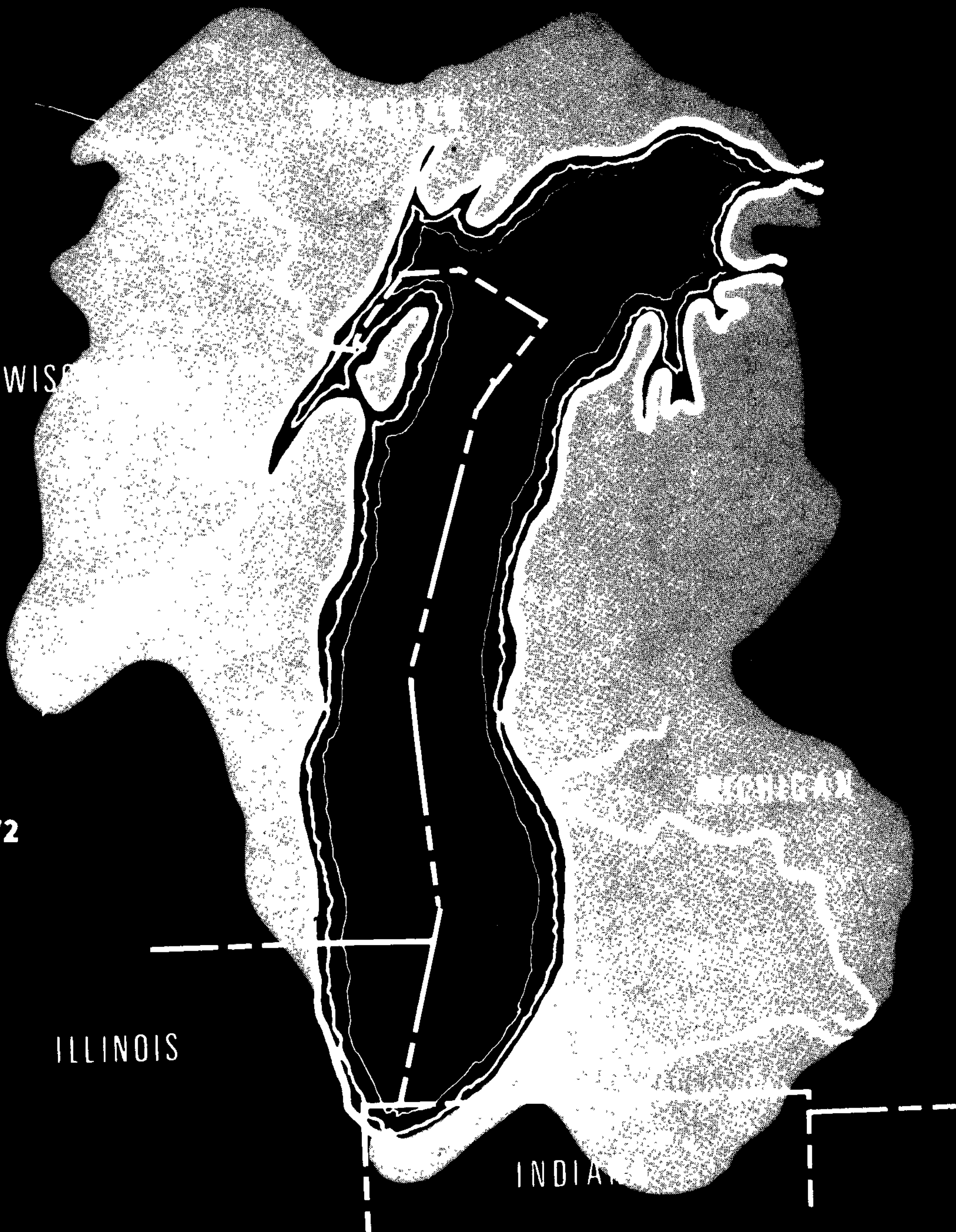
Volume 5



Fourth Session
September 19-21, 1972
Chicago, Illinois

CONFERENCE

Pollution of Lake Michigan and its Tributary Basin, Illinois, Indiana, Michigan, and Wisconsin

U.S. ENVIRONMENTAL PROTECTION AGENCY

FOURTH 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 III

(Part 3 of 3 Parts)

Bal Tabarin Room
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September 21, 1972

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ENVIRONMENTAL PROTECTION A...

ENVIRONMENTAL PROTECTION A...

the second is Dr. Verduin, who has a class of young ecologists to teach in the morning, and my experience over the last 2 years is that we are badly in need of well trained young ecologists.

With that preface, I will ask Dr. Pipes to begin with his presentation.

STATEMENT OF DR. WESLEY O. PIPES,
PROFESSOR OF CIVIL ENGINEERING,
AND PROFESSOR OF BIOLOGICAL SCIENCES,
NORTHWESTERN UNIVERSITY,
EVANSTON, ILLINOIS

DR. PIPES: Before I start, I would like to say that I am just as proud as I can be of Eileen Johnston. She is one of my neighbors at Wilmette, and she is also known as the "sixth member" of the Water Pollution Control Board. (Laughter) She attends all their meetings.

Mr. McDonald asked a question earlier about who is checking on the surveillance people. Eileen is checking on us; she is also checking on the Illinois Board; and she is checking on the Illinois EPA, and I think she does a wonderful job of that.

MR. McDONALD: Well, I know Eileen is placed in a very unfortunate position because that makes the Board without a majority. I don't know how David Currie is going to react to that. I am sure they will have a lot of three-to-three votes now. (Laughter)

DR. PIPES: Do the members of the conference have copies of the testimony that was submitted on Tuesday to the EPA? Has this been distributed? There are some extra copies of the prepared testimony.

MR. BRYSON: These were distributed to the conferees. There should be a package somewhere in that forest on their desk.

DR. PIPES: Mr. Chairman, members of the conference, ladies and gentlemen. I last testified before this conference in September 1970. Since my curriculum vitae was made a part of the record of this conference at that time, I will not further burden the record with my personal history other than to state that I am still a Professor of Civil Engineering and a Professor of Biological Sciences at Northwestern University, and that I am still a consultant to Commonwealth Edison Company.

The thrust of my testimony in 1970 was that, although there was no proof that the condenser cooling water discharge from any powerplant into Lake Michigan had caused pollution, enough questions had been raised about

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mechanisms by which such discharges might cause pollution, that it behooved the Enforcement Conference to take a conservative approach to recommending temperature standards for Lake Michigan. The conservative approach which I suggested in 1970 was to allow a limited number of condenser cooling water discharges to Lake Michigan and to require that these discharges be studied intensively to determine if any did cause pollution.

Today I am here to discuss with you some of the studies which have been carried out, which are presently under way, or which are planned for the Waukegan-Zion area of Lake Michigan. This is the area of the lake which has received the condenser cooling water discharge from Waukegan generating station for almost 50 years now and which will receive the condenser cooling water discharge from Zion Station when it goes into operation.

I am not going to report either that we have found proof of pollution due to the discharge from Waukegan station or that we have found proof that the discharges in question will not cause pollution in the future. The overall picture of our experience to date is that we have learned a great deal about the environment in this part of Lake Michigan and we have tested a number of the mechanisms by which induced water temperature changes might cause pollutional

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effects and, as a result, are somewhat more confident that such pollutional effects are not occurring and will not occur. However, in 1970 we were talking about possible long-term effects (some of the government witnesses were actually talking about effects which they thought might occur by the year 2000) and about studies of 1- to 5-years duration. Obviously we have not completed any 5-year studies since 1970 and obviously we have not studied the Zion Station discharge itself since that plant is not yet in operation.

In 1970, I submitted a document for the record which was entitled "Study Plan for Determination of Thermal Effects in Southwest Lake Michigan." This document described the general approach and rationale of the studies and presented the plans for eight projects which were then either under way or contemplated.

I requested comments on the Study Plan related to the questions which we were investigating and the methods which we were using. Early in 1971 we received comments on the Study Plan from Drs. Mount, Tarzwell, and Powers of the U.S. Environmental Protection Agency, and Dr. Linduska of the Fish and Wildlife Service, U.S. Department of the Interior. We found many of these comments quite helpful in modifying some of the projects and in developing new projects.

I do believe that it would be wise for the conference to create a more permanent group of scientific representatives of Federal and State agencies to be concerned with the studies of condenser cooling water discharges to Lake Michigan. Such a group meeting periodically could greatly facilitate the flow of information between the concerned governmental agencies and those of us who are involved in seeing that the studies are carried out and that the data collected are properly analyzed and interpreted.

I would now like to present the Study Plans which have been developed for Projects IX through XVII of the studies of the Waukegan-Zion area of Lake Michigan. Again, we would like to request official (and unofficial) comments about these plans and the methodologies which are being used.

Projects IX through XVII are written up in the same format which was used for the projects included in the 1970 Study Plan and the entire series of projects represents a continuing development. Some of the projects have been completed, some are currently under way and some have not yet been initiated. For ease in obtaining an overall perspective of the projects I have included Table I with this statement. (See p. 755) This table gives the starting

TABLE I

STATUS OF PROJECTS: WAUKEGAN-ZION AREA STUDIES

	Project	Initial Period	Status
I.	Temperature and D.O. Monitoring at Waukegan Station	1/70-2/71	Continuing for the duration of the studies
II.	Inshore Water Quality Evaluation	4/70-3/71	Complete, succeeded by Project XI
III.	Phytoplankton Study	8/70-3/71	Complete, succeeded by Project X
IV.	Physiological Effects on Fish		Abandoned, succeeded by Project XII
V.	Field Studies on Periphyton	4/70-3/71	Complete, succeeded by Project XI
VI.	Meteorological and Hydrological Monitoring	7/71- ?	Methodology being changed
VII.	Field Sampling Program	4/70-3/71	Complete, succeeded by Project X.
VIII.	Zooplankton Study	6/70-3/71	Complete, succeeded by Project X
IX.	Fish Population and Life History Program	4/71-12/71	Complete, continuing with revised study plan
X.	Field Study Program	4/71-3/72	Complete, continuing with revised study plan
XI.	Intake-Discharge Experiments at Waukegan Generating Station	5/71-4/72	Complete, continuing with new study plan as Chemical Monitoring at Waukegan Station
XII.	Temperature Response of Fish	6/72	In progress
XIII.	Not used for superstitious reasons		
XIV.	Physical Characteristics of Winter Discharge Plume from Waukegan Generating Station	2/72-3/72	Complete
XV.	Effects of Gas supersaturation on Fishes in Southwestern Lake Michigan	2/72-4/72	Complete
XVI.	Study of the Spring Thermal Bar in the Waukegan-Zion Area of Lake Michigan	3/72-5/72	Complete
XVII.	Intake-Discharge Experiments at Zion Generating Station	?	To start with plant operation
XVIII.	Zion Station Discharge Plume	?	Study plan being prepared

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date for the various projects and indicates the expected duration.

Although this is not in the prepared testimony, I would like to insert a figure here, since Mr. Comey brought up the question of the funding of Study Plans. I am informed by Commonwealth Edison Company that the studies that have been carried out on Lake Michigan over the last 3 years -- essentially starting early in 1970 -- according to the present time have been running at a rate of $1.8 million per year involved in studies in monitoring work in this area of the lake.

Now, in this table I have also included Project XVIII, which will be a study to define the location, extent, and area of the actual discharge plume from Zion Station. Preparation of the Study Plan for this project was started in August 1972 and we will have the Study Plan developed and equipment ready before the end of the year. This project is included in the table because we would very much like to have input to the development of the Study Plan from all interested agencies.

In the role of consultant to Commonwealth Edison Company, I have been concerned with studies of condenser cooling water discharges since 1968. Dr. John C. Ayers of the University of Michigan and Dr. Donald W. Pritchard of

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The Johns Hopkins University started consulting with Commonwealth Edison Company in 1969. Dr. Edward R. Raney of Cornell University (now emeritus), Dr. G. Fred Lee of the University of Wisconsin, and Dr. Andrew Robertson of Oklahoma University (now with the National Oceanic and Atmospheric Administration) started consulting on the studies in 1970. Dr. Donald C. McNaught of the State University of New York at Albany was added to the group of consultants in 1971 and Dr. Jacob Verduin of Southern Illinois University in 1972.

Although brief studies of the Waukegan-Zion area of Lake Michigan were supported by Commonwealth Edison Company in 1968 and in 1969, the intensive study related to condenser cooling water discharges in this area now represents about 2-1/2 years of effort. During this period, we have successfully completed some projects and we have also had some disappointments. We have found that in some instances it was necessary to develop new methodologies or new equipment in order to get at the questions we wanted to answer. (We have also lost a fair amount of sampling equipment in Lake Michigan and I hope that the Enforcement Conference will not consider these additions to the lake sediment to be pollutional effects.) I would like to comment briefly on some of our disappointments, some of our changes in methodology, and some of the positive results we have obtained.

One of our biggest disappointments was Project IV, the laboratory study of fish physiology. In this study, we were able to verify the Harvard Law of Animal Behavior which states that: "When held under carefully controlled laboratory conditions, organisms do as they damn well please." Actually, what we found is that it requires a talented fish culturist to keep many species of fish alive in the laboratory and that in our project excessive mortality among the control group prevented us from carrying out a sufficient number of valid experiments to achieve our objectives. We also discovered that the laboratory methodology for determining some of the physiological responses (particularly changes in haematology) are inadequate for our purposes. As a result of our experiences with this project, we completely revised the Study Plan and greatly modified the laboratory, design of new equipment, and installation and testing of the equipment. The design of new equipment, and the installation and testing of this equipment took a good part of 1971. The new laboratory study with fish (Project XII) is presently under way, but the results have not yet been evaluated. Dr. Raney will present to you some additional material which relates

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especially to the Zion type of high velocity discharge.

