	Lakes & Estuary	"The Effects on Fishes of Heated Water Discharges into Selected Estuaries and Impounded Waters"
252	73	-	Staff	Lakes	Miscellaneous lake temp studies
253	73	-	University of Texas	Lakes	Use of a 2-dimensional model to simulate a reservoir used for cooling
254*	81	Aug 1970	Texas A&M University	Lakes & Estuary	The effects on fishes of heated water discharge into selected estuaries and impounded waters

NOTES: * Same as Study #232
** Cooperating utility and field site. EEI and Johns Hopkins University - Cooling Water Studies RP-49

REGION V - SOUTH CENTRAL

Studies Proposed

Study No.	Company No.	Date Proposed	Conducted By	Type of Water	Title or Brief Description
255	30	1969-75	Texas A&M University Research Foundation	Estuary	Species diversity and abundance of the bottom fauna, macroplankton, commercially important crabs and shrimp, and fishes before and after the construction of generating station
256	30	1969	State Water Quality Board (Subcontract to Tracor)	Estuary	Development and verification of temperature model for power plant discharge
257	72	Summer 1969	Staff	Lake	Temperature survey
258	73	1969	University of Texas	Lake	Development of a modified 3-dimensional mathematical model of a cooling reservoir
259	73	1969	Staff	Lake	Use of heated discharge water in fish propagation and possible commercial applications
260	91	1969-70	State University	River	Effect of heated discharges

REGION VI - WEST CENTRAL

Completed Studies

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
261	45	June 1965	EBASCO Services	River & Lake	Site reconnaissance for 1971 Gen unit
262	45	Dec 1965 (Sup June 1966)	EBASCO Services	River vs Lake sites	Economic site selection 200 MW 1971
263	45	Jan 1967	FPC & Basin Interagency Com	River & Pond	Water requirements for thermal elec generation
264	45	1962	U S Geological Survey & State Water Com & State Geological Survey	Wells	Test drilling
265	45	Mar 1969	State Water Comm	Cooling Pond	SWC Project - Dam - Hydrology, Design and cost
266	52	Aug 1964	Dept of Health	River	Report on investigations of waste disposal at various plants

REGION VI - WEST CENTRAL

Studies Under Way

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
267	45	Continuing	Staff & Fed Water Pollution Control Ad	River	Sampling & testing natural water quality network
268	45	1970	State Water Com & U S Geological Survey	Underground water	Ground water investigation
269	52	Dec 1968	Bechtel Corp	Lake & River	Ecology and associated economics of alternate plant sites for 400 and 600 MW units

REGION VII - NORTHWEST

Completed Studies

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
270	57	June 1968	Battelle-Northwest Lab	River	Research related to the development of a power reactor site on river, includ temp regime, turbulance related to potential for mixing of discharge with main flow, current flow reversals due to tidal influences and other conditions concerned with use of the river for once thru cooling
271	57	Feb 1968	Battelle-Northwest Lab	River, Tidal, Estuary	Information on timing and abundance of fishes near plant important to the commercial or sport fisheries of the river
272	57	May 1968	Battelle-Northwest Lab	River, Tidal Estuary	Information and responses to elevated temperature of fishes near plant important to the commercial or sport fishery of the river
273	57	Mar 1, 1969	Battelle-Northwest Lab	River, Tidal Estuary	An improved estimate of the cooling effects of the dams and the effect on downstream temperature regimes, including an estimate of time during which temperature would exceed 20° C, and predictions of the effect at downstream points of the revised thermal conditions coupled with operations of a direct cooled 1,000 MW nuclear plant

REGION VII - NORTHWEST

Studies Under Way

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
274	80	1973	NALCO	River	Determine quality and chemical characteristics of river water prior to and after steam electric generating plant operation. Primary purpose to develop data to aid in selection of water treatment equipment for 1400 MW plant being constructed
275	96	Indefinite	Staff	River	Recording river temp vs plant load

REGION VII - NORTHWEST

Studies Proposed

Study No.	Company No.	Date Proposed	Conducted By	Type of Water	Title or Brief Description
276	62	Early 1970's	Architect Eng & Oceanographers	Estuary	-

REGION VIII - SOUTHWEST

Completed Studies

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
277	53	1953	Staff & J E Kerr Bechtel Corp	Estuary	Fish screening & temperature effects on fish passing through condenser tubes
278	53	1955	Staff	Estuary	Cause & solution to fish screen clogging by anchovies
279	53	1958	Staff	Estuary	Dispersion of cooling water containing radio active wastes
280	53	1961	Staff & Dr E O Salo Humboldt State College	Ocean	Dispersion of cooling water and possible effects on clams
281	53	1964	Staff & Dr E O Salo, Dr J A Gast Humboldt State College	Ocean	Temperature, current, and diffusion studies for proposed nuclear plant, and ecological survey
282	53	1962	Staff	Estuary	Temperature study for recirculating problem
283	53	1965	Staff	Estuary	Surface water temperature survey with airborne infrared thermometer-plant #1
284	53	1965	Staff	Estuary	Surface water temperature survey with airborne infrared thermometer-plant #2
285	53	1965	Staff	Ocean	Surface water temperature survey with airborne infrared thermometer-plant #3
286	53	1965	Staff	Estuary	Temperature, current, and dispersion studies for possibility of recirculation
287	53	1965	Staff	Estuary	Temperature, current, and dispersion study

REGION VIII - SOUTHWEST
Completed Studies (Cont'd)

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
288	53	1965	Dr E O Salo, University of Washington & Staff	Estuary	Concentration of Zinc-65 in oysters held in discharge water from nuclear plant
289	53	1968	Staff & Dr W J North California Institute of Technology	Ocean	Influence of thermal discharge on flora and fauna, and on dissolved oxygen along thermal gradient
290	53	1968	Dr G Allen, Humboldt State College	Estuary	Distribution of sport fish around nuclear thermal power plant outfall
291	89	July 1967	Staff	Ocean	Environmental monitoring Program
292	89	Aug 1968	Bendix Marine Advisers	Ocean	Annual Report - Oceanographic Surveys
293	89	May 1968	Oceanographic Service Inc	Ocean	Quarterly Progress Report Oceanographic Study
294	89	June 1968	State Dept of Fish & Game	Harbor	Harbor Biological Monitoring Program
295	89	June 1968	Bendix Marine Advisers	Ocean	Proposed Power Plant Discharge Oceanographic Study

REGION VIII - SOUTHWEST

Studies Under Way

Study No.	Company No.	Date to be Completed	Conducted By	Type of Water	Title or Brief Description
296	53	-	Staff	Estuary	Uptake of radioactive waste by marine organisms along discharge gradient
297*	53	1969	Staff, EEI, Johns Hopkins University	Estuary & Ocean	Pre and post-operational oceanographic survey and biological study to assess effects of discharge on benthic organisms. Part of EEI RP-49 Heater Water Discharge Study
298	53	-	Staff & Dr W J North California Institute of Technology	Ocean	Nuclear-prediction of temperature dispersion, oceanographic background, study, including ecological survey of flora and fauna
299	53	-	Staff	Estuary	Model study of effect of submerged cooling water discharge system. Infrared study using Bendix Thermal mapping system. Studies on different arrangements of intake and discharge using U S Army Corps of Eng Bay Model
300	53	-	State Dept of Fish & Game funded by company	Ocean	Baseline study of flora and fauna at proposed nuclear site
301	53	-	State Dept of Fish & Game funded by company	Estuary	Effects of power plant on opossum shrimp
302	64	Oct 1968	Bendix Marine Advisers Inc	Bay	Thermal diffusion study of bay

NOTE: * Cooperating utility and field site. EEI and Johns Hopkins University - Cooling Water Studies RP-49

REGION VIII - SOUTHWEST

Studies Proposed

Study No.	Company No.	Date Proposed	Conducted By	Type of Water	Title or Brief Description
303	53	1968	Staff	Estuary	Hydro biological survey for proposed nuclear plant
304	53	1968	Staff	Estuary & Ocean	All plants - conduct infrared surveys of all operating thermal plants using advanced infrared scanner
305	53	1969	Staff	Estuary	Biological comparison of intake and discharge area of nuclear power plant
306	53	1969	Staff	Estuary	Model study of predicted cooling water dispersion

OTHER

Completed Studies

Study No.	Company No.	Date Completed	Conducted By	Type of Water	Title or Brief Description
307	92	Jan 1968	University of "State" Dr Klaus Wyrtki	Ocean	AM evaluation of the effects of a warm water outlet from a power plant on the temp of bay

EEI RP-49
COOPERATING UTILITIES AND FIELD SITES

Site No.	Cooperating Utility	Name of Station	Site Location	Receiving Water Body	Nearest USWB Station
1*	American Elec Power Service Corp	Philip Sporn Plant	New Haven, West Virginia	Ohio River	Parkersburg, West Virginia
2	Central Illinois Light Company	E D Edwards Station	near Peoria, Illinois	Illinois River	Peoria, Illinois
3	Central Louisiana Electric Company	Coughlin Station	St Landry, Louisiana	Mountain Bayou Lake	Alexandria, Louisiana
4*	Delmarva Power & Light Company	Indian River Plant	near Millsboro, Delaware	Indian River Estuary	Salisbury, Maryland
5	Duke Power Company	Marshall Steam Station	near Charlotte, North Carolina	Lake Norman	Charlotte, North Carolina
6	Georgia Power Company	Plant Hammond	near Rome, Georgia	Coosa River	Rome, Georgia
7	Houston Lighting & Power Company	W A Parish Station	near Houston, Texas	Smithers Lake	Houston, Texas
8	Kentucky Utilities Company	Green River Station	near Central City, Kentucky	Green River	Madisonville, Kentucky
9	Pacific Gas & Electric Company	Moss Landing Station	near Monterey, California	Monterey Bay	Salinas, California
10*	Mississippi Power Co Southern Services, Inc	Plant Jack Watson	near Gulfport, Mississippi	Biloxi River Estuary	Mobile, Alabama
11	Southwestern Electric Power Company	Wilkes Station	near Jefferson, Texas	Wilkes Lake	Shreveport, Louisiana

NOTE: *Did not participate in survey.

J. C. Geyer

We believe that the work being carried out for EEI by Johns Hopkins represents a significant addition to the body of knowledge concerning the effects of thermal discharges. EEI has committed over $1 million to this work, and this amount has been multiplied by expenditures of individual companies involved in cooperative efforts at field sites. We have asked Dr. John Geyer and Dr. Loren Jensen to describe the work which has been done under EEI sponsorship and to make any additional comments which, based on their professional experience, they may feel are appropriate.

I would like to introduce Dr. Geyer at this time who will make a few comments and then in turn introduce Dr. Jensen.

STATEMENT OF DR. JOHN GEYER, DIRECTOR, PHYSICAL STUDIES, THE JOHNS HOPKINS UNIVERSITY, BALTIMORE, MARYLAND

DR. GEYER: Thank you, Jack.

Mr. Stein, conferees, and ladies and gentlemen, it is a pleasure to be asked to participate in this discussion of thermal effects. We have prepared a statement that Dr. Jensen will read for you. I would like to say at

the outset, the principle that guided us in developing the cooling water studies for the Edison Electric Institute was that we would have to get out in the field to find out what goes on, that you can't study the environment in the laboratory very satisfactorily. And so, both in our physical and biological studies, we have taken the laboratory out into the field, even to the extent of having microscopes in rowboats so that we could look at what was going on in the water in terms of biological behavior of the critters right at the time they are taken out of the water.

Now, we have prepared a number of reports of which I have three of the latest ones here, that are available from the Edison Electric Institute. Our biological studies have been going forward for a couple of years so it will be another month or two before the first reports on our field biology begin to appear, and they will come out station by station as we work up the data for the three places which the staff are studying, and three others in which we are cooperating with the staffs of the industries in biological studies.

The last report is "Surface Heat at Power Plant Cooling Lakes." This analyzes three or four of the eleven sites where we are working.

"Effects of Elevating Temperature Upon Aquatic

Invertebrates." That follows up an earlier one on effective temperatures on fish.

"Field Sites and Survey Methods." A report which describes the places that we are making these studies and the manner in which the studies are made, and the data processed.

Now, the details will be expanded a little bit by Dr. Loren Jensen who is in charge of the biological aspects of these studies, and, of course, the biology is the whole story really. We are interested in temperatures only insofar as they may affect the ecology of the environment.

MR. STEIN: Thank you, Dr. Geyer. You know, I am glad to see that you have reduced Johns Hopkins to human proportions, and you have microscopes in rowboats. When you used to have a man there who could walk water like Dr. Abel Wolman* -- he used to put rowboats in microscopes!

*Wolman, Abel
Professor Emeritus
Sanitary Engineering, Johns Hopkins University
Baltimore, Maryland

L. D. Jensen

STATEMENT OF DR. LOREN D. JENSEN,
DIRECTOR, BIOLOGICAL STUDIES, THE
JOHNS HOPKINS UNIVERSITY, BALTIMORE,
MARYLAND

DR. JENSEN: Mr. Stein, conferees. The Johns Hopkins University has conducted field research activities relative to the discharge of heated effluents into surface waters for the Edison Electric Institute specifically in this field since 1965. Initial phases of this program were directed towards physical aspects of heat dissipation from surface waters.

The objectives of the physical program of the Cooling Water Discharge Project include:

1) Evaluation of the roles of advection, dilution by mixing, and surface cooling in the overall dissipation of heat in the environment, by analyzing field data from operating thermal discharges on a nationwide basis.

2) Development of computer modeling techniques for simulating the flow behavior of receiving waters and for predicting temperatures near proposed thermal discharges.

3) Development of operations research techniques for optimizing the selection of locations for

proposed thermal discharges subject to receiving water temperature constraints.

Although the above three objectives appear to form a sequence in which output from preceding work becomes input for the following objective, for various reasons it has been considered desirable to proceed towards all three objectives concurrently. Progress since 1965 on this work may be summarized as follows:

1) Establishment of field survey instrumentation and data collection systems at eleven sites of existing thermal discharges was published in Report No. 3, available as Dr. Geyer has previously mentioned, entitled "Field Sites and Survey Methods" in June 1968. Physical and meteorological data have been collected since 1966 from these eleven sites, which are located at various latitudes in the United States.

In most cases, these data were recorded continuously through use of recording instruments located within and adjacent to surface waters used for cooling purposes. Synoptic data gathered from a large number of stations, supplements data from continuously recording instruments.

2) Results of analyses of rates of surface cooling at three of the eleven field sites were published

L. D. Jensen

in Report No. 5, as Dr. Geyer also mentioned just a moment ago, entitled "Surface Heat Exchange at Power Plant Cooling Lakes," in December 1969. This report describes the methods and results of analyses of surface heat exchange using 3 years of field data from three recirculated cooling lake sites in south-central United States. The procedure for preparing the data for analyses by computer is summarized and followed by a comprehensive description of the methods used for evaluating rates of surface heat dissipation in terms of the surface heat exchange coefficient, K, and the equilibrium temperature, E.

The results of these evaluations indicate:

1) That the capacity of a cooling lake to dissipate heat to its atmosphere during periods of low wind speed is, contrary to the findings of some previous investigations, quite appreciable, and

2) That the equilibrium temperature may be estimated reasonably accurately simply by adding to the dewpoint temperature the quotient obtained by dividing the gross solar radiation by the exchange coefficient.

This work has considerable significance for the design and performance analysis of power plant cooling lakes. Further, the exchange coefficient is currently being used to evaluate hydraulic diffusion rates near thermal

discharges into other types of receiving waters such as lakes, rivers, and estuaries.

3) Development of a preliminary integer programming model for optimal location of thermal power plants is currently in publication as Report No. 6, soon to be released, entitled "An Optimal Location Model for Thermal Plants with Temperature Constraints."

4) Development of a new technique for digital simulation of thermal discharges in three dimensions is now well advanced and is currently being applied to the evaluation of rates of turbulent diffusion (using the collected field data) at river sites. Future reports will cover application of this computer modeling technique to thermal discharges into lakes, estuaries and ocean sites, after field calibration has been completed.

As far as thermal regulation of Lake Michigan is concerned, the results of the physical program of this project to date permit the following observations:

1) If the surface area of Lake Michigan is assumed to be 22,000 $mi.^2$ and the prevailing surface cooling coefficient (Report No. 5) is assumed to be 32 $MW/mi.^2{}^\circ F.$, then a mean surface temperature increase of $1^\circ F.$ would cause the dissipation of heat to the atmosphere at an increased rate of 700,000 MW (i.e. $32 \times 22 \times 10^3$).

At current system thermal efficiencies (35%), this corresponds to a theoretical electrical generating capacity of about 2×10^6 MW (which is equal to about one-third of the current world rate of fuel energy combustion by man). This figure is immense, by man's standards, not so much because the surface cooling capacity of water is high per unit area, but because in this case the available lake surface area is extremely large.

2) Because of the rapid decay of excess temperatures that occurs near thermal discharges into open waters, the theoretical heat assimilative capacity estimated above could not be achieved in practice without some regions near the discharges exhibiting higher-than-average excess temperatures, and other more distant regions exhibiting lower-than-average temperatures. Thus, the question of realistic temperature regulations for such a water body must take into account:

a) The rates of decline of excess temperatures near individual thermal discharges due to the combined effects of advection, mixing, and surface cooling,

b) The integrated time-temperature exposures of biological organisms entrained in the condenser flow both before and after discharge,

c) The ecological consequences of the biological

responses to these temperature histories, and

d) The seasonal variations in the above factors.

Work on the physical aspects of these factors is proceeding in conjunction with the project's biological program.

Biological data collection was initated in 1968 at three utilities in the mid-Atlantic area. These studies represent collaborative investigations with individual utilities (Duke Power Company, Delmarva Power Company, and Virginia Electric Power Company), State resource agencies, local university scientists, and The Johns Hopkins staff of biological and engineering specialists. Field data have been collected over the past 2 years on a year-round basis with hydrological and meteorological data being recorded on a continuous basis.

In 1969, three additional sites were added to the project (Allen S. King site of Northern States Power Company, Wabash River Station of Public Service Indiana, and the Pittsburgh Station of Pacific Gas and Electric Company). These new sites represent previously existing environmental research projects in which the Hopkins project staff are assisting in the data collection and analysis with the respective research staffs of each site.

The biological investigations have had two

principal objectives. A first objective has been the study of populations of aquatic organisms (fishes, plankton, and benthic invertebrates) residing in the mixing zones for thermal discharges. These populations are being compared with those in similar areas that are not thermally influenced (i.e., upstream or distant stations). Changes in species diversity and population size fluctuations are under detailed surveillance with the objective of understanding the temporal and spatial distribution of significant aquatic organisms in relation to real thermal outfalls.

A second objective has been to study the effects of entrainment of microscopic organisms in waters used for cooling at these same stations. This work involves detailed comparisons of micro-biota before and after passage through cooling systems.

Results of the biological aspects of this research have been interesting. The populations of aquatic organisms located in thermally influenced zones of the three sites (an estuary, a tidal river, and a lake) have very little variance with those of comparable habitats lacking influence from artificial thermal sources. During warmer summer periods in the mid-Atlantic (July through September) fish population densities in discharge

canal areas are reduced apparently due to avoidance behavior in response to higher discharge temperatures (95 to 110°F.).

Comparisons of planktonic populations reveal that during summer periods some species of microcrustaceans are affected by the higher summer discharge temperatures in ways which we are currently attempting to clarify. In contrast, during cooler months (November through May) intake discharge comparisons do not reveal statistically different results.

Chlorination schedules and levels are being used to study their effects on microscopic animal life during such passages through the cooling systems. Phytoplankton studies involving rates of photosynthesis before and after passage through cooling systems are also under review. Tentative data suggest that, during summer periods, some reduction in the photosynthetic rates in discharge waters may occur. Winter and spring photosynthetic rates in discharge waters are higher than intake waters, suggesting an increase in productivity during cooler periods. Comparable rates in downstream mixing and cooling areas do not show large variance from control areas upstream from intake areas.

These data are under continual analysis and review with appropriate changes in collection techniques,

observation and culture techniques, etc., being made as warranted. Similar entrainment studies are either under way or planned for the three secondary sites to augment existing data programs.

In summary, our studies have not revealed conspicuous biological changes in populations of aquatic organisms residing in waters influenced by power plant discharges. It is becoming obvious that our observation techniques and data analysis will require careful supervision to locate and describe less obvious and subtle biological changes, if and when they occur.

MR. STEIN: Thank you, Dr. Jensen.

Are there any comments or questions?

MR. CURRIE: Yes, Mr. Chairman.

MR. STEIN: Yes, Mr. Currie.

MR. CURRIE: Are you trying to say, Dr. Jensen, that even within the mixing zones there will be no significant change in the biota?

MR. JENSEN: The questions we are asking relative to that is: What are the temporal and expansion changes of significant species, that is, species known to be important in the local biology within the mixing zones? And we can see effects on the discharge side of the condensers, as I mentioned here, during the warmer summer periods.

L. D. Jensen

Our research is currently attempting to verify whether these effects are serious to the local biology involved immediately adjacent to the power plant or whether they are mitigated by reproductive potential on the part of the species involved.

MR. CURRIE: Well, I would like to call your attention to some testimony that was presented before our Board by Dr. Edward Raney on behalf of the Commonwealth Edison Company last week, in which he said that most organisms including fish eggs will be denied some living space in the vicinity of outfalls, and it may be fair to characterize the type of several Edison biological discharges by saying that Lake Michigan is a big lake, and although small areas of it may be very seriously affected by heated discharges, we can spare some of the lake.

Are you trying to say that we don't even have to give up small areas?

MR. JENSEN: I am trying to say that we have not observed biological deserts, as we have had implied from numerous published articles that deal with thermal pollution. We are saying that the effects that we are observing are not year-round when we observe them. They are not a hundred percent effective among the populations

we observe them in and we are trying to clarify whether such facts as reproductive potential of the seemingly nonaffected organisms are involved.

In other words, we are trying to culture collections of animals that we know have been in condenser systems to know whether their biological potential is affected in subtle ways other than just plain death.

What other people have said regarding the existence of biological deserts downstream from thermal discharges I couldn't address myself to other than to say we have not observed uniform and year-round high death rates.

MR. CURRIE: Well, thank you. I think that helps to clarify what your conclusion is.

I wonder if you will be giving us at any time some of the reports and the facts on which your conclusions are based. I notice that there are no facts in your current statement.

DR. JENSEN: Our work is planned through the calendar year 1972.

MR. CURRIE: But you have conclusions in this report already; there must have been facts.

DR. JENSEN: We have some preliminary conclusions based on facts that have been included for the first two

years of the study at the sites concerned.

MR. CURRIE: Will you make those a part of the record?

DR. JENSEN: As Dr. Geyer suggested, there are interim reports that are currently under development now, the first to be released in a few weeks.

MR. CURRIE: But you are making conclusions without giving us the facts on which you base them.

DR. JENSEN: Well, the data that were used for drawing these conclusions for this presentation today are in these interim reports which will be available for distribution on a nationwide basis as soon as they are out of the printer's hand.

MR. STEIN: Are there any other questions?

Your reports won't be completed until 1972?

DR. JENSEN: Our field collection of data is planned through the end of 1971 and our reports are anticipated to be resolved -- our final reports -- during the calendar year 1972.

MR. STEIN: When did you think in 1972?

DR. JENSEN: Presumably late in the spring or early in the summer period.

MR. STEIN: You suggest we wait until then before we come to a conclusion?

DR. JENSEN: No, sir, I do not.

MR. STEIN: In other words, we have to move now.

DR. JENSEN: That is correct.

MR. STEIN: Let me go back. You talk about an estuary near the mid-Atlantic States. What estuary did you work with?

DR. JENSEN: The lower Chesapeake Bay.

MR. STEIN: What kind of estuary are you working with?

DR. JENSEN: This is the James River below Richmond.

MR. STEIN: And what lake?

DR. JENSEN: This is Lake Morgan, above Charlotte, North Carolina, of about a million-acre-feet-volume capacity.

MR. STEIN: How much acre feet is Lake Michigan?

DR. JENSEN: I can't tell you exactly.

MR. STEIN: All right. In other words, we get the lower Chesapeake Bay salt water operation, the James River, which is at least brackish, and a lake which is a fraction of Lake Michigan, and you want us to utilize these findings to make judgments on Lake Michigan?

DR. JENSEN: No, sir. I am only saying that in relation to observed biological effects downstream from

thermal discharges, one has to be very careful in projecting laboratory results into ecological projections.

MR. STEIN: Well, we recognize this. But you cited these; I didn't cite these. You cited an estuary, a tiny river, and a little lake, as compared to Lake Michigan on the mid-Atlantic. It is a reference point to what we are doing on Lake Michigan.

Now, if we are going to take due care to extrapolate laboratory results to field studies, what kind of comparison do you think we could do to take a salt water or brackish water and a relatively small lake compared to Lake Michigan?

DR. JENSEN: It seems to me that the research objectives, the methods of formulating the studies by going out into thermal discharges and actually making some measurements can be translated from one area of the country to another.

MR. STEIN: Would you care to make --

DR. JENSEN: Of course, the local biology is going to vary and I am not suggesting that you can translate from the Chesapeake Bay or from North Carolina to Lake Michigan. I am suggesting that you can go out and look into thermal discharges.

MR. STEIN: In other words, you say your study

does not reveal conspicuously logical changes in populations of aquatic organisms residing in water influenced by power plant discharges.

Now, some of these power plants intend to raise their water maybe by 10, 12, 14, 18 degrees. Since this cannot be demonstrated, are you suggesting that we let them go ahead?

DR. JENSEN: No, I am suggesting that you go out looking at some existing thermal discharges in the Great Lakes, those in Lake Michigan -- if you can possibly do so -- before you come to a final conclusion.

MR. STEIN: Well, how long do you think this would take?

DR. JENSEN: It would seem to me that that would have already been done by now.

MR. STEIN: But you don't think we have done it?

DR. JENSEN: Well, I have not heard it mentioned today.

MR. STEIN: Well, do you think you have done it?

DR. JENSEN: Excuse me?

MR. STEIN: Do you think you have done it?

DR. JENSEN: No, I am not suggesting we have done it.

MR. STEIN: In other words, you are not suggesting

that any material you have presented here applies to Lake Michigan.

DR. JENSEN: I am saying that in the Lake Michigan area there ought to be data that is applicable to Lake Michigan.

MR. STEIN: But nothing that you have given us here applies to it.

DR. JENSEN: That is correct. My conclusions are all based on the mid-Atlantic States.

MR. STEIN: Thank you.

Any other questions? Are there any questions from the audience?

Thank you very much.

DR. McWHINNIE: I am Mary Alice McWhinnie from DePaul University, Chicago, Illinois, engaged in a study on Lake Michigan known as the DePaul EPRO Program. I have worked in Antarctica now for 3 years. I return within 3 weeks. My objective is the study of temperature on living systems.

I think that there are basic elements of science with which we are dealing, most particularly a unit in living systems. It is imperative to recognize that whether the organism is adaptive to aquamarine or a freshwater environment, that it follows the same basic

biological laws.

I am delighted to report that organisms that die at plus 2 degrees centigrade show exactly the same temperature responses as do those that have a broad thermal latitude or broad thermal tolerance.

The point I am trying to make is that I think in the good interest of science it should be recognized that whether the organisms are in a river, a small lake, a large lake, or the marine environment, that they will follow the same laws of response to temperature.

In deference to the question of Mr. Stein, I would also like to emphasize that I do think it is critical that the hydrography of the region be learned with respect to the exposure field of the biotic system, not the response of the biotic system.

Thank you.

MR. STEIN: Can you respond to that?

Are there any other comments or questions?

Thank you very much, Dr. Jensen.

Mr. Petersen.

MR. PETERSEN: Mr. Donald H. Brandt, Director of Air and Water Quality Control for Consumers Power Company, will be spokesman for Consumers Power Company.

Mr. Brandt.

O. K. Petersen

The two doctors who were just on the stand giving statements are the two doctors who will be leaving.

MR. STEIN: From now on we will withhold other than panel comments any audience comments until all of the power industry is completed, and they will be here to answer questions, is that correct?

MR. PETERSEN: That is my understanding, Mr. Chairman. If someone should be called away, the industry will notify the Chair so that an opportunity will be given for questioning.

MR. STEIN: Right.

Thank you.

MR. PETERSEN: Thank you, Mr. Chairman.

D. H. Brandt

STATEMENT OF DONALD H. BRANDT,
DIRECTOR OF AIR AND WATER QUALITY
CONTROL, CONSUMERS POWER COMPANY,
JACKSON, MICHIGAN

MR. BRANDT: Mr. Chairman, gentlemen, ladies and gentlemen in the audience, my name is Donald H. Brandt. I am Director of Air and Water Quality Control for Consumers Power Company.

Consumers Power Company is a Michigan utility providing electric and natural gas service to 1,886 communities in a 30,800 square-mile area covering 67 of the 68 counties in the lower peninsula of Michigan.

MR. STEIN: Are you going to put in this whole report or are you going to summarize it? You can put it in in its entirety now.

MR. BRANDT: We would like it in its entirety placed in the record.

MR. STEIN: This will be placed in the record as if read.

(The report above referred to follows in its entirety.)

Consumers Power Company

LAKE MICHIGAN ENFORCEMENT CONFERENCE WORKSHOP

September 28 - October 2, 1970

Chicago, Illinois

STATEMENT BY

CONSUMERS POWER COMPANY

To Be Given at

A Workshop Ancillary to the

Third Session of the

Federal-State Enforcement Conference

on Pollution of Lake Michigan

and Its Tributaries

September 28 to October 2, 1970
Sherman House
Chicago, Illinois

Presented by:

Mr. D. H. Brandt
Director of Air & Water Quality Control

Dr. J. Z. Reynolds
Environmental Surveillance Coordinator

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I. INTRODUCTION

My name is Donald H. Brandt. I am Director of Air and Water Quality Control for Consumers Power Company.

Consumers Power Company is a Michigan utility providing electric and natural gas service to 1,886 communities in a 30,800 square mile area covering 67 of the 68 counties in the lower peninsula of Michigan.

In order to meet the service requirements of over 1,000,000 electric customers the Company has constructed, owns, maintains and operates an integrated electric generation, transmission and distribution system.

Presently, Consumers Power Company has several thermal electric generating installations in the Lake Michigan Basin which are part of this integrated network system. These are the B. C. Cobb Plant on Muskegon Lake, the James H. Campbell Plant on Lake Michigan near Holland and the Big Rock Point Nuclear Plant near Charlevoix. On tributaries to Lake Michigan the Company operates the B. E. Morrow Plant near Kalamazoo and three smaller plants in Kalamazoo, Battle Creek, and Grand Rapids. Electric production at the last three (3) plants is scheduled to be discontinued in the near future as a part of the Company's program for air quality control.

Additionally, construction has been completed on the Palisades Nuclear Plant directly on Lake Michigan, 35 miles west of Kalamazoo and it is awaiting an AEC operating license. Also, construction is underway on the Ludingtom Pumped Storage hydroelectric plant, 4 miles south of

Ludington, which will cycle lake waters to generate power to meet peak system demands.

Before proceeding with my specific comments, I want to identify, for the record, my Company's concern for the environment. For more than 50 years, Consumers Power Company or its predecessor companies, have demonstrated their concern with protecting Michigan's environment. This includes careful management of more than 700 miles of river lands. Land that was denuded by the lumber interests now has been replanted and made available to the general public. Our efforts also include application of the more effective technologies available to protect and improve the quality of air and water, such as the addition of electrostatic precipitators, conversion to gas and oil, and sponsoring research and numerous environmental studies to guide us in making decisions on these important matters.

As a public utility company, Consumers Power Company has an obligation to its customers to provide adequate, reliable and economical energy to meet their ever increasing energy requirements. At the same time, it has an obligation to protect the environment and, whenever possible, also makes life better for the people of Michigan by developing picnic areas, campsites and other recreational facilities. We are confident we can meet all of our obligations through the continued exercise of sound business judgment, consultation and guidance by technically qualified people, the application of appropriate control technology and acting in a forthright manner on environmental issues. Our responsibility to meet these obligations does not permit us the comfort, in today's

social atmosphere, of refraining from comment on these vital issues, just because the comments may be misunderstood, by some people, as opposition to pollution abatement.

We have examined the Federal Water Pollution Control Act, as amended, the Michigan water pollution control statute, consulted with counsel and we have examined the February 19, 1968 opinion from the Michigan Attorney's General's office dealing with these matters.

In view of these examinations it seems appropriate to draw the Conferee's attention to the philosophy of the Federal Act and some of its provisions.

1. First, Section 1(b) of the Federal Act provides in part:

> "it is hereby declared to be the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the States in preventing and controlling water pollution..."

A number of Federal officials often appear to forget or ignore this basic policy of primacy of the state regulation in their temperature standard setting efforts.

2. The setting of standards, according to Section 10(c)(3) requires that:

> "In establishing such standards the Secretary, the Hearing Board, or the appropriate State authority shall take into consideration their use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial and other legitimate uses."

Too many Federal officials and others have ignored this requirement to take into consideration all legitimate uses of

interstate waters. Instead, they consider exclusively the propagation of fish and wildlife. The Act obviously requires a balancing of interests and forbids the all too prevalent approach of considering other uses of the waters only to the extent that such uses will not limit or interfere in any way with propagation of fish and wildlife.

3. The legislative history of the Federal Act shows that Congress rejected the principal of effluent standards. This rejection resulted in a statute which did not confer upon the Secretary of the Interior the power to promulgate or enforce effluent standards. Nevertheless, at the last meeting of this conference a "policy" announcement of two Assistant Secretaries of the Interior was made which sought to have effluent standards imposed on Lake Michigan. Such standards would not be enforceable and standards to be meaningful must be enforceable.

4. Section 10(g) of the Federal Act provides that before any enforcement action can be undertaken there must be pollution which is endangering the health or welfare of persons. As the Michigan Attorney General's office has pointed out, "the danger must be real and immediate." Too many of the proposals regarding thermal discharge limitations deal not with real and immediate danger to the health or welfare of persons but a possible danger to some aquatic life. These proposals are predicated on extremely long-range predictions regarding the use of Lake Michigan Waters by electric utilities.