Our intake-discharge study at Waukegan Station to determine the effects of condenser passage on the zooplankton population has been quite successful. Initially we discovered that small sampling pumps and drift nets tended to mash up many of the zooplankters. We tried several modifications of the sampling techniques in order to avoid this mechanical damage during sampling. Our techniques improved over a period of months and ultimately resulted in the development of an isokinetic sampling pump which treats the zooplankters very gently. Dr. McNaught will discuss some of these results describing thermal effects and mechanical effects on zooplankton passing through the condensers.

Our phytoplankton sampling program has resulted in the collection of a large number of data on the numbers of algae which occur in this part of the lake. This year we have adopted a technique developed by Dr. Verduin which allows us to estimate phytoplankton biomass as well as obtain counts of the various species present. We expect that this technique will allow us to develop better quantitative relationships between phytoplankton populations and other environmental factors. Dr. Verduin will describe some of the information we have been able to derive from our previous phytoplankton sampling projects.

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We have also accumulated large amounts of data on the chemical substances and physical conditions in the Waukegan-Zion area of the lake. Dr. Lee will discuss some of the conclusions he has reached about the chemical substances, especially as they relate to the effect a cooling tower would have on water quality. While it is not part of our study program, Commonwealth Edison gave you cost estimates on cooling towers in 1970, and I understand that Mr. Butler will reappear at this session to update that material. Shortly after I finish, Dr. D. W. Pritchard will discuss some of the often misunderstood physical conditions in the lake, both existing and as expected after Zion begins operation.

Earlier in this statement, I stated that we have learned a great deal about the environment in that part of Lake Michigan which borders the Zion-Waukegan area. I would like to elaborate in a general way on this topic.

Lake Michigan is a very large lake and its largeness alone requires a massive data collection effort to characterize the environment. However, there is very little habitat diversity in the area we are studying. The benthic community does vary with depth but the components of the benthic community are much the same at all the depths we have studied. The variation is in the total community and

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in the relative abundances of the different components. There are rare pockets of different types of sediment but usually the variation is continuous without large discontinuities. Likewise the organisms making up the plankton communities are essentially the same throughout our study area. The counts and the relative abundances of specific components of these populations do change in a rather "patchy" manner with depth and with the season of the year, but we are dealing with the same community in all parts of the area. The fish appear to be free to select the particular location which is dictated by their behavioral pattern at a particular season of the year without being blocked off from any location in this area. The periphyton community is present only in shallow water where there are suitable substrates and the area available for its growth is very limited in relation to the total study area. The chemical substances dissolved in the water vary from the shore outward as would be expected since the shore receives land runoff and the discharges from some cities and industries; however, the variation is continuous without any large discontinuities.

What I am saying is that it really is just one big lake and a lake with continuous rather than discontinuous variation in the chemical and biotic components of the ecosystem. Throughout the study area we are dealing with the

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same components. We have found no evidence to support the hypothesis that there is a distinct "beach water zone" at depths less than 30 feet separable from the rest of the lake nor to support the hypothesis that there is an "inshore zone" at depths less than 100 feet. An understanding that the water depth is only one factor interacting with a large number of other environmental factors to determine the nature of the ecosystem is thus one of the general propositions our studies have affirmed. The witnesses who follow me will elaborate on several of those factors.

Now, if I could make a small addition. We were very pleased to have Mr. Barber's laundry list of concerns this morning. We have been asking for input and information of this type for some time -- for 2 years, I would say. And we greet these concerns as hypotheses describing mechanisms about how these dischargers or about how the powerplants might cause damage to the lake's ecology; and treating them as hypotheses, they can be treated in a scientific manner.

Actually six of the seven witnesses who follow me with their prepared testimony will describe studies which relate to many of the concerns which Mr. Barber expressed this morning.

We have been trying for this period of time really

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to get input or to try to get ideas from the Federal agencies and from the State agencies about the type of things which should be studied and which should be monitored out here. We have made several requests for comments for some type of scientific group that we could talk to about our studies and report our findings to and go over the data with them.

Last year, in the summer of 1971, a group of us made two trips into Washington to talk with people in the Federal EPA, talking through Mr. Quarles. We met both times in Mr. Quarles' office and met with him briefly one time, and met with Dr. Everett, a member of his staff.

At one of these meetings in Washington, I remember Mr. Barber was present at the meeting which ran over an hour's time, and at that time we were talking about the things that we should study. Mr. Barber has very little to say about the type of things we should study. This was in the summer of 1971. And we have continually asked for information about the type of thing we should be studying and the methodology we should be using.

I think that Mr. McDonald's question which he raised about a mechanism of who was going to make an over-all evaluation, who is going to take a look at the lake, is a very important question, and I think it is a mechanism that should be established so we have really somebody to talk with about what we are doing and the data we are getting.

MR. MAYO: Are there any questions or comments, gentlemen?

MR. BRYSON: Yes, I have a few comments and questions.

On page 10 of your statement, there is a rather lengthy laundry list of projects that are under way or contemplated or in various stages of completeness.

What is the general availability of the data gathered from these studies? How much has been released to the general public, or is generally available?

DR. PIPES: Well, in answer to your question: I would cite the document that the EPA made available at this conference, the review document that was prepared by Argonne Laboratory under contract with the Federal EPA. There are 135 references cited in that document and out of those 135, 13 of them are based on data which we have collected in these studies.

MR. BRYSON: Have those 13 been made generally available? The Argonne report is a summary document that hits the high points.

DR. PIPES: Well, yes, the data from these studies have been made generally available. We have not spent a

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great deal of time as yet preparing fancy reports, final publications on these; but the information is generally available to various scientific groups.

For instance, on Project XII -- pardon me -- Project IX, a field sampling program, the group who has been carrying out this study, has participated in the deliberations of the Lake Michigan Study Commission of the Great Lakes Fisheries Commission the last 2 years, and reported to that group about their finding. I talked with the fellow who was in charge of this project last week and he told me that he gets calls from the Great Lakes Fisheries Commission on the average of about once every 2 weeks asking what kind of information he is getting, what kind of data he is collecting on the fisheries up there.

And so in terms of its availability to the scientific community and for examination and interpretation of data, I think this has been very good.

MR. BRYSON: With respect to the study outlines and the comments by Federal agencies, if my memory serves me correctly, has not Dr. Mount of the National Water Quality Laboratory met with you a couple of times to go over study outlines and general details of desirable studies?

DR. PIPES: We had a good deal of correspondence with Dr. Mount in the winter of 1970-1971 and the spring of

1971, and found his comments very helpful, and he helped us a great deal in giving us guidance and technology on the things we should be studying.

We haven't really had much communication with him since the summer of 1971.

MR. BRYSON: I was under the impression that there have been some exchanges of information between yourself and Dr. Mount.

DR. PIPES: There, I believe, have been some exchanges of data information between some of the people involved in actually carrying out the study and some of the personnel in his laboratory, but we haven't been getting any kind of official communication from him.

MR. BRYSON: I was also under the impression that subsequent to your Washington meeting with Mr. Quarles and Dr. Everett of Mr. Quarles' staff, that there was some communication back and forth between the two of you and that it was left subsequent to that communication that you would get back to Dr. Everett with some of the revised study outlines, and that he was awaiting for the receipt of that information.

DR. PIPES: Well, quite recently this is true. In August of 1971 -- just last month -- we received some additional comments and requests for additional Study Plans

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from Dr. Everett of his office to supply these, and I understand there is a Dr. McErlean who is now working in his office. I was able to meet Dr. McErlean yesterday here and chat with him briefly, and from my conversation with him I understand there is an intention to establish some type of continuing relationship with him so we can supply him with information about what we are doing and get comments from him.

MR. BRYSON: I have one final question. On page 8 of your statement, the first sentence in the last paragraph -- can you elaborate in greater detail on what you mean by that statement? That is page 8, the first sentence of the last paragraph that reads: "What I am saying is that it really is just one big lake and a lake with continuous rather than discontinuous variation in the chemical and biotic components of the ecosystem."

DR. PIPES: Well, I think I would have to agree that I probably got a little over-enthusiastic when I wrote that particular sentence.

The study area that we have been concerned with is the Waukegan-Zion area of Lake Michigan, and we have gone something in the neighborhood of about 6 miles in either direction down the shore and roughly 6 miles out in the lake in our sampling program, and my comments should really be

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confined to this area of sampling which we have been involved in.

I understand that the conferees heard some reports, information on algal forms on Tuesday, which showed a considerable difference between inshore and offshore forms. Although I wasn't here to hear Dr. Stoermer's presentation, my understanding is -- in his terminology talking about inshore and offshore -- he was going back to perhaps the older terminology. This has been a terminology used in Lake Huron and Lake Michigan going back some decades between inshore samples and offshore samples, and the usage traditionally has been related to a distance of 10 miles from the shore.

In other words, any sample collected more than 10 miles from the shore was considered to be an offshore sample. Any sample collected less than 10 miles from shore was considered to be an inshore sample.

I think there is perhaps some scientific basis for this type of a designation between offshore and inshore sampling.

The argument here is related to the inshore existence -- well, the geologists call this a littoral shelf that is formed by certain geological processes when the lake is formed. There is offshore in the southern basin of Lake

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Michigan at a depth somewhere like 250 or 300 feet a ridge that shows up on the contour and this is roughly 10 miles from shore.

Some of the older literature -- some of the 19th century literature interprets this as being the edge of the littoral shelf, and I think this is where the 10-mile inshore-offshore idea came from. That is the best I can tell. Some of the more recent geological interpretations tend to indicate that this ridge may even be caused by the existence of another lake -- Lake Chippewa -- some several thousand years ago. It may not have been related to the formation of the littoral shelf at all.

In Hutchinson's book -- Hutchinson's "Treatise on Limnology" -- he has quite a discussion on the formation of the littoral shelf, and he cites Lake Michigan as an example of a lake which has an extremely wide littoral shelf.

Well, anyway -- I am wandering here -- the point I am trying to get at is: There was an older usage of "onshore" and "offshore" and "inshore" samples which was 10 miles from the shoreline. Now, this definition was picked up by the Public Health Service and the Great Lakes Illinois River Basin Project, and they used this designation in their sampling program.

In 1970, the group from the Department of Interior who prepared the "white paper" -- "Physical and Ecological Effects of Waste Heat on Lake Michigan" -- for some reason came up with a different definition of "inshore zone" and "beachwater zone," for which we haven't been able to find any historical precedent, and our studies since that time have been related to trying to test this as a hypothesis. You can consider any definition to be a hypothesis. We can hypohesize that there is an inshore zone at 100 foot depth, and what I am saying here is that we really found no data to substantiate this hypothesis.

MR. McDONALD: Dr. Pipes, I would say -- you say that your enthusiasm got the better of you -- I think one of the points we have been developing here today is that it is one big lake, and if your enthusiasm got the better of you I think that was a good move.

DR. PIPES: Good.

MR. McDONALD: What do you think is the most significant piece of information that has come to your attention regarding these problems since the spring of 1971 session of the conference?

DR. PIPES: The most significant single piece of information?

MR. McDONALD: Is there an outstanding piece of information that you would identify to support the Illinois position?

DR. PIPES: Well, we have an awful lot of pieces of information. I really don't carry all of the conclusions of all these studies around in my head; it would be very difficult for me to make a selection from the available --

MR. McDONALD: Well, I bring it up in this context. This morning we asked Mr. Bryson if he thought there was anything really new on the basis of the Argonne information. He indicated that there was nothing outstandingly new.

And in that Argonne summary there is some -- what? -- 13 pieces of information from your studies, and I am wondering if Mr. Bryson was on target with this, or if you would in any way change that?

DR. PIPES: Well, this is really not the way that science usually progresses. It normally is a long-term process of accumulating a great many bits and pieces of information, and of testing a great many hypotheses. And we have looked at this, looked at many things. One of the more interesting things that I might throw out -- although we are still in the process really of analyzing the data -- there is a study there which is described as a study on the spring thermal bar, which was carried out in March, April, and May. There have been a good many allegations and questions about this being some kind of a barrier to mixing. And we collected a great deal of data last spring. As I say, we are still very much in the process of analyzing this data. I imagine this could be a few months before we have the things fully put together; although, again, most of the data is available to the people who are scientifically interested in looking at it.

I think that some of our spot checks on data show that we have, I think, pretty clear evidence that the thermal bar is no barrier whatsoever to the advection of heat from the shoreward side and the offshore side of the bar. And so there is a question coming up in many respects in terms of the water quality matters of Lake Michigan. I really think I think of this because I have been looking at those data most intensively quite recently.

MR. MAYO: If there are no other questions, gentlemen, thank you, Dr. Pipes.

MR. FELDMAN: Dr. Verduin is next, Mr. Mayo.

MR. MAYO: May I presume that, for purposes of the record, we would have the study that Dr. Pipes presented to us introduced as an exhibit?

MR. FELDMAN: Would you please?

Document, "Evaluation of Thermal Effects in Southwestern Lake Michigan, January 1970--April 1971" is on file at U.S. EPA Headquarters, Washington, D.C., and Region V

Office, Chicago, Illinois.

MR. FELDMAN: I might say that Dr. Verduin's piece is the first of a series which will present new data. I suppose that the conferees have to arrive at their own conclusion about the significance of the new data.