5. Sections 10(c) (5) and 10(h) of the Federal Act both contain provisions concerning court action on pollution. Where standards are involved the Court will make a complete review of the standards pertaining to the alleged violation, and the Court must give due consideration to the practicability and to the physical and economic feasibility of

complying with standards or otherwise securing abatement of proved pollution. In the words of the Michigan Attorney General's Office:

> "...the government must prove that it is physically and economically feasible to abate the particular pollution complained of, that it is in the public interest to so abate the pollution and that it is equitable to do so. In view of these considerations, the Court must find not only that the pollution exists as defined in the statute, but that it is economically feasible, physically possible, and equitable to order its abatement. ...it certainly would be an anomoly to require states to adopt standards for water quality or to take measures in the abatement of pollution if such standards of water quality are not enforceable in a suit brought by the US Government. It would seem that it was the Congressional intent to require the states to adopt standards of water quality, which if not adhered to would be enforceable in a suit brought by the US."

Consumers Power Company has on numerous occasions endeavored to make clear its concern for the environment. Our management has publicly stated that if a plant is found to be harmful to the environment, the Company will act promptly to correct the situation. Furthermore, this commitment is included in the Orders of Determination issued by the Michigan Water Resources Commission for all recently authorized electric generating facilities. The Company also believes that unnecessary equipment should not be required or built simply because of unsubstantiated anxiety that adverse conditions might exist. To install such equipment without first establishing the need for it would consitute an unnecessary burden on the financial resources of our economy without achieving a meaningful contribution to environmental quality.

I agree with Representative Craig Hosmer, Republican from California, when he said:

> "Environmental protection does not necessarily mean sending the world back to whence it came to be refurbished in its original pristine condition, nor does it involve turning off air conditioners, abolishing the automobile and uninventing the wheel. Rather the solution lies in achieving a satisfactory accommodation between the demands of the environment and of social benefits of technology."

This Enforcement Conference, prior to its May 7, 1970 meeting, was reported to have made progress by reaching an agreement between the Conferees on April 16, 1970 on a uniform procedure for the establishment of monthly maximum temperatures. The so-called one degree "policy" statement made at the opening of the May 7 conference and the "White Paper", belatedly issued for this conference, are not in our opinion, of sufficient value to warrant much attention on the part of the Conferees. The "one degree" statement clearly goes beyond reason as well as the intent of Congress. The "White Paper", drafted over a four month period, fails to take into account the technical data gained through years of experience with existing thermal electric generating plants (on the Great Lakes). Scientific studies, and actual observations of existing heated discharges in Lake Michigan, conducted by the staff of the Michigan Water Resources Commission and other qualified groups, have documented on numerous occasions that these plants have been operating many years without demonstrable adverse effects to the aquatic environment. These and other studies being made on the basis of data obtained from actual field observations warrant careful attention of the Conferees. FWQA is now proposing to subject all electric generating plants to temperature standards predicated on theories misapplied because of inadequate recognition of natural ecological factors.

Site studies made at existing plants (along the Great Lakes) should be evaluated before subjecting them to temperature standards which may require millions of dollars of capital expenditure because past studies and present surveillance programs offer no evidence that these waters require greater protection.

Gentlemen, we ask that you continue on your way to reaching conclusions supported by the law rather than emotion, and fact rather than fancy. We are confident you will reach conclusions which will adequately protect all of the legitimate uses of this natural resource for future generations.

Other individuals who Consumers Power Company has asked to present information to this workshop are Dr. John Z. Reynolds and representatives of the firm of Sargent & Lundy Engineers.

They will present Consumers Power Company's experience with thermal discharges into the Great Lakes, the results of studies and environmental surveillance programs and how they relate to the issue of regulating such discharges, and our assessment of the procedures by which such water use should be restricted.

II. LAKE MICHIGAN THERMAL DISCHARGES AND TEMPERATURE REGULATIONS

A. SUMMARY OF EXPERIENCE WITH THERMAL DISCHARGES

(1) Known Effects of Thermal Discharges in Lake Michigan

In recognition of a need for data collected from systematic surveillance, and for an expanded research effort on thermal discharges, electric utilities around Lake Michigan have launched an unprecedented effort to determine the effects of these discharges. Some of the studies of Consumers Power Company will be described in detail later. It would be appropriate at this point, however, to summarize the results of the various studies to date, and how they relate to the issue of establishing a basis for setting meaningful temperature standards, or otherwise limiting thermal discharges.

Thermal discharges into the Lake Michigan Basin have existed at numerous locations for many years. Most of these have been studied to determine their physical behavior under various conditions and some have ~~been studied to determine their physical behavior under various conditions and some have~~ been studied to detect any related biological effects.

It has been observed in all cases that discharges that are warmer than the ambient waters are buoyant and tend to spread into relatively thin layers on the surface. Mixing of the thermal discharge with the adjacent waters causes some entrainment into the plume. The relative amount of entrainment is primarily a function of the velocity conditions and the density differences at the interface. Theoretically, the least amount of mixing would occur when the temperature differentials are greatest and when the relative velocities are smallest.

With any degree of entrainment, the resulting mixed fluid will still be less dense than the ambient waters, and cause the combined volume to be buoyant. The commonly observed plume therefore tends to float on the surface of the lake until the excess heat has been dissipated to the atmosphere.

The "White Paper" purports to make a case that a large proportion of the heat from a thermal discharge is effectively mixed with the lake to accumulate and result in unacceptably high temperatures. We would like to cite just a few examples of the misleading way technical reports were abstracted in the paper to document the case.

It was quoted that Hoops et al (1968) "concluded, on the basis of work at a Lake Monona (Wisconsin) power plant, that surface heat losses were about 5 percent of the heat discharged by the power plant; the remaining 95 percent was dissipated by dilution with lake water." It was not stated, however, that this result was based on analysis of a discharge, contained by a baffle, from two days of field data on January 25 and 26, 1967, during a period of significant atmospheric warming. It might also be noted that these researchers concluded from the results of 22 field surveys during the remainder of the year that "power production increases of less than 100% will have a negligible effect on ... lake temperatures."

Work by Palmer (1969) was cited as supporting the notion that excess heat diffuses into the lake, as opposed to any significant atmospheric losses occurring. Our review of the paper failed to identify any point that would support this view. His studies of a cooling water discharge into Lake Ontario showed "that the warmer water stays near the

surface and the shore. The subsurface cooling water had acquired lake temperature by 4,000 feet while the surface cooling water (was) still $4^{\circ}F$ warmer than the lake water at 4,000 feet." Model studies were cited that assumed no atmospheric heat transfer, to simplify, in a conservative way, the mathematical predictions.

Similarily, work by Sundaram et al (1969) was cited where they "concluded that the heated discharge of the proposed Bell Nuclear Station on Cayuga Lake (New York) would increase the average surface temperature of this 66.4 square mile lake about $0.7^{\circ}F$." The Sundaram report, however, went on to note that "for a given amount of heat that is discharged into the lake, the far-field effects will be greater if the discharge temperatures were close to the ambient lake surface temperatures than if the discharge temperatures were significantly higher than the ambient lake surface temperatures, since in the latter case a greater fraction of the total heat can be lost to the atmosphere directly than in the former case."

Benedict's (1970) shoreline discharge model of the Campbell Plant and Prichard-Carpenter Consultants (1969 and 1970) computations for Toledo Edison were cited in the "White Paper" as further support that the "assumption of little or no waste heat loss to the atmosphere is reasonable, at least during a great deal of the annual temperature cycle." In both cases the assumption that surface heat loss was limited was arbitrarily made to simplify the model. No evidence is given or even implied by the original authors that this was a realistic assumption.

It's not realistic, or even honest, to use such model studies to support such a viewpoint, when much field data, from actual installations, are available that can be used for this purpose.

No evidence has been presented of which we are aware that the physical presence of a thermal plume on Lake Michigan has interferred with or otherwise caused injury to any beneficial use of the waters. In fact, the areas of heated discharge are often observed to appeal to swimmers, since the lake waters are normally too cold for comfortable water contact activities.

Researchers evaluating the results of biological studies that have been conducted in the vicinities of thermal discharges in Lake Michigan have similarly concluded that no adverse effects have occurred as a result of this use of the waters. Electric utilities, consultants, universities and governmental agencies have been unable to document significant biological effects outside of the localized influences on fish that prefer or avoid the region of increased temperature. Fishing in the vicinities of thermal discharges has been observed to be favored for the greater portion of the year, even for some of the so-called cold water, heat sensitive species.

Consumers Power Company has maintained parking areas in the vicinities of some of the plant discharges to facilitate access for fishermen and others. We have received requests from the Fish Division and the Bureau of Water Management of the Michigan Department of Natural Resources to provide more facilities to accommodate the public because of the "recreation potential in year-round fishing" in these areas.

The only reference in the "White Paper" purporting actual evidence of harmful effects of a thermal discharge into Lake Michigan concerns an alleged fish kill at the Consumers Power Company Campbell Plant on August 29, 1968. While it was indicated that a drop in temperature due to natural upwelling may have been a major factor resulting in the conditions observed, the paper does not give any indication of the scope of the adverse condition noted.

The observations were made by John Robinson, Aquatic Biologist, employed by the Michigan Water Resources Commission. He stated that the water temperature at the point of discharge was 64.4°F and that the temperature dropped in a short distance to 59°F and then gradually declined to the ambient of 50°F in one-half mile. This is the lowest temperature recorded at the plant for any day in August since the plant has been in operation, and occurred only a few days after a water intake temperature of 76°F had been observed.

Mr. Robinson noted there were live catfish and carp near the discharge and schools of alewives in the area. Some dead alewives were observed, but no estimates were made of the numbers involved. The only other dead fish reported were a catfish and/or carp approximately every 150 feet along one mile of shoreline. This amounts to a total of about 35 fish. Apparently no sport fish were involved. Mr. Robinson concluded that the fish affected were apparently indigenous to the long cooling water discharge canal and that the very unusual combination of natural temperature fluctuations was partly responsible for their condition. It has been reported that this phenomenon of rapid natural temperature variations has caused fish to be in distress at other locations, around the Great Lakes.

At the recommendation of the conferees of the Lake Michigan Enforcement Conference in 1968, an interagency Committee on Nuclear Power Plant Waste Disposal was formed which reported to the conferees in November 1968. They stated:

> "The effects of localized temperature increases on the aquatic life in Lake Michigan are impossible to predict from the limited information available. Only a few observations have been made to date of the effects of existing thermal discharges on Lake Michigan biota. However, laboratory investigations and observations elsewhere suggest that increase in temperature can result in damage to the aquatic environment."

The Committee recommended, with regard to thermal discharges, that:

> "Coordinated study of the thermal effects on water quality and aquatic life of one or more fossil fuel plants now discharging cooling water to Lake Michigan, and of various methods of cooling water dispersion be undertaken by FWPCA."

and

> "FWPCA coordinate a comprehensive study of the effects on water quality and aquatic life of thermal wastes from a large nuclear power plant on Lake Michigan, with attention to various methods of cooling water dispersion."

It is apparent that the Federal Water Quality Administration (formerly FWPCA) has not carried out either recommendation of the Committee inasmuch as no notice has been made of such comprehensive studies by FWQA. Fortunately, even before the Committee's report, the electric utilities around Lake Michigan were concerned about the early detection of any possible adverse effects that thermal discharges might cause. These companies instituted comprehensive studies on their own or in cooperation with the appropriate state agencies. The scope and methodology of these studies are such that it can be assured that, if harmful effects are caused, they will be detected.

(2) Relative Significance of Thermal Discharges in Lake Michigan

The previously mentioned report of the Committee on Nuclear Power Plant Waste Disposal to the Conferees of the Lake Michigan Enforcement Conference included the following comment on thermal discharges into Lake Michigan:

> "In spite of the known adverse effects which temperature change can have on aquatic life, it is not certain that they will occur in the unique environment of Lake Michigan. Much of the shoreline is seldom inhabited by aquatic animals because the bottom materials consist of shifting sand. There are rocky shoals that support game fish population. Whether or not local increases in temperatures will accelerate the eutrophication of Lake Michigan is uncertain at present. It is tempting to speculate on this but only intensive longterm studies will reveal the facts. Local increases in algal growth very probably will develop if sufficient nutrients are available, since biological activity is greater in warmer than in cooler water. The magnitude of these increases must be known before there can be evaluation of the potential problem."

Then, after discussing the relative merits of low or high velocity, and offshore or onshore discharges, the Committee reported that:

> "A recommendation that one or the other (type of discharge) be routinely required for all power plants would have to be supported by firm information on damages to water quality and uses that would result from failure to require such devices. Available information on potential damages does not provide a basis for such a position at this time. Such information can be obtained through studies by aquatic biologists of areas in Lake Michigan where large fossil fuel plants presently discharge large quantities of cooling water."

To our knowledge the biological data that have been compiled since the Committee's report have failed to substantiate any significant biological effects.

It is also interesting to note that in the same report, after computing the total heat input into Lake Michigan from existing and

proposed power plants, the Committee concluded that "there is minimum need for immediate concern over the effect of temperature on the lake as a whole." They went on to say that the probable long-range effects deserve consideration. We agree there may be some future point at which the effects of substantial additional thermal discharges might cause significant effects for the lake as a whole. We demonstrate our concurrence with their observation that the possible local effects are of more practical and immediate concern in that our ecological investigations are largely oriented to detect such influences of thermal discharges.

B. STANDARDS FOR LIMITING THERMAL DISCHARGES

(1) Recommendations of National Technical Advisory Committee

> "On February 27, 1967, the Secretary of the Interior established the first National Technical Advisory Committee on Water Quality Criteria to the Federal Water Pollution Control Administration. The Committee's principal function was to collect into one volume a basic foundation of water quality criteria."

As described in the introduction to the Report of the National Technical Advisory Committee on Water Quality Criteria dated April 1968:

> "The Committee was concerned abouve several issues relating to water quality standards for the control and abatement of water pollution. Foremost among these is the lack of adequate knowledge concerning many of the quality characteristics upon which criteria and, hence, standards should be based. The unknowns still outweigh the knowns. Complicating factors in setting standards are varying natural conditions affecting water quality, such as climate, geography, and geology of a specific location. The Committee does not want to be dogmatic in recommending these criteria. They are meant as guidelines only, to be used in conjunction with a thorough knowledge of local conditions. Further, it is anticipated that future research will provide considerable basis for refinements in the recommendations."

> "The Committee recognizes that the protection of water quality for legitimate uses requires far more than scientific information. There is an urgent need for data collected from systematic surveillance of waters and waste sources and for an expanded research effort."

While the Committee observed that for lakes the situation is complex and cannot be specified in simple terms, their recommendation for both warm and cold water lakes was that the temperature of the epilimnion should not be raised more than $3^{\circ}F$ by the addition of heat of artificial origin. They further qualified that position in the case of warm waters saying that "in those areas where important organisms are most likely to be adversely affected, (the temperature) should not be raised more than $3^{\circ}F$ above that which existed before the addition of heat of artificial origin." The committee members clearly implied that they felt temperatures in excess of $3^{\circ}F$ within a mixing zone were of no special significance unless, of course, it could be demonstrated that harmful effects would occur.

It should be pointed out that while the Committee made no specific reference to mixing zones with regard to freshwater organisms, in discussing criteria for marine and estuarine organisms it was stated that the suggested temperatures were to apply outside of mixing zones, which would be related to required zones of passage. The situation regarding heated discharges into very large lakes, such as Lake Michigan, would be comparable to ocean discharges in this respect.

The Committee could be critized, however, for not making a distinction between mixing zones involving temperature and those that would involve contaminating substances. They stated, in effect, that dilution flows should be very large to limit the area of mixing. While

this would be generally true for contaminating substances which would remain in the water body, discharge of heated waters involving buoyancy effects and dissipation of heat to the atmosphere complicates the task of defining mixing and zones of passage. The significance of the configuration of the mixing zone or its dimensions can only be based on individual site considerations and the nature of the aquatic life or other beneficial uses to be protected.

(2) Various Proposals and Recommendations Related to Temperature Standards

STATE ACTION - In accordance with the Federal Water Pollution Control Act, as amended by the Water Quality Act of 1965, the Governor of the State of Michigan wrote to the Secretary of Health, Education and Welfare on December 17, 1965, that it was the intent of the State to adopt criteria applicable to interstate waters under the authority of Act 245, Public Acts of 1929, as amended. The Michigan Statute declares to be unlawful, the discharge of any substance:

> "which is or may become injurious to public health, commercial, industrial, agricultural, recreational or other uses which are being or may be made of such waters; or which is or may become injurious to the value or utility of riparian lands; or which is or may become injurious to livestock, wild animals, birds, fish, aquatic life or plants or the growth or propagation thereof be prevented or injuriously affected; or whereby the value of fish and game is or may be destroyed or impaired."

Section 5 of the Act declares in part:

> "The Commission (Michigan Water Resources Commission) shall establish such pollution standards for lakes, rivers, streams and other waters of the state in relation to the public use to which they are or may be put, as it shall deem necessary."

In June 1967, water temperature standards for the Great Lakes were adopted by the Michigan Water Resources Commission (MWRC) and submitted by the State to the Federal Government for approval. It reads as follows:

> "For the Great Lakes and connecting waters no heat load in sufficient quantity to create conditions which are or may become injurious to the public health, safety or welfare; or which are or may become injurious to domestic, commercial, industrial, agricultural, recreational or other uses which are being or may be made of such waters; or which are or may become injurious to the value or utility of riparian lands; or which are or may become injurious to livestock, wild animals, birds, fish or aquatic life or the growth or propagation thereof."

FEDERAL ACTION - Even though the temperature standards adopted by the MWRC in 1967 appeared to contain all the necessary restrictions defined in the Federal Water Pollution Control Act, and met the constitutional requirement that beneficial uses unrelated to any injury could not be prohibited, the Secretary of the Interior did not approve them.

Then, on October 23, 1969, H. W. Poston, Regional Director of the Federal Water Pollution Control Administration (FWPCA), U. S. Department of the Interior, sent to R. W. Purdy, Executive Secretary of the MWRC, a proposed Lake Michigan Temperature Standard, stating "This standard is the result of a comprehensive review of temperature and aquatic life data for Lake Michigan conducted by the National Water Quality Laboratory in Duluth."

The recommendations for monthly maximum surface temperature in ^{o}F were:

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
50	50	50	50	55	70	85	85	85	85	70	55

No recommendations were made regarding the definition of mixing zones and the only comments on discharge areas were related to the possibility of fish kills and the blockage of tributaries supporting anadromous fish.

STATE ACTION - On February 17, 1970, Carlos Fetterolf, Supervisor of the Water Quality Appraisal Section, MWRC, reported to the Commission that his staff had explored the reasons for disapproval of the Michigan temperature standards by the Federal Government. He then submitted new standards for consideration. The principal changes for the Great Lakes involved substitution of a $5^{\circ}F$ temperature rise limitation and the setting of monthly maximum temperature values outside of mixing zones to be defined by the MWRC. Lake Michigan was divided into northern and southern sectors at Pentwater, Michigan. No increase would be allowed greater than $5^{\circ}F$ nor any temperature above 80 or $85^{\circ}F$ for the northern and southern sectors, respectively.

He reaffirmed the MWRC staff position that mixing zones should be established based on individual site conditions and stated further that Dr. Mount of the FWPCA Duluth Laboratory had questioned the advisability of subjecting mixing zones to formula identification. Apparently some FWPCA representatives had informally suggested that formulas would be appropriate.

The MWRC scheduled a public hearing for March 19, 1970, to review the staff recommendations. In the meantime, however, the staff felt that approval from FWPCA could be expedited by complying with their further request for numerical monthly temperature maximums for the Great Lakes, and by adding some general considerations as to philosophy of regulation.

The proposed monthly temperature limitations for the southern sector of Lake Michigan, for instance, in °F were:

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
50	50	60	65	75	85	85	85	85	70	60	50

The maximum temperature limit for the northern sector would be 80°F.

FEDERAL ACTION - Representatives of FWPCA testified at the public hearing on March 19, 1970, at which time they presented an edited copy of the proposed State regulations. They suggested striking any reference that mixing zones be related to the value of aquatic life and physical characteristics of the receiving water body, and all qualifying statements as to the extent of adverse effects. It was suggested that mixing zones be defined by formula but should not exceed one mile in radius.

They further suggested that the Great Lakes be separated into loosely defined open waters and inshore waters. For Lake Michigan the recommended temperature limits for open waters in °F were:

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
42	37	37	44	53	65	71	74	72	65	54	50

It was pointed out at the hearing by Mr. Purdy of MWRC that these suggested limits are exceeded, due to natural causes, on a regular basis.

Consumers Power Company has collected a considerable amount of temperature data from two power plants on Lake Michigan that are somewhat representative of lake temperatures. One, the Big Rock Point Plant, has an intake that is located 1450 feet from shore at a depth of approximately 25 feet and would be subject somewhat to stratification influences. The

range of maximum daily average temperatures for each month for a six year period of record are shown on Exhibit II-A, as are the temperature limitations proposed in March 1970. It should be noted that for seven of the twelve months during this short period of record the natural intake temperatures equaled or exceeded the limitations proposed by FWPCA for open waters in Lake Michigan.

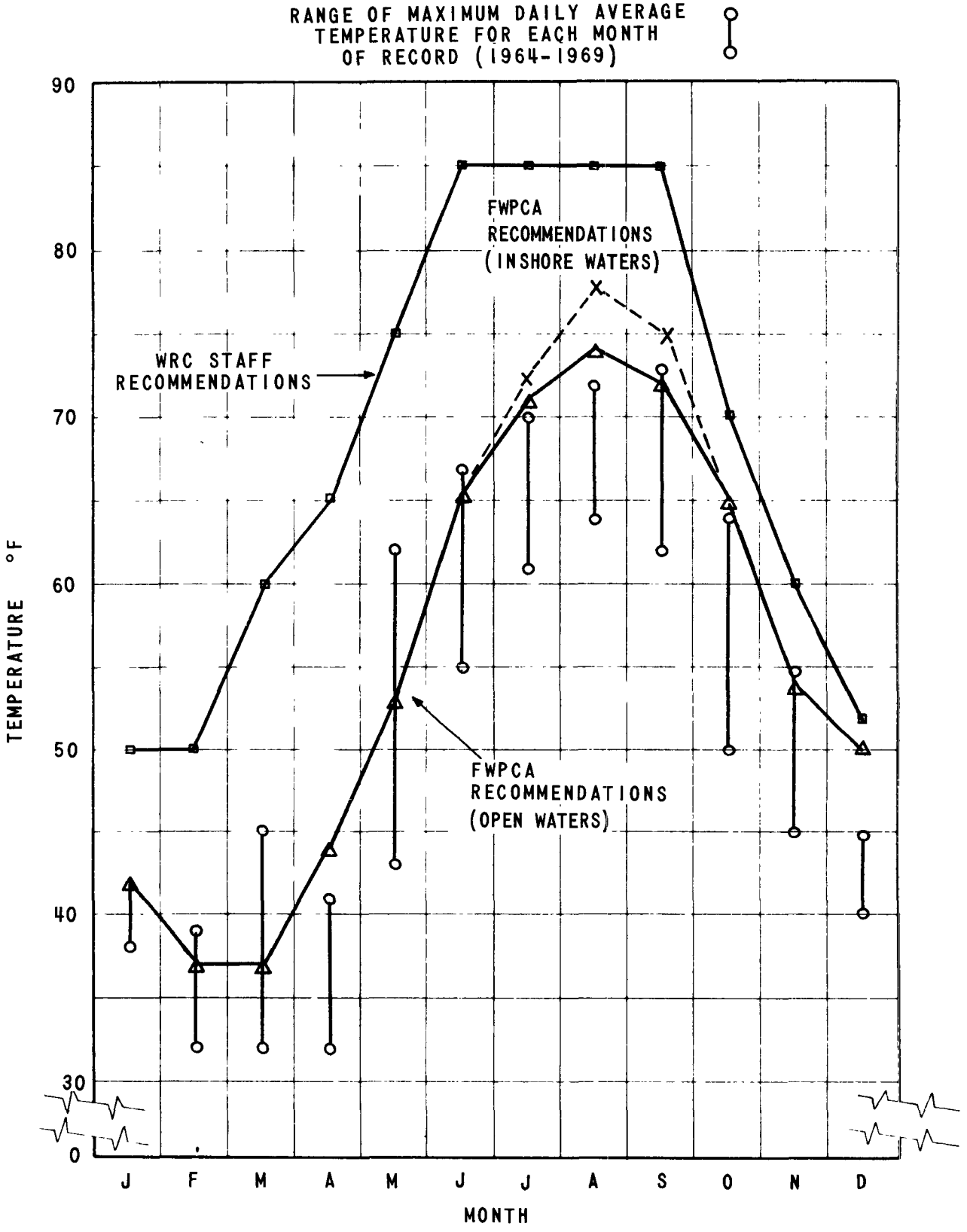
The J. H. Campbell Plant intake is located on Pigeon Lake into which Lake Michigan water flows. From a temperature standpoint the intake is indicative of "inshore" conditions, though some recirculation from the discharge occurs periodically. The range of maximum daily average temperatures for each month for a six year period of record is shown on Exhibit II-B, with the proposed temperature limitations for open and inshore waters. For several months the maximum daily average temperature exceeded the proposed FWPCA limitations for every year of record. In three months the proposed limit was exceeded by over $10^{\circ}F$, which would be difficult to account for by considering the maximum effect of recirculated discharge from the plant.

FWPCA representatives further recommended that a $3^{\circ}F$ temperature rise outside the mixing zone be the limitation for Lake Michigan.

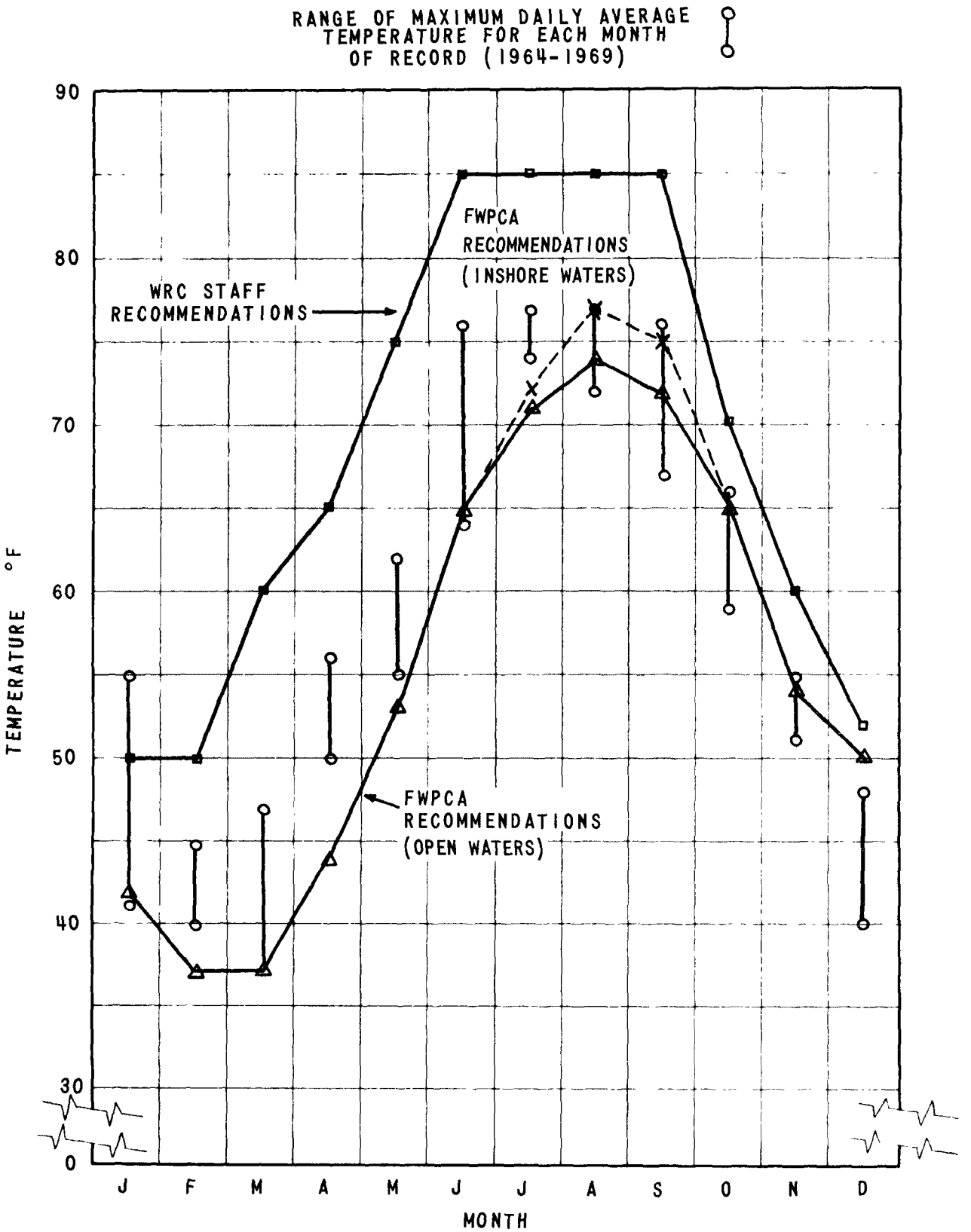
Their testimony supported the MWRC staff proposal that the water resources be protected for the "optimum use by fish, wildlife and other aquatic life," without mention of other beneficial uses. They further recommended that "at no place in a mixing zone shall the 96-hour median tolerance limit (96 hr. TL_m) to aquatic life be exceeded." The recommendation did not define what aquatic life was to be protected. No explanation or justification for such a restrictive limitation was given.

EXHIBIT II-A

BIG ROCK POINT
INTAKE TEMPERATURE



J. H. CAMPBELL PLANT
INTAKE TEMPERATURE



On April 10, 1970, F. T. Mayo of the FWPCA regional office submitted additional recommendations. The suggested monthly maximum temperature limits for Lake Michigan inshore waters in °F were:

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
42	37	37	44	53	65	72	77	75	65	54	50

It was further recommended that mixing zones should not include waters within 600 feet of shore.

STATE ACTION - After the March 1970 hearing, the MWRC released the results of a study consisting of approximately 24,000 temperature readings from eight Lake Michigan water intakes in Michigan which are unaffected by heated discharges and over 300 shoreline temperatures from 20 swimming beach stations. This study was initiated after consultation with Federal Water Quality Administration (FWQA) representatives.

At a meeting in Ann Arbor, Michigan, on April 16, 1970, it was agreed by the Lake Michigan Enforcement Conferees representatives that the States and FWQA would tabulate existing temperature data for Lake Michigan. The 90th percentile value to be determined from this data would then serve to establish monthly maximum temperature limitations. This information would be the basis for discussions at the Executive Session of the Lake Michigan Enforcement Conference scheduled to be held in Chicago on May 7, 1970.

FEDERAL ACTION - The meeting in Chicago on May 7, 1970, although scheduled as an executive session, actually became a public hearing. The following statement issued by Carl L. Klein and Leslie Glasgow, Assistant Secretaries of the Interior, was read before the Lake Michigan Enforcement Conference:

"The minimum possible waste heat shall be added to the waters of Lake Michigan. In no event will heat discharges be permitted to exceed a 1°F rise over ambient (existing temperature) at the point of discharge. This will preclude the need for mixing zones."

This declaration effectively negated the substantial efforts of the State conferees and the staff of FWQA, during the previous months, to resolve differences in concepts and to secure a reasonable basis for temperature standards.

STATE ACTION - The MWRC requested FWQA to provide written clarification of the policy statement issued by Carl L. Klein and Leslie Glasgow, and scientific documentation which would show the need for such a strict policy.

On September 18, 1970, the MWRC expressed its support of a revised set of temperature standards, as recommended by the staff. Their proposed maximum monthly temperature standards for the open waters of the southern sector of Lake Michigan in °F are as follows:

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
35	35	39	49	57	67	74	76	73	64	54	43

Similarly, the proposed standards for the inshore waters of this sector in °F are:

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
38	38	42	54	63	78	82	82	80	70	60	48

The maximum temperature limit proposed for the inshore waters of the northern sector of Lake Michigan is 76°F.

The proposed temperature standards for inshore waters are based on the 90th percentile, adjusted for 3°F increase at the edge of the mixing zone.

This recitation of exchanges between the Department of the Interior and the MWRC has been primarily for the purpose of illustrating the confusion that prevails concerning the adoption of temperature standards. The sincere and honest efforts of many who have worked to develop reasonable temperature standards, based on the technical evidence, have been repeatedly destroyed by inconsistent and confused pronouncements and recommendations by others.

(3) Water Use Parameters and Restrictions on Uses

It is the philosophy of the Federal Water Pollution Control Act to assure that all waters will be equally protected for all legitimate uses. Propagation of fish and wildlife is one of those legitimate uses. Utilization by industry is another one. This is particularly true for those rivers and lakes where either or both of these uses are already established. Industry must not be allowed to pollute a body of water and destroy the fish and wildlife that exist. Similarly, propagation of fish and wildlife must not be such as to destroy or pose intolerable burdens upon the industries that utilize the waters. We believe it is possible to set standards that will satisfy both requirements.

In view of this, we objected to several statements and suggestions made by the representatives of FWPCA at the March 19, 1970, MWRC hearing regarding thermal discharges, effects, and regulations.

Their basic rationale, as stated by Dr. Donald Mount of the National Water Quality Laboratory, Duluth, Minnesota, that "when protecting aquatic life we normally protect the waters for all beneficial uses," and their suggestion that the 96-hour median temperature tolerance

limit to aquatic life not be exceeded at any point, is meaningless unless related to specific aquatic life to be protected.

Dr. Mount's statement, that "fishes are repelled by temperatures that are unacceptably high during the summer months and, therefore, these pose no particular problem except that the habitat available is reduced in area," is clearly inconsistent with the FWPCA position taken at the same meeting that at no point should temperatures exceed values that have been shown to cause detrimental effects in confined laboratory conditions.

Likewise, a rigid definition of lake mixing zones based solely on a rate of discharge, as they suggested, does not recognize either the potential effects of thermal discharges on aquatic life or a beneficial use concept. Dr. Mount's brief statement that "every mixing zone should be defined geographically," oversimplifies the ecological complexity of the waters involved, as does the FWPCA recommendation that uniform temperature limits should be imposed on each of the Great Lakes.

Dr. Mount was concerned that fish residing in warmwater effluents during the winter be protected in case the plant must be shut down. The fish that are most likely to inhabit this relatively small area would not find the normally cold lake temperatures suitable. As such, these warmwater areas provide for greater diversity of fish habitat for the lake as a whole, and, although these fish might be temporarily adversely affected by plant shutdown, the natural populations should not be significantly affected.

Similarly, the importance of maintaining the "normal daily fluctuations" for the Great Lakes has been overstated in the various proposed standards, in view of the great natural temperature fluctuations

that occur from day to day. This situation is described in the "White Paper" and is well documented in the records of the staff of the MWRC and others.

While the FWPCA concept in March 1970, of differentiating between inshore waters and open waters is ecologically sound, the definition set forth by FWPCA was not complete enough to allow for confident prediction of these limits, either spatially or temporally. They stated simply that "inshore waters are those waters which are affected by tributary stream plumes (other than connecting channels), near shore thermal bars, natural shore erosion, or bottom sediment resuspended by wave action. Waters not defined as inshore waters would be considered as open waters."

The "White Paper" now defines the inshore zone as "that volume of water which lies between the shoreline and the 100-foot depth contour," and includes what is called a "beach water zone, a sub-area that extends from the shoreline out to the 30-foot depth contour." This vacillation in establishing basic definitions does not facilitate efforts to set standards.

Whether for inshore or open waters, any temperature regulations should reflect naturally occurring conditions, and allow for variations consistent with those known to occur without any thermal discharges.

It was pointed out at the March 1970 hearing that a 58°F limitation, as proposed by FWPCA for migratory routes of salmonid species during migration, was unrealistic considering the fact that healthy migrations occur in 70°F water. Similarly, lake water temperatures should

not be arbitrarily restrictive, in view of the fact that extreme temperature excursions have occurred in the past by natural and artificial means, with no apparent damage to the aquatic ecology.

Dr. Mount made the statement, when questioned about the natural conditions exceeding his recommendations, "that if the temperature is unacceptable, it is unacceptable whether it has been caused by the sun or man." This should cause us to pause and consider the nature of the situation. Because if the artificial aquatic habitat mankind has nurtured, in the lakes particularly, is truly unsuited to this climate, the concept of beneficial use of these waters by all citizens should receive prompt and thorough review. According to the law, other beneficial uses should not be placed in jeopardy because an especially delicate fishery has been developed, as Dr. Mount suggests.

Consumers Power Company is convinced that this is not the situation, and based on years of experience with thermal discharges on the Great Lakes, is certain that even greater heat loads can be added to the lakes without harming the aquatic ecology as it exists today or otherwise interfering with other reasonable beneficial uses.

III. COMPANY ENVIRONMENTAL PROGRAMS

A. COMPANY SURVEYS ON THE GREAT LAKES

As mentioned earlier, concern for preserving the environment has historically been the corporate policy of Consumers Power Company. This concern for preserving water quality in Michigan can best be demonstrated by describing our water quality surveillance programs conducted in the past several years at all our major generating stations.

The Company has engaged the services of university and private consultants in all facets of the aquatic sciences, cooperated with efforts of state agencies, and has added technically qualified staff in this field. As a result of this combined effort, over 80 temperature surveys and 20 biological surveys have been conducted to date in the cooling water discharges of the Company's seven major electrical generating sites. Exhibit III-A summarizes these studies. It should be noted the list of surveys shown in Exhibit III-A includes only surveys related to thermal effects and does not include numerous radiological and other surveys that have been conducted relative to water quality.

EXHIBIT III-A

WATER QUALITY SURVEILLANCE STUDIES
AT CONSUMERS POWER COMPANY
MAJOR STEAM GENERATING PLANTS, 1967 - 1970

PLANT NAME	TEMPERATURE SURVEY	INFRARED IMAGERY SURVEY	BIOLOGICAL SURVEY
A. BY CONSUMERS POWER COMPANY			
1. J. R. Whiting	6	1	0
2. D. E. Karn - J. C. Weadock	8	1	1
3. Big Rock Point	1	2	0
4. B. C. Cobb	8	1	0
5. J. H. Campbell	8	2	2
6. Palisades	13	0	11
7. B. E. Morrow	13	1	0
Sub Total	57	8	14
B. COOPERATIVE STUDIES WITH OTHER UTILITIES, STATE AGENCIES AND UNIVERSITIES			
1. J. R. Whiting	1	1	0
2. D. E. Karn - J. C. Weadock	0	0	0
3. Big Rock Point	4	0	1
4. B. C. Cobb	4	0	0
5. J. H. Campbell	4	1	3
6. Palisades	1	1	3
7. B. E. Morrow	0	0	1
Sub Total	14	3	8
Total	71	11	22

B. C. COBB PLANT - MUSKEGON LAKE - Beginning in 1967, a series of temperature surveys have been conducted at the 531 MWe B. C. Cobb Plant on Muskegon Lake. Most have been made during fish migratory seasons to determine the plant's influence on the zone of passage in Cedar Creek (North Branch Muskegon River). These studies have demonstrated that a zone of passage was maintained in Cedar Creek from the point of condenser water discharge to Muskegon Lake. As an example, the thermal plume observed on July 17, 1970, is shown on Exhibits III-B, C and D for the surface, 2 ft depth and bottom, respectively. Other temperature surveys have been conducted on Muskegon Lake and include an infrared aerial survey in 1970.

BIG ROCK POINT PLANT - LAKE MICHIGAN - Since 1960, Consumers Power Company, in cooperation with various state agencies, has conducted a routine radiological monitoring program of the biota in the vicinity of the 71 MWe Big Rock Point Plant on Lake Michigan near Charlevoix. In addition, temperature surveys have been conducted, including two infrared flights. The surface plume observed on June 18, 1968, is shown on Exhibit III-E, as an example.

KARN-WEADOCK PLANTS - SAGINAW BAY - A comprehensive biological survey has been conducted at the 1226 MWe Karn-Weadock facility on Saginaw Bay, which includes bottom fauna, plankton and macrophytes. In conjunction with the study, the results of which will be available later this year, extensive fish surveys were conducted in the discharge vicinity. In addition, numerous thermal plume measurements were made, including an infrared aerial survey in 1970. The thermal plume observed on August 7, 1970,

B. C. COBB PLANT
July 17, 1970

Surface Water Temperature Survey
Ambient Temperature 76°F

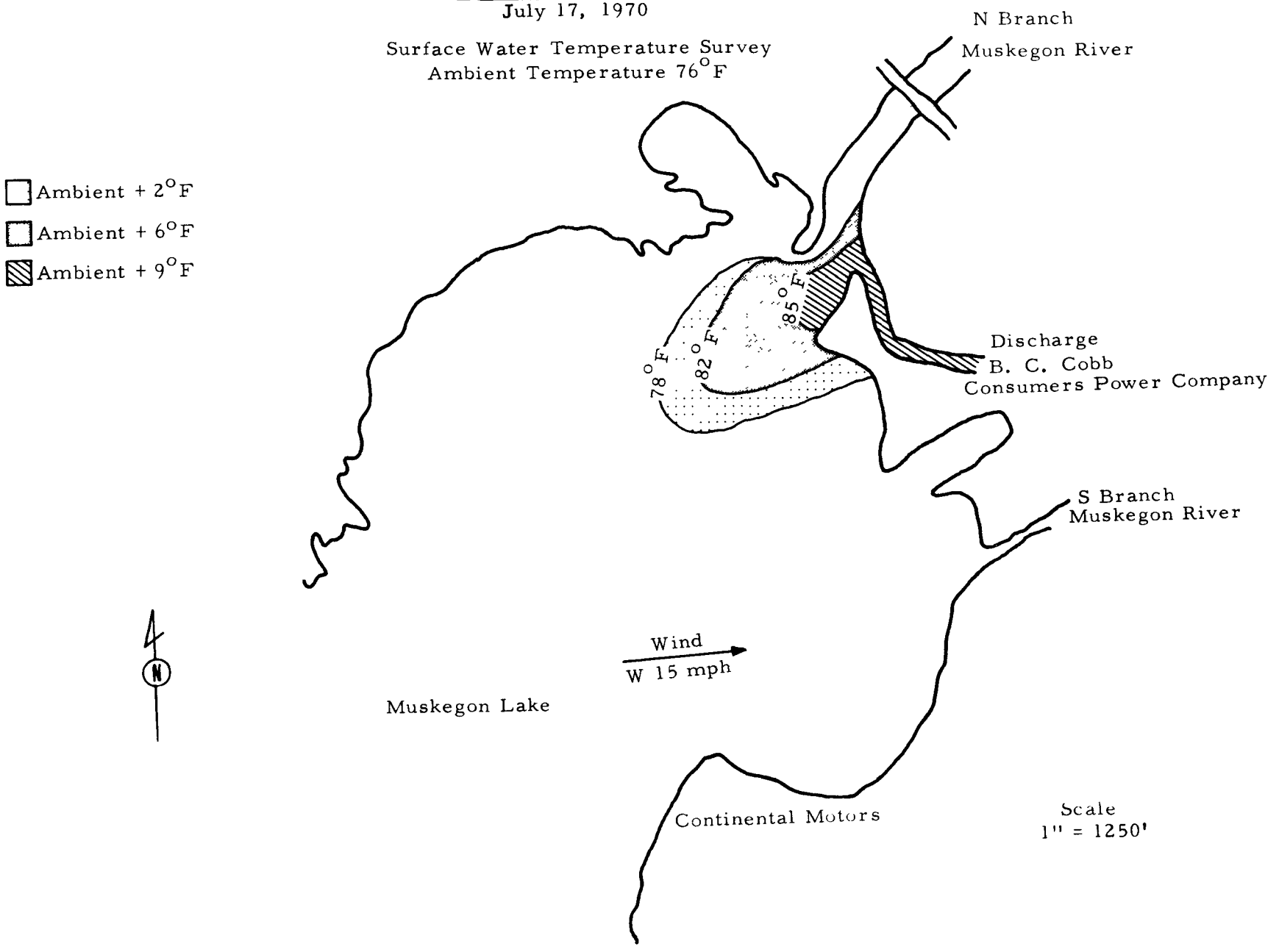


EXHIBIT III-B

B. C. COBB PLANT
July 17, 1970

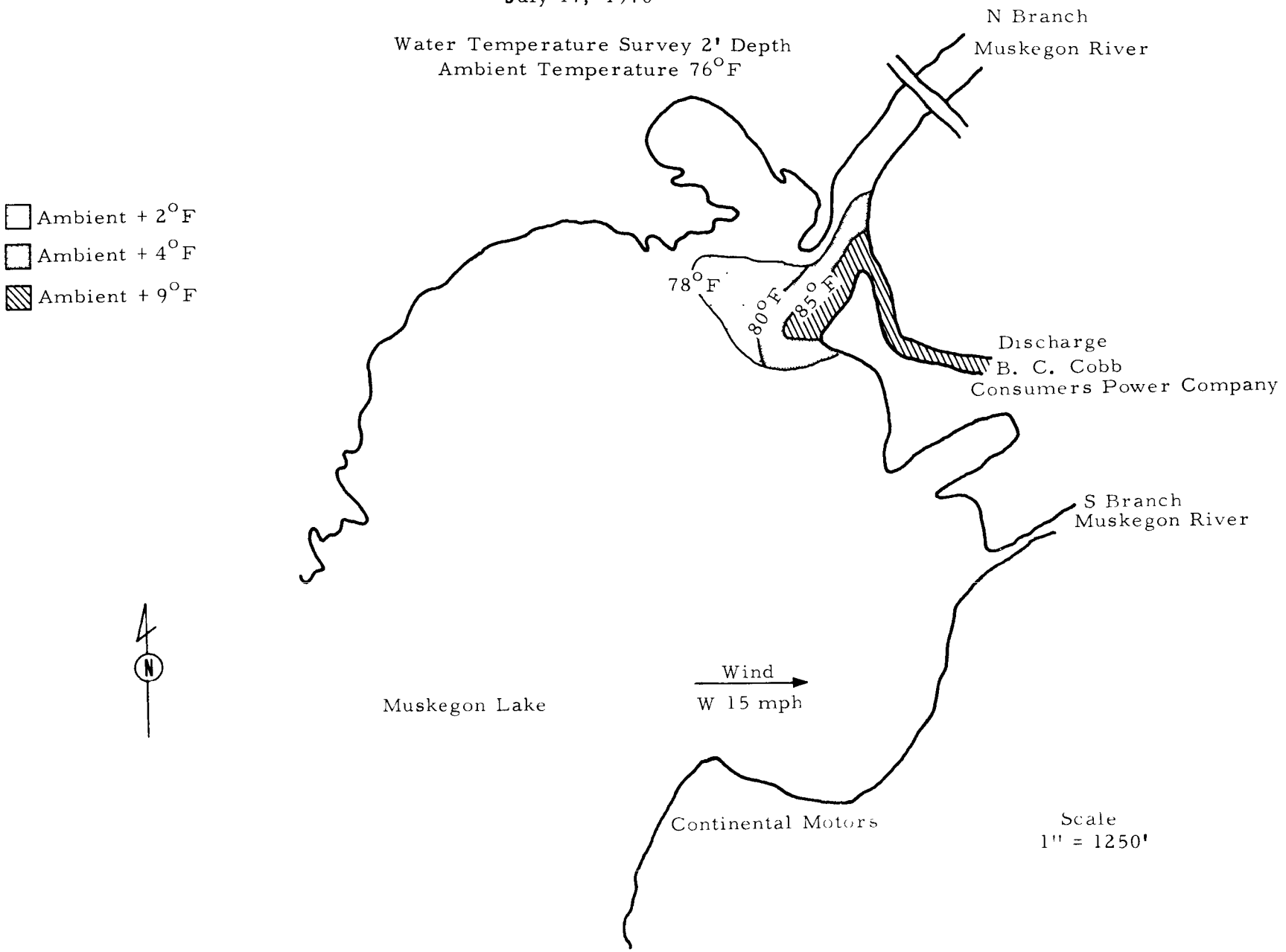


EXHIBIT III-C

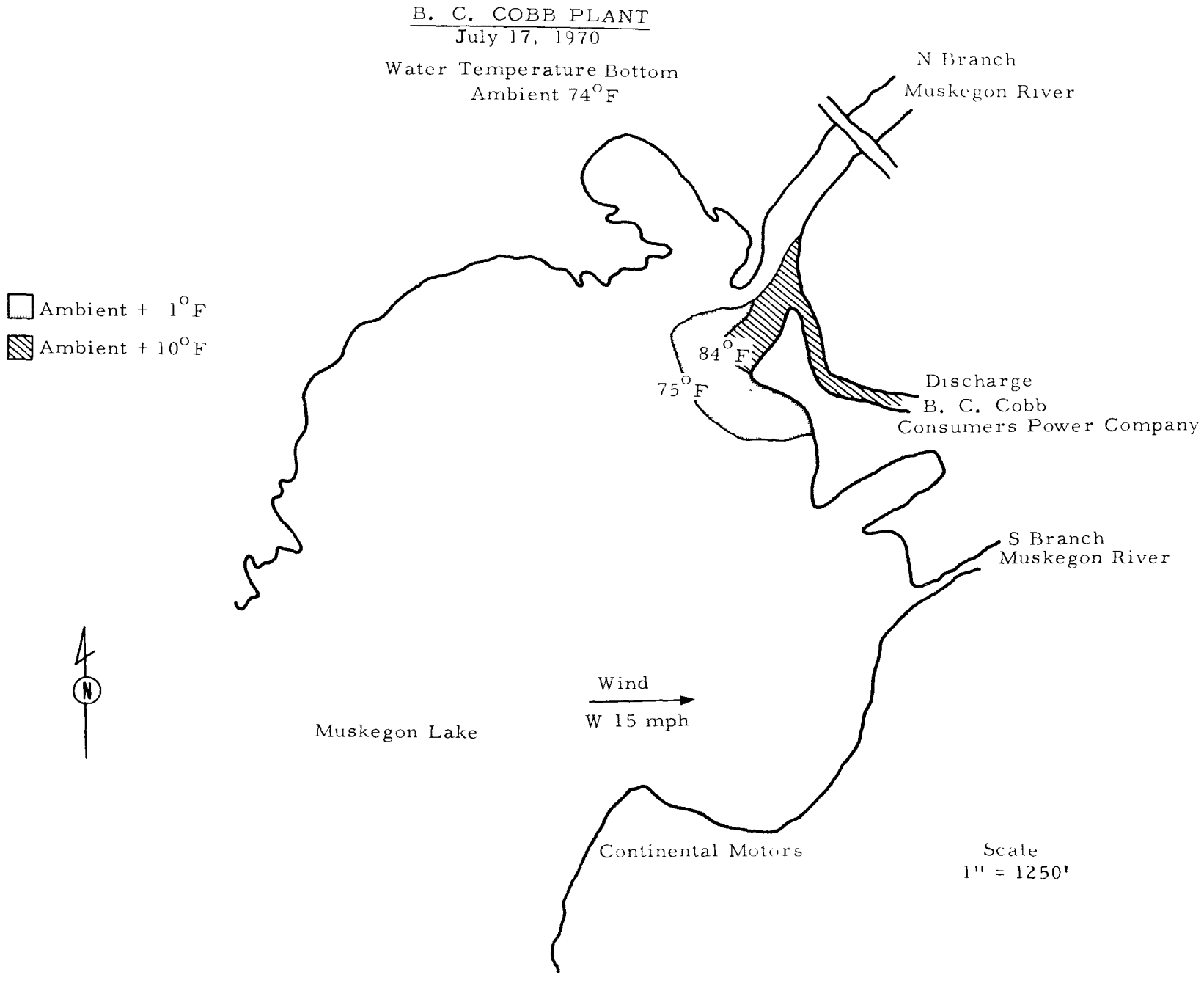


EXHIBIT III-B

BIG ROCK POINT NUCLEAR PLANT
June 18, 1968

Surface Temperatures
Ambient 52°F

Wind S 5-10 Mph

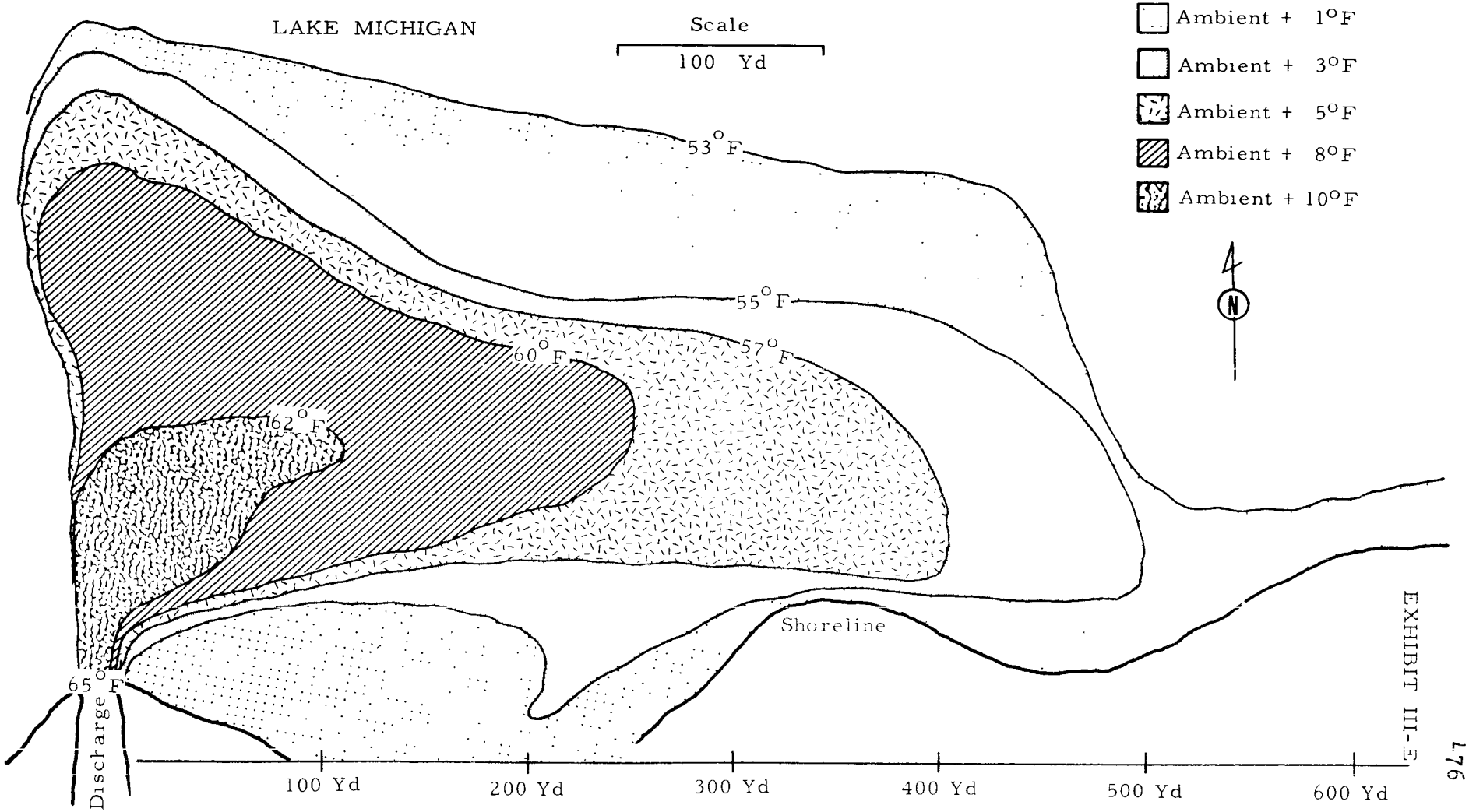


EXHIBIT III-E

is shown on Exhibits III-F, G and H for the surface, 2 ft and 5 ft depths, respectively.

J. R. WHITING PLANT - LAKE ERIE - Since 1966, several thermal plume surveys have been conducted at the 342 MWe J. R. Whiting Plant on Lake Erie, including two infrared aerial surveys this year. The thermal plume observed on June 17, 1970 is shown on Exhibits III-I and J for the surface and 5 ft depth, respectively.

It is not practical to include in this report the full details of the above studies. However, some graphic illustrations from a few of the thermal surveys have been shown because they document various plume characteristics for different plant locations, loads and meteorological conditions.

B. J. H. CAMPBELL PLANT BIOLOGICAL AND TEMPERATURE SURVEYS

Ten temperature and two biological surveys have been conducted at the Company's J. H. Campbell Plant site on Lake Michigan near Holland. The following information includes some of the results of these surveys.

TEMPERATURE SURVEYS - The condenser cooling water for the J. H. Campbell Plant is drawn through Pigeon Lake and discharged into Lake Michigan at a maximum rate of about ~~3,000,000~~ gpm, with an average temperature rise of about 17°F. The Campbell Plant has two units and is capable of producing 647 MWe.

On July 10, 1970, a surface water temperature survey of the J. H. Campbell Plant condenser cooling water discharge, as shown on Exhibit III-K, was made when the plant intake temperature was 66°F and the discharge temperature was 82°F. The plant was discharging approximately