STATEMENT OF DR. JACOB VERDUIN,

PROFESSOR OF BOTANY,

SOUTHERN ILLINOIS UNIVERSITY,

CARBONDALE, ILLINOIS

DR. VERDUIN: My name is Jacob Verduin. I am a Professor of Botany at Southern Illinois University at Carbondale, Illinois. I obtained a Master of Science and a Doctor of Philosophy Degrees in Plant Physiology under the direction of Dr. W. E. Loomis at Iowa State University at Ames. In 1948, I joined the staff of the Franz Theodore Stone Institute of Hydrobiology at Put-in-Bay, Ohio. This is a station of The Ohio State University, and is located on South Bass Island in western Lake Erie. I have continued an active research program in the Great Lakes ever since that time.

I was one of the first to point out the spectacular increase (450%) in phosphorus concentrations which occurred

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in western Lake Erie between 1948 and 1955. I am convinced that this is the singlemost important factor in the undesirable enrichment that Lake Erie has experienced during the past 20 years. A twofold increase in phytoplankton photosynthesis was correlated with this increase in phosphorus, and I have continued to monitor the photosynthetic rate in western Lake Erie every summer. During the past summer, two of my graduate students worked on this project, pursuant to an Environmental Protection Agency Training Grant in Aquatic Ecology which I administer through Southern Illinois University.

I have a mobile limnological laboratory (a pontoon-type houseboat) which is now based at Memphis, Tennessee, where we will investigate the effect of Memphis discharges on the Mississippi River. This mobile laboratory was constructed with the aid of a National Science Foundation Grant (1967) and it is subsidized partly by the same EPA Training Grant that I mentioned previously.

During the last 2 weeks of August just past (1972), I carried out a study of photosynthetic rates in Lake Superior, on board the University of Michigan research ship "Inland Seas." I also spent 6 weeks on board that ship in 1969, studying both Lake Michigan and Lake Superior.

During the summer of 1971, I traveled from Chicago to Hamburg, Germany, and returned to compare photosynthetic rates in the Great Lakes, the St. Lawrence River, and the Atlantic Ocean. The diatoms collected on this trip are now being identified and their biomass is being calculated by a graduate student at Southern Illinois University.

I have published 47 papers during the past 26 years on various aspects of aquatic ecology and plant physiology.

My testimony today concerns the phytoplankton data gathered by Industrial Bio-Test Laboratories in the Zion and Waukegan areas, as they relate to the concept of changes between nearshore and offshore areas in western Lake Michigan. I will confine my remarks today primarily to data gathered between May 1970 and March 1971, which are contained in a Bio-Test Report prepared by J. M. Piala. The data are less complete than will be available for the 1971-1972 studies, but they appear sufficient to support some tentative conclusions. This study included monitoring the phytoplankton at three locations one-half mile from shore (Waukegan, Zion, and Dead River) and at one location 6 miles offshore from the Zion station. The three inshore stations represent waters from the so-called "inshore" zone and the 6-mile station is within the zone designated by some as "open water."

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When the three "nearshore" zone stations are compared, it is evident that their average phytoplankton populations are closely similar both in the level of population and in the species composition. There is one minor exception to this statement: The Waukegan station showed a slightly higher (10 to 20 percent) average phytoplankton population than the other two nearshore stations. This statistic probably reflects nutrient enrichment from the city of Waukegan.

However, when the average phytoplankton data from the three nearshore stations are compared with the 6-mile offshore Zion station, a large difference is evident. I have prepared a graph to demonstrate this comparison. (See Figure 1, p. 777) In this graph, I have combined the data from the three nearshore stations into a single curve for comparison with the data from the 6-mile station. The graph shows two interesting features:

1. The nearshore populations show their highest values during winter and early spring, and their lowest values are observed during the periods of warmest temperature (August to September).

2. The nearshore stations are about threefold higher in phytoplankton population during the winter and spring than the 6-mile station, but when the low values are observed in August and September, the nearshore and the

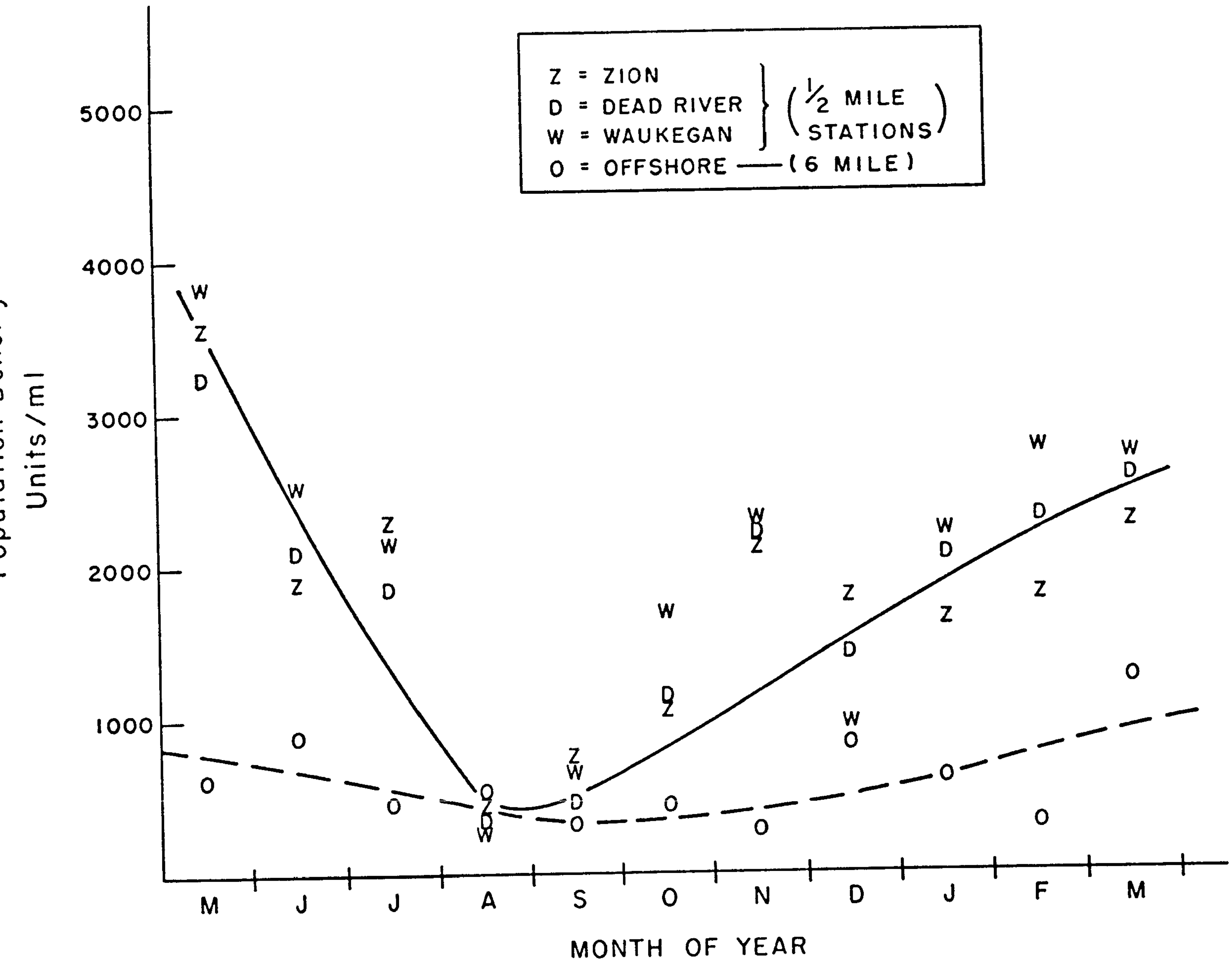

Figure 1. Monthly Phytoplankton Abundance at 3 Stations ½ Mile Offshore and at 1 Station 6 Miles Offshore (May 1970-March 1971)

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6-mile station data are practically identical. I should say, also, that a threefold difference is less than some have projected and certainly does not indicate that the offshore area is incapable of supporting productive growth. Based on my experience elsewhere, I had expected, in fact, that there would be about a sixfold difference. Furthermore, although the Figure 1 curves do not show it, the species composition shows the same kind of convergence in August and September as is evident in the population levels of Figure 1. The fact that a threefold difference in phytoplankton population is established between the nearshore and the 6-mile station during winter and spring suggests that the nearshore area has a higher nutrient supply and greater energy supply per unit of water volume available, so as to allow a higher population to develop. During August and September, relative nutrient supply is so nearly the same at the five stations that the phytoplankton population levels converge. Indeed we could reasonably say that the distinction between nearshore and offshore areas is obliterated under these conditions.

Given these data, what kinds of conclusions can one draw? I should like to examine briefly two questions often raised in discussions of Lake Michigan, but sometimes misunderstood or misused. The two questions relate to the

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rate of exchange of nearshore and open waters and relative productivity of those waters. The first question I would like to examine is this: What kind of mixing rates are present when a threefold higher population is found in the nearshore zone? To discuss this question, I wish to introduce the concept of "Mean Residence Time," and I will phrase the question in this way: "How long does a parcel of water take to move from the nearshore area to those 5 miles offshore?"

Let me discuss briefly here the situation that prevails in western Lake Erie, because we know the average residence time in the western basin and we have compared the waters in lower Lake Huron with the waters of western Lake Erie. As the waters from Huron enter Lake Erie they experience an eightfold increase in phytoplankton population and they experience an almost total displacement in major species composition, and this is accomplished during a residence time of 2 months. Consequently, I believe that if the average residence time in the nearshore area of western Lake Michigan were as long as 2 months, then we would find a similarly spectacular difference both in population level and in species composition there. Because the population differences are smaller and because the species composition in the nearshore area and the 6-mile station are

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closely similar, the mean residence time in the nearshore must be considerably less than 2 months.

Studies of the generation time in inshore zones and in western Lake Erie have shown that a doubling of a phytoplankton population occurs in about 1 week, compared to a 3- to 5-week generation time in offshore waters. If doubling of a population occurs in 1 week, then a threefold difference in phytoplankton could arise in a period of less than 2 weeks. Therefore, on the basis of these considerations, I would like to estimate the mean residence time in the nearshore area of western Lake Michigan during the periods when a threefold distinction is observed between nearshore and the 6-mile station populations. I estimate that this mean residence time is less than 2 weeks.

Finally, I wish to comment on phytoplankton productivity in the nearshore as compared to a zone several miles from shore. There is a concept, rather widely accepted, that the nearshore zone is considerably more productive than the areas farther offshore. In the case of the area we are considering here it is obvious that during much of the year the nearshore has a phytoplankton concentration about threefold higher than the zone 6 miles offshore. This means that a small fish, or a given zooplankter, grazing nearshore, will need to expend only one-third as much effort to graze his fill as would such an organism in the 6-mile zone. However, this is not a result of greater phytoplankton productivity, but a result of a higher population density per unit volume. When we consider total phytoplankton productivity it is necessary to express production not in terms of a unit of water volume but in terms of an integrated value that contains a summation of all the water in the vertical column. This fact has been recognized by most limnologists and oceanographers. Consequently, they usually express phytoplankton productivity in terms of yield per square meter of water surface. During the summer of 1969, I made such computations from my Lake Michigan data. We repeatedly occupied two stations, one about one-half mile from shore and another about 5 miles offshore, near Grand Haven, Michigan. The yields were expressed as millimoles of carbon dioxide fixed per square meter per day. The comparison revealed the following result:

<u>Table 1.</u> Comparison of Inshore and Offshore Phytoplankton Photosynthesis in Lake Michigan (Millimoles/M^2 Day)

Inshore (1/2 mile)	Offshore (5 miles)
200	280

This comparison reveals that the 5-mile station actually had a higher yield per square meter than the station one-half mile from shore. This is a result of the fact that we were integrating the yield from a considerably longer vertical water column at the 5-mile offshore station. Notice, however, that this is a realistic situation. The organisms that live on the bottom at a depth of 30 meters of water have access to all the materials settling out of the 30-meter column, while those living beneath 5 meters of water have access only to the materials that settle out of that 5-meter water column.

Let me now summarize the principal conclusions in this testimony:

1. The mean residence time of water in the so-called nearshore of western Lake Michigan is relatively short -- probably less than 2 weeks -- and the nearshore distinction is apparently obliterated during the summer months. Therefore the concept of the nearshore as a discrete zone that does not exchange with the rest of the lake is not a valid concept.

2. The phytoplankton productivity in the nearshore when compared on a unit area basis with offshore productivity is not higher but may even be somewhat lower than the offshore productivity.

Thank you.

MR. MAYO: Any questions or comments, gentlemen?

MR. BRYSON: I do have a couple.

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On page 6, when you are discussing the dynamics between or making a comparison between the dynamics in Lake Michigan and Lake Erie, I have trouble with a concept that the dynamics of both lakes are the same -- the western basin of Lake Erie and the nearshore-offshore of Lake Michigan.

Can you elaborate somewhat on that, on that comparison?

DR. VERDUIN: Well, I am using western Lake Erie as a reference because it is an area in which we have about a 30-foot depth, and we have a known residence time as a result of through-flow information, and we know what happens there. And in comparison of Lake Huron, the water goes from Lake Huron into Lake Erie in just a few days and then it resides there for 2 months and we see these spectacular changes.

I think that as far as injections per mile of shoreline are concerned, they aren't comparable. In other words, I rather doubt if the rivers that flow into Lake Michigan carry a lot less in the way of input than the rivers that flow into western Lake Erie, you see.

MR. BRYSON: You say you doubt they do?

DR. VERDUIN: Yes. I rather think the farming communities of Wisconsin and Illinois, and the cities of Wisconsin and Illinois inject along the shore of Lake

Michigan similar inputs to those that flow from Michigan into Lake Erie. I think the main difference between them is the fact that the water is held in the western basin, and the injections go in there and the water is held there for 2 months. And if the inshore zone of Lake Michigan were actually held fairly stable for a period of 2 months, we would see the same kind of thing in the inshore zone that we see in Lake Erie.