KARN-WEADC .< PLANTS

August 7, 1970

Surface Water Temperature Survey

Ambient Temp 75°F

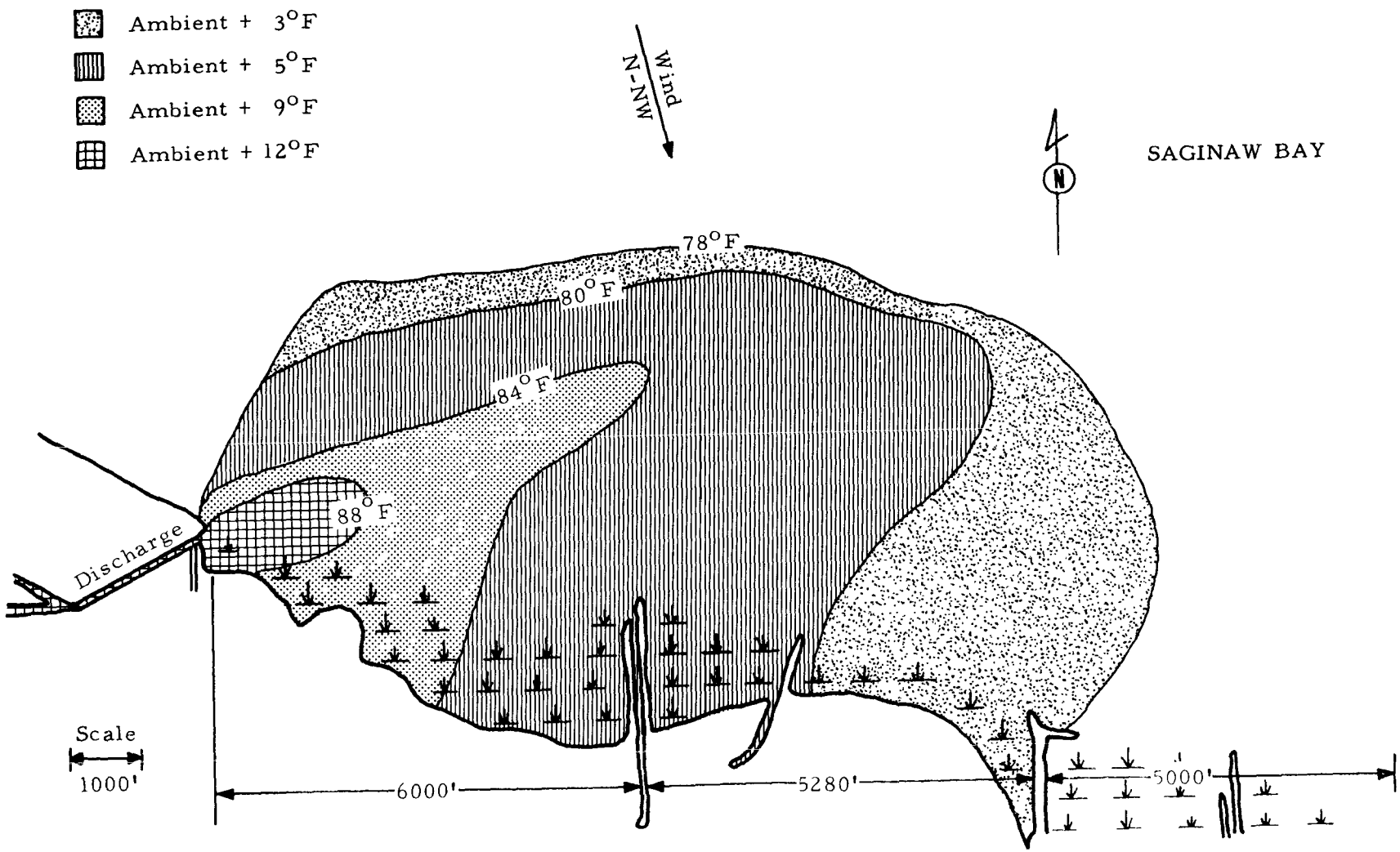


EXHIBIT III-F

KARN-WEADOCK PLANTS

August 7, 1970

Water Temperature Survey, 2' Depth
Ambient Temp 75°F

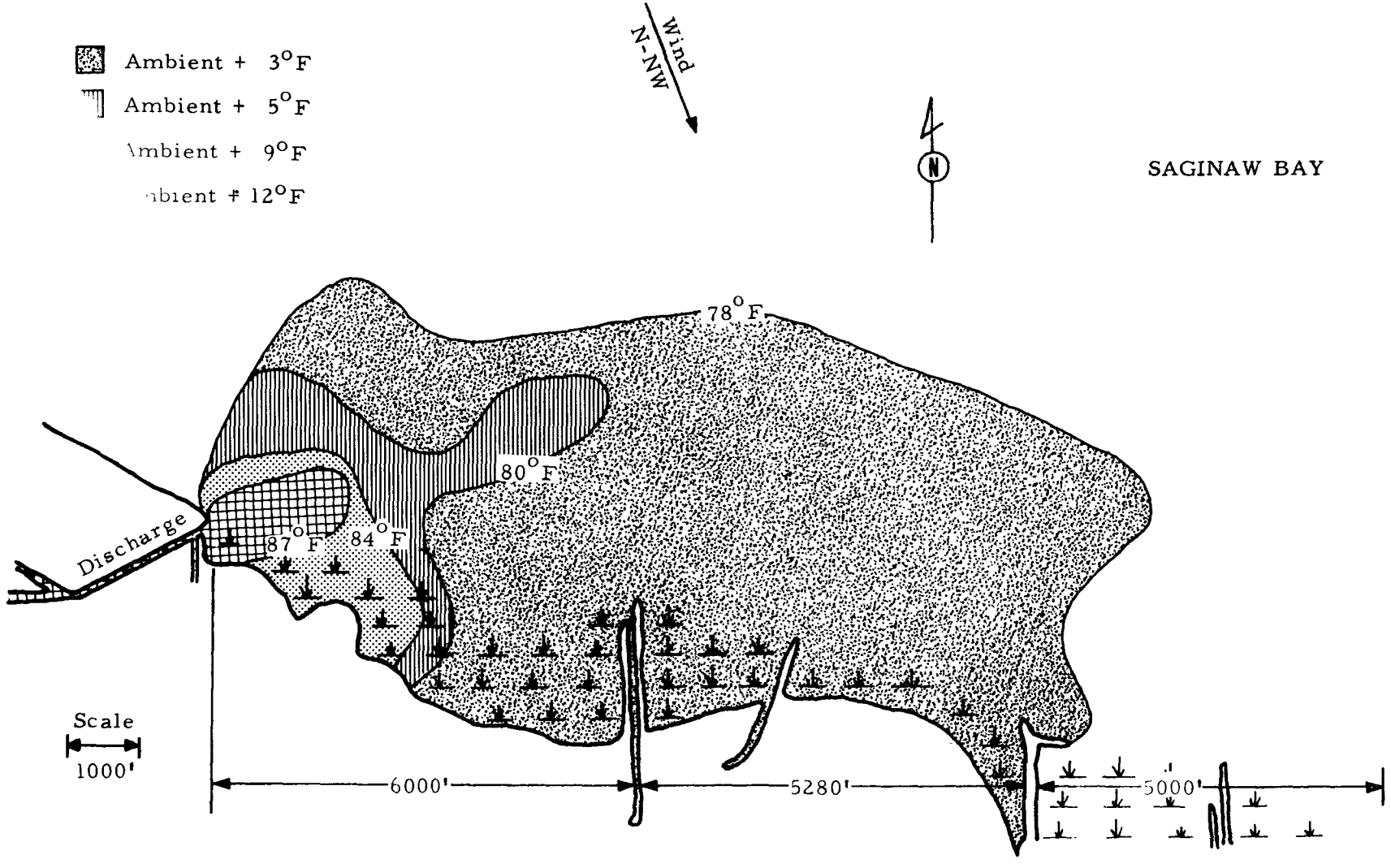


EXHIBIT III-G

KARN-WEADOCK PLANTS

August 7, 1970

Water Temperature Survey, 2'-5' Depth

Ambient Temp 75°F

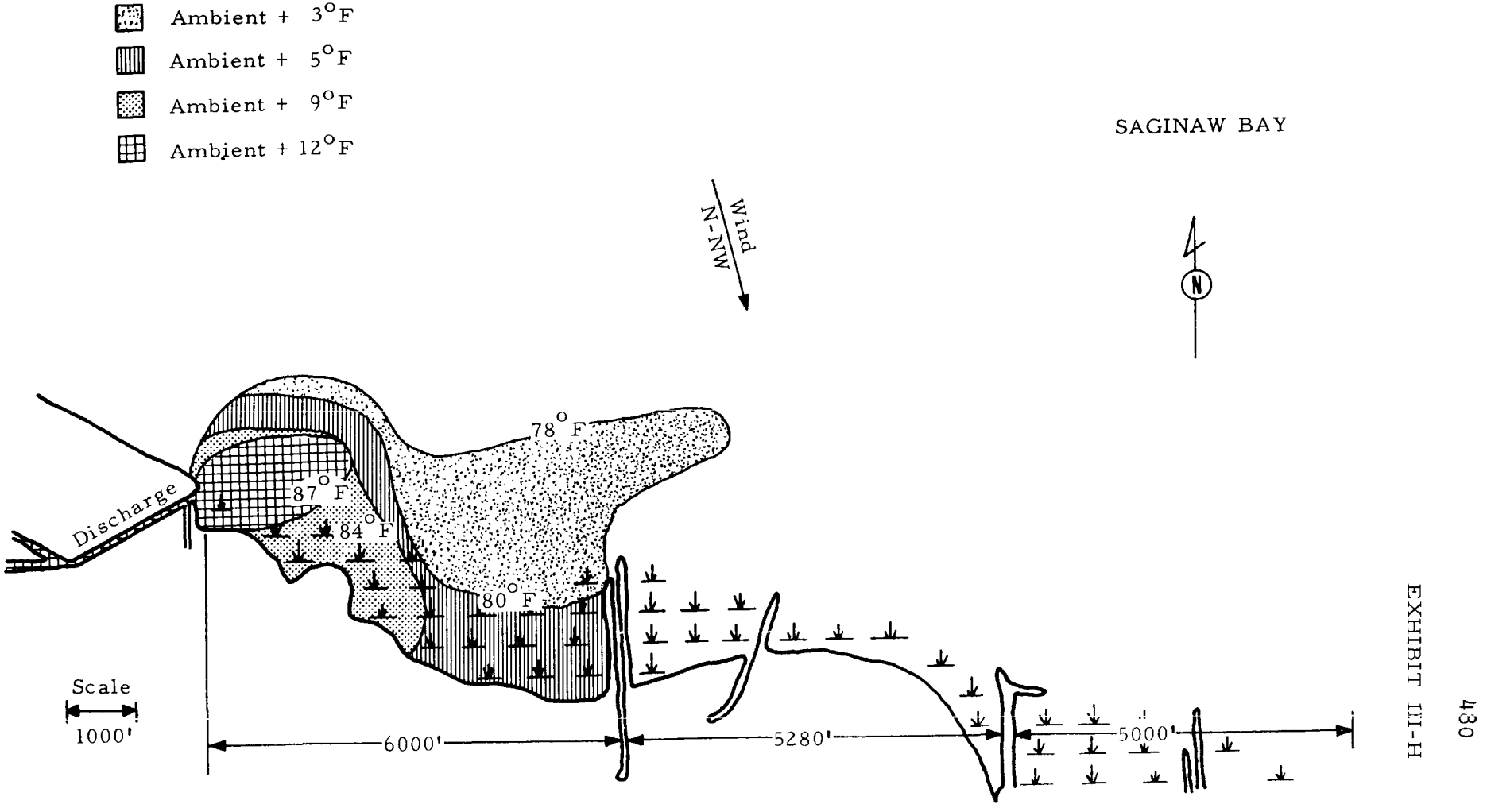


EXHIBIT III-H

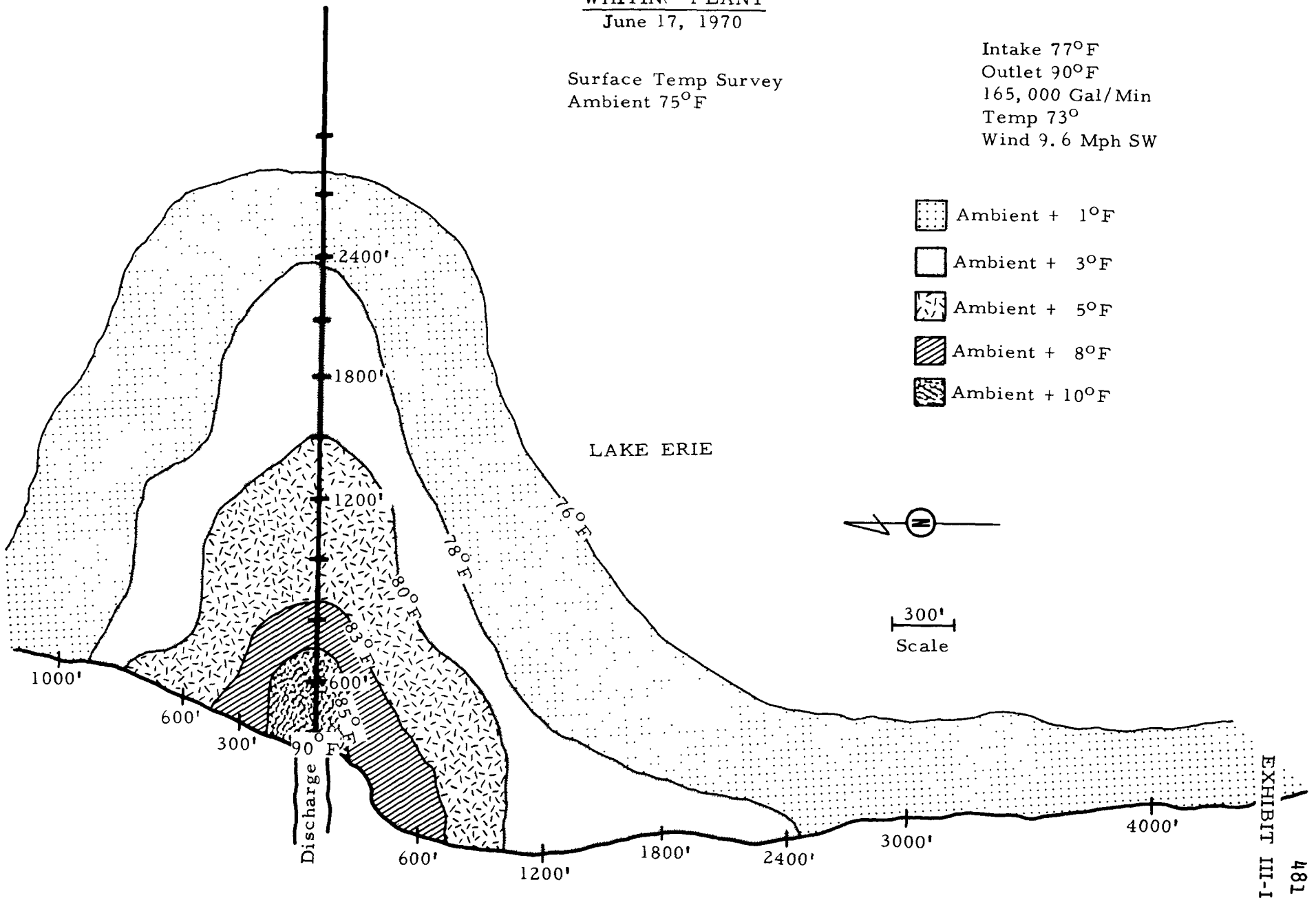


EXHIBIT III-1

WHITING PLANT
June 17, 1970

5' Temp Survey
Ambient, 75°F
Wind - 9.6 Mph SW

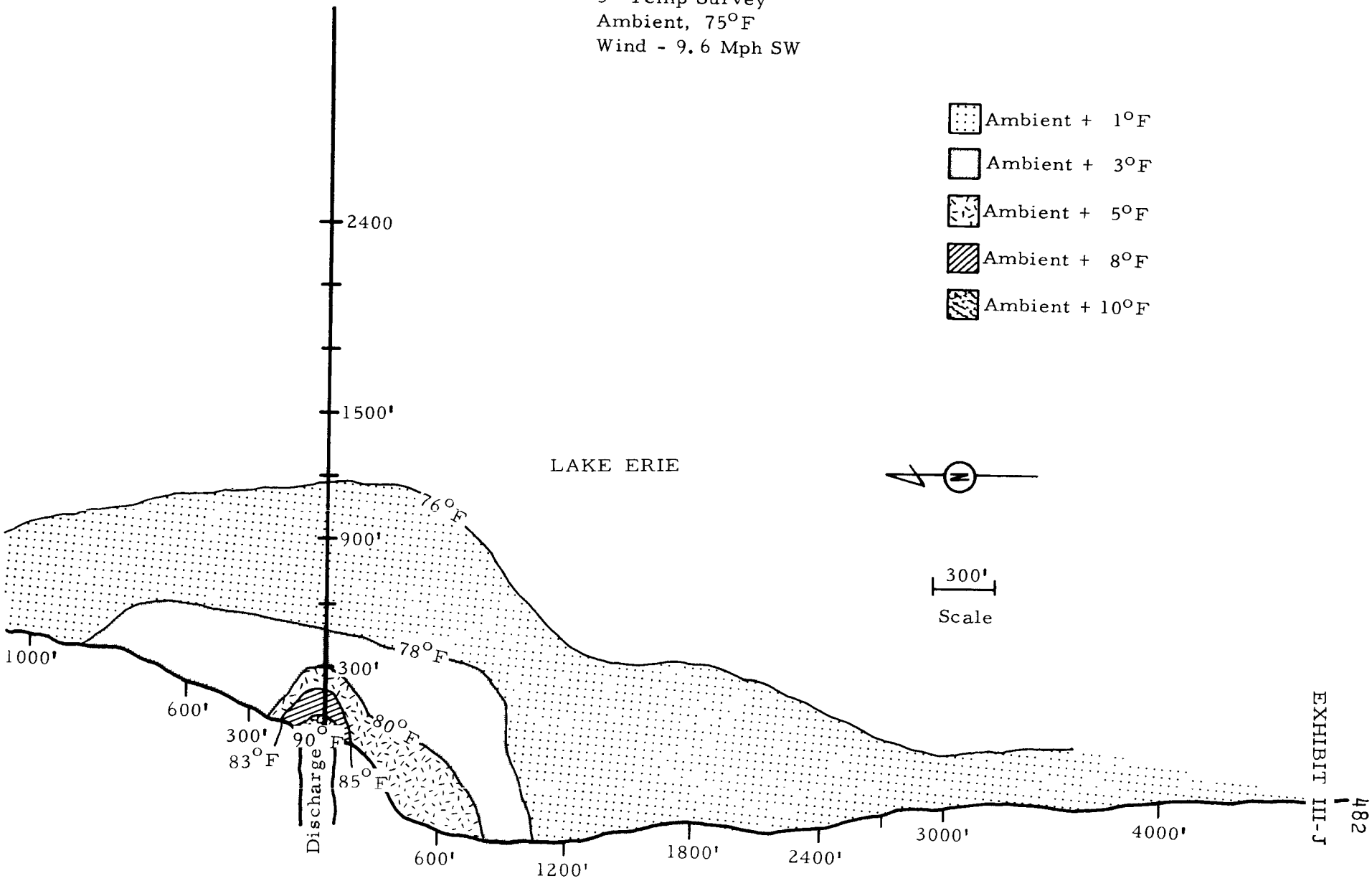


EXHIBIT III-J

J. H. CAMPBELL PLANT
July 10, 1970

Surface Water Temperature Survey
Ambient Lake Temperature 66°F

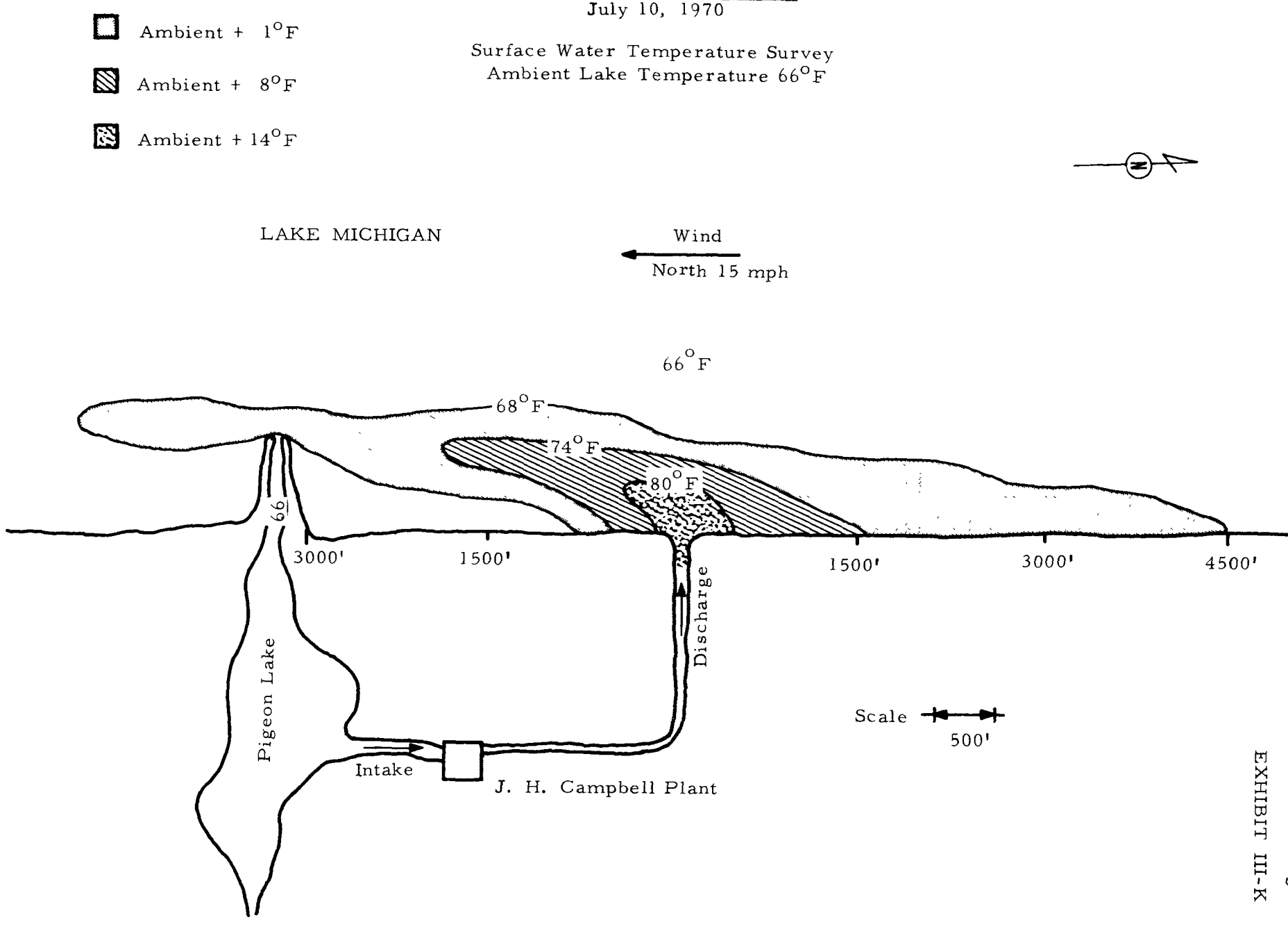


EXHIBIT III-K

300,000 gpm. Due to unfavorable lake conditions (rough water), temperature profiles were not made. A 15 mph north wind caused the main portion of the plume to travel south for approximately one mile before it dissipated. The unusual plume configuration, shown on this exhibit, resulted from a change in wind direction during the preceeding 10 hour period. At points 6,000 ft north and south of the discharge the temperature was 66°F from the shore lakeward. The maximum offshore extent of the plume was approximately 1,000 ft.

On August 26, 1970 another surface water temperature survey was conducted as shown on Exhibit III-L. The plant was operating only with Unit #1 and was producing 247 MWe. The discharge was approximately 120,000 gpm, with intake and discharge temperatures of 74°F and 85°F, respectively. During the survey the wind was from the S-SW at about 10 mph and the plume was traveling northward alongshore in a relatively narrow ban. The maximum offshore extent of the plume was about 800 ft at the point of discharge. The plume at 6,000 ft to the north was within 1°F of the ambient lake temperature. There was no measurable increase above ambient temperature, 6,500 ft to the north.

Another surface water temperature survey was conducted, as shown on Exhibit III-M, on September 9, 1970. An additional objective of this survey was to gather ground-truth data for an infrared imagery flight made on that day. The plant load was 568 MWe and the discharge was approximately 300,000 gpm. The intake temperature was 72°F and the discharge temperature was 89°F. The wind was from the S-SW at speeds

J. H. CAMPBELL PLANT

August 26, 1970

Surface Water Temperature Survey
Ambient Temperature 74°F

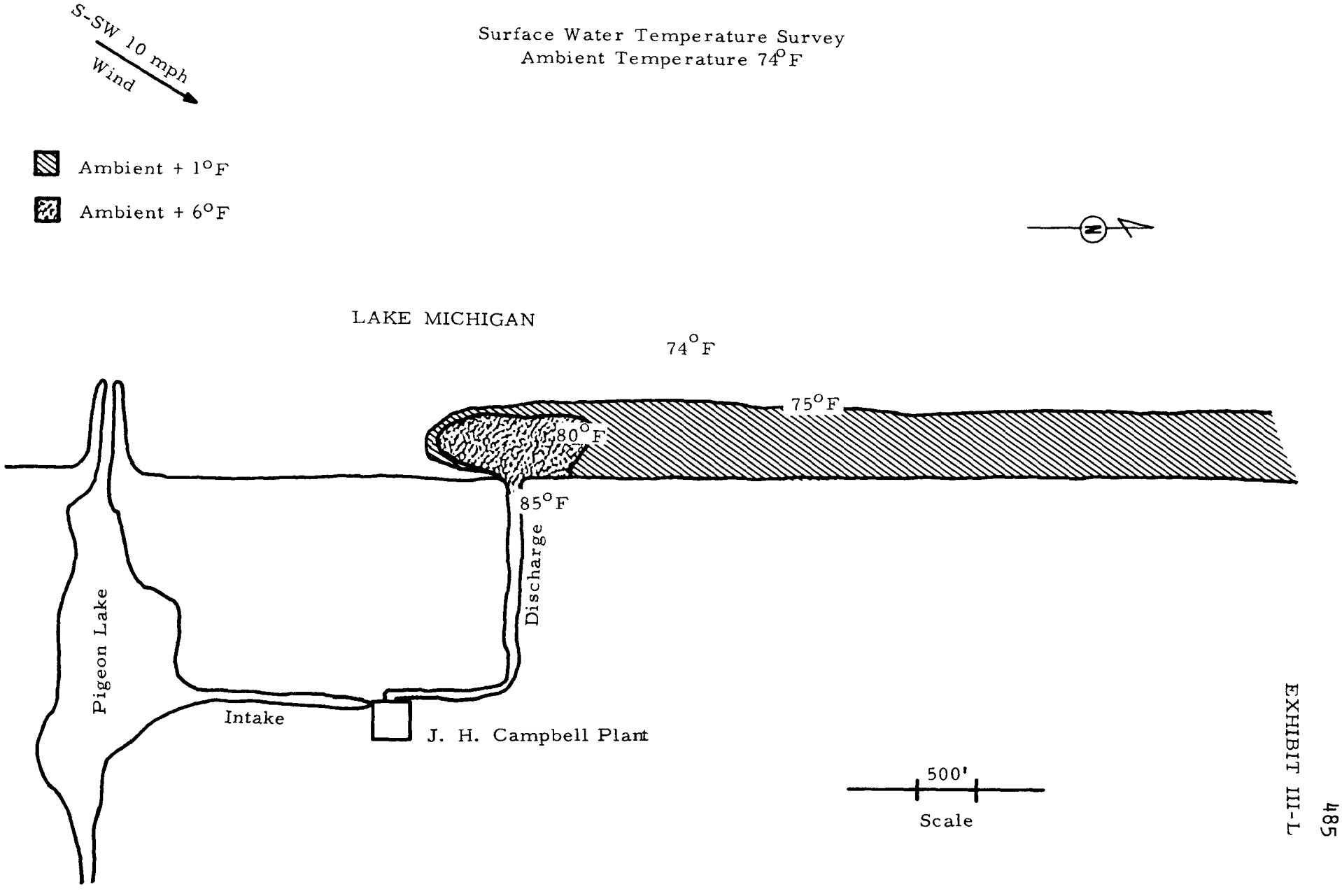


EXHIBIT III-L

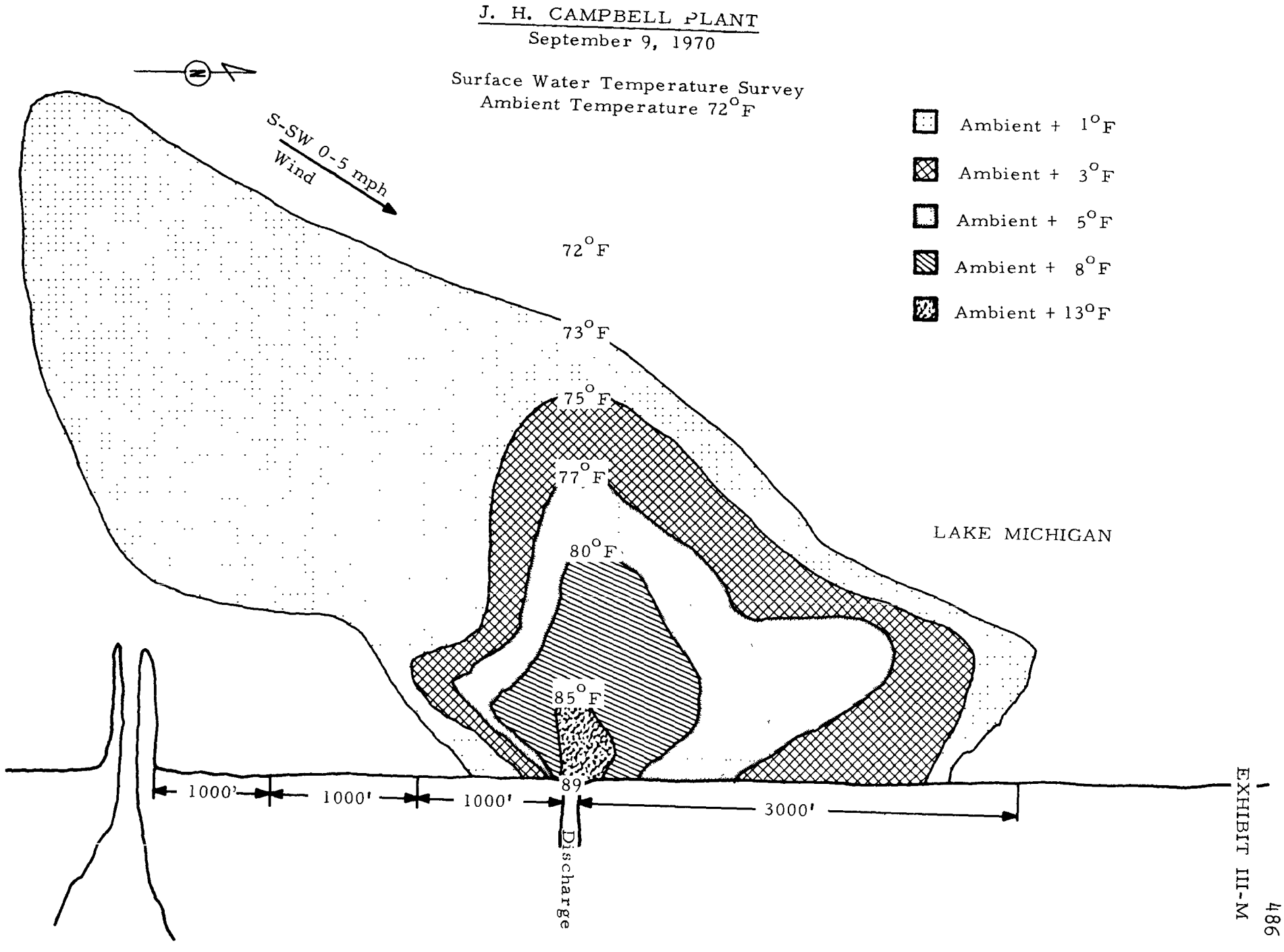


EXHIBIT III-M

up to 5 mph. It was evident during this survey that the plume was shifting to the north. The northern boundary of the plume moved 500 ft further north in approximately 1-1/2 hours. Near the point of discharge, where the surface temperature was about 88°F, the temperature at 3 ft depth was 74°F. Where the surface temperature was observed to be 79°F, the ambient temperature of 72°F was found at 2 ft depth.

1968 BIOLOGICAL SURVEY - To assist Consumers Power Company in evaluating the impact of heated water discharges on the biota of southeastern Lake Michigan, T. W. Beak Consultants Limited were retained to carry out a biological survey in the vicinity of the J. H. Campbell Plant. The survey work was carried out on August 30, 1968. Field work was accomplished by T. W. Beak Consultants Limited and a crew from the Michigan Department of Conservation, assisted by Consumers' technical staff.

Eight sampling stations were selected; seven in the vicinity of the cooling water discharge point and one, a control, three miles south of the plant. Station locations are shown in Exhibit III-N. Distances and directions were measured by means of an electronic range finder and compass headings. At each station, six bottom samples were taken by means of a Ponar dredge. This is a clam-shell type device which cuts out about one-half sq ft of the bottom to a depth of 2 to 6 inches, depending on texture. Samples were washed in a 30-mesh screen, to remove sand and mud, and preserved for shipment to the laboratory. There, the benthic macroinvertebrate organisms were hand sorted, classified to major taxonomic groups and counted.

J. H. CAMPBELL PLANT
August 30, 1968

Benthic Sampling Stations

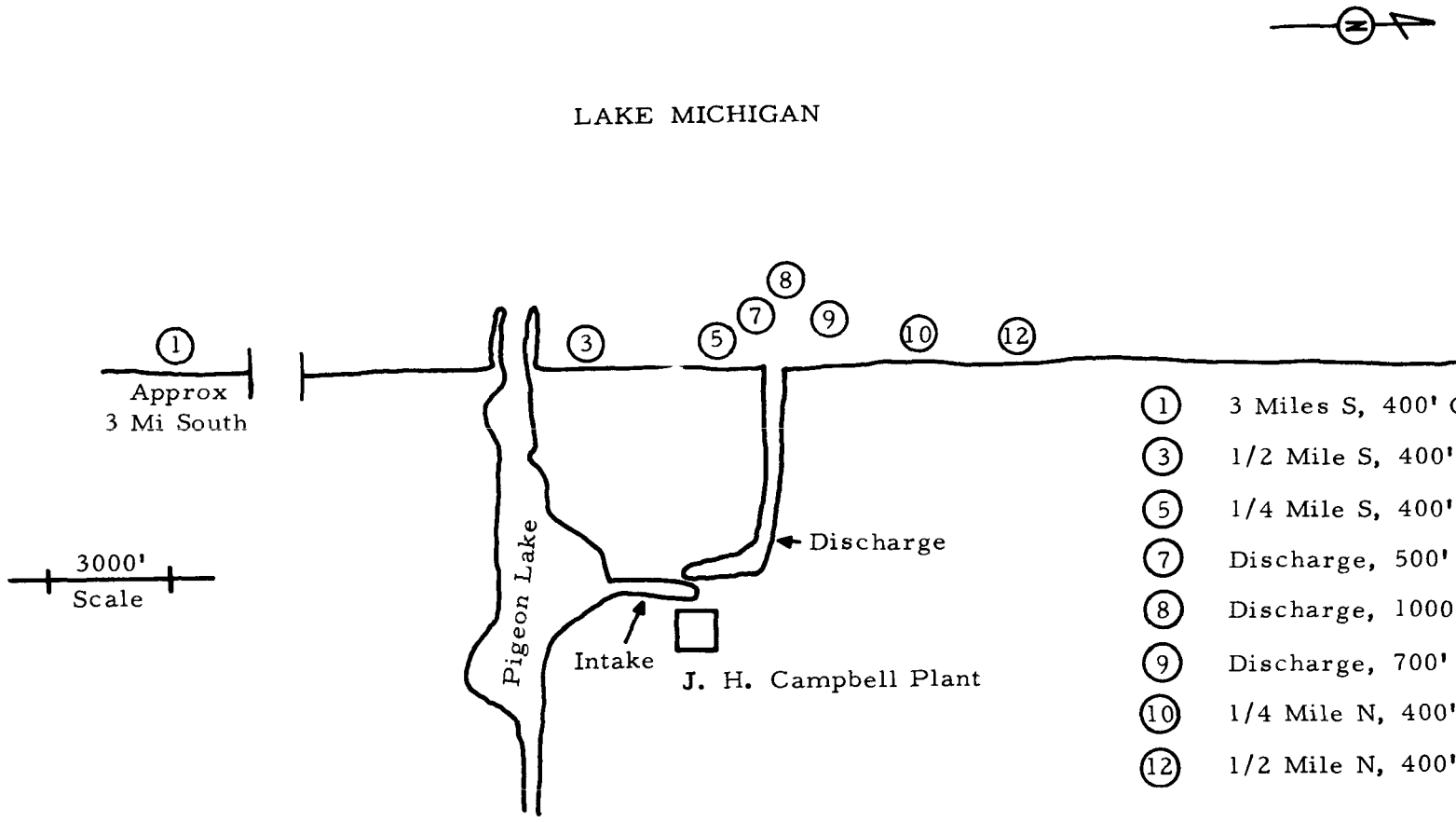


EXHIBIT III-N

Plankton samples were collected at each station by means of an electric pump with a calibrated intake hose which could be lowered to the desired depth. To obtain a sample, about 40 liters of water from a 5 ft depth were strained through a Wisconsin plankton net aboard the boat. One additional sample from a 10 ft depth was taken at Station 8, where the water was deeper. The concentrated plankton samples were preserved and sent to the laboratory for analysis.

The lake bottom in the study area consists mainly of fine, loose sand, mixed with some gravel at the inshore stations. There were no stable deposits of silt or organic debris.

The prevailing movement of heated water away from the discharge point is northward along the coast, following the general counterclockwise circulation pattern in the southern basin of Lake Michigan. The biological results from the control station, 3 miles south, indicate the makeup and density of the benthic community outside the warmwater plume.

In order to compare the density and diversity of organisms, the number of general taxonomic groups found and their average numbers per square foot at each station were calculated. The principal observation which can be made concerning these data is that there is very little difference between the animal communities in the plume and control areas. The dominant animal forms in both areas were midge larvae (Chironomidae) and scuds (Amphipoda). The density of organisms at all inshore stations (400 ft offshore) was quite similar.

Stations 8 and 9, which were the furthest offshore, yielded numbers of midge larvae and scuds approaching those found at the "1/2 mile"

stations near South Haven, Michigan in May. This suggests that distance from shore is an important factor in explaining the observed animal distribution. Station 7, which was slightly closer to shore, yielded results similar to those at the 400 ft line. The extreme scarcity of aquatic segmented worms, which are detritus feeders, probably reflects the absence of significant sources of organic wastes in the area. The bottom fauna were found to be sparse and restricted in variety. Two main factors appear to be responsible for this; the sand bottom, which is not highly productive even when not mechanically disturbed and the shallow depth which results in bottom sediment disturbance by waves.

On the basis of the study results, the biological consultants concluded that there appeared to be no gross thermal damage to the benthic fauna of the main plume area at the Campbell site.

1970 BIOLOGICAL SURVEY - To further document the effects of condenser water discharges into Lake Michigan, another biological survey was conducted in 1970 at the J. H. Campbell Plant. The 1968 biological sampling stations and five additional offshore stations were sampled on August 26, 1970 for benthic organisms. Three Ponar dredge samples were collected at each of the thirteen stations on Exhibit III-0. The samples are being analyzed as they were in 1968 and the results will be available later this year.

The temperature and biological studies which have been conducted at the J. H. Campbell Plant have shown; (1) the ecology of Lake Michigan in the condenser water discharge area has not been significantly affected, (2) wind velocity and direction influence the maximum extent and pattern

J. H. CAMPBELL PLANT
August 26, 1970

Benthic Sampling Stations

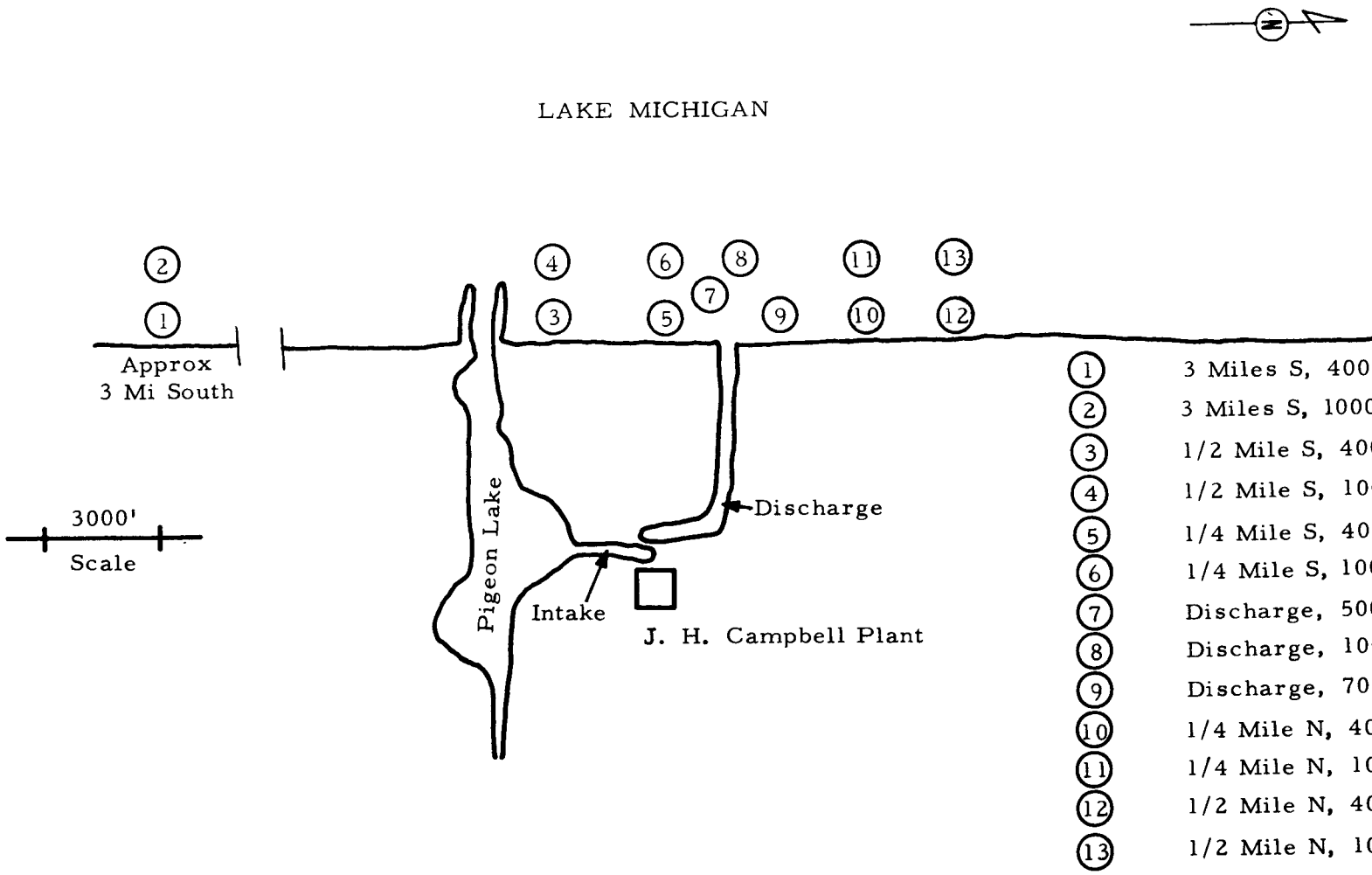


EXHIBIT III-6
491

of the thermal plume, (3) temperature profile data have shown that outside the immediate area of the discharge the plume is confined primarily to the surface waters.

C. PALISADES PLANT COMPREHENSIVE SURVEYS

The Palisades Nuclear Plant, located on the eastern shoreline of Lake Michigan, five miles south of South Haven, Michigan, is designed for initial operation at 2200 MWt and 710 MWe. The ultimate capacity is expected to be approximately 2600 MWt, corresponding to 845 MWe. Condenser cooling water is withdrawn through a crib intake 20 to 25 feet below the lake surface, about 3300 feet from shore, at a rate of 390,000 gpm, and is discharged through a simple diverging pile structure at the shoreline as shown on Exhibit III-P.

Concern about the environmental effects of the plant prompted Consumers Power Company to engage the services of University of Michigan biologists to develop a study plan to detect any effects of the heated discharge on the aquatic biota of Lake Michigan. The biological collection and analysis are being done by T. W. Beak Consultants, Limited, in cooperation with the Michigan Department of Natural Resources.

Temperature and biological surveys conducted at the J. H. Campbell Plant in 1968, as described earlier, indicated no significant ecological effects from that heated discharge. The Palisades Plant, however, is larger, and a more cautious approach of thoroughly studying its discharge effects was initiated to ensure that if subtle ecological changes take place they will be detected.

EXHIBIT III-P

PALISADES NUCLEAR PLANT

PALISADES NUCLEAR PLANT Job 5935
Aerial View Looking North
October 21, 1969

The biological studies at Palisades are sufficiently comprehensive in scope to detect, either directly or indirectly, virtually any significant effect on the local aquatic ecosystem attributable to the thermal discharge. These studies are concentrated on the benthos, plankton, periphyton, fish, and, of course, temperature.

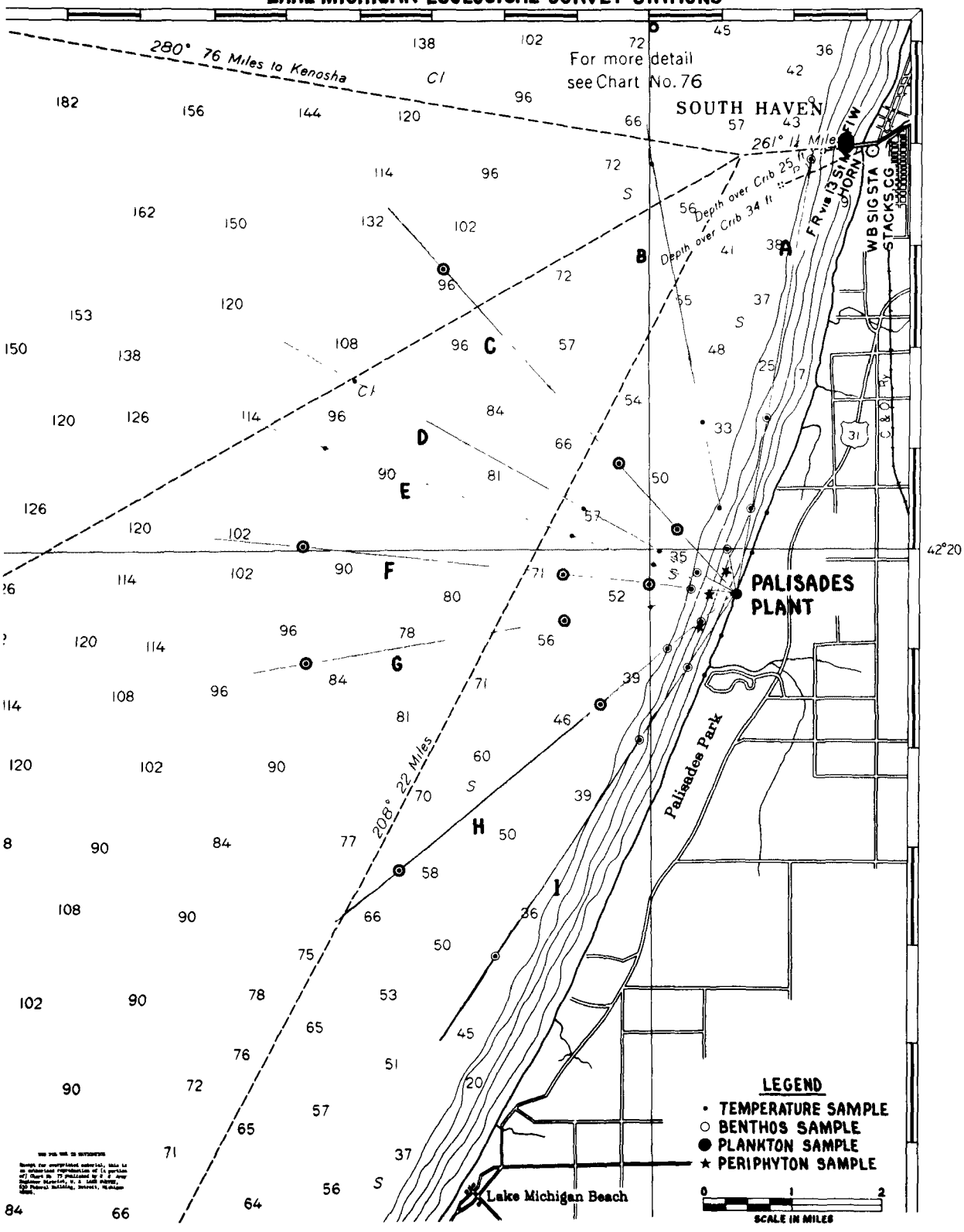
The benthos are considered to be the most delicate indicators of ecological change since they are relatively sessile and cannot escape environmental stress conditions. Plankton and periphyton are also good indicators of change, being relatively low in the food chain and only passively moved, and provide direct indications of nuisance conditions should their populations increase drastically. Limited fish sampling is conducted since, aside from being highly mobile, fish are relatively slow in reacting to environmental changes providing toxic conditions are not a factor.

SURVEY PROCEDURES AND RESULTS - The survey area near the plant is shown on Exhibit III-Q and the basic fan-shaped sampling grid is identified. Sampling stations were established on 1/4-, 1/2-, 1-, 2- and 5-mile radii on nine radial lines. In addition, there are two control stations located near each of the cities of South Haven and Benton Harbor, about 7 miles north and 16 miles south of the plant site, respectively. The surveys began in 1968 with samples scheduled to be gathered in early May, late June, August and October. The initial survey is planned to extend for five years. The sampling stations are not marked in the field, but are accurately located by means of an electronic range finder.

EXHIBIT III-Q

PALISADES PLANT

LAKE MICHIGAN ECOLOGICAL SURVEY STATIONS



Indicated on Exhibit III-Q is the initial basic plan for collection of benthos, plankton and periphyton at the various locations. The basic sampling grid, not counting control stations, contains 21 stations for benthos, 10 for plankton and 3 for periphyton. Some minor modifications since the survey began included the addition of several more inshore benthic stations in exchange for two benthic stations at five miles, and the addition of several plankton and periphyton stations. Adverse weather conditions have precluded the collection of a few samples, but without loss to the integrity of the coverage.

BENTHOS - All benthos samples are collected by means of a Ponar dredge, as shown in Exhibit III-R.

The bottom deposits of the study area consist of mixed gravel and coarse sand inshore, grading outward to medium, then fine sand, and then to fine sand mixed with silt at approximately two miles offshore. At five miles offshore, fine sand is overlain in irregular patches by organic detritus.

In 1968, six replicate samples of benthos were collected at each station, the macroinvertebrate organisms screened out and preserved for shipment to the laboratory. The samples were analyzed for all benthic macroinvertebrate and identified to family in all cases and to genus wherever possible. In addition, one sample from each station from each survey was analyzed and the organisms identified to species, or as close to species as taxonomy permitted. The replicate samples were sufficiently uniform in 1968 that the procedure in 1969 was modified to collect only three replicates.

EXHIBIT III-R

PALISADES PLANT
BENTHIC SAMPLING

Analysis of benthic data to assess environmental conditions and changes in the aquatic ecosystem can proceed along several different lines. For example, indicator organisms can be selected for detailed study, and the relative numbers compared before and after plant operation, and in proximity to the plant discharge. Such an organism representative of clean water conditions, and widely prevalent in Lake Michigan, might be the crustacea, amphipoda (commonly called aquatic scuds), consisting of the dominant species Pontoporeia affinis. An example of the relative distribution of this organism is shown in Exhibit III-S for the August 1968 sampling period.

Another approach would be to examine an organism that is known to be relatively pollution tolerant or to compare relative numbers of tolerant and intolerant species. The dominant representative of tolerant organisms would be the oligochaeta (made up of numerous species known as aquatic earthworms, tubificids or sludgeworms). The relative distribution of these organisms observed in August of 1968 is shown in Exhibit III-T as an example.

The relative populations of other benthic organisms will also be studied and correlated, not only within the project area, but also in relation to similar data being gathered at other locations around the lake.

Species diversity of the entire benthic community is another tool for assessing the influence of environmental factors and is readily adaptable to statistical analysis. A crude illustration of the variation of species number with depth for August 1968 is shown in Exhibit III-U. The scarcity of benthic organisms in the sandy, wave-swept shallows should be noted,

EXHIBIT III-S

PALISADES PLANT

LAKE MICHIGAN ECOLOGICAL SURVEY STATIONS

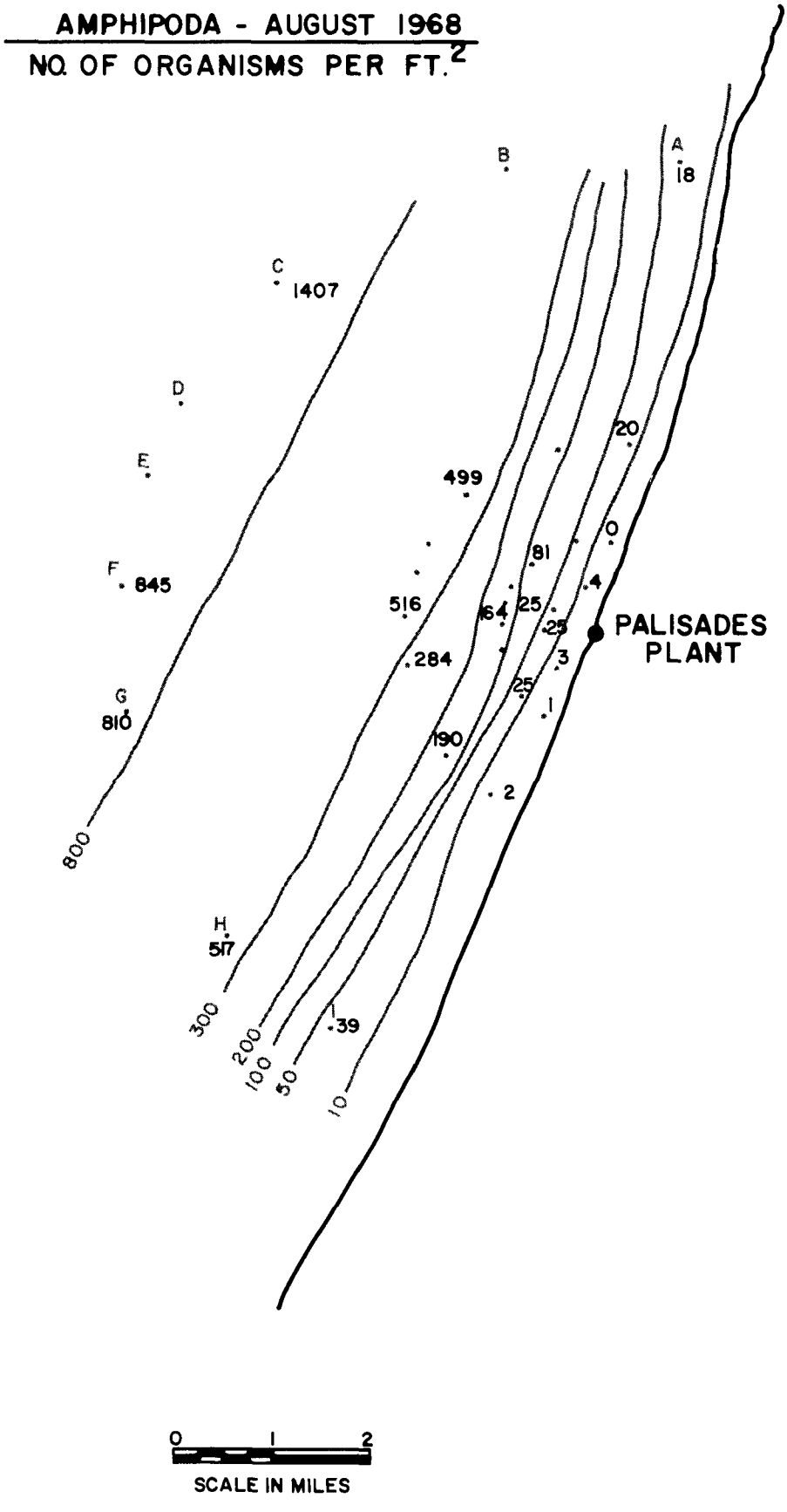


EXHIBIT III-T

PALISADES PLANT

LAKE MICHIGAN ECOLOGICAL SURVEY STATIONS

OLIGOCHAETA - AUGUST 1968

NO. OF ORGANISMS PER FT.^{2}

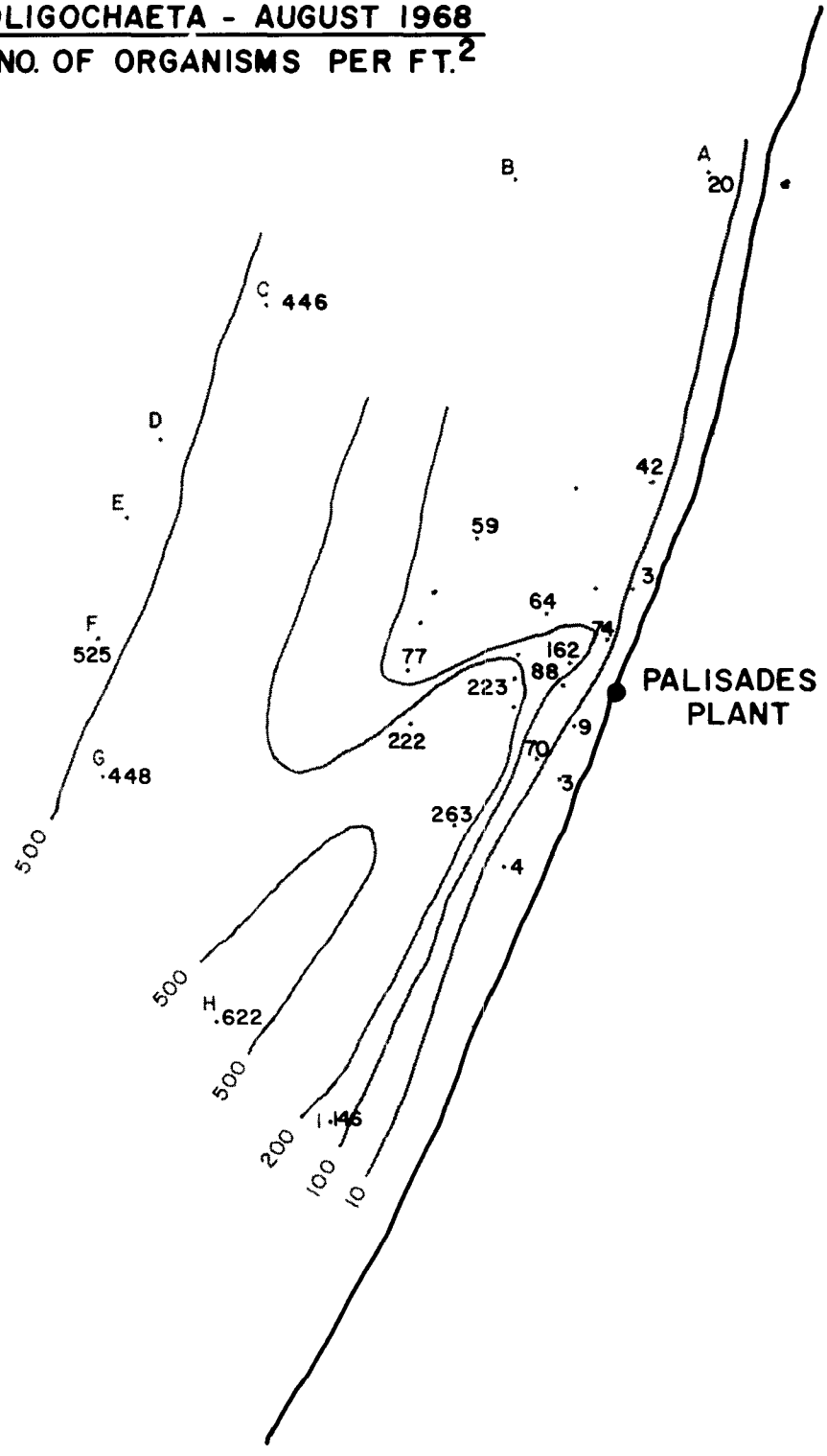
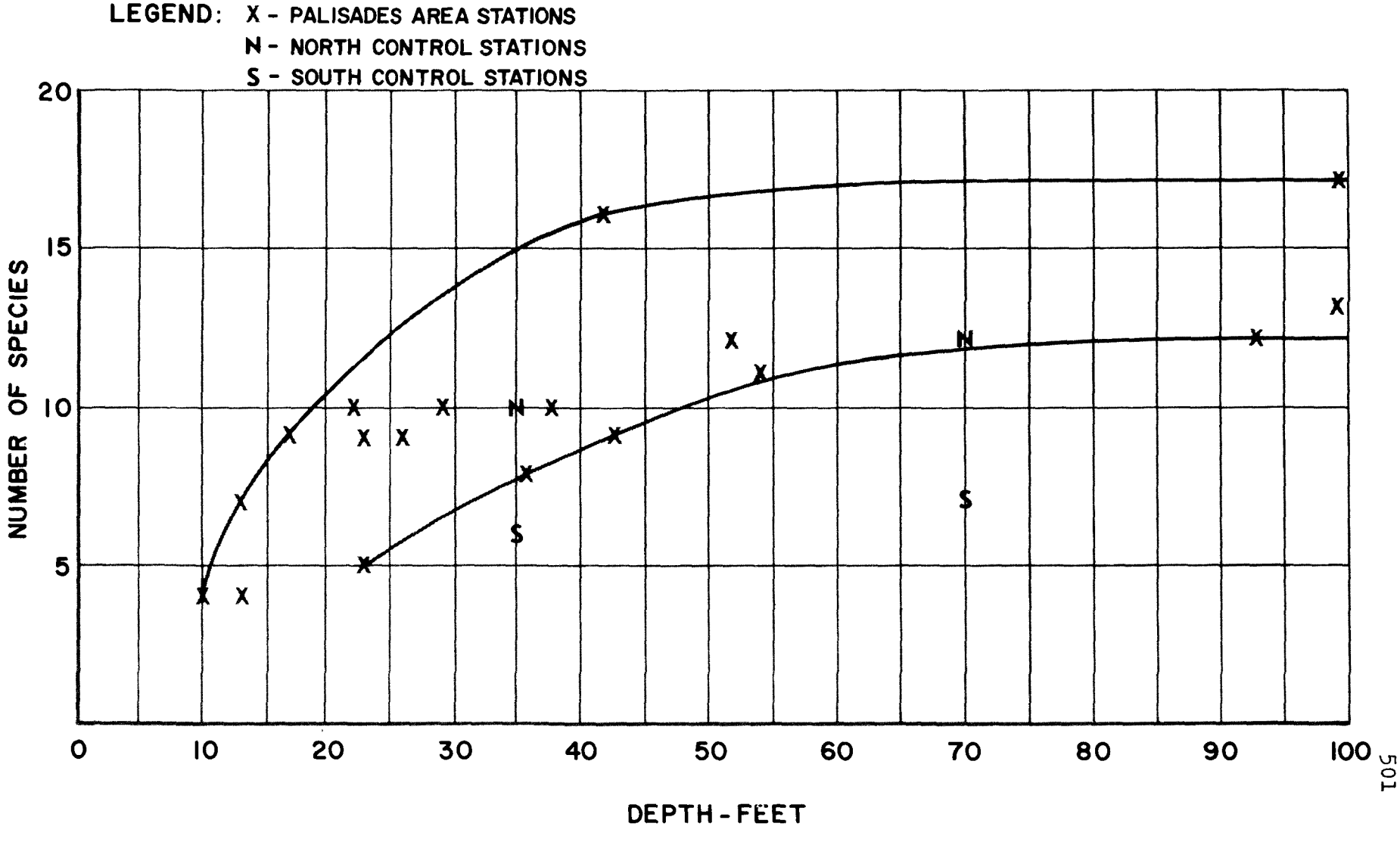


EXHIBIT III-U

PALISADES PLANT BENTHIC SAMPLING

AUGUST - 1968



along with the apparent evidence that the southern control stations are relatively sparse and unrepresentative of the project area in this respect.

PLANKTON - Plankton samples are obtained by passing 40 liters of water through a Wisconsin plankton net as shown in Exhibit III-V. At each station, samples are collected at depths of 5, 10 and 15 feet. The preserved samples are received at the laboratory where they are centrifuged and the volume of plankton concentrate measured.

Relative changes in plankton concentrations, both within the project area and as related to the control stations, will indicate whether the thermal discharge is having a substantial impact on these organisms. Stimulation of algae growth, such as the filamentous green algae Cladophora, to nuisance proportions would be so detected. Subtle changes in relative numbers of the various types of plankton can only be verified through microscopic examination. When the plant is in operation, samples will be collected for such detailed analysis in the immediate vicinities of the intake and discharge.

Typical results of the plankton concentrate analysis are shown in Exhibits III-W and X. Exhibit III-W shows the seasonal succession of plankton concentrations at the 5 ft level one, two and five miles from shore. Exhibit III-X similarly shows concentrations at 5, 10 and 15 feet deep at the one-mile station. This data clearly shows the general cyclic nature of the phytoplankton production. This fluctuation is typical of Lake Michigan in which diatom populations dominate and bloom in early spring and late fall.

EXHIBIT III-V

PALISADES PLANT
PLANKTON SAMPLING

EXHIBIT III-W

PALISADES PLANT

PLANKTON SAMPLING

1968

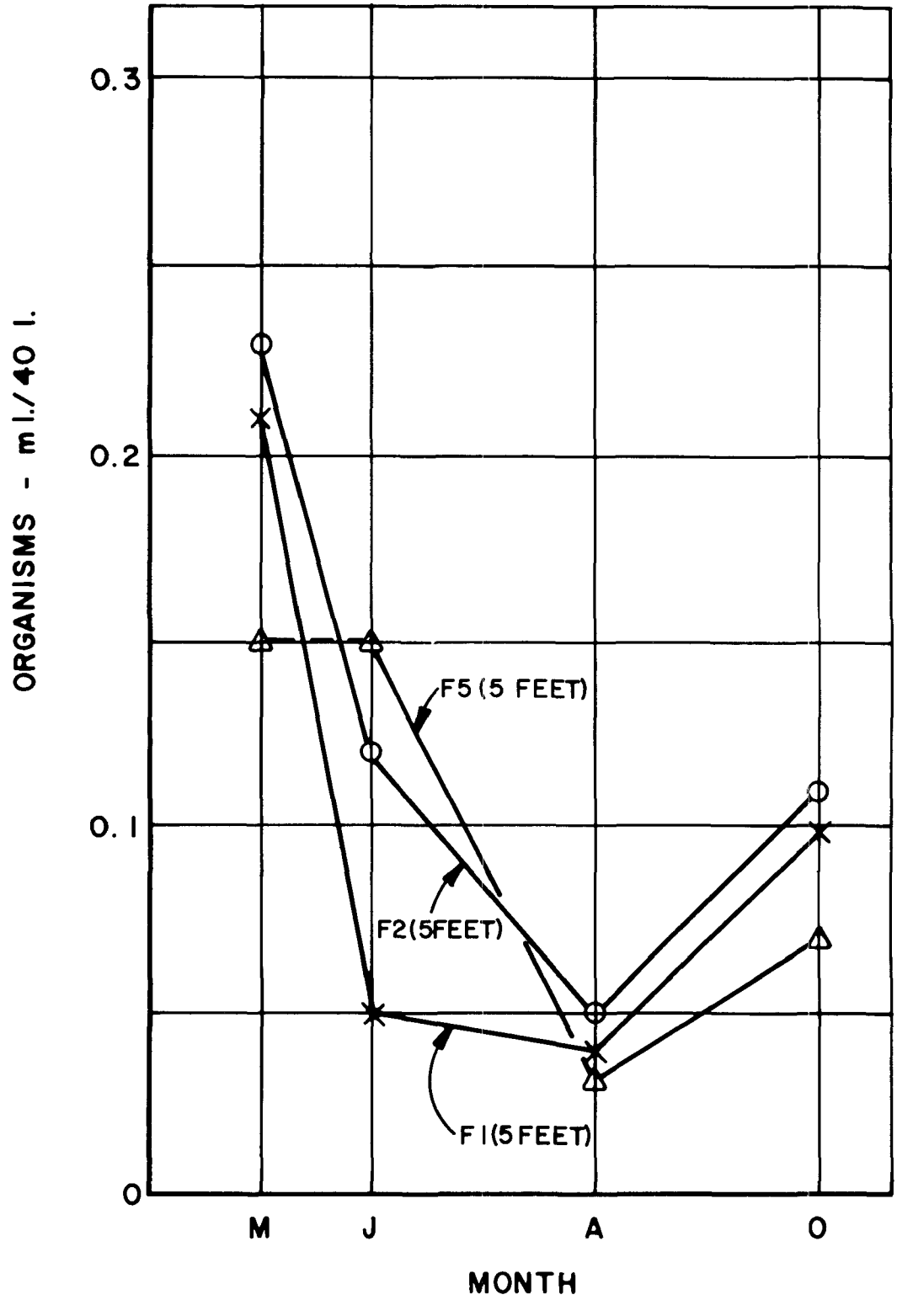
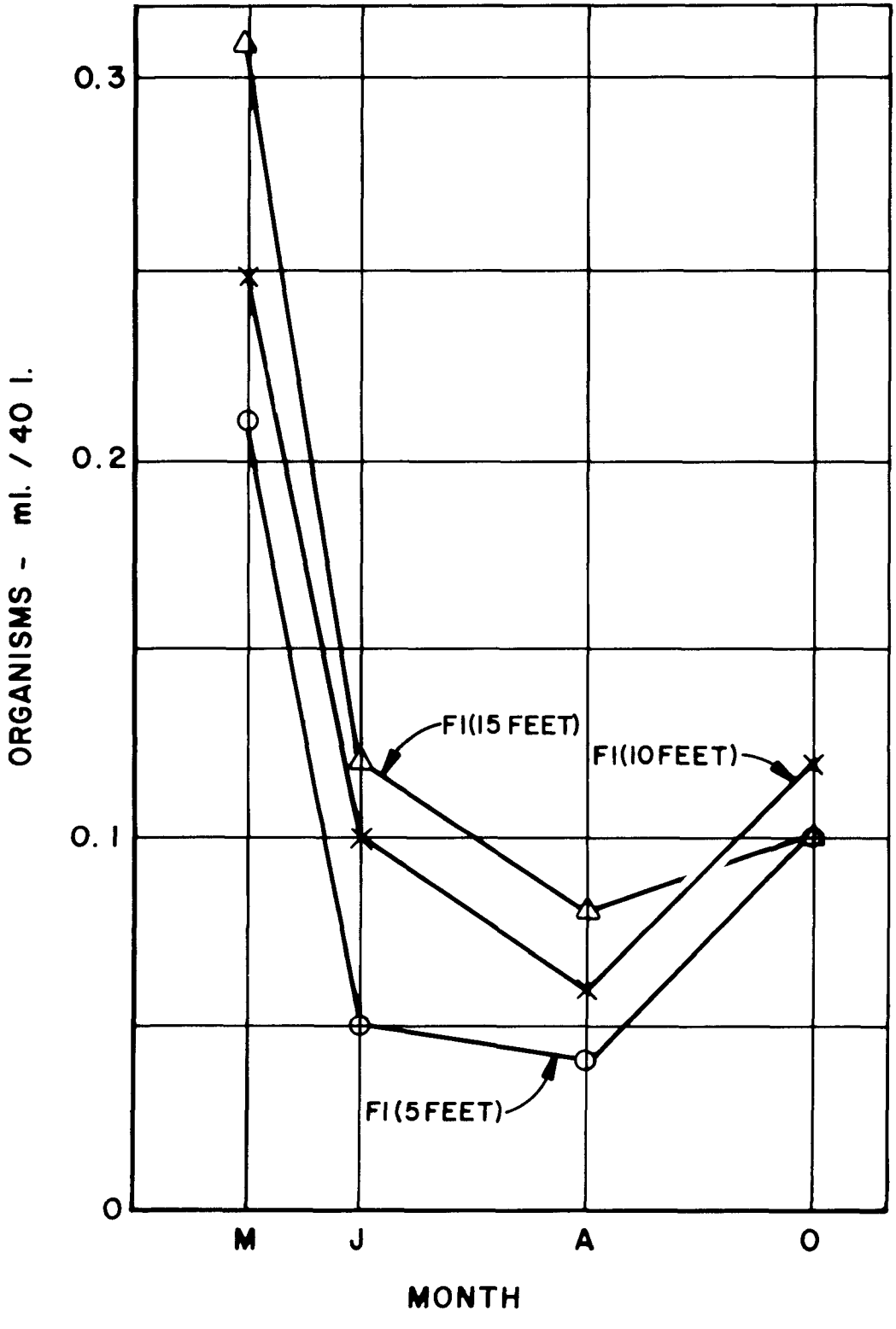


EXHIBIT III-X

PALISADES PLANT

PLANKTON SAMPLING

1968



PERIPHYTON - Periphyton organisms are collected on artificial substrate, constructed of Plexiglas plates, which are suspended from metal supports imbedded in concrete blocks. The samplers are placed in 15 feet of water and after suitable exposure, at least four weeks, they are retrieved. The preserved plates are sent to the laboratory where the periphyton scrapings from the plates are extracted with acetone and the amount of chlorophyll determined spectrophotometrically.

The periphyton sampling program was beset with considerable difficulties in both 1968 and 1969. Intermittent storms hampered the retrieval of the collection plates. In addition, public destruction resulted in the loss of all but a few marker buoys. The addition of several more unmarked samples to be recovered by divers has been instituted to compensate for these problems.

Chlorophyll analysis for the one-month exposure in May-June 1968 yielded concentrations ranging from 0.0 to 0.0056 micrograms per square centimeter. Sufficient data are not available for confident representation of seasonal fluctuations or other natural variations. Information gathered on periphyton during plant operation will be analyzed primarily to detect correlation between growth and proximity to the plant outfall.

FISH - The Michigan Department of Natural Resources has provided the vessel used in the biological sampling program and their personnel have been in charge of all fish sampling and analysis. Their sampling schedule calls for gill nets of various mesh sizes to be set for two 24-hour periods four times a year at depths of 20 feet, 40 feet and 55 feet.

All fish captured are measured and counted, and many are scale sampled, sexed, and weighed.

In addition to the gill nettings, a bag seine was used on five occasions in 1969 to sample fish populations along 1200 feet of shoreline north of the plant. Data on offshore populations are also available for two dates in 1969 from the trawling efforts of the Bureau of Commercial Fisheries, United States Fish and Wildlife Service.

The results of the various fish studies to date indicate that at least 22 species of fish live in the area, of which perch and alewives are most abundant. While both yearling and adult salmonids have been captured, their numbers have been very small and all have been planted fish, as identified by their markings.

TEMPERATURE - Lake temperatures have been measured periodically at various depths and locations since before the biological sampling program began. The objective of the preoperational temperature surveys has been to define the general natural variations that occur. For this purpose, a series of measurements has been made approximately every month, weather permitting.

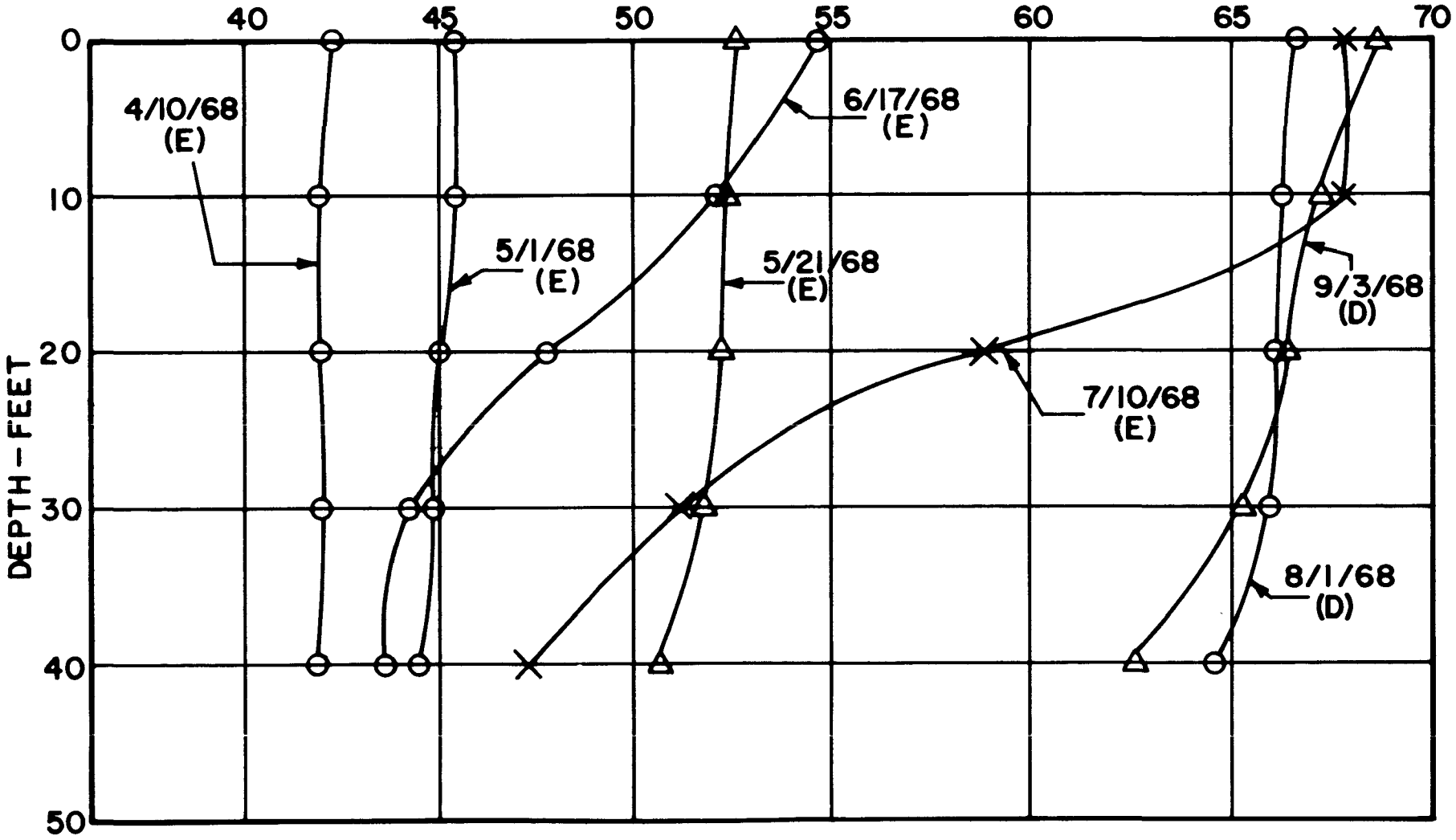
A representative series of temperature profiles for 1968 is shown in Exhibit III-Y for a location one mile from shore. It can be seen that a relatively shallow thermocline developed in the spring and early summer, but typically the thermocline in Lake Michigan will reach depths exceeding 100 feet by early fall.

The thermal structure of Lake Michigan is a highly variable phenomenon and can change significantly in a relatively short period of

EXHIBIT III-Y

PALISADES PLANT TEMPERATURE DATA - 1968 AT 1 MILE

TEMPERATURE - °F



time as well as from year to year. The great influence of the shoreline is typified in Exhibit III-Z for April 10, 1968, at which time the temperature variation from shore to five miles out exceeded 13°F. Such widespread natural temperature excursions have certainly had a major influence in the establishment of aquatic life populations as they exist today. Artificial thermal discharges to the lake, as from power plants, can and should be evaluated in the context of these natural variations.