That is my assumption. That is the assumption on which this computation is based. And if you don't want to accept that assumption, then, of course, the computation also falls apart.

MR. BRYSON: How deep were these samples taken at the half-mile station and at the 6-mile station; and also how deep was the water at those points?

DR. VERDUIN: Well, the water at the half-mile station is between 25 and 35 feet deep, and we have samples from both surface and depth which show that you cannot detect a vertical difference in phytoplankton distribution, so it wouldn't matter whether we took them from the bottom or the top; they are the same.

MR. BRYSON: Which was the next question I had. Is that the case with the 6-mile station also?

DR. VERDUIN: Well, no. At the 6-mile station you do get some vertical differences, but we have both surface and depth, and the data are the average of the two. The points that appear at the 6-mile station are the average of the two depths. We just averaged them because we thought they were more representative than either one of them would be independently.

MR. BRYSON: I am not too sure I understand. Page 8 --

DR. VERDUIN: Yes.

MR. BRYSON: -- the bottom paragraph, 5 lines up from the bottom, this says: "The organisms that live on the bottom at a depth of 30 meters of water have access to all the materials settling out of the 30-meter column ..." hence you integrated over the full depth.

DR. VERDUIN: I am talking there about benthic animals. I am talking about the benthic animal food supply, which is an integrated supply from a vertical column. This should not be confused with my sampling of the phytoplankton. I am simply saying that integrating the vertical column is a realistic integration, it isn't just an academic exercise. So that when I express phytoplankton productivity as millimoles per square meter, this is a better way of expressing productivity than millimoles per cubic meter. That is essentially what I am saying there. And then I also point out that the organisms on the bottom are all of the time integrating their food supply in the same fashion by hatching it as it settles from the whole vertical column. The only exception to that statement is the poor organism that has to graze per unit volume and he, of course, has the big advantage inshore where the concentration per unit volume is greater.

MR. MAYO: Any other questions, gentlemen?

Thank you, Dr. Verduin.

Mr. Currie, I would like to suggest that we consider interrupting the Illinois presentation at this time in order to take a break.

MR. CURRIE: That suits me just fine, Mr. Chairman.

MR. MAYO: Pardon?

MR. BLASER: Was there going to be another presentation in this --

MR. CURRIE: Mr. Feldman, I believe --

MR. MAYO: Excuse me.

Mr. Feldman.

MR. FELDMAN: Yes. We have five more people. They are available for as long as the conferees are available. I am told that one can lose a lawsuit by keeping the jury past its dinner hour, and I do not want to run that risk. You people handle it as you wish.

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MR. MAYO: You had indicated that you had Dr. Pipes and Dr. Verduin who needed to leave.

MR. FELDMAN: Right.

MR. MAYO: Okay. Then, I would like to acknowledge that that has been accommodated, and I think we should take a break. I would like to get some expression from the conferees on what they think would be a reasonable time, and from Mrs. Hall whether she has some suggestions on how long it would take her to recover.

MRS. HALL: I'm beyond recovery!

MR. MAYO: Let's ask Mr. Feldman how long he thinks it will take?

MR. FELDMAN: It is a little hard to estimate Dr. Pritchard's piece; and I think Dr. McNaught and Dr. Lee can probably summarize their material and do it quite quickly. I think the Pritchard thing is already boiled down so that it is hard to understand without being longer. I don't think it can be summarized. Dr. Raney is a direct response to Mr. Barber, and I think you ought to hear that. Mr. Butler is cooling tower costs and not very long, and maybe that could be summarized some. Done that way, it is a minimum of another hour and probably more.

MR. MAYO: A minimum of another hour for Illinois.

You have approximately a half hour for

Wisconsin, Mr. Frangos?

MR. CURRIE: There are several additional Illinois citizens on the Illinois list, Mr. Chairman.

MR. MAYO: Any estimate of how much time they would require?

MR. CURRIE: Forty minutes.

MR. MAYO: We are faced with something in the neighborhood of 2 to 2 and a half hours.

MR. MILLER: Two to 2 and a half hours is going to result in about 5 hours before we get through.

MR. MAYO: Well, the alternative, gentlemen, is to try to meet tomorrow.

MR. MILLER: We can't meet tomorrow.

MR. MAYO: I would suggest, then, that we stick with it, take a break now of a half hour to 45 minutes. I would suggest, gentlemen, we try to finish up this evening. We will break now and come back at 7:30.

(Short recess.)

MR. MAYO: Ladies and gentlemen, I believe Mrs. Johnston has returned, so it would be appropriate for us to get back into session!

Mr. Feldman.

MR. FELDMAN: Dr. Pritchard is ready, Mr. Mayo.

MR. MAYO: Thank you. Dr. Pritchard.

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STATEMENT OF DR. DONALD W. PRITCHARD,
DIRECTOR, CHESAPEAKE BAY INSTITUTE,
PROFESSOR OF OCEANOGRAPHY,
THE JOHNS HOPKINS UNIVERSITY,
BALTIMORE, MARYLAND

DR. PRITCHARD: Members of the conference and audience, my name is Donald W. Pritchard. I am the Director of the Chesapeake Bay Institute and also Professor of Oceanography, Department of Earth and Planetary Science, The Johns Hopkins University. I appeared before the conference in 1970.

Departing briefly from my prepared statement, I presume that my curriculum vitae that appeared in the record at that time will be a part of the record, and so I don't have to further qualify myself.

I would refer just briefly to two aspects of that testimony which the Four-State Conference might again consider. Both of these deal with my own long term concern with obtaining information pertinent to management of the environment for the benefit of man; and the second is some rather extensive testimony dealing with the subject of the large-scale effects of heated discharges versus the small-

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scale, local effects of heated discharges. I will not repeat any of that testimony.

Today I am going to speak about two additional features. The first concerns mixing and exchange between the open waters of Lake Michigan and the so-called "inshore" zone.

A concept originally set out in the 1970 FWQA "white paper" postulates that certain zones exist in Lake Michigan which have insignificant exchange with the major volume of the lake. Specifically, the FWQA "white paper" defined two zones: one, called the beach zone, included all waters shoreward of the 30-foot depth contour; the second, called the inshore zone, was defined as extending from the outer edge of the beach zone to the 100-foot depth contour. These are quite arbitrary divisions. No physical barrier exists which would limit the advective transport or turbulent mixing of waters between the offshore waters of the lake and the inshore zone, or between the inshore zone and the beach zone.

There are a number of processes which promote advective exchange and turbulent mixing between these artificial zones and the offshore waters of the lake. One is the motion set up by the direct stress of the wind on the water surface. The wind stress induces a motion in the

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surface layers of the lake which, in the offshore waters of the lake, flows in a direction slightly to the right of the wind direction, and at a speed of about 2-1/2 percent of the wind speed. Thus, along the western coastline of the lake, any wind coming from the sector NNW to about ESE would have an onshore component. Surface water from the offshore lake would pass shoreward past the 100-foot depth contour into and through the inshore zone, and into the so-called beach zone. This flow cannot, of course, continue through the shoreline and, in fact, will not, as a direct advective flow, move all the way to the shore. Continuity is maintained by two processes. Within a few thousand feet of the shoreline the flow turns and runs essentially parallel to the coast, in the direction of the longshore component of the wind. This does not account for all of the surface water which moves into the inshore and beach zones, since the shoreward directed surface flow is in part compensated for by an offshore flow of water below the surface layers from the inshore and beach zone out into the offshore lake area. The wind is never uniform in speed and direction along the entire coastline, or even any major segment of the coastline of the lake. The longshore current in the beach zone induced by a strong wind in one sector of the lake will dissipate the move offshore again in regions of weaker winds.

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A 15-knot wind blowing from the quadrant North to East would produce an advective flow of offshore lake water into the inshore zone of about 500,000 c.f.s., over a 10-mile stretch of coastline. There would be an equivalent flow out from the inshore zone resulting from the combination of a subsurface countercurrent, and a return of water flowing alongshore into the offshore lake area from regions having lower onshore wind stress.

Similarly, along the western coastline of the lake, a wind from the sector SSE to about WNW produces a surface current with an offshore component, which carries water from the beach zone into the inshore zone, and from the inshore zone out into the offshore lake area. In this case there is a compensating subsurface current directed from the offshore region toward the coast.

Basically the lake, including both the so-called beach zone and inshore zone, is a dynamic, not a static, system as implied in the FWQA "white paper." Not only does the wind induce relatively steady advective flows between the offshore lake waters and these two zones for short periods (a few hours to a few days), but the periodic fluctuations in wind speed and direction produce large horizontal current shears, and transient eddies which result in large-scale turbulent exchange of water and of dissolved and suspended materials between the beach and inshore zones and the offshore lake area.

Another mechanism for exchange of water between the nearshore and offshore areas is one also related to the wind, but in a more indirect way. During periods of vertical stratification the wind fluctuations can induce internal seiches which, in addition to vertical motion in the layers of maximum vertical density gradient, often produce an influx of cold water from offshore up over the inshore shelf region. These massive movements of water between the offshore lake area and the nearshore shelf region have been well documented by a number of investigators, notably Clifford Mortimer. Though such seiche-induced exchanges between the offshore and nearshore regions of the lake are aperiodic events (i.e., occurring from time to time with no set pattern), they do contribute a significant, though at present an unquantified, addition to the other modes of exchange.

The shoreline is the source of all of man's chemical input to the lake, plus the major part of the natural chemical input via rivers, streams, and surface runoff. The basic physical laws require that there be a gradient in concentration of such dissolved and suspended material from the shoreline outward. Thus the fact that

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nearshore waters have higher concentrations of dissolved and suspended material does not imply a lack of exchange of these waters with the rest of the lake. Based on the chemical data available, it is possible to make an estimate of the mean exchange rate of water in the inshore zone with the waters of the offshore lake area. This is accomplished by comparing the total mass of a given chemical resident in the inshore zone at any given time with the rate of introduction of that constituent into the lake at the shoreline. Such a computation indicates that the long-term exchange of water between the inshore zone along the southern half of Lake Michigan and the offshore lake area represents a flux of about 1.5 million c.f.s. This represents about 75 times the volume rate of water usage by all existing powerplants, plus all those now under construction or announced as being planned, on Lake Michigan.

A much maligned villain in the fantasy of isolation of the inshore zone from the offshore waters of the lake is the thermal bar. The misconception that the thermal bar is a barrier which confines the water and all of the introduced wastes to the shoreward side probably arises from a misunderstanding of the meaning of the term "bar." As used in the phrase "thermal bar," the "bar" simply means an elongated region identified by some readily recognizable feature. In the present case, the identifying feature is the 4° C. isotherm, the temperature of maximum density for freshwater. On one side of this isotherm is water which is colder, and hence less dense, than the 4° C. water. On the other side the water is warmer, and also less dense, than the 4° C. water. The use of the term "bar" in the phrase "thermal bar" has a connotation similar to the use of this term in the phrase "oyster bar," which is used to designate elongated oyster beds in tidal estuaries. Departing, sometimes this indicates an elongated table from which one gets fresh oysters.

The main point to be made about the thermal bar is that it is a strongly dynamic phenomenon. It is a region of minimum stability and is consequently associated with strong convective stirring. In early springtime the thermal bar forms near shore as the increased solar radiation increases the temperature of the nearshore waters more rapidly than the deeper offshore waters.

Prior to this warming period, the waters of the lake in the upper 100 feet or so have had temperatures close to 0° C. As the nearshore waters are progressively warmed, there develops a transition region between the shallower waters having temperatures greater than 4° C. and the offshore waters having temperatures less than 4° C. This

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transition region, or thermal bar, generally moves in an offshore direction. Even when, for short periods of time, the bar does not show much movement, turbulent exchange does occur across this region of minimum stability. When the thermal bar is in motion it is obvious that the basic principle of mass continuity requires a transport of water through the bar from the offshore area into the nearshore zone, thus increasing the rate of exchange between nearshore and offshore waters.

In late April of 1970 and again in 1971, measurements made off the Zion nuclear powerplant site showed an average rate of movement of the thermal bar in an offshore direction past the 100-foot depth contour of about 0.02 f.p.s. This corresponds to a transport of water through the bar of about 118,000 c.f.s. for a 10-mile long stretch of the coastline.

Thus there are several mechanisms which, though aperiodic and variable in intensity, when taken together are more than adequate to provide for the effective 1.5 million c.f.s. steady-state exchange rate between the waters of the inshore and beach zones and the waters of the offshore lake area as estimated from available data on chemical inputs and concentration distributions.

The second subject I would like to discuss

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concerns the winter sinking thermal plume. As indicated in the previous and my just-completed discussion of the thermal bar, freshwater has a number of physical properties which make it a unique fluid, including the fact that the density of water is maximum at a temperature above the freezing point. Thus pure water (i.e., water containing no dissolved solids), which freezes at a temperature of 32° F. (0° C.), attains maximum density at 39.2° F. (4.0° C.). The temperature of maximum density of water decreases as the concentration of dissolved solids increases. However, for the range of dissolved solid concentrations found in Lake Michigan, the temperature of maximum density is for all practical purposes the same for lake water as for pure water.

Thus the density of lake water decreases as the temperature decreases from 39.2° F. to the freezing point, and also decreases as the temperature increases from 39.2° F. to the boiling point. The density of water at 39.2° F. is about 0.013 percent greater than the density at 32° F., the freezing point. The density of water at 46.65° F. is the same as the density at 32° F.

During wintertime when the temperature of the lake water is less than 39.2° F., and often at or near 32° F., a heated effluent with a temperature, say, 20° F. above the

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lake water temperature will initially be less dense than the receiving waters and will spread into the lake as a surface plume. However, as mixing and surface cooling cause the temperature of the dispersing thermal plume to decrease, the density of the plume will increase. When the temperature of the plume has been reduced to 46.6° F. or lower (depending on the ambient lake temperature) the density of the thermal plume will become just equal to the density of the ambient lake water. Further decrease in temperature of the plume due to mixing and cooling results in a plume density greater than that of the ambient lake waters. If the heated effluent is discharged to the lake at low discharge velocities, so that at the point where the density of the thermal plume exceeds the density of the ambient lake water there is little excess horizontal momentum in the plume, the water in the plume will sink or, more properly, bottom out, and spread over the bottom as a thin layer of water having temperatures somewhat warmer than the ambient lake water. The rate of mixing of the water in this bottom thermal plume with the colder lake water is much slower than in the case of a surface plume, and since the warmer plume water is separated from the surface no loss of excess heat to the atmosphere can occur. Consequently, the area covered by the winter sinking plume may be much greater

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than the area covered by the thermal plume during the rest of the year when it remains in the surface layers.

If the thermal plume has sufficient excess horizontal momentum the sinking plume phenomenon described above will not occur at the point where density of the plume first exceeds the density of the ambient lake waters. Instead, the plume will continue to spread horizontally, mixing rapidly with the cooler lake waters and losing excess heat by surface cooling, until the excess horizontal momentum has been decreased to some critical value which permits the higher density water of the plume to sink through the cooler ambient lake water and to spread out over the bottom. Thus the temperatures in the sinking plume and in the spreading bottom plume are determined by the excess horizontal momentum (or, simply, the excess horizontal velocity) of the thermal plume. Other things being equal, the higher the speed of discharge of the heated effluent, the lower the temperature in the winter plume at which sinking occurs.

Theory is not yet adequate to provide estimates of the value of the excess horizontal velocity at which the sinking plume phenomenon occurs. However, on 29 February 1972 and again on 16 March 1972 Bio-Test made very extensive field surveys of the thermal plume from the Waukegan power station. On both these occasions a strongly developed

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sinking plume was observed. Each of these surveys involved the measurement of the vertical temperature profile at over 140 stations in Lake Michigan waters adjacent to the Waukegan power station. To my knowledge, no other such intense temperature surveys of the winter sinking plume phenomenon have been carried out.

During the 29 February survey, the ambient lake temperatures decreased slightly with distance offshore, being 34° F. at the shoreline, 33° F. at a distance of between 2,000 and 5,000 feet offshore, and 32° F. at a distance of between 8,500 and 12,000 feet offshore. The ambient temperature in the vicinity of the sinking plume was close to 33° F. The temperature rise across the condenser in the Waukegan powerplant was 13° F., but because of re-circulation of some of the plant discharge back into the intake canal, the temperature of the heated effluent was about 50° F., or 17° F. above the ambient lake temperature. Water at 50° F. is less dense than water at 33° F., and hence the thermal plume initially extended horizontally out into the lake from the mouth of the discharge canal. Because of the small density difference between the thermal plume and the receiving waters, the rapidly mixing heated effluent extended from surface to bottom in the relatively shallow waters off the Waukegan power station. The density

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of the water in the thermal plume became just equal to the density of the 33° F. ambient lake water at the point where the temperature of the thermal plume had decreased to 45.6° F. At plume temperatures less than 45.6° F. the density of the thermal plume should have been greater than the density of the ambient lake water, and conditions favorable for a sinking plume should have existed. However, sinking of the plume did not occur until the temperature of the plume had been reduced to about 37° F.

On 16 March 1972 the ambient lake temperature in the vicinity of the sinking plume was 32.5° F. As a result of recirculation of some of the heated discharge back into the intake canal, the temperature of the effluent was about 16.5° F. above the ambient lake temperature. In this case, the density of the heated plume would be equal to the density of the 32.5° F. ambient lake water at the point where the temperature of the thermal plume had been reduced to 46.1° F. However, sinking of the thermal plume did not occur until the temperature of the plume had been reduced by mixing and cooling to 39° F.

The fraction of the 1949 c.f.s. condenser cooling water flow which was being recirculated on these two occasions is not precisely known. A conservative estimate of the volume rate of flow of the heated effluent discharged

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to the lake is 1,500 c.f.s., which would result in an excess horizontal velocity at the point of discharge of the thermal plume of 3.0 f.p.s. At the point in the thermal plume on 29 February where the temperature had been reduced from 50° F. to 37° F., the excess horizontal velocity in the plume would have been reduced to 0.71 f.p.s. At the point in the thermal plume on 16 March where the temperature had been reduced from 49° F. to 39° F., the excess horizontal velocity in the plume would have been reduced to 1.18 f.p.s.

On the basis of these data it can be concluded that in Lake Michigan sinking of the thermal plume will not occur in that part of the plume in which the excess horizontal velocity exceeds 1.2 f.p.s.

At the Zion nuclear powerplant of Commonwealth Edison Company the speed of the heated effluent at the point of discharge to the lake will be 9.3 f.p.s. The excess temperature in the thermal plume where the excess horizontal velocity will have been reduced to 1.2 f.p.s. will be less than 2.6° F. (for an initial temperature rise of 20° F.). Thus any sinking plume which might develop at Zion will have excess temperatures less than 3° F.

I would add just two comments that are not in my written testimony. There was an earlier question addressed to Dr. Pipes concerning whether studies conducted in recent years and since the last meeting of this group had resulted in new findings.

I would suggest that the presentation I have just made concerning the sinking plume is new. Also there have been some very good new work and results concerning entrainment of phytoplankton and zooplankton, their survival rates; on fish behavior with respect to avoidance behavior; and on time-temperature exposure relationships for species which might be entrained in the plume and into the intake or entrained in the plume. Some of these results will be reported by speakers who follow me.

That is all.

MR. MAYO: I would like to suggest to the conferees that we consider holding our questions in connection with the remainder of the Commonwealth Edison presentation until we have gotten each of the speakers, in order to avoid any redundant questioning.

If that is all right with the conferees, may we proceed that way?

MR. BRYSON: Assuming the speakers stay around.

MR. MAYO: Yes.

I do have some questions of Dr. Pritchard.

DR. PRITCHARD: I am spending the night.

MR. FELDMAN: Dr. McNaught is next, Mr. Mayo.

D. McNaught

STATEMENT OF DR. DONALD C. McNAUGHT,
ASSOCIATE PROFESSOR OF BIOLOGICAL SCIENCES,
STATE UNIVERSITY OF NEW YORK,
ALBANY, NEW YORK

DR. McNAUGHT: Mr. Chairman, ladies and gentlemen. I am very happy to say that we do have some new and exciting information on condenser passage. So before I give you my prepared statement, I would like to give you the main conclusions so that you can look, during my presentation of data, for the evidence that will be used to make these conclusions.

1. We have discovered that zooplankton mortalities, during condenser passage, are roughly a magnitude lower than many statements that we see in the literature today.

2. We have discovered that most of this mortality is due to mechanical effects and not to thermal effects.

With these conclusions, then, I will proceed to my prepared testimony.

I am Donald McNaught, Associate Professor of Biological Sciences at the State University of New York at Albany. Previous to the 4 years I have been in this position, I was Assistant Professor of Zoology at Michigan

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State University. I hold B.S. and M.S. Degrees in Fisheries Biology from the University of Michigan and a Ph.D. from the University of Wisconsin in Zoology (limnology). Attached hereto is a complete list of my professional experience, awards, memberships in professional societies, and publications. (See pp. 806-808)

My own studies have included an investigation of the zooplankton of Lake Michigan beginning in 1964. More recently we have been examining zooplankton production in Lake Ontario, with emphasis on the effect of waste heat on such production (see publications listed in vitae).

The Commonwealth Edison Company has invited me to present this statement and I welcome the opportunity to express my views regarding the potential effects of condenser passage on zooplankton, specifically as we predict for the Zion nuclear plant.

Zooplankton constitute a portion of the ecological basis for fish production in Lake Michigan. To seriously reduce the production of zooplankton would be to interfere with fish production. However, it is obvious from investigations by personnel from Industrial Bio-Test that zooplankton mortalities during condenser passage never approach 100 percent and are, in fact, usually closer to 10 percent, even following return to ambient temperatures for 24 hours

CURRICULUM VITAE OF DONALD C. McNAUGHT

1. Personal:

   a. Born: Detroit, Michigan, 1 May 1934
   b. Married: Mary E. Flach McNaught, 29 December 1962
   c. Children: Four (1964, 1967, 1969, 1971)
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2. Academic:

   a. B.S., 1956, Fisheries, University of Michigan, Ann Arbor
   b. M.S., 1957, Fisheries, University of Michigan, Ann Arbor
   c. Ph.D., 1965, Limnology (Zoology), University of Wisconsin, Madison

3. Training and Experience:

   a. 1953-1956: Michigan Department of Conservation; 1953 (summer), Fish Division, Stream Improvement Crew; 1955 (summer), Institute for Fisheries Research, Stream Survey Crew; 1956 (summer), Institute for Fisheries Research, Lake Survey Crew.
   b. 1957-1965: University of Wisconsin
      1. 1957-60, Research Assistant, research for Ph.D.
      2. 1960-65, Project Assistant, research for Ph.D., administrative duties, Laboratory of Limnology.
      3. Jan.-Sept. 1965, Project Associate, post-doctoral research, zooplankton of Lake Michigan.
   c. Sept. 1965-Sept. 1968: Michigan State University, Assistant Professor, W. K. Kellogg Biological Station and Department of Zoology.
   d. Sept. 1968-present: State University of New York at Albany, Associate Professor and Director of Cranberry Lake Biological Station.
   e. 1971: Consultant, Commonwealth Edison, Chicago, on problems of thermal discharge.

4. Awards:

   a. ASLO Travel Award, 16th Congress Limnology, Warsaw, $400 (1965).
   b. All-University Research Grant, MSU, 1965, $400.
   c. Research Grant, National Science Foundation, 1966-68, $48,300.
   d. Renewal from N.S.F., 1968-71, $35,300.
   e. U.S. Lake Survey, 1969-70, $10,000 (joint award).
   f. Research Foundation, State University of New York, 1969-71, $7,870.
   g. National Science Foundation, U.S. International Biological Program, 1970-71, $19,078.
   h. Renewal from N.S.F.-I.B.P., 1971-72, $22,450.
   i. ASLO Travel Award, 18th Congress Limnology, Leningrad, $600 (1971).
   j. Environmental Protection Agency, 1972-74, 149,665 (contract 1972-73 for 79,758).

5. Professional Societies:

a. American Society of Limnology and Oceanography
b. Ecological Society of America
c. International Association of Theoretical and Applied Limnology
d. American Society of Zoologists
e. Michigan Academy of Science
f. American Fisheries Society
g. Wisconsin Academy of Science

6. Research Interests:

a. State University of New York at Albany, 1968-present.

Eutrophication of lakes of New York State, including studies of secondary production using acoustical techniques and effects of thermal loading on production of zooplankton; adaptability of Cladoceran zooplankters to extreme photic environments; evolution of visual systems of planktonic cladocerans.

b. Michigan State University, 1965-1968.

Physiological ecology of the zooplankton; migratory behavior and photochemistry of the visual pigments of the Cladocera and Copepoda; use of acoustical methods in the study of zooplankton distributions.

c. University of Wisconsin, 1957-65.

Ecology of Daphnia, including studies of migratory behavior and the role of vision in depth control; investigations of zooplankton scattering layers in Lake Michigan; studies of relationships between a planktophage fish and its zooplankton prey.

d. University of Michigan, 1956-1957.

Studies of comparative food habits of brook trout and burbot.

7. Committee Activities:

1968-present: Site Committee, Inter. Biol. Program; 1970-present: Coordinator, Secondary Production, Deciduous Forest Biome, IBP; 1969-present: Chairman, Subcommittee on Biology in Public Affairs, Committee on Biology for SUNY; 1970-1972: President's (SUNYA) Advisory and Steering Committees on Environmental Studies; Environmental Decisions Comm. (SUNYA Campus): 1971-; Coordinator, U.S.-I.B.P. team to International I.B.P. Conference, Reading, England (Sept. 1972).

8. Publications:

1. Lake Mendota and the science of limnology. Wis. Acad. Rev., 7(1):1-4 (1960) (with R. M. Horrall).

2. Surface schooling and feeding behavior in the white bass, Roccus chrysops (Rafinesque), in Lake Mendota Limnol. Oceanogr., 6(1):53-60 (1961) (with A. D. Hasler).

3. The fishes of Lake Mendota. Trans. Wis. Acad. Sci., 52:37-55 (1963).

4. Rate of movement of populations of Daphnia in relation to changes in light intensity. J. Fish. Res. Bd. Can., 21(2):291-318 (1964) (with A. D. Hasler).

5. Depth control by planktonic cladocerans in Lake Michigan. Proc. 9th Conf. Great Lakes Res., Great Lakes Res. Div., University of Michigan, Pub. 15:98-108 (1966).

6. Photoenvironments of planktonic crustacea in Lake Michigan. Verh. Int. Ver. Limnol., 16:194-203 (1966) (with A. D. Hasler).

7. Fishing potential of inland lakes. Papers 12th Conf. Mich. Nat. Resources Council (1968):8-11.

8. Acoustical determination of zooplankton distributions. Proc. 11th Conf. Great Lakes Res. 1968:76-85.

9. Short internal waves near their high-frequency limit in Central Lake Michigan. Proc. 11th Conf. Great Lakes Res. 1968:454-469 (with C. H. Mortimer and K. M. Stewart).