When the Palisades Plant is in operation, the thermal discharge will be mapped periodically to define the extent and magnitude of its influence under various meteorological and natural lake conditions. Studies of lakeshore currents have indicated that the buoyant thermal plume will flow northward about 33% of the time, southward 23% of the time and drift almost directly offshore about 38% of the time. The remaining 6% of the year the plume is expected to more or less remain as a stationary water mass nearshore.

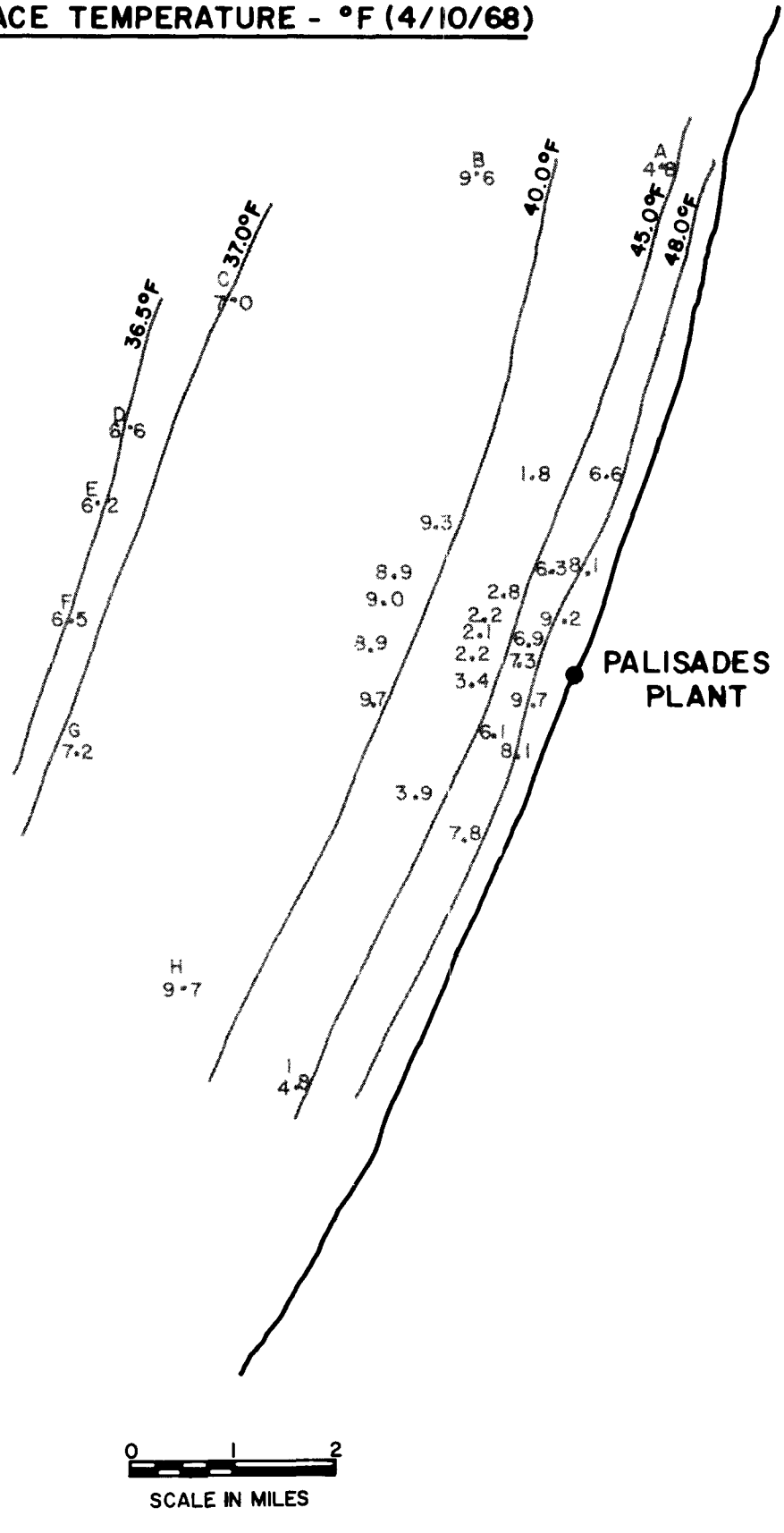
Data on the spatial and temporal influence of the thermal discharge will, when correlated with the biological data, make possible an accurate assessment of the impact of plant operations on the aquatic ecology of Lake Michigan.

EXHIBIT III-Z

PALISADES PLANT

LAKE MICHIGAN ECOLOGICAL SURVEY STATIONS

SURFACE TEMPERATURE - °F (4/10/68)



IV. STATUS OF THERMAL DISCHARGE CONSIDERATIONS

A. POPULAR VIEW VERSUS TECHNICAL EVIDENCE

Passage of the Water Quality Act of 1965, to amend the Federal Water Pollution Control Act, set into motion a widespread review of water quality criteria to be used in the standard setting process. For many contaminants and water quality parameters the determination of the necessary restrictions to protect aquatic life or other beneficial uses was rather simple. Agreement on standards for such things as dissolved oxygen and certain toxic substances was secured rather early because of the demonstrated need to control waste discharges to minimize almost certain harmful effects. Recognized pollution conditions caused by such discharges had clearly been shown.

The situation with regard to temperature was not so well defined. It was known that if heated waters were discharged into a relatively small body of water the local aquatic ecology would be changed. But such things as fish kills or other adverse effects associated with such discharges were relatively rare, and research to determine potential damage was considered frivolous, under the circumstances. Utilities around the country, however, recognizing the accelerated rate at which thermal discharges would be made from power plants, initiated studies to attempt to detect adverse effects. In the case of the Great Lakes, short-term studies have failed to show harmful effects and the long-term studies, by their nature, have not provided much definitive information to date.

The US Depártment of the Interior, because they were charged by Congress to approve Water Quality Standards has felt obliged to require numerical limits to restrict thermal discharges into the Great Lakes.

However, until technically supportable evidence concerning harmful effects of such a discharge has been presented, there is no rational or legal basis for such a dogmatic viewpoint. The popular view of the possible consequences of thermal discharges promoted by FWQA is not consistent with existing factual information and does not enjoy any broad recognition by the scientific community.

B. RATIONALE FOR CONTROLLING THERMAL DISCHARGES

(1) Probable Versus "Possible" Effects

Considerable effort has been expended, by both scientists and laymen, in theorizing on the possible adverse effects of thermal discharges. A considerable amount of this activity has been stimulated by governmental pressure and the misguided urgings to set specific numerical temperature standards. But a clear distinction must be made between what can be considered "possible effects" and what is truly probable, based on existing evidence and scientifically valid projections.

It is postulated, for instance, that there will be long-term deleterious biological effects caused by the thermal discharges from power plants. Lake Michigan, as has been shown, is in no immediate danger of being significantly warmed by heated discharges. The seasonal succession of the lower aquatic life forms is so dramatic due to natural causes that the relatively minor circulation through power plants could not be a significant factor in their overall populations. And the fish management program by the Federal Government and the bordering states is evidence in itself that we are not tampering with natural ecological phenomena as far as fish are concerned. There is, therefore, no reasonable

basis for asserting that the existing level of thermal discharges could have long-term effects.

The "White Paper" discusses at length the possible effects of heated water on fish, as if they were confined to these waters and would not naturally avoid temperatures not to their liking. The paper describes very well the significant historical succession of fish species, the considerable management efforts that have been instituted to change the natural balance of species, and the variability of habitat and its importance in the succession of life stages. But on the basis of the evidence presented, it certainly does not follow that any significant thermal discharge, at any place, at any time, would jeopardize the existence or otherwise interfere with the population of any species of fish in Lake Michigan.

Another misleading implication made in the "White Paper" is that if thermal discharges are eliminated, the accelerated rate of eutrophication of Lake Michigan will be checked, even though nutrient build-up may continue unabated. Such an assertion fails to recognize the relative causes of the existing rate of eutrophication, the insignificant warming of the lake caused by existing thermal discharges, the natural heat inputs to the lake, or the historical temperature conditions of the lake.

The predictions that thermal discharges will cause significant undesirable shifts in predominance of planktonic forms of aquatic life, such as algae and Type E botulinum, as so dramatically identified in the White Paper, does not take into consideration that thermal plumes are transitory, self-renewing water masses and the generation times of the

organisms contained therein would not allow for growths that could be construed as proliferation.

(2) Priorities for Environmental Improvement

As we all know, thermal discharges are only one result of man's activities that can have apparent or possible adverse effects on the environment. The principles of ecology would demand that priorities be established as to the potentially harmful effects of all forces impinging on man and his environment, so that manpower, economic and other resources can be apportioned accordingly to deal with the problems.

This philosophy is obviously lacking in the procedures and pronouncements of the Department of the Interior regarding environmental problems in the Great Lakes area. The recommendation of standards that would commit vast resources, to prevent imagined damage or to allay baseless fears predicated on unreasonably extrapolated data, is not in the best interests of the people or the natural environment. There are real, presently existing environmental problems that deserve a higher measure of our attention than that presently being allotted thermal discharges. The easiest targets of criticism and control should not be the criteria for selecting the priority for dealing with environmental effects.

(3) Alternative Considerations and Economic Significance

(a) Impact of $1^{o}F$ or No Heat Discharge Recommendation

Consumers Power Company has reviewed the problems involved with reducing the temperature of the discharge of cooling water to $1^{o}F$ over the ambient temperature of the receiving body of water for each of our plants on the Great Lakes.

To do this would, in each case, require us to install closed loop cooling systems with evaporative cooling devices such as powered draft cooling, natural draft cooling, spray ponds or possibly a combination of these.

Each of these systems has its own particular disadvantage, but common to all of the systems would be:

1. A loss of unit capacity of 4-6% due to increased turbine back pressure. This would have to be made up with new capacity costing about $175/kW.

2. A decrease in unit cycle efficiency of 2-3% during the summer period. This would increase the fuel requirements proportionately.

3. An increase in capital expenditures for cooling systems and associated changes.

4. A decrease in the net plant capability for pumping energy which would have to be made up with new plant capacity costing about $175/kW.

5. Increased maintenance cost required to maintain spray nozzles, tower fill, pumps and electrical equipment, etc.

6. Increased operating costs for water treatment of the water in the closed loop.

7. An increase in water evaporated and discharged to the atmosphere.

8. Possible problems with blowdown due to the concentration of solids because of the evaporation of water by the cooling towers.

9. Possible problems with drift and fallout of condensed water that cannot be fully assessed until a ~~model~~ study of each plant area is made.

10. Increased problems with insulators and other electrical equipment because of the increased humidity in the immediate plant area.

11. Problems with icing, particularly when a single unit is operated or when the plant is operated as a peaking plant.

To approach compliance with such a restrictive standard for the plants on Lake Michigan would cost millions of dollars per year. It is frequently stated that because this represents only a few percent of operating revenues, it is an insignificant expenditure for environmental controls. Many millions of dollars spent for any purpose cannot be considered insignificant. This represents a considerable amount of society's financial resources and should not be diverted from more deserving uses because of unsubstantiated fears of "thermal pollution." Considering the known adverse environmental effects of artifical cooling facilities, expenditures for these devices based on arbitrary restrictions, assumed to protect the lake, cannot be supported under the guise of improving environmental quality.

(b) Palisades Plant Alternatives

The Company has conducted preliminary feasibility studies for the Palisades plant with Bechtel Corp, on three alternative systems to modify the possible effects of the thermal discharge on the adjacent inshore area. These alternatives and a discussion of each are listed below.

Alternate I - Cooling Towers - A closed cycle cooling tower system has been considered which would for the most part isolate the plant from the lake. This would require three structures about 75' x 400' which would be placed to the south of the existing plant. This system would utilize forced air circulation towers rather than the natural draft towers due to performance and site location considerations.

The approximate engineering-procurement-construction schedule for this alternate is twenty (20) months.

Alternate II - Dilution of Discharge Flow - This system would provide additional dilution water to the discharge structure to reduce the outlet temperature to 10°F higher than the plant inlet flow. Modifications include additional (1) inlet line(s) parallel to the existing inlet line, (2) intake structure(s), (3) pumps, and (4) discharge structure(s) to accommodate the approximate tripling in quantity of discharge flow.

The approximate lead time for this alternate is twenty-eight (28) months.

Alternate III - Extended Discharge Piping - This system would provide for the addition of a pump structure, pumps and discharge pipe. The condenser discharge would flow to an enclosed discharge structure, from where it would be pumped to offshore points of discharge selected to minimize warm water effects along the lakeshore. A disadvantage of this scheme would be the dissipation of more heat into the lake water and less to the atmosphere from the surface cooling effect.

The approximate lead time for this alternate is twenty-eight (28) months.

An additional alternative which would be immediately available to reduce temperature rise, if required, would be the curtailment of plant power output. Since the circulating water temperature rise across the condenser is an approximate linear function with respect to power, reduction of plant power output would reduce the temperature rise accordingly. This measure could be taken at any time adverse effects are indicated and, of course, could be continued until some permanent solution such as the alternates listed above was implemented. A major disadvantage of this method would be the sacrifice of installed electrical capability during any periods when a power curtailment would be in effect.

All of the various alternatives would effectively reduce the capability of the plant and tend to reduce the reliability of the electrical system. Energy not available from nuclear plants must necessarily be supplied by older fossil-fueled generating stations that inherently have a greater impact on air quality. The adverse environmental effects of reducing the availability and reliability of electrical energy should certainly be weighed in any decisions made to ostensively improve environmental quality.

V. CONCLUSIONS

We would restate, in concluding, that the Federal position regarding thermal discharges into Lake Michigan is not warranted by the known facts concerning such discharges, or the potential effects of these discharges in the foreseeable future. Further, the vacillation in the Federal position has interfered with rational standard setting. Moreover, Consumers Power Company is profoundly disturbed by the misleading information which has been released on this subject and by the escalation of groundless fears in the minds of the public. The result of these needless anxieties is even more serious coming, as it does, at a time of rapid growth in electrical requirements and increasing energy shortages.

The Company is deeply involved in environmental studies to detect effects of thermal discharges into the Great Lakes, and is publicly committed to make corrections should damage occur. We would urge the conferees to carefully consider our statement and proceed with the business of developing a reasonable position concerning regulation of thermal discharges.

D. H. Brandt

In order to meet the service requirements of over 1 million electric customers the company has constructed, owns, maintains and operates an integrated electric generation, transmission and distribution system.

Presently, Consumers Power Company has several thermal electric generating installations in the Lake Michigan basin which are part of this integrated network system. These are the B. C. Cobb Plant on Muskegon Lake, the James H. Campbell Plant on Lake Michigan near Holland, and the Big Rock Point Nuclear Plant near Charlevoix. On tributaries to Lake Michigan the company operates the B. E. Morrow Plant near Kalamazoo and three smaller plants in Kalamazoo, Battle Creek, and Grand Rapids. Electric production at the last three plants is scheduled to be discontinued in the near future as a part of the company's program for air quality control.

Additionally, construction has been completed on the Palisades nuclear plant directly on Lake Michigan, 35 miles west of Kalamazoo and it is awaiting an AEC operating license. Also, construction is under way on the Ludington pumped storage hydroelectric plant, 4 miles south of Ludington, which will cycle lake waters to generate power to meet peak system demands.

Before proceeding with my specific comments, I

want to identify, for the record, my company's concern for the environment. For more than 50 years Consumers Power Company or its predecessor companies, have demonstrated their concern with protecting Michigan's environment. This includes careful management of more than 700 miles of river lands. Land that was denuded by the lumber interests now has been replanted and made available to the general public. Our efforts also include application of the more effective technologies available to protect and improve the quality of air and water, such as the addition of electrostatic precipitators, conversion to gas and oil, and sponsoring research and numerous environmental studies to guide us in making decisions on these important matters.

As a public utility company, Consumers Power Company has an obligation to its customers to provide adequate, reliable, and economical energy to meet their ever increasing energy requirements. At the same time, it has an obligation to protect the environment and, whenever possible, also makes life better for the people of Michigan by developing picnic areas, campsites and other recreational facilities. We are confident we can meet all of our obligations through the continued exercise of sound business judgment, consultation and guidance by technically qualified people, the application of appropriate control

technology and acting in a forthright manner on environmental issues. Our responsibility to meet these obligations does not permit us the comfort, in today's social atmosphere, of refraining from comment on these vital issues, just because the comments may be misunderstood by some people as opposition to pollution abatement.

We have examined the Federal Water Pollution Control Act, as amended, the Michigan water pollution control statute, consulted with counsel and we have examined the February 19, 1968, opinion from the Michigan Attorneys General's office dealing with these matters.

In view of these examinations it seems appropriate to draw the conferees' attention to the philosophy of the Federal Act and some of its provisions.

1) First, section 1(b) of the Federal Act provides in part:

"It is hereby declared to be the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the States in preventing and controlling water pollution ..."

MR. STEIN: It might save a little time, when you get down to 1 and 2 and you talk about the Federal officials, whether you can be specific in your general

allegations that follow.

MR. BRANDT: Yes, sir.

A number of Federal officials often appear to forget or ignore this basic policy of primacy of the State regulation in their temperature-standard-setting efforts.

2) The setting of standards, according to section 10(c)(3) requires that:

"In establishing such standards the Secretary, the hearing board, or the appropriate State authority shall take into consideration their use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial and other legitimate uses."

Too many Federal officials and others have ignored this requirement to take into consideration all legitimate uses of interstate waters. Instead, they consider exclusively the propagation of fish and wildlife. The Act obviously requires a balancing of interests and forbids the all-too-prevalent approach of considering other uses of the waters only to the extent that such uses will not limit or interfere in any way with propagation of fish and wildlife.

3) The legislative history of the Federal Act

shows that Congress rejected the principle of effluent standards. This rejection resulted in a statute which did not --

MR. STEIN: I take it, Mr. Brandt, that you did not want to accept the opportunity of being specific, and we will get to those general statements as they come up.

Thank you. Go on.

MR. BRANDT: Mr. Chairman, they will be in the body of the report; the specifics will be in there, sir.

MR. STEIN: All right, go on.

MR. BRANDT: This rejection resulted in a statute which did not confer upon the Secretary of the Interior the power to promulgate or enforce effluent standards. Nevertheless, at the last meeting of this conference a "policy" announcement of two Assistant Secretaries of the Interior was made which sought to have effluent standards imposed on Lake Michigan. Such standards would not be enforceable and standards to be meaningful must be enforceable.

4) Section 10(g) of the Federal Act provides that before any enforcement action can be undertaken there must be pollution which is endangering the health or welfare of persons. As the Michigan Attorney General's

office has pointed out, "The danger must be real and immediate." Too many of the proposals regarding thermal discharge limitations deal not with real and immediate danger to the health or welfare of persons, but a possible danger to some aquatic life. These proposals are predicated on extremely long-range predictions regarding the use of Lake Michigan waters by electric utilities.

5) Sections 10(c)(5) and 10(h) of the Federal Act both contain provisions concerning court action on pollution. Where standards are involved the court will make a complete review of the standards pertaining to the alleged violation, and the court must give due consideration to the practicability and to the physical and economic feasibility of complying with standards or otherwise securing abatement of proved pollution. In the words of the Michigan Attorney General's office:

" ... the government must prove that it is physically and economically feasible to abate the particular pollution complained of, that it is in the public interest to so abate the pollution and that it is equitable to do so. In view of these considerations, the court must find not only that the pollution exists as defined in the statute, but that it is economically feasible, physically possible, and equitable to order its abatement.

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... it certainly would be an anomaly to require States to adopt standards for water quality or to take measures in the abatement of pollution if such standards of water quality are not enforceable in a suit brought by the U.S. Government. It would seem that it was the Congressional intent to require the states to adopt standards of water quality, which if not adhered to would be enforceable in a suit brought by the U.S."

Consumers Power Company has on numerous occasions endeavored to make clear its concern for the environment. Our management has publicly stated that if a plant is found to be harmful to the environment the company will act promptly to correct the situation. Furthermore, this commitment is included in the Orders of Determination issued by the Michigan Water Resources Commission for all recently authorized electric generating facilities. The company also believes that unnecessary equipment should not be required or built simply because of unsubstantiated anxiety that adverse conditions might exist. To install such equipment without first establishing the need for it would constitute an unnecessary burden on the financial resources of our economy without achieving a meaningful contribution to environmental quality.

I agree with Representative Craig Hosmer,

Republican from California, when he said:

"Environmental protection does not necessarily mean sending the world back to whence it came to be refurbished in its original pristine condition, nor does it involve turning off air conditioners, abolishing the automobile and uninventing the wheel. Rather the solution lies in achieving a satisfactory accommodation between the demands of the environment and of social benefits of technology."

This Enforcement Conference, prior to its May 7, 1970, meeting, was reported to have made progress by reaching an agreement between the conferees on April 16, 1970, on a uniform procedure for the establishment of monthly maximum temperatures. The so-called 1-degree policy statement made at the opening of the May 7 conference and the "white paper" belatedly issued for this conference, are not in our opinion, of sufficient value to warrant much attention on the part of the conferees.

The 1-degree statement clearly goes beyond reason as well as the intent of Congress. The "white paper," drafted over a 4-month period, fails to take into account the technical data gained through years of experience with existing thermal electric generating plants on the Great Lakes. Scientific studies and actual observations of

existing heated discharges in Lake Michigan, conducted by the staff of the Michigan Water Resources Commission and other qualified groups, have documented on numerous occasions that these plants have been operating many years without demonstrable adverse effects to the aquatic environment. These and other studies being made on the basis of data obtained from actual field observations warrant careful attention of the conferees. FWQA is now proposing to subject all electric generating plants to temperature standards predicated on theories misapplied because of inadequate recognition of natural ecological factors.

Site studies made at existing plants along the Great Lakes should be evaluated before subjecting them to temperature standards which may require millions of dollars of capital expenditure because past studies and present surveillance programs offer no evidence that these waters require greater protection.

Gentlemen, we ask that you continue on your way to reaching conclusions supported by the law rather than emotion, and fact rather than fancy. We are confident you will reach conclusions which will adequately protect all of the legitimate uses of this natural resource for future generations.

Other individuals who Consumers Power Company has

asked to present information to this workshop are Dr. John Z. Reynolds and two representatives of the firm of Sargent and Lundy Engineers, Mr. A. F. Aschoff and Mr. Robert W. Patterson.

At this time I would like to call on Dr. Reynolds.

STATEMENT OF JOHN Z. REYNOLDS,
ENVIRONMENTAL SURVEILLANCE COORDINATOR,
CONSUMERS POWER COMPANY, JACKSON, MICHIGAN

DR. REYNOLDS: Mr. Chairman, conferees, ladies and gentlemen, my name is John Z. Reynolds. I am the Environmental Surveillance Coordinator for Consumers Power Company.

In recognition of a need for data collected from systematic surveillance, and for an expanded research effort on thermal discharges, electric utilities around Lake Michigan have launched an unprecedented effort to determine the effects of these discharges. Some of the studies of Consumers Power Company will be described in detail later. It would be appropriate at this point, however, to summarize the results of the various studies to date and how they relate to the issue of establishing a basis for setting

meaningful temperature standards, or otherwise limiting thermal discharges.

Thermal discharges into the Lake Michigan basin have existed at numerous locations for many years. Most of these have been studied to determine their physical behavior under various conditions and some have been studied to detect any related biological effects.

It has been observed in all cases that discharges that are warmer than the ambient waters are buoyant and tend to spread into relatively thin layers on the surface. Mixing of the thermal discharge with the adjacent waters causes some entrainment into the plume. The relative amount of entrainment is primarily a function of the velocity conditions and the density differences at the interface. Theoretically, the least amount of mixing would occur when the temperature differentials are greatest and when the relative velocities are smallest.

With any degree of entrainment, the resulting mixed fluid will still be less dense than the ambient waters, and cause the combined volume to be buoyant. The commonly observed plume therefore tends to float on the surface of the lake until the excess heat has been dissipated to the atmosphere.

The "white paper" purports to make a case that

a large proportion of the heat from a thermal discharge is effectively mixed with the lake to accumulate and result in unacceptably high termperatures. We would like to cite just a few examples of the misleading way technical reports were abstracted in the paper to document the case.

It was quoted that Hope et al (1968) "concluded, on the basis of work at a Lake Monona (Wisconsin) power plant, that surface heat losses were about 5 percent of the heat discharged by the power plant; the remaining 95 percent was dissipated by dilution with lake water." It was not stated, however, that this result was based on analysis of a discharge, contained by a baffle, from 2 days of field data on January 25 and 26, 1967, during a period of significant atmospheric warming. It might also be noted that these researchers concluded from the results of 22 field surveys during the remainder of the year that "power production increases of less than 100 percent will have a negligible effect on ... lake temperatures."

Work by Palmer (1969) was cited as supporting the notion that excess heat diffuses into the lake, as opposed to any significant atmospheric losses occurring. Our review of the paper failed to identify any point that would support this view. His studies of a cooling water discharge into Lake Ontario showed "that the warmer water

stays near the surface and the shore. The subsurface cooling water had acquired lake temperature by 4,000 feet while the surface cooling water (was) still 4 degrees F. warmer than the lake water at 4,000 feet." Model studies were cited that assumed no atmospheric heat transfer, to simplify, in a conservative way, the mathematical predictions.

Similarly, work by Sundaram et al., (1969) was cited where they "concluded that the heated discharge of the proposed Bell Nuclear Station on Cayuga Lake (New York) would increase the average surface temperature of this 66.4-square-mile lake about .7 degrees F." The Sundaram report, however, went on to note that, "for a given amount of heat that is discharged into the lake, the far-field effects will be greater if the discharge temperatures were close to the ambient lake surface temperatures than if the discharge temperatures were significantly higher than the ambient lake surface temperatures, since in the latter case a greater fraction of the total heat can be lost to the atmosphere directly than in the former case."

Benedict's (1970) shoreline discharge model of the Campbell plant and Pritchard-Carpenter Consultants (1969 and 1970) computations for Toledo Edison were cited in the "white paper" as further support that the "assumption of little or no waste heat loss to the atmosphere is

reasonable, at least during a great deal of the annual temperature cycle." In both cases the assumption that surface heat loss was limited was arbitrarily made to simplify the model. No evidence is given or even implied by the original authors that this was a realistic assumption.

It is not realistic, or even honest, to use such model studies to support such a viewpoint, when much field data, from actual installations, are available that can be used for this purpose.

No evidence has been presented of which we are aware that the physical presence of a thermal plume on Lake Michigan has interferred with or otherwise caused injury to any beneficial use of the waters. In fact, the areas of heated discharge are often observed to appeal to swimmers, since the lake waters are normally too cold for comfortable water contact activities.

Researchers evaluating the results of biological studies that have been conducted in the vicinities of thermal discharges in Lake Michigan have similarly concluded that no adverse effects have occurred as a result of this use of the waters. Electric utilities, consultants, universities and governmental agencies have been unable to document significant biological effects

outside of the localized influences on fish that prefer or avoid the region of increased temperature. Fishing in the vicinities of thermal discharges has been observed to be favored for the greater portion of the year, even for some of the so-called cold water, heat sensitive species.

Consumers Power Company has maintained parking areas in the vicinities of some of the plant discharges to facilitate access for fishermen and others. We have received requests from the Fish Division and the Bureau of Water Management of the Michigan Department of Natural Resources to provide more facilities to accommodate the public because of the "recreation potential in year-round fishing" in these areas.

The only reference in the "white paper" purporting actual evidence of harmful effects of a thermal discharge into Lake Michigan concerns an alleged fish kill at the Consumers Power Company Campbell Plant on August 29, 1968. While it was indicated that a drop in temperature due to natural upwelling may have been a major factor resulting in the conditions observed, the paper does not give any indication of the scope of the adverse condition noted.

The observations were made by John Robinson, Aquatic Biologist, employed by the Michigan Water Resources

Commission. He stated that the water temperature at the point of discharge was 64.4 degrees F. and that the temperature dropped in a short distance to 59 degrees F. and then gradually declined to the ambient of 50 degrees F. in one-half mile. This is the lowest temperature recorded at the plant for any day in August since the plant has been in operation, and occurred only a few days after a water intake temperature of 76 degrees F. had been observed.

Mr. Robinson noted that there were live catfish and carp near the discharge and schools of alewives in the area. Some dead alewives were observed, but no estimates were made of the numbers involved. The only other dead fish reported were a catfish and/or carp approximately every 150 feet along 1 mile of shoreline. This amounts to a total of about 35 fish. Apparently no sport fish were involved. Mr. Robinson concluded that the fish affected were apparently indigenous to the long cooling water discharge canal and that the very unusual combination of natural temperature fluctuations was partly responsible for their condition. It has been reported that this phenomenon of rapid natural temperature variations has caused fish to be in distress at other locations, around the Great Lakes.

At the recommendation of the conferees of the

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Lake Michigan Enforcement Conference in 1968, an interagency Committee on Nuclear Power Plant Waste Disposal was formed which reported to the conferees in November 1968. They stated:

"The effects of localized temperature increases on the aquatic life in Lake Michigan are impossible to predict from the limited information available. Only a few observations have been made to date of the effects of existing thermal discharges on Lake Michigan biota. However, laboratory investigations and observations elsewhere suggest that increase in temperature can result in damage to the aquatic environment."

The committee recommended with regard to thermal discharges that:

"Coordinated study of the thermal effects on water quality and aquatic life of one or more fossil fuel plants now discharging cooling water to Lake Michigan, and of various methods of cooling water dispersion be undertaken by FWPCA," and "FWPCA coordinate a comprehensive study of the effects on water quality and aquatic life of thermal wastes from a large nuclear power plant on Lake Michigan, with attention to various methods of cooling water dispersion."

It is apparent that the Federal Water Quality Administration has not carried out either recommendation of

the committee inasmuch as no notice has been made of such comprehensive studies by FWQA. Fortunately, even before the committee's report, the electric utilities around Lake Michigan were concerned about the early detection of any possible adverse effects that thermal discharges might cause. These companies instituted comprehensive studies on their own or in cooperation with the appropriate State agencies. The scope and methodology of these studies are such that it can be assured that, if harmful effects are caused, they will be detected.

The previously mentioned report of the Committee on Nuclear Power Plant Waste Disposal to the conferees of the Lake Michigan Enforcement Conference included the following comment on thermal discharges into Lake Michigan;

"In spite of the known adverse effects which temperature change can have on aquatic life, it is not certain that they will occur in the unique environment of Lake Michigan. Much of the shoreline is seldom inhabited by aquatic animals because the bottom materials consist of shifting sand. There are rocky shoals that support game fish population. Whether or not local increases in temperatures will accelerate the eutrophication of Lake Michigan is uncertain at present. It is tempting to speculate on this, but only intensive long-term studies

will reveal the facts. Local increases in algal growth very probably will develop if sufficient nutrients are available, since biological activity is greater in warmer than in cooler water. The magnitude of these increases must be known before there can be evaluation of the potential problem."

Then, after discussing the relative merits of low or high velocity, and offshore or onshore discharges, the committee reported that:

"A recommendation that one or the other (type of discharge) be routinely required for all power plants would have to be supported by firm information on damages to water quality and uses that would result from failure to require such devices. Available information on potential damages does not provide a basis for such a position at this time. Such information can be obtained through studies by aquatic biologists of areas in Lake Michigan where large fossil fuel plants presently discharge large quantities of cooling water."

To our knowledge the biological data that have been compiled since the committee's report have failed to substantiate any significant biological effects.

It is also interesting to note that in the same report after computing the total heat input into Lake Michigan

from existing and proposed power plants, the committee concluded that "there is a minimum need for immediate concern over the effect of temperatures on the lake as a whole." They went on to say that the probable long-range effects deserve consideration. We agree there may be some future point at which the effects of substantial additional thermal discharges might cause significant effects for the lake as a whole. We demonstrate our concurrence with their observation that the possible local effects are of more practical and immediate concern in that our ecological investigations are largely oriented to detect such influences of thermal discharges.

Mr. Chairman, Mr. Brandt will continue with this report.

MR. BRANDT: Mr. Chairman, at this point we would like to take a few moments to review with the conferees the sequence of events experienced in the State of Michigan in setting temperature standards for Lake Michigan and for the other waters of Michigan.

We start off with -- it was a recommendation of the National Technical Advisory Committee that I would like to refer to first in the so-called "green book," quote, "On February 27, 1967, the Secretary of the Interior established the first National Technical Advisory Committee

on Water Quality Criteria to the Federal Water Pollution Control Administration. The committee's principal function was to collect into one volume a basic foundation of water quality criteria."

As described in the introduction to the report of the National Technical Advisory Committee on Water Quality Criteria dated April 1968:

"The committee was concerned about several issues relating to water quality standards for the control and abatement of water pollution. Foremost among these is the lack of adequate knowledge concerning many of the quality characteristics upon which criteria and, hence, standards should be based. The unknowns still outweigh the knowns. Complicating factors in setting standards are varying natural conditions affecting water quality, such as climate, geography, and geology of a specific location. The committee does not want to be dogmatic in recommending these criteria. They are meant as guidelines only, to be used in conjunction with a thorough knowledge of local conditions. Further, it is anticipated that future research will provide considerable basis for refinements in the recommendations."

"The committee recognizes that the protection of water quality for legitimate uses requires far more than

scientific information. There is an urgent need for data collected from systematic surveillance of waters and waste sources and for an expanded research effort."

While the committee observed that for lakes the situation is complex and cannot be specified in simple terms, their recommendation for both warm and cold water lakes was that the temperature of the epilimnion should not be raised more than 3 degrees F. by the addition of heat of artificial origin. They further qualified that position in the case of warm waters saying that, "In those areas where important organisms are most likely to be adversely affected (the temperature) should not be raised more than 3 degrees F. above that which existed before the addition of heat of artificial origin." The committee members clearly implied that they felt temperatures in excess of 3 degrees F. within a mixing zone were of no special significance unless, of course, it could be demonstrated that harmful effects would occur.

It should be pointed out that while the committee made no specific reference to mixing zones with regard to freshwater organisms, in discussing criteria for marine and estuarine organisms it was stated that the suggested temperatures were to apply outside of mixing zones, which would be related to required zones of passage. The situation

regarding heated discharges into very large lakes, such as Lake Michigan, would be comparable to ocean discharges in this respect.

The committee could be criticized, however, for not making a distinction between mixing zones involving temperature and those that would involve contaminating substances. They stated, in effect, that dilution flows should be very large to limit the area of mixing. While this would be generally true for contaminating substances which would remain in the water body, discharge of heated waters involving buoyancy effects and dissipation of heat to the atmosphere complicates the task of defining mixing and zones of passage. The significance of the configuration of the mixing zone or its dimensions can only be based on individual site considerations and the nature of the aquatic life or other beneficial uses to be protected.