10. Developments in acoustic plankton sampling. Proc. 12th Conf. Great Lakes Res. 1969:61-68.

11. A mathematical analysis of the niches of Lake Michigan zooplankton. Proc. 13th Conf. Great Lakes Res. 1970:47-57 (with P. A. Lane).

12. Plasticity of Cladoceran visual systems to environmental changes. Trans. Amer. Micros. Soc. 90(1):113-114 (1971).

13. Measurements of zooplankton production compatible with ecosystem analysis. Trans. Amer. Micros. Soc. 90(1):107-108 (1971).

14. Influences of thermal effluents upon aquatic production. Proc. 14th Conf. Great Lakes Res. 1971:21-26 (with M. W. Fenlon and G. D. Schroder).

15. "Notes on the Clarke-Bumpus Sampler", pg. 11-12 in A manual on methods for the assessment of secondary productivity in fresh waters. Blackwell Scientific, Oxford, 1971.

16. A niche analysis of the Gull Lake (Michigan, U.S.A.) zooplankton community. Verh. int. Ver. Limnol. 18 (in galley) (with P. A. Lane).

17. The effects of thermal effluents upon secondary production. Verh. int. Ver. Limnol. 18 (in galley) (with M. Fenlon).

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to illustrate the insignificance of delayed mortality.

Results of Waukegan Studies

Estimates of zooplankton motility, used as an indicator of survival, were made following condenser passage, as well as at 4- and 24-hour intervals, so as to estimate either recovery or later death. Effects of condenser passage were examined at a maximum Δ T of 12° to 13° C. to imitate passage at Zion, as well as a normal Waukegan Δ T of 4.5° to 9.5° C. Furthermore, mechanical effects of passage were separated from thermal effects by pumping water and sampling at the discharge when the plant was not operative.

Zooplankters passing through any condenser and associated pumps suffer both mechanical and thermal stress. For the period of the Waukegan study, 0.7 ± 3.0 percent of entrained zooplankton suffered immotility due to thermal stress, while 6.5 ± 4.2 percent were rendered immotile due to mechanical abrasion. (Figure 1) (See p. 808a)

These figures are illustrated at Figure 1 which was inadvertently left out of my testimony and is available on the floor at this time.

While those who have not carefully examined the effects of condenser passage might assume increased Δ T's to be the critical factor, it is now obvious that mechanical abrasion is the most important cause of immotility,

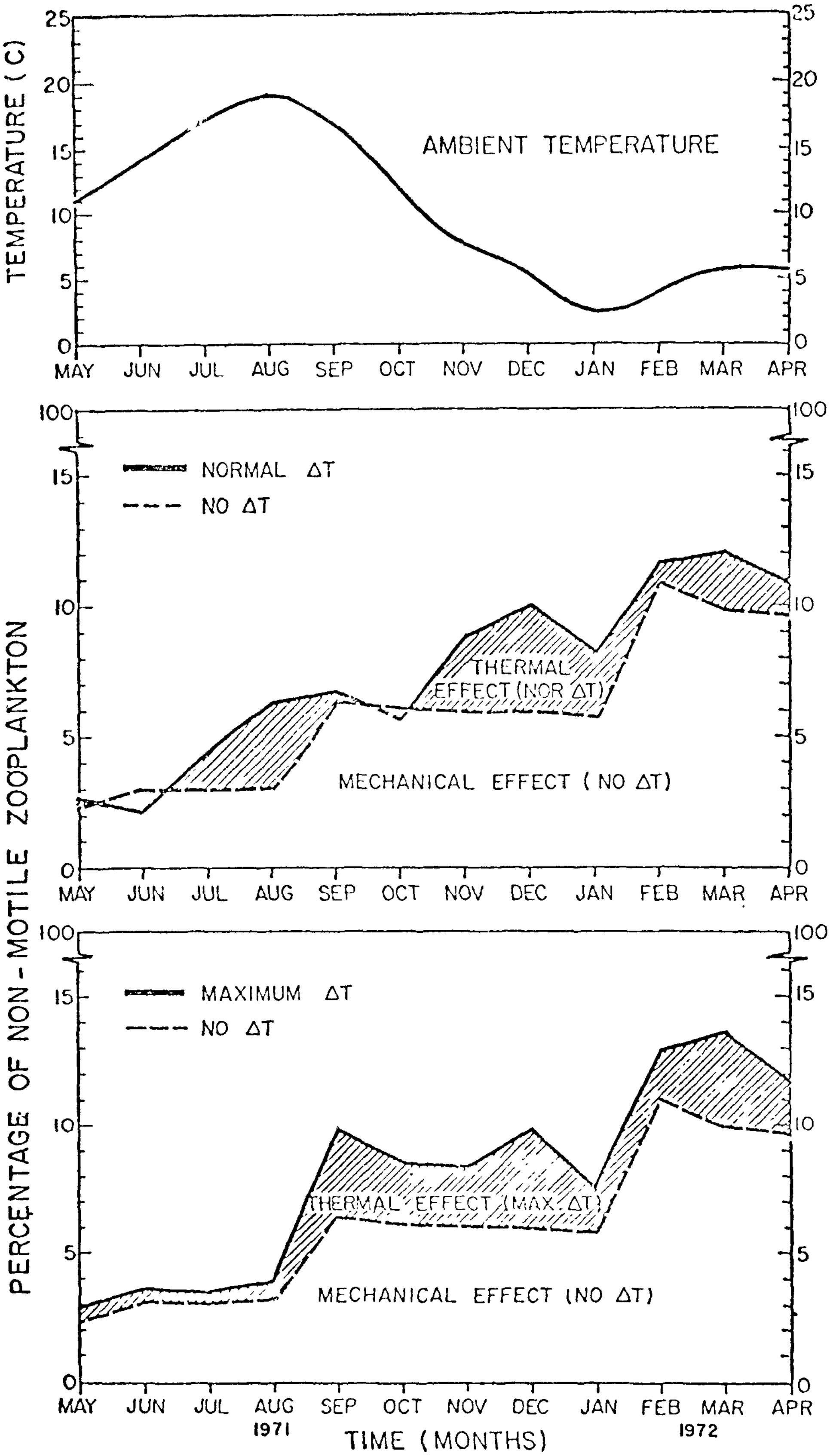

Fig. 1 Effects of condenser passage on zooplankton with maximum Δ T of 12-13 C, normal Δ T of 4.5 - 9.5 C, and no Δ T (ambient temp.) at Waukegan generating station, May 1971 - April 1972.

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accounting for the mean of 6.5 percent mentioned above. Mechanical effects fluctuate seasonally, likely with changes in species composition and size. The number of immotile organisms resulting from abrasion and other factors was less than 3.1 percent (± 4.5) from May to August when copepod nauplii and small cladocerans were abundant. Immotility due to mechanical effects increased to 7.2 percent from September to January when larger cladocerans (Daphnia and Diaptomus) and copepods predominated. When the large relict copepod Limnocalanus macrurus appeared, mortality due to mechanical abrasion jumped significantly ($P > 0.05$) to 11 percent. Thus one important challenge for the future will be to construct pumps and condensers to reduce this mortality resulting from the mechanical effects we have observed.

Tests at Waukegan illustrate clearly that a second effect of condenser passage, immotility from thermal stress, does not significantly increase with the Δ T across the condenser. If an animal is warmed but remains below its lethal temperature, it doesn't matter if it is warmed 5.5° C. (9.9° F.) or 12.5° C. (22.5° F.) above ambient. Approximately 7.2 ± 2.3 percent of the zooplankton are rendered immobile at a Δ T of 5.5° C., while 7.7 ± 3.5 percent are immobilized at a Δ T of 12.5° C. That is, the increase in

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temperature change (ΔT) is not harmful as long as discharge temperatures do not surpass the upper lethal temperature. It is not expected that Zion discharge temperatures will exceed lethal limits; if this is the case it doesn't matter to the zooplankton whether the ΔT experienced is 5° C. or 12° C.

Thus we have examined two basic concepts. First, we have illustrated that mechanical effects are minor, leading to mortalities of about 6.5 percent of zooplankton passing the condensers. Secondly, thermal effects are even more insignificant, causing immotility in 0.7 percent of animals. Now we want to examine the seasonal aspects of condenser mortalities of zooplankton.

In recent Bio-Test studies it has been demonstrated that the upper lethal temperature limits for most Lake Michigan zooplankton are higher than the maximum summer lake temperatures of 23° to 25° C. (73° to 77° F.). Thus it is not surprising we found no severe thermal effects at the Waukegan discharge at 32° C. (98.6° F.) In fact, seasonal immotility following passage is highest in February and March (Figure 1), and we have already attributed these thermal effects to large size (*Limnocalanus*). The summer months are not critical at Zion, for we are dealing with a mechanical problem.

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Thus far we have discussed immotility as a measure of mortality. However, all immobile organisms leaving the discharge do not perish. We have demonstrated a total immobility of 7.2 percent, based on animals observed immediately after passage. But after 24 hours, less than 6 percent are immobile indicating a decrease of 1.8 percent; i.e., 25 percent of the organisms initially immobilized have recovered after 24 hours.

Estimate of Zooplankton Immobility at Zion

At this point we have predicted that immotility, and likely the mortality, of zooplankton due to condenser passage at Zion is on the order of 7.7 percent for temperature increases expected across the Zion condensers. How many pounds of zooplankton would be immobilized in a given year at Zion? From a careful analysis of Bio-Test data on zooplankton abundance at Zion, and conservatively assuming that dry weight is 5 percent of wet weight, we have calculated that 1.21×10^6 lb. of zooplankton will be immobilized at the Zion plant in a year (Table 1). Parenthetically, I give you the necessary figures to make these calculations.

I will not read the review of the literature. This review, which you can read, essentially says that the literature substantiates the Bio-Test findings of Waukegan and, as I said, you can read that yourself.

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At this time, then, I would like to comment on the AEC draft Environmental Statement and the EPA reply. Certainly the most recent results from intensive Bio-Test investigations at the Waukegan station are inconsistent with the draft Environmental Statement of the AEC, which suggests a 15 to 30 percent kill at Waukegan, with a 100 percent kill most likely for invertebrates. In intensive studies at Waukegan, investigators at Bio-Test have predicted that Zion will experience a kill of 7.7 ± 3.5 percent.

Likewise, these same Bio-Test investigations refute the EPA comments to the effect that excessive losses of fishfood organisms will occur if intake velocities are not reduced to 1 f.p.s. It is highly unlikely that reduced intake velocities would, in any way, reduce these already low levels of likely zooplankton mortality.

For the future, then, I feel it is vital that the Commonwealth Edison Company examine the effects of condenser passage on zooplankton once the Zion plant is operative. Such investigations will support or refute Bio-Test estimates of minimal environmental damage.

Thank you.

(Dr. McNaught's presentation follows in its entirety.)

THE POTENTIAL EFFECTS OF CONDENSER PASSAGE ON THE ENTRAINED ZOOPLANKTON AT ZION STATION

By Donald C. McNaught

I am Donald McNaught, Associate Professor of Biological Sciences at the State University of New York at Albany. Previous to the four years I have been in this position I was Assistant Professor of Zoology at Michigan State University. I hold B.S. and M.S. degrees in Fisheries Biology from the University of Michigan and a Ph.D. from the University of Wisconsin in Zoology (limnology). Attached hereto is a complete list of my professional experience, awards, memberships in professional societies, and publications.

My own studies have included an investigation of the zooplankton of Lake Michigan, beginning in 1964. More recently we have been examining zooplankton production in Lake Ontario, with emphasis on the effect of waste heat on such production (see publications listed in vitae).

The Commonwealth Edison Company has invited me to present this statement and I welcome the opportunity to express my views regarding the potential effects of condenser passage on zooplankton, specifically as we predict for the Zion nuclear plant.

The Problem

Zooplankton constitute a portion of the ecological basis for fish production in Lake Michigan. To seriously reduce the production of zooplankton would be to interfere with fish production. However, it is obvious from investigations by personnel from Industrial Bio-Test that zooplankton mortalities during condenser passage never approach 100% and are, in fact, usually closer to 10%, even following return to ambient temperatures for 24 hours to illustrate the insignificance of delayed mortality.

Results of Waukegan Studies

Estimates of zooplankton motility, used as an indicator of survival, were made following condenser passage, as well as at 4 and 24 hour intervals, so as to estimate either recovery or later death. Effects of condenser passage were examined at a maximum Δ T of 12 - 13 ^{o}C to imitate passage at Zion, as well as a normal Waukegan Δ T of 4.5 - 9.5^{o}C. Furthermore, mechanical effects of passage were separated from thermal effects by pumping water and sampling at the discharge when the plant was not operative.

Zooplankters passing through any condenser and associated pumps suffer both mechanical and thermal stress. For the period of the Waukegan study, 0.7 $\pm$ 3.0% of entrained zooplankton suffered immotility due to thermal stress, while 6.5 $\pm$ 4.2% were rendered immotile due to mechanical abrasion (Fig. 1).

While those who have not carefully examined the effects of condenser passage might assume increased Δ T's to be the critical factor, it is now obvious that mechanical abrasion is the most important cause of immotility, accounting for the mean of 6.5% mentioned above. Mechanical effects fluctuate seasonally, likely with changes in species composition and size. The number of immotile organisms resulting from abrasion and other factors was less than 3.1% (± 4.5) from May to August when copepod nauplii and small caldocerans were abundant. Immotility due to mechanical effects increased to 7.2% from September to January when larger cladocerans (<u>Daphnia</u> and <u>Diaptomus</u>) and copepods predominated. When the large relict copepod <u>Limnocalanus</u> <u>macrurus</u> appeared, mortality due to mechanical abrasion jumped significantly ($P < 0.05$) to 11%. Thus one important challenge for the future will be to construct pumps and condensers to reduce this mortality resulting from the mechanical effects we have observed.

Tests at Waukegan illustrate clearly that a second effect of condenser passage, immotility from thermal stress, does not significantly increase with the Δ T across the condenser. If an animal is warmed but remains below its lethal temperature, it doesn't matter if it is warmed 5.5°C (9.9°F) or 12.5°C (22.5°F) above ambient. Approximately 7.2 ± 2.3% of the zooplankton are rendered immobile at a Δ T of 5.5°C, while 7.7 ± 3.5% are immobilized at a Δ T of 12.5°C. That is, the increase in temperature change (Δ T) is not harmful as long as discharge temperatures do not surpass the upper lethal temperature. It is not expected that Zion discharge temperatures will exceed lethal limits; if this is the case it doesn't matter to the zooplankton whether the Δ T experienced is 5°C or 12°C.

Thus we have examined two basic concepts. First we have illustrated that mechanical effects are minor, leading to mortalities of about 6.5% of zooplankton passing the condensers. Secondly, thermal effects are even more insignificant, causing immotility in 0.7% of animals. Now we want to examine the seasonal aspects of condenser mortalities of zooplankton.

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Thus far we have discussed immotility as a measure of mortality. However, all immobile organisms leaving the discharge do not perish. We have demonstrated a total immobility of 7.2%, based on animals observed immediately after passage. But after 24 hours, less than 6% are immobile indicating a decrease of 1.8%; that is, 25% of the organisms initially immobilized have recovered after 24 hours.

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Table 1. Calculation of loss of zooplankton in condenser waters from Zion plant.

1.)	Mean yearly biomass of zooplankton, grams per meter^3 dry-weight	.116 gm/m^3
2.)	Mean yearly biomass of zooplankton, pounds per gallons X 10^6	1.0 lb/gal X 10^6
3.)	Zion Capacity: 1.5 X 10^6 gal/minute or 7.88 X 10^{11} gal/year	
4.)	Dry-weight zooplankton per year	7.88 X 10^5 lb.
5.)	Wet-weight zooplankton per year (dry-weight X 20)	1.57 X 10^7 lb.
6.)	Wet-weight zooplankton immobilized (7.7% of total) per year at Zion	1.21 X 10^6 lb.

Review of Literature Concerned with Effects of Condenser Passage

A review of the literature reveals relatively few controlled studies of zooplankton mortality in condenser waters. It appears that students of thermal effects have not determined precise mortality curves (TL_{50}) for zooplankton. However, it is important that results reported in the literature tend to support the results of Bio-Test investigations.

Casual observations of the conditions of zooplankters following condenser passage suggest strongly that an increase in temperature alone has little effect on survival. Flemer *et al*. (1971) found only slight mortality of 10% for one copepod (*Eurytemora*). Staining techniques were used to tell live animals from dead. Adams (1968) quoted Dryer and Benson, who found no significant changes in numbers of zooplankters in the discharge of the Johnsonville (Tenn.) steam plant. Protozoans are an important component of many aquatic communities. Lorton et al. (1971) discovered that condenser passage does not reduce the diversity of protozoan populations.

It is not known how many observations of mortality due to temperature are effected by compounding factors. Mihursky (1969) has observed at the Chalk Point fossil fuel plant that copepods (as Acartia) are particularly susceptible to chlorine; temperature increases accompanied by chlorine injections often cause 100% mortality.

In a rather careful study Heinle (1969) has observed that the upper thermal limits for marine zooplankters are near their natural summer thermal maxima. This observation may explain the Bio-Test results previously discussed.

Comment on AEC Draft Environmental Statement and EPA Reply

Certainly the most recent results from intensive Bio-Test investigations at the Waukegan station are inconsistent with the Draft Environmental Statement of the AEC, which suggests a 15 - 30% kill at Waukegan, with a 100% kill most likely for invertebrates. In intensive studies at Waukegan, investigators at Bio-Test have predicted that Zion will experience a kill of 7.7 ± 3.5%.

Likewise, these same Bio-Test investigations refute the EPA comments ("Environmental Impact Statement Comments: Zion Nuclear Power Station Units 1 and 2", dated August 1972, EPA, Washington, D.C.)

to the effect that excessive losses of fish-food organisms will occur if intake velocities are not reduced to 1 foot per second. It is highly unlikely that reduced intake velocities would, in any way, reduce these already low levels of likely zooplankton mortality.

Future Investigations at Zion

I feel that it is vital that the Commonwealth Edison Company examine the effects of condenser passage on zooplankton once the Zion plant is operative. Such investigations will support or refute Bio-Test estimates of minimal environmental damage.

REFERENCES

Adams, J. R. 1969. Ecological investigations around some thermal power stations in California tidal waters. Ches. Science, 10(3/4):145-154.

Flemer, D. A., D. R. Heinle, R. P. Morgan, C. W. Keefe, M. C. Grote and J. A. Mihursky. 1971. The effects of steam electric station operation on entrained organisms. In Postoperative Assessment of the Effects of Esturarine Power Plants. Ches. Bay Lab. Ref. # 71-24a, pp. 1-17.

Heinle, D. R. 1969. Temperature and zooplankton. Chesapeake Science, 10(3/4):186-209.

Lorton, E. D. and J. Cairns. 1971. A preliminary report on the effect of simulated passage of potential colonizing protozoans through the condenser of a steam electric power generating plant upon downstream protozoan community development. Revista de Biologia, 7(3/4):215-227.

Mihursky, J. A. 1969. Patuxent thermal studies. Summary and recommendations. N.R.I. Special Report 1:1-20.

MR. FELDMAN: Dr. Raney.

STATEMENT OF DR. EDWARD C. RANEY,
PROFESSOR OF ZOOLOGY, EMERITUS,
CORNELL UNIVERSITY,
ITHACA, NEW YORK

DR. RANEY: My name is Edward C. Raney. I am Professor of Zoology, Emeritus, Cornell University, and Director of Ichthyological Associates, Ithaca, New York. I hold the Ph.D. Degree in Zoology from Cornell University. My specialty is the study of ecology, behavior and systematics of fishes. Details of my qualifications in the field of ichthyology and aquatic ecology were submitted to the Four-State Conference held in September 1970 when I made a presentation entitled "Heated Discharges and Fishes in Lake Michigan."

Since I appeared before this conference in 1970, I have continued to make and direct literature and field studies related to heated discharges and fishes. You may recall, in 1969 we published a bibliography of 470 pages which included 1,870 references dealing with this subject. Continued search in the last 3 years has produced more than 2,200 additional references which will be available shortly as a computer printout.

Parenthetically, I noted that earlier some of the younger people have spoken and mentioned that there really wasn't very much known. I think that there is a great deal that is known, but you have to know where to go and find it, and we assume that these bibliographies will be used by these people who really want to get at the truth.

Field studies of aquatic habitats, including reservoirs, rivers and ocean with reference to present or potential heated plumes have continued in the eastern United States. I have either advised or have acted as director of projects on the Connecticut, the Hudson, the Delaware and the Susquehanna Rivers, the upper Chesapeake Bay, the Chesapeake and Delaware Canal and the Atlantic Ocean off New Jersey. Personnel of Ichthyological Associates have undertaken a series of experimental studies which include determination of swim speed and stamina of fishes, swim speed and guidance capacity of ocean fishes off southern California, laboratory experiments dealing with temperature preference of fishes and their temperature avoidance or attraction, and shock experiments. Similar experiments on preference, avoidance and attraction for a number of chemicals and chemical bioassays are continuing. The results of these studies have furnished insight with regard to the potential problems in Lake

Michigan near Zion.

During the past 2 years I have conferred with biologists and others associated with Commonwealth Edison, and have had an opportunity to make suggestions and read progress reports of studies being done off the Zion and Waukegan plants by Industrial Bio-Tests Laboratories, Inc. Particularly I have consulted with Peter H. Howe, Biologist, Commonwealth Edison, Dr. Robert G. Otto, who has been doing experiments on temperature preference of fishes found in Lake Michigan and have seen reports by and conferred with Michael C. Cochran of Bio-Tests who has studied fish populations in southwestern Lake Michigan.

In my presentation made before this conference in September 1970, I discussed the history of the fish populations of Lake Michigan and generally discussed temperature requirements of fishes, preferred temperature, lethal temperature, winter temperature, avoidance temperature, and made a number of predictions regarding behavior of fishes and the effects on fish populations in reference to the Zion plume.

In this presentation, I will attempt to bring you up to date with regard to the studies which have been made which will help in explaining my position in regard to what some environmentalists have thought would be a serious

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problem.

Great changes have occurred in Lake Michigan fisheries over the past 25 years. Many of the changes accompanied the introduction of the landlocked form of the sea lamprey, the alewife and the smelt. The major changes in fish populations were not associated particularly with the industrial activities of man but were mainly as a result of the interaction of fish species. At times and with some species, commercial overfishing may have been important. Monumental efforts appear to have brought the populations of lamprey under control. Recently other species such as the coho, chinook and kokanee salmon, which are native to the Pacific Coast, were introduced, and in 1972 the Atlantic salmon was introduced. The stocking programs also involve the lake trout and other trouts.

I have included a short section on fish stocking in 1972 but in view of the lateness of the hour, I think that I will skip that because it is mostly of general information.

I think also that I will skip reading the section that I have prepared with regard to recent fishing in Lake Michigan.

I just might say that fishery biologists are attempting to bring Lake Michigan back to a state where it will be worthwhile as a sport fishery. It seems highly unlikely that it ever will be important as a commercial fishery in the future, but that remains to be seen.

We go next to a discussion of the fish fauna in the Zion area, or in the area of the Zion plant. Studies were made by personnel of Industrial Bio-Test Laboratories, Inc. of fishes which occur in the Waukegan-Zion area. During the period from April through December 1971, those captured include the alewife (66.8 percent) by weight, lake trout (12.4 percent), rainbow smelt (10.8 percent), and bloater (6.1 percent). Fishes taken occasionally included brown trout, lake whitefish, yellow perch, carp, white sucker, chinook salmon and coho salmon. Those which were considered scarce were slimy sculpin, lake herring, goldfish, spottail shiner, rainbow trout, brook trout, longnose sucker, emerald shiner, trout-perch, golden shiner, longnose dace, ninespine stickleback, mud minnow, and johnny darter. Other species taken rarely in the area include spoonhead sculpin, mottled sculpin, emerald shiner, lake sturgeon and whitefish.

I pointed out in my 1970 presentation that a section of Lake Michigan cannot be all things to all fishes at all times. In other words, the distribution of species changes daily and with season. Much of this change appears

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to be associated with the preferred temperature of the species, but other variables are involved such as daily migrations, either vertically or inshore-offshore, the presence and abundance of food organisms and the necessity for finding suitable spawning substrate.

The inshore waters (that is up to possibly 20 feet in depth), we find, is an inhospitable environment in the winter when water temperatures approach 32° F. and other factors such as bottom scour with high winds are adverse.

Off the Waukegan-Zion area, Bio-Test has found alewife in all months of the year except December. Smelt have been found during all months. However the abundance may vary with species from month to month and place to place within the study area. The lake trout is usually found in water 30 feet or deeper. I am talking now with reference to the Zion plant. The coho salmon appears to be in the area mostly in June. Alewife, smelt and carp seem to spawn to a moderate extent in the area. And parenthetically I have information recently from Bio-Test that they have found some slight evidence of spawning of yellow perch.

For Lake Michigan there is no lack of suitable spawning substrate and nursery for these species. We are talking now about Lake Michigan as a whole. The yellow perch has been scarce in recent years. Ultimately it may

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be found to spawn in the Zion area, as it, in fact, did this last year. None of the large important fishes appear to spawn in this area. For some such as the lake trout the type of spawning substrate which is needed is a hard substrate -- either rocks or hard clay -- and this is absent or very limited.

Fishes which are known to overwinter in the deeper water offshore, such as alewife, bloater, smelt, salmon and trout, undertake spring migrations into the shallows. Actually this may be spring or early summer. The reverse type of migration was noted for the slimy sculpin, which, incidentally is used as food for the larger salmonid fishes.

The heated plume from the Waukegan discharge has attracted, at various times, young alewives and several species of minnow, including the carp.

Water temperature in the depths offshore was more stable than those of the inshore waters during the period from April through December 1971. However in the deeper water, fluctuations during a month may be as much as 5.4° F. The water temperature is basically the same even in the deeper water. This is in a 90-foot depth.

Water temperatures, as measured from north to south, in the shore zones were similar but they had

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variations up to approximately 3.6° F. I just want to emphasize here that you don't have constant temperature, the temperature can vary from top to bottom, from place to place, from time to time, and certainly with upwelling, which is a matter which Dr. Pritchard discussed briefly.

I would like to reemphasize -- and it is very important -- my 1970 testimony that small differences in temperature, including those up to 5° F., have little or no ecological significance to fishes found in temperate regions.

The thermal plume at Zion and its relation to fishes: The design of the cooling water system with a submerged jet, as described by Dr. Pritchard in April 1970, is such that the area inside the 5° F. isotherm is less than 6 acres. I get back to my contention which is supported by numerous field observations and by laboratory experiments that up to the 5° isotherm is not particularly significant. But we might say that within 5° or higher, we have about 6 acres. So that, basically, when we say this area would be denied the fishes at the Zion plant -- now, it is denied not only because of temperature, but because of velocity. In other words, the jet design is such that a fish, in order to get inside the 6° isotherm would have to swim at approximately 4 f.p.s. Some large salmonid fishes can do this

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easily enough, but it is highly unlikely that they would swim against this high velocity at the same time they would be going into a higher heat. We have some evidence from experimental evidence on this point.