Now, in the past 3 years there has been an ongoing effort to obtain approval of the Michigan water temperature standards. We would like to take a moment to touch on a few significant exchanges in that regard.

Initally in the State of Michigan, in accordance with the Federal Water Pollution Control Act, as amended by the Water Quality Act of 1965, the Governor of the State

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of Michigan wrote to the Secretary of Health, Education, and Welfare on December 17, 1965, that it was the intent of the State to adopt criteria applicable to interstate waters under the authority of Act 245, Public Acts of 1929, as amended. The Michigan statute declares to be unlawful the discharge of any substance "which is or may become injurious to public health, commercial, industrial, agricultural, recreational or other uses which are being or may be made of such waters; or which is or may become injurious to the value or utility of riparian lands; or which is or may become injurious to livestock, wild animals, birds, fish, aquatic life or plants or the growth or propagation thereof be prevented or injuriously affected; or whereby the value of fish and game is or may be destroyed or impaired."

Section 5 of the Act declares in part:

"The Commission (Michigan Water Resources Commission) shall establish such pollution standards for lakes, rivers, streams and other waters of the state in relation to the public use to which they are or may be put, as it shall deem necessary."

In June 1967, water temperature standards for the Great Lakes were adopted by the Michigan Water Resources Commission and submitted by the State to the Federal

Government for approval. It reads as follows:

"For the Great Lakes and connecting waters no heat load in sufficient quantity to create conditions which are or may become injurious to the public health, safety, or welfare; or which are or may become injurious to domestic, commercial, industrial, agricultural, recreational or other uses which are being or may be made of such waters; or which are or may become injurious to the value or utility of riparian lands; or which are or may become injurious to livestock, wild animals, birds, fish or aquatic life or the growth or propagation thereof."

The Federal action following that: Even though the temperature standards adopted by the Michigan Water Resources Commission in 1967 appeared to contain all the necessary restrictions defined in the Federal Water Pollution Control Act, and met the constitutional requirement that beneficial uses unrelated to any injury could not be prohibited, the Secretary of the Interior did not approve them.

Then, on October 23, 1969, H. W. Poston, Regional Director of the Federal Water Pollution Control Administration, U. S. Department of the Interior, sent to R. W. Purdy, Executive Secretary of the Michigan Water Resources Commission, a proposed Lake Michigan temperature

Standard, stating, "This standard is the result of a comprehensive review of temperature and aquatic life data for Lake Michigan conducted by the National Water Quality Laboratory in Duluth."

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The recommendations for monthly maximum surface temperature in degrees F. were: January, 50; February, 50; March, 50; April, 50; May, 55; June, 70; July, 85; August, 85; September, 85; October, 85; November, 70; December, 55.

No recommendations were made regarding the definition of mixing zones and the only comments on discharge areas were related to the possibility of fish kills and the blockage of tributaries supporting anadromous fish.

State action: On February 17, 1970, Carlos Fetterolf, Supervisor of the Water Quality Appraisal Section, Michigan Water Resources Commission, reported to the Commission that his staff had explored the reasons for disapproval of the Michigan temperature standards by the Federal Government. He then submitted new standards for consideration.

The principal changes for the Great Lakes involved substitution of a 5 degree F. temperature rise limitation and the setting of monthly maximum temperature values outside of mixing zones to be defined by the Michigan Water

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Resources Commission. Lake Michigan was divided into northern and southern sectors at Pentwater, Michigan. No increase would be allowed greater than 5 degrees F. nor any temperature above 80 or 85 degrees F. for the northern and southern sectors, respectively.

He reaffirmed the MWRC staff position that mixing zones should be established based on individual site conditions and stated further that Dr. Mount of the FWPCA Duluth Laboratory had questioned the advisability of subjecting mixing zones to formula identification. Apparently some FWPCA representatives had informally suggested that formulas would be appropriate.

The MWRC scheduled a public hearing for March 19, 1970, to review the staff recommendations. In the meantime, however, the staff felt that approval from FWPCA could be expedited by complying with their further request for numerical monthly temperature maximums for the Great Lakes, and by adding some general considerations as to philosophy of regulation.

The proposed monthly temperature limitations for the southern sector of Lake Michigan, for instance, in degrees F. were: --

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MR. STEIN: Let's have the lights on, please.

D. H. Brandt

MR. MAYO: What page are you leading to, Mr. Brandt?

MR. BRANDT: This would be II-13, sir, at the top of the page.

January, 50; February, 50; March, 60; April, 65; May, 75; June, 85; July, 85; August, 85; September, 85; October, 70; November, 60; December, 50.

The maximum temperature limit for the northern sector would be 80 degrees F.

Federal action: Representatives of FWPCA testified at the public hearing on March 19, 1970, at which time they presented an edited copy of the proposed State regulations. They suggested striking any reference that mixing zones be related to the value of aquatic life and physical characteristics of the receiving water body, and all qualifying statements as to the extent of adverse effects. It was suggested that mixing zones be defined by formula but should not exceed 1 mile in radius.

They further suggested that the Great Lakes be separated into lossely defined open waters and inshore waters. For Lake Michigan the recommended temperature limits for open waters in degrees F. were:

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January, 42; February, 37; March, 37; April, 44;

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May, 53; June, 65; July, 71; August, 74; September, 72; October, 65; November, 54; December, 50.

It was pointed out at the hearing by Mr. Purdy of MWRC that these suggested limits are exceeded, due to natural causes, on a regular basis.

Consumers Power Company has collected a considerable amount of temperature data from two power plants on Lake Michigan that are somewhat representative of lake temperatures. One, the Big Rock Point plant, has an intake that is located 1,450 feet from shore at a depth of approximately 25 feet and would be subject somewhat to stratification influences. The range of maximum daily average temperatures for each month for a 6-year period of record are shown on Exhibit II-A (See P.462), as are the temperature limitations proposed in March 1970. It should be noted that for 7 of the 12 months during this short period of record, the natural intake temperatures equaled or exceeded the limitations proposed by FWPCA for open waters in Lake Michigan.

The J. H. Campbell plant intake is located on Pigeon Lake into which Lake Michigan water flows. From a temperature standpoint the intake is indicative of "inshore" conditions, though some recirculation from the discharge occurs periodically. The range of maximum daily average

temperatures for each month for a 6-year period of record is shown on Exhibit II-B (See P. 463), with the proposed temperature limitations for open and inshore waters. For several months the maximum daily average temperature exceeded the proposed FWPCA limitations for every year of record. In 3 months the proposed limit was exceeded by over 10 degrees F. which would be difficult to account for by considering the maximum effect of recirculated discharge from the plant.

FWPCA representatives further recommended that a 3 degree F. temperature rise outside the mixing zone be the limitation for Lake Michigan.

Their testimony supported the MWRC staff proposal that the water resources be protected for the "optimum use by fish, wildlife and other aquatic life," without mention of other beneficial uses. They further recommended that "at no place in a mixing zone shall the 96-hour median tolerance limit (96 hr. TL_m) to aquatic life be exceeded." The recommendation did not define what aquatic life was to be protected. No explanation or justification for such a restrictive limitation was given.

On April 10, 1970, F. T. Mayo of the FWPCA regional office submitted additional recommendations. The

suggested monthly maximum temperature limits for Lake Michigan inshore waters in degrees F. were: January, 42; February, 37; March, 37; April 44; May, 53; June, 65; July, 72; August, 77; September, 75; October, 65; November, 54; December, 50.

It was further recommended that mixing zones should not include waters within 600 feet of shore.

State action: After the March 1970, hearing, the MWRC released the results of a study consisting of approximately 24,000 temperature readings from eight Lake Michigan water intakes in Michigan which are unaffected by heated discharges and over 300 shoreline temperatures from twenty swimming beach stations. This study was initiated after consultation with Federal Water Quality Administration representatives.

At a meeting in Ann Arbor, Michigan, on April 16, 1970, it was agreed by the Lake Michigan Enforcement conferee representatives that the States and FWQA would tabulate existing temperature data for Lake Michigan. The 90th percentile value to be determined from this data would then serve to establish monthly maximum temperature limitations. This information would be the basis for discussions at the Executive Session of the Lake Michigan Enforcement Conference scheduled to be held in Chicago on

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May 7, 1970.

Federal action: The meeting in Chicago on May 7, 1970, although scheduled as an executive session, actually became a public hearing. The following statement issued by Carl L. Klein and Leslie Glasgow, Assistant Secretaries of the Interior, was read before the Lake Michigan Enforcement Conference:

"The minimum possible waste heat shall be added to the waters of Lake Michigan. In no event will heat discharges be permitted to exceed a 1 degree F. rise over ambient (existing temperature) at the point of discharge. This will preclude the need for mixing zones."

This declaration effectively negated the substantial efforts of the State conferees and the staff of FWQA, during the previous months, to resolve differences in concepts and to secure a reasonable basis for temperature standards.

State action: The MWRC requested FWQA to provide written clarification of the policy statement issued by Carl L. Klein and Leslie Glasgow, and scientific documentation which would show the need for such a strict policy.

On September 18, 1970, the MWRC expressed its support of a revised set of temperature standards, as recommended by the staff. Their proposed maximum monthly

temperature standards for the open waters of the southern sector of Lake Michigan in degrees F. are as follows: January, 35; February, 35; March, 39; April, 49; May, 57; June, 67; July, 74; August, 76; September, 73; October, 64; November, 54; December, 43.

Similarly, the proposed standards for the inshore waters of this sector in degrees F. are: January, 38; February, 38; March, 42; April, 54; May, 63; June, 78; July, 82; August, 82; September, 80; October, 70; November, 60; December, 48.

The maximum temperature limit proposed for the inshore waters of the northern sector of Lake Michigan is 76 degrees F.

The proposed temperature standards for inshore waters are based on the 90th percentile, adjusted for 3 degrees F. increase at the edge of the mixing zone.

This recitation of exchanges between the Department of the Interior and the MWRC has been primarily for the purpose of illustrating the confusion that prevails concerning the adoption of temperature standards. The sincere and honest efforts of many who have worked to develop reasonable temperature standards, based on technical evidence, have been repeatedly destroyed by inconsistent and confused pronouncements and recommendations

by others.

It is the philosophy of the Federal Water Pollution Control Act to assure that all waters will be equally protected for all legitimate uses. Propagation of fish and wildlife is one of those legitimate uses. Utilization by industry is another one. This is particularly true for those rivers and lakes where either or both of these uses are already established. Industry must not be allowed to pollute a body of water and destroy the fish and wildlife that exist. Similarly, propagation of fish and wildlife must not be such as to destroy or pose intolerable burdens upon the industries that utilize the waters. We believe it is possible to set standards that will satisfy both requirements.

In view of this, we objected to several statements and suggestions made by the representatives of FWPCA at the March 19, 1970, MWRC hearing regarding thermal discharges, effects, and regulations.

Their basic rationale, as stated by Dr. Donald Mount of the National Water Quality Laboratory, Duluth, Minnesota, that "when protecting aquatic life we normally protect the waters for all beneficial uses," and their suggestion that the 96-hour median temperature tolerance limit to aquatic life not be exceeded at any point is

meaningless unless related to specific aquatic life to be protected.

Dr. Mount's statement that "fishes are repelled by temperatures that are unacceptably high during the summer months and, therefore, these pose no particular problem except that the habitat available is reduced in area," is clearly inconsistent with the FWPCA position taken at the same meeting that at no point should temperatures exceed values that have been shown to cause detrimental effects in confined laboratory conditions.

Likewise, a rigid definition of lake mixing zones based solely on a rate of discharge, as they suggested, does not recognize either the potential effects of thermal discharges on aquatic life or a beneficial-use concept. Dr. Mount's brief statement that "every mixing zone should be defined geographically," oversimplifies the ecological complexity of the waters involved, as does the FWPCA recommendation that uniform temperature limits should be imposed on each of the Great Lakes.

Dr. Mount was concerned that fish residing in warm-water effluents during the winter be protected in case the plant must be shut down. The fish that are most likely to inhabit this relatively small area would not find the normally cold lake temperatures suitable. As such, these

warm-water areas provide for greater diversity of fish habitat for the lake as a whole, and, although these fish might be temporarily adversely affected by plant shutdown, the natural populations should not be significantly affected.

Similarly, the importance of maintaining the "normal daily fluctuations" for the Great Lakes has been overstated in the various proposed standards, in view of the great natural temperature fluctuations that occur from day to day. This situation is described in the "white paper" and is well documented in the records of the staff of the MWRC and others.

While the FWPCA concept in March 1970, of differentiating between inshore waters and open waters is ecologically sound, the definition set forth by FWPCA was not complete enough to allow for confident prediction of these limits, either spatially or temporally. They stated simply that, "Inshore waters are those waters which are affected by tributary stream plumes (other than connecting channels), near shore thermal bars, natural shore erosion, or bottom sediment resuspended by wave action. Waters not defined as inshore waters would be considered as open waters."

The "white paper" now defines the inshore zone

as, "That volume of water which lies between the shoreline and the 100-foot depth contour," and includes what is called a "beach water zone, a sub-area that extends from the shoreline out to the 30-foot depth contour." This vacillation in establishing basic definitions does not facilitate efforts to set standards.

Whether for inshore or open waters, any temperature regulations should reflect naturally-occurring conditions, and allow for variations consistent with those known to occur without any thermal discharges.

It was pointed out at the March 1970, hearing that a 58-degree F. limitation, as proposed by FWPCA for migratory routes of salmonid species during migration, was unrealistic considering the fact that healthy migrations occur in 70-degree F. water. Similarly, lake water temperatures should not be arbitrarily restrictive, in view of the fact that extreme temperature excursions have occurred in the past by natural and artificial means, with no apparent damage to the aquatic ecology.

Dr. Mount made the statement, when questioned about the natural conditions exceeding his recommendations, "That if the temperature is unacceptable, it is unacceptable whether it has been caused by the sun or man." This should cause us to pause and consider the nature of

the situation. Because if the artificial aquatic habitat mankind has nurtured, in the lakes particularly, is truly unsuited to this climate, the concept of beneficial use of these waters by all citizens should receive prompt and thorough review if, according to law, other beneficial uses should not be placed in jeopardy because an especially delicate fishery has been developed, as Dr. Mount suggests.

Consumers Power Company is convinced that this is not the situation, and based on years of experience with thermal discharges on the Great Lakes, is certain that even greater heat loads can be added to the lakes without harming the aquatic ecology as it exists today or otherwise interfering with other reasonable beneficial uses.

Dr. Reynolds will now speak about the environmental programs that the company has conducted and is conducting at the present time.

DR. REYNOLDS: As mentioned earlier, concern for preserving the --

MR. STEIN: Dr. Reynolds, how long will this paper continue, for another hour? How long do you expect to have?

DR. REYNOLDS: Don, do you have the time on this?

MR. STEIN: That we have left on the paper.

DR. REYNOLDS: How much time do you estimate we have left?

MR. PETERSEN: Forty-five minutes on this part of the presentation and another 45 minutes after that.

MR. STEIN: Let's recess for 10 minutes.

(Short recess.)

MR. STEIN: Let's reconvene.

Would you continue?

DR. REYNOLDS: Mr. Chairman, before I proceed, on section II, page 20, I would like to correct a typographical error for the record.

The second paragraph, the last sentence where it starts out, "According to the --" there should have been an, "If, according to the law."

MR. STEIN: Where is that?

Would you give us the citation again, please? Let's have the page.

DR. REYNOLDS: Page 20, section II.

MR. STEIN: Where do you want the "if"?

DR. REYNOLDS: In the second paragraph the last sentence where it starts out, "According to the law."

MR. STEIN: Where do you want the "if"?

DR. REYNOLDS: Start out the sentence, "If

according to the law, other beneficial uses should not be placed in jeopardy because an especially delicate fishery has been developed, as Dr. Mount suggests."

MR. STEIN: I know I went to these effete English schools, but that isn't a sentence the way you changed it.

DR. REYNOLDS: I am sorry, that shouldn't be a new sentence, that should be a comma.

MR. STEIN: How do you want that now?

DR. REYNOLDS: A comma where the period went before that sentence, insert "if" and make that a small "a" and go ahead.

O.K.?

MR. STEIN: O.K. Let's go on.

DR. REYNOLDS: As mentioned earlier, concern for preserving the environment has historically been the corporate policy of Consumers Power Company. This concern for preserving water quality in Michigan can best be demonstrated by describing our water quality surveillance programs conducted in the past several years at all our major generating stations.

The company has engaged the services of university and private consultants in all facets of the aquatic sciences, cooperated with efforts of State agencies,

and has added technically-qualified staff in this field. As a result of this combined effort, over 80 temperature surveys and 20 biological surveys have been conducted to date in the cooling water discharges of the company's seven major electrical generating sites. Exhibit III-A summarizes these studies. (See P. 471) It should be noted the list of surveys shown in Exhibit III-A includes only surveys related to thermal effects and does not include numerous radiological and other surveys that have been conducted relative to water quality.

Beginning in 1967, a series of temperature surveys have been conducted at the 531 MWe B. C. Cobb plant on Muskegon Lake. Most have been made during fish migratory seasons to determine the plant's influence on the zone of passage in Cedar Creek (North branch Muskegon River). These studies have demonstrated that a zone of passage was maintained in Cedar Creek from the point of condenser water discharge to Muskegon Lake. As an example, the thermal plume observed on July 17, 1970, is shown on Exhibits III-B, C, and D (See p.. 473, 474, 475) for the surface, 2-foot depth and bottom, respectively. Other temperature surveys have been conducted on Muskegon Lake and include an infrared aerial survey in 1970.

Since 1960, Consumers Power Company, in cooperation

with various State agencies, has conducted a routine radiological monitoring program of the biota in the vicinity of the 71 MWe Big Rock Point plant on Lake Michigan near Charlevoix. In addition, temperature surveys have been conducted, including two infrared flights. The surface plume observed on June 18, 1968, is shown on Exhibit III-E, as an example. (See P. 476)

A comprehensive biological survey has been conducted at the 1226 MWe Karn-Weadock facility on Saginaw Bay, which includes bottom fauna, plankton and macrophytes. In conjunction with the study, the results of which will be available later this year, extensive fish surveys were conducted in the discharge vicinity. In addition, numerous thermal plume measurements were made, including an infrared aerial survey in 1970. The thermal plume observed on August 7, 1970, is shown on Exhibits III-F, G, and H (See p. 478, 479, and 480) for the surface, 2-foot and 5-foot depths, respectively.

Since 1966, several thermal plume surveys have been conducted at the 342 MWe J. R. Whiting plant on Lake Erie, including two infrared aerial surveys this year. The thermal plume observed on June 17, 1970, is shown on Exhibits III-I and J (See p. 481, 482) for the surface and 5-foot depth, respectively.

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It is not practical to include in this report the full details of the above studies. However, some graphic illustrations from a few of the thermal surveys have been shown because they document various plume characteristics for different plant locations, loads and meteorological conditions.

Ten temperature and two biological surveys have been conducted at the company's J. H. Campbell plant site on Lake Michigan near Holland. The following information includes some of the results of these surveys.

Temperature surveys: The condenser cooling water for the J. H. Campbell plant is drawn through Pigeon Lake and discharged into Lake Michigan at a maximum rate of about 300,000 g.p.m., with an average temperature rise of about 17 degrees F. The Campbell plant has two units and is capable of producing 647 MWe.

On July 10, 1970, a surface water temperature survey of the J. H. Campbell plant condenser cooling water discharge, as shown on Exhibit III-K (See P.483), was made when the plant intake temperature was 66 degrees F. and the discharge temperature was 82 degrees F. The plant was discharging approximately 300,000 g.p.m. Due to unfavorable lake conditions (rough water), temperature profiles were not made. A 15 m.p.h. north wind caused the

main portion of the plume to travel south for approximately 1 mile before it dissipated. The unusual plume configuration, shown on this exhibit, resulted from a change in wind direction during the preceding 10-hour period. At points 6,000 feet north and south of the discharge the temperature was 66 degrees F. from the shore lakeward. The maximum offshore extent of the plume was approximately 1,000 feet.

On August 26, 1970, another surface water temperature survey was conducted as shown on Exhibit III-L. (See P. 485) The plant was operating only with Unit No. 1 and was producing 247 MWe. The discharge was approximately 120,000 g.p.m. with intake and discharge temperatures of 74 degrees F. and 85 degrees F., respectively. During the survey the wind was from the S-SW at about 10 m.p.h. and the plume was traveling northward alongshore in a relatively narrow ban. The maximum offshore extent of the plume was about 800 feet at the point of discharge. The plume at 6,000 feet to the north was within 1 degree F of the ambient lake temperature. There was no measurable increase above ambient temperature, 6,500 feet to the north.

Another surface water temperature survey was conducted, as shown on Exhibit III-M (See P. 486), on September 9, 1970. An additional objective of this

survey was to gather ground-truth data for an infrared imagery flight made on that day. The plant load was 568 MWe and the discharge was approximately 300,000 g.p.m. The intake temperature was 72 degrees F. and the discharge temperature was 89 degrees F. The wind was from the S-SW at speeds up to 5 m.p.h. It was evident during this survey that the plume was shifting to the north. The northern boundary of the plume moved 500 feet further north in approximately 1 1/2 hours. Near the point of discharge, where the surface temperature was about 88 degrees F., the temperature at 3-ft. depth was 74 degrees F. Where the surface temperature was observed to be 79 degrees F., the ambient temperature of 72 degrees F. was found at 2-ft. depth.

1968 biological survey: To assist Consumers Power Company in evaluating the impact of heated water discharges on the biota of southeastern Lake Michigan, T. W. Beak Consultants Limited were retained to carry out a biological survey in the vicinity of the J. H. Campbell plant. The survey work was carried out on August 30, 1968. Field work was accomplished by T. W. Beak Consultants Limited and a crew from the Michigan Department of Conservation, assisted by Consumers' technical staff.

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Eight sampling stations were selected; seven in the vicinity of the cooling water discharge point and one, a control, 3 miles south of the plant. Station locations are shown in Exhibit III-N. (See P.488) Distances and directions were measured by means of an electronic range finder and compass headings. At each station, six bottom samples were taken by means of a Ponar dredge. This is a clam-shell type device which cuts about 1/2 sq. ft. of the bottom to a depth of 2 to 6 inches, depending on texture. Samples were washed in a 30-mesh screen, to remove sand and mud, and preserved for shipment to the laboratory. There the benthic macroinvertebrate organisms were hand-sorted, classified to major taxonomic groups and counted.

Plankton samples were collected at each station by means of an electric pump with a calibrated intake hose which could be lowered to the desired depth. To obtain a sample, about 40 liters of water from a 5-ft. depth were strained through a Wisconsin plankton net aboard the boat. One additional sample from a 10-ft. depth was taken at station 8, where the water was deeper. The concentrated plankton samples were preserved and sent to the laboratory for analysis.

The lake bottom in the study area consists mainly

of fine, loose sand, mixed with some gravel at the inshore stations. There were no stable deposits of silt or organic debris.

The prevailing movement of heated water away from the discharge point is northward along the coast, following the general counterclockwise circulation pattern in the southern basin of Lake Michigan. The biological results from the control station, 3 miles south, indicate the makeup and density of the benthic community outside the warm-water plume.

In order to compare the density and diversity of organisms, the number of general taxonomic groups found and their average numbers per square foot at each station were calculated. The principal observation which can be made concerning these data is that there is very little difference between the animal communities in the plume and control areas. The dominant animal forms in both areas were midge larvae (Chironomidae) and scuds (Amphipoda). The density of organisms at all inshore stations (400 ft. offshore) was quite similar.

Stations 8 and 9 which were the furthest offshore yielded numbers of midge larvae and scuds approaching those found at the 1/2-mi. stations near South Haven, Michigan, in May. This suggests that distance from shore is an

important factor in explaining the observed animal distribution. Station 7, which was slightly closer to shore, yielded results similar to those at the 400-ft. line. The extreme scarcity of aquatic segmented worms, which are detritus feeders, probably reflects the absence of significant sources of organic wastes in the area. The bottom fauna were found to be sparse and restricted in variety. Two main factors appear to be responsible for this—the sand bottom, which is not highly productive even when not mechanically disturbed , and the shallow depth which results in bottom sediment disturbance by waves.

On the basis of the study results, the biological consultants concluded that there appeared to be no gross thermal damage to the benthic fauna of the main plume area at the Campbell site.

1970 biological survey: To further document the effects of condenser water discharges into Lake Michigan, another biological survey was conducted in 1970 at the J. H. Campbell plant. The 1968 biological sampling stations and five additional offshore stations were sampled on August 26, 1970, for benthic organisms. Three Ponar dredge samples were collected at each of the thirteen stations on Exhibit III-O. (See P.491) The samples are

being analyzed as they were in 1968, and the results will be available later this year.

The temperature and biological studies which have been conducted at the J. H. Campbell plant have shown:

1) The ecology of Lake Michigan in the condenser water discharge area has not been significantly affected.

2) Wind velocity and direction influence the maximum extent and pattern of the thermal plume.

3) Temperature profile data have shown that outside the immediate area of the discharge the plume is confined primarily to the surface waters.

The Palisades nuclear plant, located on the eastern shoreline of Lake Michigan, 5 miles south of South Haven, Michigan, is designed for initial operation at 2,200 MWt and 710 MWe. The ultimate capacity is expected to be approximately 2,600 MWt, corresponding to 845 MWe. Condenser cooling water is withdrawn through a crib intake 20 to 25 feet below the lake surface, about 3,300 feet from shore, at a rate of 390,000 g.p.m., and is discharged through a simple diverging pile structure at the shoreline as shown on Exhibit III-P. (See P. 493).

Concern about the environmental effects of the plant prompted Consumers Power Company to engage the services of University of Michigan biologists to develop a

study plan to detect any effects of the heated discharge on the aquatic biota of Lake Michigan. The biological collection and analysis are being done by T. W. Beak Consultants, Limited, in cooperation with the Michigan Department of Natural Resources.

Temperature and biological surveys conducted at the J. H. Campbell plant in 1968, as described earlier, indicated no significant ecological effects from that heated discharge. The Palisades plant, however, is larger, and a more cautious approach of thoroughly studying its discharge effects was initiated to insure that if subtle ecological changes take place they will be detected.

The biological studies at Palisades are sufficiently comprehensive in scope to detect, either directly or indirectly, virtually any significant effect on the local aquatic ecosystem attributable to the thermal discharge. These studies are concentrated on the benthos, plankton, periphyton, fish, and, of course, temperature.

The benthos are considered to be the most delicate indicators of ecological change since they are relatively sessile and cannot escape environmental stress conditions. Plankton and periphyton are also good indicators of change, being relatively low in the food chain and only passively moved, and provide direct indications or

nuisance conditions should their populations increase drastically. Limited fish sampling is conducted since, aside from being highly mobile, fish are relatively slow in reacting to environmental changes providing toxic conditions are not a factor.

The survey area near the plant is shown on Exhibit III-Q (See P. 495) and the basic fan-shaped sampling grid is identified. Sampling stations were established on 1/4-, 1/2-, 1-, 2- and 5-mi. radii on nine radial lines. In addition, there are two control stations located near each of the cities of South Haven and Benton Harbor, about 7 miles north and 16 miles south of the plant site, respectively. The surveys began in 1968 with samples scheduled to be gathered in early May, late June, August and October. The initial survey is planned to extend for 5 years. The sampling stations are not marked in the field, but are accurately located by means of an electronic range finder.

Indicated on Exhibit III-Q is the initial basic plan for collection of benthos, plankton and periphyton at the various locations. The basic sampling grid, not counting control stations, contains 21 stations for benthos, 10 for plankton, and 3 for periphyton. Some minor modifications since the survey began included the addition

of several more inshore benthic stations in exchange for two benthic stations at 5 miles, and the addition of several plankton and periphyton stations. Adverse weather conditions have precluded the collection of a few samples, but without loss to the integrity of the coverage.

All benthos samples are collected by means of a Ponar dredge, as shown in Exhibit III-R. (See P. 497) The bottom deposits of the study area consist of mixed gravel and coarse sand inshore, grading outward to medium, then fine sand, and then to fine sand mixed with silt at approximately 2 miles offshore. At 5 miles offshore, fine sand is overlain in irregular patches by organic detritus.

In 1968, six replicate samples of benthos were collected at each station, the macroinvertebrate organisms screened out and preserved for shipment to the laboratory. The samples were analyzed for all benthic macroinvertebrate and identified to family in all cases and to genus wherever possible. In addition, one sample from each station from each survey was analyzed and the organisms identified to species, or as close to species as taxonomy permitted. The replicate samples were sufficiently uniform in 1968 that the procedure in 1969 was modified to collect only three

replicates.

Analysis of benthic data to assess environmental conditions and changes in the aquatic ecosystem can proceed along several different lines. For example, indicator organisms can be selected for detailed study, and the relative numbers compared before and after plant operation, and in proximity to the plant discharge. Such an organism representative of clean water conditions, and widely prevalent in Lake Michigan, might be the crustacea, amphipoda (commonly called aquatic scuds), consisting of the dominant species Pontoporeia affinis. An example of the relative distribution of this organism is shown in Exhibit III-S (See P. 499) for the August 1968, sampling period.

Another approach would be to examine an organism that is known to be relatively pollution-tolerant or to compare relative numbers of tolerant and intolerant species. The dominant representative of tolerant organisms would be the oligochaeta (made up of numerous species known as aquatic earthworms, tubificids or sludge-worms). The relative distribution of these organisms observed in August of 1968 is shown in Exhibit III-T as an example. (See P. 500)

The relative populations of other benthic

organisms will also be studied and correlated, not only within the project area, but also in relation to similar data being gathered at other locations around the lake.

Species diversity of the entire benthic community is another tool for assessing the influence of environmental factors and is readily adaptable to statistical analysis. A crude illustration of the variation of species number with depth for August 1968, is shown in Exhibit III-U. (See P. 501) The scarcity of benthic organisms in the sandy, wave-swept shallows should be noted, along with the apparent evidence that the southern control stations are relatively sparse and unrepresentative of the project area in this respect.

Plankton samples are obtained by passing 40 liters of water through a Wisconsin plankton net as shown in Exhibit III-V. (See P. 503) At each station, samples are collected at depths of 5, 10, and 15 feet. The preserved samples are received at the laboratory where they are centrifuged and the volume of plankton concentrate measured.

Relative changes in plankton concentrations, both within the project area and as related to the control stations, will indicate whether the thermal discharge is having a substantial impact on these organisms. Stimulation

of algal growth, such as the filamentous green algae Cladophora, to nuisance proportions would be so detected. Subtle changes in relative numbers of the various types of plankton can only be verified through microscopic examination. When the plant is in operation, samples will be collected for such detailed analysis in the immediate vicinities of the intake and discharge.

Typical results of the plankton concentrate analysis are shown in Exhibits III-W and -X. (See Pp. 504 and 505) Exhibit III-W shows the seasonal succession of plankton concentrations at the 5-ft. level 1, 2, and 5 miles from shore. Exhibit III-X similarly shows concentrations at 5, 10, and 15 feet deep at the 1-mi. station. This data clearly shows the general cyclic nature of the phytoplankton production. This fluctuation is typical of Lake Michigan in which diatom populations dominate and bloom in early spring and late fall.

Periphyton organisms are collected on artificial substrate, constructed of Plexiglas plates, which are suspended from metal supports imbedded in concrete blocks. The samplers are placed in 15 feet of water and after suitable exposure, at least 4 weeks, they are retrieved. The preserved plates are sent to the laboratory where the periphyton scrapings from the plates are extracted with acetone and the amount of chlorophyll determined

spectrophotometrically.

The periphyton sampling program was beset with considerable difficulties in both 1968 and 1969. Intermittent storms hampered the retrieval of the collection plates. In addition, public destruction resulted in the loss of all but a few marker buoys. The addition of several more unmarked samples to be recovered by divers has been instituted to compensate for these problems.

Chlorophyll analysis for the 1-month exposure in May-June 1968, yielded concentrations ranging from 0.0 to 0.0056 micrograms per square centimeter. Sufficient data are not available for confident representation of seasonal fluctuations or other natural variations. Information gathered on periphyton during plant operation will be analyzed primarily to detect correlation between growth and proximity to the plant outfall.

The Michigan Department of Natural Resources has provided the vessel used in the biological sampling program and their personnel have been in charge of all fish sampling and analysis. Their sampling schedule calls for gill nets of various mesh sizes to be set for two 24-hour periods four times a year at depths of 20 feet, 40 feet and 55 feet. All fish captured are measured and counted, and many are scale sampled, sexed, and weighed.

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In addition to the gill nettings, a bag seine was used on five occasions in 1969 to sample fish populations along 1,200 feet of shoreline north of the plant. Data on offshore populations are also available for two dates in 1969 from the trawling efforts of the Bureau of Commercial Fisheries, United States Fish and Wildlife Service.

The results of the various fish studies to date indicate that at least 22 species of fish live in the area, of which perch and alewives are most abundant. While both yearling and adult salmonids have been captured, their numbers have been very small and all have been planted fish, as identified by their markings.

Lake temperatures have been measured periodically at various depths and locations since before the biological sampling program began. The objective of the preoperational temperature surveys has been to define the general natural variations that occur. For this purpose, a series of measurements has been made approximately every month, weather permitting.

A representative series of temperature profiles for 1968 is shown in Exhibit III-Y (See P. 508) for a location 1 mile from shore. It can be seen that a relatively shallow thermocline developed in the spring and early

summer, but typically the thermocline in Lake Michigan will reach depths exceeding 100 feet by early fall.

The thermal structure of Lake Michigan is a highly variable phenomenon and can change significantly in a relatively short period of time as well as from year to year. The great influence of the shoreline is typified in Exhibit III-Z (See P. 510) for April 10, 1968, at which time the temperature variation from shore to five miles out exceeded 13 degrees F. Such widespread natural temperature excursions have certainly had a major influence in the establishment of aquatic life populations as they exist today. Artificial thermal discharges to the lake, as from powerplants, can and should be evaluated in the context of these natural variations.

When the Palisades plant is in operation, the thermal discharge will be mapped periodically to define the extent and magnitude of its influence under various meterorological and natural lake conditions. Studies of lakeshore currents have indicated that the buoyant thermal plume will flow northward about 33 percent of the time, southward 23 percent of the time and drift almost directly offshore about 38 percent of the time. The remaining 6 percent of the year the plume is expected to more or less remain as a stationary water mass near shore.

Data on the spatial and temporal influence of

the thermal discharge will, when correlated with the biological data, make possible an accurate assessment of the impact of plant operations on the aquatic ecology of Lake Michigan.

Passage of the Water Quality Act of 1965, to amend the Federal Water Pollution Control Act, set into motion a widespread review of water quality criteria to be used in the standard-setting process. For many contaminants and water quality parameters the determination of the necessary restrictions to protect aquatic life or other beneficial uses was rather simple. Agreement on standards for such things as dissolved oxygen and certain toxic substances was secured rather early because of the demonstrated need to control waste discharges to minimize almost certain harmful effects. Recognized pollution conditions caused by such discharges had clearly been shown.

The situation with regard to temperature was not so well defined. It was known that if heated waters were discharged into a relatively small body of water the local aquatic ecology would be changed. But such things as fish kills or other adverse effects associated with such discharges were relatively rare, and research to determine potential damage was considered frivolous, under the

circumstances. Utilities around the country, however, recognizing the accelerated rate at which thermal discharges would be made from powerplants, initiated studies to attempt to detect adverse effects. In the case of the Great Lakes, short-term studies have failed to show harmful effects and the long-term studies, by their nature, have not provided much definitive information to date.

The U. S. Department of the Interior, because they were charged by Congress to approve water quality standards has felt obliged to require numerical limits to restrict thermal discharges into the Great Lakes. However, until technically supportable evidence concerning harmful effects of such a discharge has been presented, there is no rational or legal basis for such a dogmatic viewpoint. The popular view of the possible consequences of thermal discharges promoted by FWQA is not consistent with existing factual information and does not enjoy any broad recognition by the scientific community.

Considerable effort has been expended, by both scientists and laymen, in theorizing on the possible adverse effects of thermal discharges. A considerable amount of this activity has been stimulated by governmental pressure and the misguided urgings to set specific numerical temperature standards. But a clear distinction must be made

between what can be considered "possible effects" and what is truly probable, based on existing evidence and scientifically valid projections.

It is postulated, for instance, that there will be long-term deleterious biological effects caused by the thermal discharges from powerplants . Lake Michigan, as has been shown, is in no immediate danger of being significantly warmed by heated discharges. The seasonal succession of the lower aquatic life forms is so dramatic due to natural causes that the relatively minor circulation through powerplants could not be a significant factor in their overall populations. And the fish management program by the Federal Government and the bordering States is evidence in itself that we are not tampering with natural ecological phenomena as far as fish are concerned. There is, therefore, no reasonable basis for asserting that the existing level of thermal discharges could have long-term effects.

The "white paper" discusses at length the possible effects of heated water on fish, as if they were confined to these waters and would not naturally avoid temperatures not to their liking. The paper describes very well the significant historical succession of fish species, the considerable management efforts that have been

instituted to change the natural balance of species, and the variability of habitat and its importance in the succession of life stages. But on the basis of the evidence presented, it certainly does not follow that any significant thermal discharge, at any place, at any time, would jeopardize the existence or otherwise interfere with the population of any species of fish in Lake Michigan.

Another misleading implication in the "white paper" is that if thermal discharges are eliminated, the accelerated rate of eutrophication of Lake Michigan will be checked, even though nutrient buildup may continue unabated. Such an assertion fails to recognize the relative causes of the existing rate of eutrophication, the insignificant warming of the lake caused by existing thermal discharges, the natural heat inputs to the lake, or the historical temperature conditions of the lake.

The predictions that thermal discharges will cause significant undesirable shifts in predominance of planktonic forms of aquatic life, such as algae and Type E botulinum, as so dramatically identified in the "white paper," does not take into consideration that thermal plumes are transitory, self-renewing water masses and the generation times of the organisms contained therein would not allow for growths that could be construed as proliferation.

J. Z. Reynolds

As we all know, thermal discharges are only one result of man's activities that can have apparent or possible adverse effects on the environment. The principles of ecology would demand that priorities be established as to the potentially harmful effects of all forces impinging on man and his environment, so that manpower, economic and other resources can be apportioned accordingly to deal with the problems.

This philosophy is obviously lacking in the procedures and pronouncements of the Department of the Interior regarding environmental problems in the Great Lakes area. The recommendation of standards that would commit vast resources to prevent imagined damage or to allay baseless fears predicated on unreasonably extrapolated data, is not in the best interests of the people or the natural environment. There are real, presently-existing environmental problems that deserve a higher measure of our attention than that presently being allotted thermal discharges. The easiest targets of criticism and control should not be the criteria for selecting the priority for dealing with environmental effects.

Impact of the 1 degree F. or no heat discharge recommendation: Consumers Power Company has reviewed the

problems involved with reducing the temperature of the discharge of cooling water to 1 degree F. over the ambient temperature of the receiving body of water for each of our plants on the Great Lakes.

To do this would, in each case, require us to install closed loop cooling systems with evaporative cooling devices such as powered draft cooling, natural draft cooling, spray ponds or possibly a combination of these.

Each of these systems has its own particular disadvantage, but common to all of the systems would be:

1) A loss of unit capacity of 4 to 6 percent due to increased turbine back pressure. This would have to be made up with new capacity costing about $175/kw.

2) A decrease in unit cycle efficiency of 2 to 3 percent during the summer period. This would increase the fuel requirements proportionately.

3) An increase in capital expenditures for cooling systems and associated changes.

4) A decrease in the net plant capability for pumping energy which would have to be made up with new plant capacity costing about $175/kw.

5) Increased maintenance cost required to maintain spray nozzles, tower fill, pumps and electrical equipment, etc.

6) Increased operating costs for water treatment of the water in the closed loop.

7) An increase in water evaporated and discharged to the atmosphere.

8) Possible problems with blowdown due to the concentration of solids because of the evaporation of water by the cooling towers.

9) Possible problems with drift and fallout of condensed water that cannot be fully assessed until a study of each plant area is made.

10) Increased problems with insulators and other electrical equipment because of the increased humidity in the immediate plant area.

11) Problems with icing, particularly when a single unit is operated or when the plant is operated as a peaking plant.

To approach compliance with such a restrictive standard for the plants on Lake Michigan would cost millions of dollars per year. It is frequently stated that because this represents only a few percent of operating revenues, it is an insignificant expenditure for environmental controls. Many millions of dollars spent for any purpose cannot be considered insignificant. This represents a considerable amount of society's financial resources and

should not be diverted from more deserving uses because of unsubstantiated fears of "thermal pollution." Considering the known adverse environmental effects of artificial cooling facilities, expenditures for these devices based on arbitrary restrictions, assumed to protect the lake, cannot be supported under the guise of improving environmental quality.

The company has conducted preliminary feasibility studies for the Palisades plant with Bechtel Corporation on three alternative systems to modify the possible effects of the thermal discharge on the adjacent inshore area. These alternatives and a discussion of each are listed below.

Alternate I - Cooling Towers. A closed cycle cooling tower system has been considered which would for the most part isolate the plant from the lake. This would require three structures about 75 ft. x 400 ft. which would be placed to the south of the existing plant. This system would utilize forced air circulation towers rather than the natural draft towers due to performance and site location considerations.

The approximate engineering-procurement-construction schedule for this alternate is 20 months.

Alternate II - Dilution of Discharge Flow. This

system would provide additional dilution water to the discharge structure to reduce the outlet temperature to 10 degrees F. higher than the plant inlet flow. Modifications include additional (1) inlet line(s) parallel to the existing inlet line, (2) intake structure(s), (3) pumps, and (4) discharge structure(s) to accommodate the approximate tripling in quantity of discharge flow.

The approximate leadtime for this alternate is 28 months.

Alternate III - Extended Discharge Piping. This system would provide for the addition of a pump structure, pumps and discharge pipe. The condenser discharge would flow to an enclosed discharge structure, from where it would be pumped to offshore points of discharge selected to minimize warm-water effects along the lakeshore. A disadvantage of this scheme would be the dissipation of more heat into the lake water and less to the atmosphere from the surface cooling effect.

The approximate leadtime for this alternate is 28 months.

An additional alternative which would be immediately available to reduce temperature rise, if required, would be the curtailment of plant power output.

Since the circulating water temperature rise across the condenser is an approximate linear function with respect to power, reduction of plant power output would reduce the temperature rise accordingly. This measure could be taken at any time adverse effects are indicated and, of course, could be continued until some permanent solution such as the alternates listed above was implemented. A major disadvantage of this method would be the sacrifice of installed electrical capability during any periods when a power curtailment would be in effect.

All of the various alternatives would effectively reduce the capability of the plant and tend to reduce the reliability of the electrical system. Energy not available from nuclear plants must necessarily be supplied by older fossil fueled generating stations that inherently have a greater impact on air quality. The adverse environmental effects of reducing the availability and reliability of electrical energy should certainly be weighed in any decisions made to ostensibly improve environmental quality.

We would restate, in concluding, that the Federal position regarding thermal discharges into Lake Michigan is not warranted by the known facts concerning such discharges or the potential effects of these discharges in the

foreseeable future. Further, the vacillation in the Federal position has interfered with rational standard-setting. Moreover, Consumers Power Company is profoundly disturbed by the misleading information which has been released on this subject and by the escalation of groundless fears in the minds of the public. The result of these needless anxieties is even more serious coming, as it does, at a time of rapid growth in electrical requirements and increasing energy shortages.

The company is deeply involved in environmental studies to detect effects of thermal discharges into the Great Lakes, and is publicly committed to make corrections should damage occur. We would urge the conferees to carefully consider our statement and proceed with the business of developing a reasonable position concerning regulation of thermal discharges.

D. H. Brandt

MR. STEIN: Thank you, Dr. Reynolds.

I think this is the last statement we are going to have, and we just have comments and questions from the conferees.

I followed your statement, Mr. Brandt, very carefully, and unless I can't believe my ears -- but let me state what I think your conclusion states. It is that you don't believe you are doing any damage, that you don't believe you want to change your operation, and if damage occurs, you will take that into consideration.

I take it this makes you among the only major industries and municipalities discharging to Lake Michigan -- after we have had this tremendous program of cleanup -- to think that what they are doing is all right, and you don't have to do anything else until you demonstrate damage. This is how I understand the main thrust of your paper. Do I understand that correctly?

MR. BRANDT: I think there is a fundamental difference between thermal discharges and other contaminants that you might be referring to in other industries.

The basic scientific evidence would indicate that effects of thermal discharges, if such damaging effects might occur, are certainly not irreversible.

MR. STEIN: In other words, I am correct that we

have the steel companies, the oil companies, the cities, the plating plants -- all of the plants committed to a program of correction of pollution of Lake Michigan in an abatement program, but you don't think you need anything at the present time.

I think we are in agreement on what you said. I just want to make sure, because it boggles the imagination. If that is what you say, I guess we can proceed from there.

MR. BRANDT: I think our statement is clear that should pollution exist from our operations we are going to correct them.

MR. STEIN: But you don't believe it exists. Isn't that what you said?

MR. BRANDT: Essentially, sir.

MR. STEIN: That is right. All right. Have any of the conferees anything?

Mr. Currie.

MR. CURRIE: Yes, Mr. Chairman. I would like, at this point, first to repeat the suggestion that I made in my letter to Secretary Hickel of September 17, that expert witnesses be required to submit their statements in writing in advance so that the public and the conferees would have an opportunity to read them beforehand.

In past conference sessions and in this session,

voluminous and detailed reports have been presented with no time for the conferees or the public to thoroughly review them.

Comments and questions would be much more meaningful if advance copies are required. It is rather difficult to evaluate and comment on the factual or technical material without time to read it in advance. Happily, however, the statement we have just heard is neither factual nor technical and, therefore, relatively simple to deal with.

Now, as I understand it, we are being urged here to look at the facts and not be swayed by emotion, and as far as I can tell, the facts that are relevant are a one-day's study of a middle-sized fossil-fueled plant conducted on August 30, 1968, which purports to show that there was no gross thermal damage to the benthic fauna in the main thermal plume.

Now, I take it we are not concerned only with gross thermal damage, and I take it we are not concerned only with damage to benthic organisms, and in view of the -- in connection with the adequacy of such a survey, I would like to quote from a statement made to our Board last week by Dr. Wesley Pipes, who says, "Our current estimate of the numbers of samples required to demonstrate

the subtle effects on the statistically significant basis is between 500 and 1,000 samples collected over a 1-year period."

MR. BRANDT: Mr. Currie.

MR. CURRIE: Yes.

MR. BRANDT: I would like you to recognize that the sample biological survey referred to was conducted in 1968 before there was really any public discussion, so to speak, about thermal pollution.

MR. CURRIE: Well, do you have any facts to give us?

MR. BRANDT: And our Palisades survey, coming at a point in time when this question has been raised, is designed to detect or to measure all of these parameters you have indicated, and I would certainly have as many samples as I am sure that Dr. Pipes said we should have.

MR. CURRIE: Do you have any existing studies that can help us?

MR. BRANDT: No other studies, no.

There are other studies available. The Michigan Water Resources Commission has conducted independent surveys. I am sure they will make them available to the conferees.

MR. CURRIE: I have no further questions.

D. H. Brandt

MR. STEIN: Are there any other comments or questions?

MR. PURDY: I have just one comment, Mr. Stein, with respect to the statement made on page II-15 under the State action, the second paragraph, relating to a meeting in Ann Arbor on April 16, and I don't believe that this was attended by the conferees themselves. It would be representatives of the conferees who met in Ann Arbor on this date.

MR. STEIN: All right. Thank you.

Are there any other comments or questions?

Mr. Frangos.

MR. FRANGOS: Yes, Mr. Chairman.

On page IV-5, there is included a listing of the disadvantages for installing a closed cooling system, and I am wondering if people from Consumers Power might indicate any cost estimates that they may have, if they added all of the detrimental problems that they have listed here, how those figures would compare with the figures presented by the Interior people this morning.

MR. BRANDT: We don't have that here now. We can look into that for you and perhaps provide it later.

MR. STEIN: May I ask one question on this, so we keep the record straight?

D. H. Brandt

I noted on page IV-5 you listed eleven reasons why the closed cooling system wasn't feasible. Of those eleven, eight of them related to the operation of the power plant and only three of them related to what might happen to the environment, and of these three, I think all of them have been covered by Mr. Tichenor in his paper where he said there wouldn't be any problem. But I think it is of interest to note that the vast majority of the reasons why the system cannot be closed were not because of relationship of damage to the environment but to the operation, or possible additional costs to a power plant.

Mr. Frangos.

MR. FRANGOS: One other question. Following this discussion on page IV-6 and IV-7 of the discussion are some alternative investigations that are being made by the company, and I am wondering if you could perhaps make it a little bit more clear what the motivation of the company is in pursuing these studies at the Palisades plant.

In other words, if indeed you may not have any problems, why are you making these inquiries?

MR. BRANDT: There has been some public comment and some intervention in our Atomic Energy Commission hearings for an operating license that would lead us to

believe that this information would be desirable.

MR. FRANGOS: Thank you.

MR. PURDY: I have a comment with respect to that, Mr. Chairman.

MR. STEIN: Yes, go ahead.

MR. PURDY: These studies are being made at the request of the Michigan Water Resources Commission to demonstrate the compliance with the order of the Commission that these injuries cannot occur. It is part of our plant approval for their operations.

MR. STEIN: Are there any other comments or questions?

If not, let me go through I-2 -- this was right at the beginning of your statement. You had a very optimistic observation.

You say, "We are confident we can meet all our obligations through the continued exercise of sound business judgment, consultation and guidance by technically qualified people, the application of appropriate control technology and acting in a forthright manner on environmental issues."

Do you mean to say that you think that the rest of your statement supports that, I take it?

MR. BRANDT: Yes, sir, I do.

MR. STEIN: Now, you said, and I call this to

your attention, at the beginning, "A number of Federal officials often appear to forget or ignore this basic policy of primacy of the State regulation in their temperature standard-setting efforts," page I-3.

I have listened to your presentation and read with candor your paper. You said it would be apparent. I didn't see it. What do you mean that we don't recognize the primary responsibilities and rights of the States?

MR. BRANDT: I believe, sir, I can best answer that by recalling the 3-year experience that the State has had in struggling to try to find acceptable standards.

MR. STEIN: What State are you talking about, sir?

MR. BRANDT: Michigan.

MR. STEIN: How many States border Lake Michigan?

MR. BRANDT: There are four States.

MR. STEIN: Would you suggest that we can have a standard that is going to be equitable to Michigan and the other three States without getting uniformity of all four and the Federal Government?

MR. BRANDT: I can appreciate, sir, the need for a uniform approach in procedure, and this is why we were, in our company, very pleased to see at a Michigan Public Service Commission meeting, that there was identity at the April 16 meeting where the -- and Mr. Purdy corrected the

fact that it was representatives of the conferees that had agreed. But it seemed to us that this was a very positive step in the right direction.

I do not believe, and I believe this body has indicated, that the numbers -- maximum monthly numbers, and so on, would not be identical for the various areas of the lake. However, the approach to it would have to be uniform, and we certainly appreciate this.

MR. STEIN: And I think that is why we are here, sir, with all these States, and we would hope that we can have uniformity of opinion, and agreement, and that is how we have handled all of the other problems.

I think the record indicates -- just look at those at this table here -- rather than ignoring the primary rights and responsibilities of the States, the fact that we are here shows that we recognize those, and I just don't see your point on our ignoring them.

Why are we here with all these States? We have other methods of setting water quality requirements, but we are sitting here with four States with us, and we are striving to get uniformity of judgment.

Now, in the face of this, and in the face of the conferences that we have had in Lake Michigan, and our achievement in every instance of uniformity with the four

Lake Michigan States, how can you say that we have a record of ignoring the principle of law which asks us to recognize the primary rights and responsibilities of the States?

MR. BRANDT: I draw that conclusion from having, in the past 23 years, attended a large majority of the Michigan Water Resources Commission meetings, and seeing the staff present recommendations for either precise values or philosophies to be used in the standard-setting process that were predicated on their expert capability, agreed to by the Commission on the recommendation of staff, to be overruled or further delayed in finalizing because of the points that I brought up, sir, in the vacillation in basis for recommendation.

MR. STEIN: I don't see any vacillation here, because we don't have any, but you can go on and continue this. I think the record on that speaks for itself. If you don't want to say anything, let me make the next point.

You say, "Too many Federal officials and others have ignored this requirement to take into consideration all legitimate uses of interstate waters. Instead, they consider exclusively the propagation of fish and wildlife."

Now, the trouble is, I think, here -- and I almost hate to push this issue because we have a large delegation

from our Fish and Wildlife Service here and they wish this were true. But if you think -- I want to know in what instances we have considered exclusively in all our causes -- and these are standards of enforcement action -- the propagation of fish and wildlife and have not considered all legitimate water uses.

MR. BRANDT: I believe, sir, that the recommendations of the FWQA Regional Office to the State of Michigan in their March 19 public hearing will bear that out by some of the language and definitions. I do not have a copy of it with me at the moment.

MR. STEIN: Maybe you would make that allegation to the next conference of the Audobon Society or the Izaak Walton League that we consider exclusively the propagation of fish and wildlife,and I would like to see the reception we get.

To my mind, nothing is so far from the fact. We get criticized constantly by the conservation organizations that we are taking into consideration the other water uses other than fish and wildlife, and how anyone can -- this is the first time I have ever heard the allegation that the Federal people exclusively consider the consideration of fish and wildlife, and I guess there are many conservationists in the audience. This is a remarkable way

of looking at things, I think.

Now, again, I think -- let me go to the next point. You talked to our Act and you say -- and I have the greatest respect for -- I guess Mr. Kelly is your Attorney-General yet, isn't he?

MR. PURDY: Yes.

MR. STEIN: You talk about the Federal Act and then you point out, as the Michigan Attorney-General's office has pointed out, and then you go to another section of the Federal Act and talk about the Michigan Attorney-General's office and his opinion.

Again, I have the highest regard for Mr. Kelly. I have worked with him through the years. I consider him an old friend and colleague. But I think he would be the first to agree that the people who interpreted the Federal Act are the Federal people, and I would agree that the people who interpret the Michigan Act is Mr. Kelly. I am not looking for reciprocity in this regard, but I wonder what Michigan would think if in interpreting their Act you quoted our Solicitor's opinion on what the Michigan Act meant.

This may be the way of doing business, but I don't quite --

Let me ask you another question. What do you mean

when you get on page II-4, that "thermal plume ... has interfered with or otherwise caused injury to any beneficial use of the waters"? What do you mean by "beneficial use"?

MR. BRANDT: What area are you quoting from?

MR. STEIN: You repeated it several times, but page II-4, paragraph 2.

DR. REYNDOLDS: What was the question, sir?

MR. STEIN: What do you mean by "beneficial use"?

DR. REYNOLDS: This was in reference to the fish activities at the discharge point.

MR. STEIN: No, I want to understand what you mean by "beneficial use."

DR. REYNOLDS: Fishing is a beneficial use of water. This is what we are referring to.

MR. STEIN: Do you mean by "beneficial use," the word "fishing"?

DR. REYNOLDS: Yes.

MR. STEIN: And the last point, I am not sure I agree with: "In fact, the areas of heated discharge are often observed to appeal to swimmers, since the lake waters are normally too cold for comfortable water contact activities."

When we were on the Raritan Bay, we found that appealed to the swimmers, too, but they were swimming in

the discharge of the Perth Amboy sewer. It was nice and warm.

DR. REYNOLDS: I don't think the comparison was quite appropriate.

MR. STEIN: There are other water uses other than swimming.

MR. MACKIE: This morning we were presented with a table which listed the increases in costs of electrical productions for a number of alternatives over the once-through design. I am wondering if sometime perhaps tomorrow the power industry could be prepared to comment on these increases in cost, or shall we at the conference consider these to be reasonable in this case?

I am referring here to Table 2 of the presentation of the Department of Interior report on "Feasibility of Alternative Means of Cooling for Thermal Power Plants Near Lake Michigan."

The point is: Shall the conferees consider that the power interests agree with the figures in Table 2?

MR. BRANDT: We will have two more witnesses appearing on behalf of Consumers Power Company -- the gentlemen I mentioned in my opening remarks from Sargent and Lundy. We will make sure that some comments on that point will be included, sir.

D. H. Brandt

MR. MACKIE: Thank you.

MR. STEIN: Let me go on.

Running a careful operation here, let me refer to II-12, next to the last paragraph, last sentence, talking about Dr. Mount's suggestion.

Again, this reminds me something of Freud's definition of paternity. The presumption is based on supposition, for anyone that is really as careful as this. You say -- and let me read this -- "Apparently some FWPCA representatives had informally suggested t h at formulas would be appropriate."

MR. BRANDT: Yes, sir. Again, the basis for that statement is that there had not, to my knowledge, been a formal presentation to the Michigan Water Resources Commission with that statement or that position set forth, sir.

MR. STEIN: No, I am not talking about that. I am talking about all of the provisos and qualifications. "Apparently some ... informally ..." -- one of the radio stations in Washington has a little song that goes to the tune, I guess, of "Home on the Range," about what goes on in Washington, and they say, "And seldom is heard an unqualified word."

Now, on page II-17 it says, "The sincere and honest efforts of many who have worked to develop reasonable

temperature standards, based on the technical evidence, have been repeatedly destroyed by inconsistent and confused pronouncements and recommendations by others."

Do you consider yourselves included among those who have made sincere and honest efforts to have worked to develop reasonable temperature standards for Lake Michigan?

MR. BRANDT: Yes, sir, I do.

MR. STEIN: Then, let me refer you to page IV-3 where you say, "It certainly does not follow that any significant thermal discharge, at any place, at any time, would jeopardize the existence or otherwise interfere with the population of any species of fish in Lake Michigan."

DR. REYNOLDS: I don't see any inconsistency, sir.

MR. STEIN: I guess not.

All right, now. You say, "'that if the temperature is unacceptable, it is unacceptable whether it has been caused by the sun or man.'"

I want to make this clear for the record. In dealing with thermal discharges, we know that from the beginning of time there have probably been fish kills from heat due to natural causes. This probably has occurred ever since there were fish and a world, and it will continue in the future. But that doesn't mean that

since we are going to have natural fish kills caused by heat that we are not going to try and prevent manmade fish kills caused by heat.

MR. BRANDT: Mr. Chairman, if I may.

MR. STEIN: Yes.

MR. BRANDT: That particular quotation was extracted from the testimony of Dr. Mount.

MR. STEIN: Yes.

MR. BRANDT: And it was associated with the fact that the recommendation of specific maximum temperature for certain water bodies was found by the Commission staff in their comments, I believe, that it exceeded the natural condition and also this -- if my memory is correct -- was a reference to the Muskegon River, and the statement by Dr. Mount was a suggestion of something in the order of 58 degrees, I believe, as a maximum, in order to facilitate the fish run.

MR. STEIN: Well, I am familiar with the views of Dr. Mount, but Dr. Mount is very interested in controlling natural sources of discharges to the lake.

Now, are you people familiar with what is generally called the "green book"? What do they call that, the National Technical Advisory Commission?

MR. BRANDT: Advisory Committee Report, yes, sir.

D. H. Brandt

MR. STEIN: And are you familiar with the temperature requirements in there?

MR. BRANDT: Yes, sir.

MR. STEIN: And the numbers?

MR. BRANDT: Yes, sir.

MR. STEIN: Well, then, this is my last question. You say, "The popular view of the possible consequences of thermal discharges promoted by FWQA is not consistent with existing factual information" -- which may be your conclusion -- "and does not enjoy any broad recognition by the scientific community."

As far as I know, that "green book" has the broadest recognition and most of the scientific community involved in the aquatic biology field has signed off on it. I don't know what you are talking about.

MR. BRANDT: Sir, the criticism was not of the "green book."

MR. STEIN: Well, this is a flat statement.

You said that what we have put forth is not by the scientific community.

Now, the "green book" -- let's get down to this -- for lakes says "not more than" -- I repeat -- and I had it marked here on this stuff where it said "not more than" -- and you thought that was ambiguous and meant to

be over. "Not more than" is not any more ambiguous to me than is "less than." But that is in your statement somewhere.

But the "green book" talks about lakes and talks about a maximum rise in that "green book" of not more than 3 degrees. Do I take it that your industry is ready to abide by that -- of not more than three?

MR. BRANDT: The recommendation that was presented by the Michigan staff to the Water Resources Commission this last monthly Commission meeting recommended 3 degrees as the maximum at the edge of the mixing zone.

MR. STEIN: I didn't ask you that question.

Do I take it that you are in favor of the not more than 3 degrees and subscribe to the "green book"?

MR. BRANDT: I subscribe to the concept that is identified in the Michigan standards, at this point in time, which I further believe are in accordance with the philosophies of the "green book," sir.

MR. STEIN: Then, what we are talking about -- and we really have a very small scope and if we can continue this and maybe you can talk to the rest of the industry, I think we have made an agreement. If we are talking of a rise between 1 and 3 degrees -- not talking about raising the temperature 18 or 20 degrees -- we are a lot closer

together than we thought. If that is what you mean, I think we can recess here on a very optimistic note.

MR. BRANDT: Sir, I qualified my statement as being in support of the philosophy applied in the present proposed Michigan temperature standards.

MR. STEIN: Not the "green book."

MR. BRANDT: I believe they are compatible.

MR. STEIN: As I understand the "green book," it is not more than 3 degrees. If I am wrong, I wish someone would correct me.

MR. BRANDT: That is what the Michigan standard says then.

MR. STEIN: If that is what they say, then we are really talking about a difference of a proposal, say, of 6 months ago of 1 degree or no significant rise, which may mean zero to 1 or something like that, and a maximum of 3.

Now, if that is the scope in our difference possibly or some of the technical difference with the industries, I think we should be able to resolve that.

MR. BRANDT: Sir, I would call your attention to the FWQA Regional Office comments at the March 19 hearing of the Michigan Public Service Commission.

It was after considerable discussion with the

Commission members of Michigan and Mr. Dumelle that just about the same statement was made -- that, apparently, if the discussions were carried on consistently in that level, there perhaps was not too much difference in view, at that point in time, between the State of Michigan staff and the FWQA Regional Office.

But I call your attention, sir, within 30 days, there was the announcement of the 1-degree limit as an effluent standard.

MR. STEIN: I think our purpose here is to try to come to an agreement among ourselves with the parties here. Now, if we are talking in terms of a rise in temperature of between zero and 3 degrees, I think we have really narrowed the issue.

Now, if the industry will agree that that is the issue and the States will agree that that is the issue, I think we can move on hopefully very rapidly. But there is a difference between a rise of zero degrees up to and not more than 3 degrees and a rise from zero up to 18 or 20. I think we have a fundamental problem there. If we can narrow down what we are talking about, and I am asking, to try to get this on the track, I don't see that problem quite as acute if one considers the scope of what we are talking about here will range somewhere up to 3 degrees rise.

D. H. Brandt

MR. BRANDT: I believe, sir, the difficulty we are having here in communicating is the fact that you have indicated earlier today the approach that you are applying that number at the outlet point. The philosophy to us, as we had tried to illustrate in our presentation, is that if you include a mixing zone in a site-by-site evaluation, then I think we could certainly find some common ground.

MR. STEIN: I don't know whether I had difficulty in communicating, because I have communicated this idea to many, many people and they had no difficulty understanding it. But I don't think you quite understand what I said. I think the record will bear this out.

What I am talking about is establishing a theoretical mixing zone. What I said -- and I think the record will bear this out -- if we place a degree limitation on temperature at that pipe, that will be for the purpose of regulatory control. This will oblige us to deal with the effect that that has on a theoretical mixing zone, as I see it.

Now, I do think that the industry will be much better off -- this is my view, and as far as I can see, when I have discussed this, I see no one in the industry who really disagrees with it -- you will be much better off if you will just be responsible for the temperature of

the water as it comes out of your pipe than 5 miles away or 200 yards away or 300 yards away on a current that is going in and out.

I am not saying, nor did I say that that 3 degrees will necessarily apply to the temperature coming out of your pipe. I hope I am communicating that very clearly. We are talking about a regulatory system of control, and I think we have to think this through very carefully. And the other is the impact on a theoretical mixing zone.

MR. BRANDT: I appreciate the problem that is somewhat associated.

I have heard you recite it and I have no quarrel with that as an enforcement standpoint problem.

However, we feel that the studies going forth, the data and evaluation of the operations of existing plants have not to this point indicated any need for going to the cooling tower concept on the basis of evidence of data.

MR. STEIN: Well, I think the issue is drawn. Maybe we don't see this philosophically. I think your point is that, for plants in existence, you would be

opposed to any plant that you know on Lake Michigan now requiring a cooling facility or doing more than they are doing at the present time.

I think I have stated that fairly, haven't I? I don't know. You may not want to answer that. But I think the issue is that for any plant in existence, as far as I understand your proposal, you would be against putting in any cooling device. You think they are all all right doing what they are doing.

MR. BRANDT: I would not take the position that I would be against doing it in toto. We would look at the result of that effluent. If there is no basis, no harmful effect, and it does not interfere with other uses of that water body, I feel that the resource should be utilized as long as it is not damaged.

MR. STEIN: All right. I think we are in agreement there. And whose job is it to show that it isn't being damaged--the people who use it or us?

MR. BRANDT: To show that it is not being damaged, sir, I believe that for over 2 hours we have identified the efforts that we are making. It will take time to produce the number of samples that you referred to. We would certainly suggest that the Palisades plant be permitted to go into service so that the 3 years of

pre-operational testing to provide a base for comparison will be a meaningful effort, and that it can be carefully observed by ourselves and the regulatory agencies in its operation.

MR. STEIN: Well, let me make this very clear. And I think we really have to think about this. I think you have heard what Mr. Currie said about your report -- your proposal that we allow you to put heated water into the lake from the Palisades plant -- it is not going to raise the water 3 degrees at least at the pipe; it will raise the water about 18 degrees -- do a 3-year study and see if it is causing any damage and afterward, then, if we see that it is causing any damage we do something about it.

The theory that we have now -- at least the purport of the legislation that we have to administer now -- and I think the States do too -- is not only do we have to correct pollution but we have to prevent it before it occurs.

How are we going to carry out our obligation with that kind of an approach?

MR. BRANDT: Sir, I think the 3 years is misplaced. I defined the pre-operational effort as the effort going on for 3 years. It is my opinion that we would

conduct a very comprehensive surveillance program, and if within the first 3 months or 3 days, 3 samples -- whatever it takes -- for the people qualified to evaluate it, if there is harmful effect, we have said we would modify the facility. We also identified that reduction level of power generation from that station is one of the alternatives that could control the effluent from that plant until such time as another alternative could be developed.

MR. STEIN: Sir, I read your material in here where you had the distinguished firm of Bechtel as consultants, and dealing with the leadtime that they say you are going to need to correct these things, you are going to condemn that lake, if you think it is bad, to a couple of years of damage before it is corrected, right by your own report. Is that what you are proposing?

MR. BRANDT: Mr. Chairman, that is why I mentioned that the fourth alternative identified there was the reduction of load as a solution, so that we don't encounter the condition that you are speaking of.

MR. STEIN: Sir, again -- and we have gone through this in many, many places, and the people are out here and we are out here -- when you are talking about the reduction of load, once we let you build the plant, you are going to leave us only the Hopkins choice

of either having a brownout or pollution of the lake.

We are going to recess very shortly, but I really hope you will rethink that position before you ask the regulatory agencies to get into that kind of spot where we are going to be faced a year from now -- or as we are faced with some plants down in south Florida right now -- with the alternative of giving the people brownouts and not enough electricity, or causing many, many acres of Biscayne Bay to become a biological desert for several years.

Now, I would hope that you would not place a choice on us in Lake Michigan, and I would hope that the conferees would think long and hard before they put themselves in that position. I don't think that the shutting down of power and the cutting back of power in this age of power demands and power shortages is a realistic one.

MR. BRANDT: Mr. Chairman, we are not suggesting damaging this resource. We have not in any indication said so. We are saying that the experience to date on the existing plant has not indicated any harmful effect from the presence of their discharge. We, therefore, feel that there is evidence -- and the other speakers that will follow us I am sure will point this out in more detail.

MR. STEIN: Are there any other comments or

D. H. Brandt

questions?

Again, I am not sure that we are very far apart. But I hope the industry, and I hope our people will try to rethink this, and let's try to see if we can get some method of accommodation whereby we can solve this. Because the way this is operating, I think it would be unfortunate to have a confrontation on this. I don't think we are very far apart.

Let us recess. We have the same room tomorrow, don't we? We are going to start at 9:00 a.m. tomorrow instead of 9:30.

We stand recessed. Tomorrow we meet in Louis XVI Suite on the first floor.

(The conference adjourned at 5:45 p.m.)

☆ U. S. GOVERNMENT PRINTING OFFICE : 1971 O - 422-409 (Vol. 1)