So, then, I reemphasize, it is obvious that only a few acres would be denied to fishes by this combination of high temperature and high velocity. Now there is a very great advantage to this system of having a high jet because kills which have been known to occur because of high temperature alone are highly improbable in this situation, because the fish would have to be swimming into very hot water at a very high speed, and our experimental evidence is that they know that the water is 5° or 6° and they turn around and get out of there. It is basically like, you know, walking or running into a shower.

Basically, heat kills are a very rare occurrence when you consider all powerplants in the temperate regions of the world. In a few cases, there have been kills, as has been pointed out here earlier today. Most of these have had to do with long discharge canals. That is a very important point.

The Oyster Creek kill of last winter was mentioned. Two of my people happened to be there at the time the kill occurred. The water temperature dropped from approximately

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70° F. to approximately 36° F., and a lot of fish were killed. A lot of the fish continued to live in the area and were not killed. They fed on the dead fish. We made some estimates of the poundage of menhaden that were killed and we estimated it might be about what an ordinary, successful commercial fisherman off New Jersey might catch in a half hour.

Another thing that I think should be put in perspective, which was mentioned earlier, was the kill at Brunner Island. It is located on the Susquehanna River.

The water temperature in the canal, again, was 80°. Through a misfortune in operation, one of the pumps continued, and in any event 36° of water was pumped into 80°, and the 80° water very quickly cooled, and the concentration of fishes in this canal were killed.

However, we estimated -- and a chap who works for me happened to be fishing there that morning, so we have very good data on this -- that maybe a third of the fishes were killed. It has been estimated that maybe 15,000 game fish were killed. Most of these were small. The company paid something in the order of $12,000 for this damage, and the State got a bargain. It was a political bargain. The fish people working for the State of Pennsylvania obviously had to get something because there was a great hue and cry.

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However, this particular place is the only place that you can fish along the Susquehanna in winter. It is a great sport fishery for muskellunge and bass, and has been for the last 20 years.

The point here is that these kind of kills that are overemphasized, as I think they were this morning, are basically not significant in an ecological sense, and in most cases, these heated plumes add very significantly to sport fishery.

Now, what about Zion? The situation for a winter kill does not, in my opinion, exist at Zion even if fishes are found in the heated plume during winter. Why is this? That outside the 5° isotherm, or inside the 5° isotherm, you will have velocities of 5 or 6 f.p.s. Outside the 5° isotherm you may have a concentration of fishes -- if you drop below, what are you going to get? You are going to get a drop of 5°.

Now, our experimental evidence over and over again, with 30 different species of fish -- and I could cite you evidence that was given here earlier by Mr. Barber of 8° or more that it takes to cause a fish kill of coho salmon -- it is highly unlikely that we would ever get a winter kill in the plume at Zion.

Now, a few words about the movement of fishes in

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relation to plumes. Field observations and experimental data indicate that a species of fish which is acclimated to a given water temperature may move toward or away from a higher or lower temperature, depending upon its preferred temperature. This preferred temperature will vary with the acclimation temperature; the acclimation temperature varies through the year.

Now, this has been illustrated by the results of many experiments done since my last presentation and, as Dr. Pritchard mentioned, I think this is one of the real significant contributions that we have been able to make to the literature. These results are published for estuarian fishes. Further tests are under way, at the present time, by Bio-Test and will be available shortly.

Fishes found in Lake Michigan may be divided roughly into three groups. The so-called cold water fishes include the trouts, salmons, smelt, bloater, whitefish, ninespine stickleback, and slimy sculpin. These fishes all have preferred temperatures of something in the fifties or maybe low sixties.

Then we have a group which we call warm water fishes. These, in the Zion area, include fishes like the large mouth bass, spottail shiner, central mudminnow, carp, mottled sculpin, and white sucker. Also in the Zion area,

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we have an intermediate group which, for want of a better term, you could call cool water fishes. These include the alewife and the yellow perch. The smallmouth bass, which is not very common in this area and, as a matter of fact, I don't think it was taken by Bio-Test but ultimately will be, I am confident, and the burbot, which normally is a deep water fish, might be classified as intermediate. In other words, smallmouth is somewhat intermediate in its preference for warmer water, and the burbot is intermediate in its preference for cold water. So that the basic point here is that each of these fish has its own preferred temperature.

Now, all of these fishes may live in winter with temperatures that are as low as 32° to 40° F. It is very important to remember this, however: that all can tolerate this range, but none of them prefer it, if other temperatures are available, and most importantly if there is a drainage leading to a higher temperature. In other words, there may be a lot of heated plumes in a given lake, but unless there are gradients leading into those heated plumes, the fish have no way of knowing this.

Now, in Lake Michigan, during the summer, the inshore waters and the upper layers -- surface layers -- are warmer than is the deep water which is essentially 40° F.

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The distribution of the fishes in spring and fall depend in large part on preferred temperature. They are usually found fairly within a range of temperature close to their preferred temperature. Now this position may be quantified to some extent by the previous temperature experience or its acclimation and other factors such as water current, oxygen -- which is not an important factor in Lake Michigan because the water is mostly saturated -- availability of food, and availability of spawning substrate.

The behavior of fishes in Lake Michigan toward a heated plume is predicted to be basically the same as their reaction to the water in the lake as it changes with season. There is nothing strange and mysterious about this, and biologists have recognized this for 100 years. The behavior of fishes of Lake Michigan toward a heated plume is predicted to be basically the same as their reactions to the water in the lake as it changes with the season. Because they are able to discern very small changes in temperature, they move toward their preferred temperature. However, if the change in water temperature is too great, they may stop or move away from the higher or lower temperature until a degree of acclimation is reached. These reactions have been noted over and over again, I am told,

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by myself, and it has been demonstrated by experiments recently by Drs. Meldrim and Gift in our tests at Delaware Laboratory.

For example, we worked on 30 species of fish in this connection but, for example, you take specimens of the largemouth bass which is classified as a warm water fish, and we did, and we acclimated them to 77° on July 8. They were given a choice of higher temperatures. They avoided a temperature of 87° F. In other words, they went up toward a preferred temperature; when they got to 87° they backed off.

On July 16, at the same acclimation temperature, 77° F., they were given a range of higher temperatures, they backed off when it was 91°.

Another example: The yellow perch, which may be classified as a cool water fish, although it goes in its natural range as far south as South Carolina -- after having been acclimated to 77° on July 13, it avoided 93° water. And on July 21, when acclimated to 77°, it avoided 92° water.

In other words, they go up into or toward this heated water and when it gets too hot for them they turn around and they get out. And this is in accord with observations that have been made over and over again at thousands of different plants in the temperate regions of the world

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involving several hundreds of species of fish.

When we get to the alewife, which I view with mixed blessings, as I think some of you do, in the lake -- obviously it is a very important sports fish and also it is a damned nuisance.

We have done a series of experiments on the alewife, and normally it is classified as a cool water fish. Although the sea-run alewife, of course, lives in rivers during the first year of its life and it goes back to sea where it lives 3 to 4 years before returning to fresh water rivers in order to spawn.

We took alewife acclimated to 77° and tested them. They avoided water of 86°. I think these temperatures are higher than we are going to see in Lake Michigan at most times, but these are mere illustrations of an important point.

On October 21, those acclimated to 64° avoided water at 76°; and on November 3, those acclimated to 63° avoided water of 79°.

The important point here is: the avoidance temperature or the attraction temperature can vary with the acclimation temperature.

Now the important thing to remember is illustrated by data from these same fishes. For instance, in August,

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we took six specimens of alewife, acclimated them to 77° for 48 hours, introduced them into an experimental apparatus where the water temperature was 74°, and they were offered two alternatives: 74° or 82°. Well, what do you think they would do? They proceeded to the area and occupied the water that was 82°. Well, after a short period, these same six specimens were introduced into a similar experimental tank where the water temperature was 80° but where the alternative temperature was 86°. What did they do? They avoided 86°. In other words, they moved away from it.

I have another experiment listed in the paper with similar results. I won't repeat it.

I go into the matter of final preferred temperature and give a table showing the final preferred temperature of some of the fishes which occur in Lake Michigan, but I am not going into a further discussion of that except to say a few words about the plume and the behavior of fishes toward the plume, as I predict them, based upon what I have seen, as I say, over the last 35 years in temperate regions.

The plume will vary in temperature with the seasons. During the summer it will be attractive to warm water fishes provided they come into contact with a gradient which leads to it.

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In the plume adjacent to the Waukegan discharge during the summer, fishes classified as warm water and some cool water species have been found.

Now, I have predicted with regard to the plume in the Zion area that during late fall, winter, and early spring, when the warmest natural water in Lake Michigan is close to 40° F., the so-called cold water fishes which prefer water in the 53° to 63° F. range may be found around the periphery of a heated plume. However, they would be found there only if their inshore-offshore migrations were such that they had an opportunity to sense the gradient leading to the plume. This should allay the fears of some who might think that all of the salmonid fishes that are in the Zion-Waukegan area are going to pile into that heated water in the winter. It does not work that way in other places that have been observed over and over again, including stations on Lake Michigan.

It is predicted that the heated plumes from all large plants on Lake Michigan will produce plume conditions that will concentrate game fishes in areas where they may be more readily taken by anglers. This has been the almost universal experience around the world in temperate regions, and I regard this as one of the pluses for a large plume. If you want to go fishing in the fall or the spring, a very

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good bet and an easy place to find them is a heated plume, and any place that you go in the temperate regions before the ice comes or goes, you could see people fishing in this area.

Now, the matter of avoidance of plumes: Some people like to work on lethal maximum temperatures of fishes. It has no meaning as far as motile organisms are concerned -- in particular fishes with relation to the Zion plant -- because they are inappropriate to predict the effects when a fish comes in contact with higher temperatures, because motile organisms can and do react. In other words, they behave. If the water is too warm for them, they avoid it; if it is toward their preferred temperature, they will enter it.

So a far more appropriate measure for fishes is the upper avoidance temperature, and these experiments are under way now by Bio-Test with the fishes that occur in Lake Michigan. The Ichthyological Associates have also done enough experiments on temperate fishes that we know and can predict what the effects would be.

Now, if we go into the literature just briefly -- and, as I say, so far in this field, I have studied more than 4,000 references that have had to do with this subject. I just point out a few of the results.

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The effects of a heated reactor on -- or of a heated effluent was studied at Hanford on the Columbia River. Now, the plant at Hanford has been in operation for 25 years or more. The heated plume goes to the center of the river which, quite by accident, was a good place to put it, because salmon and trout, when migrating, take their clues from along shore. On the other hand, shad, eastern fish migrate in the channel.

Over that 25-year period, there were no thermal kills of any significance observed according to the review by Nakatani (1969). Charles Coutant, whose name was taken in vain, I am sure, by someone this afternoon, also worked out there for several years. He drifted young chinook salmon, which is a species that we have here, through the heated effluent at Hanford, where as I recall the Δ T is something in the order of 20° to 25°. And the heated effluent produced no direct or latent mortalities. However, the upper temperature was only 77°, which does not exceed the lethal limit for chinook salmon.

In England, Alabaster made studies of fish mortalities for 20 years. In 1969, he reported that, based upon field and laboratory experiments, kills are extremely rare and insignificant in the population sense. Now, I will get back to this later in connection with some of the -- I was going

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to say propaganda that we have had today about trout fishing.

Now, another very good example that I had the pleasure of being associated with, as far as the study is concerned, is the Connecticut River. The Connecticut Yankee plant, which was referred to this afternoon, has been in operation for about 5 years. Studies have been made in depth in those 5 years and for the 2 years preceding the operation of the plant, and there is a very extensive heated plume there.

We have been able to find no evidence -- and we have a lot of evidence -- no evidence of any harmful effect, either on resident or anadromous species.

Now, in summary, much of the sport fishery for large species is based on stocking. It is slow. Much of this work is done out of Ann Arbor. Their labor sometime will be productive and we will return ultimately to a case where we nave a natural population of lake trout.

I have lived on Cayuga Lake for the last 40 years. Cayuga Lake is a minor edition of Lake Michigan, and we have lake lamprey and have had them since the ice went out 12,000 years ago, and we don't have a very good lake trout fishing and what we do have is based upon stocking. So I think you can expect probably what is going to happen if you want lake trout is to continue to stock. I hope not. I

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hope we have licked the lamprey problem. In the natural experiment over 10,000 years it was not licked in Cayuga Lake nor was it licked in Seneca Lake, which is another small edition of Lake Michigan.

There is little or no spawning of lake trout and other sport fisheries in the Zion area. Now, this is based upon several years work by Bio-Test.

There are no tributaries that serve as a spawning area for large salmonid fishes which occur in the Zion area. I am thinking now of migratory species such as the coho, chinook, sockeye salmon, that is called -- lacustrine samples which are called kokanee, and the newly-introduced 1972 Atlantic salmon.

You see basically what you have in Lake Michigan now is nothing like your original fishery. You are dealing with a bunch of fish that have been brought in and hope springs eternally and I do, too. I hope it is successful.

Now, most organisms, including fishes, because of the Zion plant, will be denied a very small area close to the heated outfall. We admit this -- up to about 6 acres are going to be denied. However, even during the worst summer conditions, the isotherms produced by using the jet effluent indicate that outside a very small mixing zone of approximately 5 or 6 acres most summer temperatures

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would be below the upper lethal limit for the fishes and associated organisms normally found in the Zion plant area in the summer.

Another important point: The shallow shore area located near the Zion plant will not be blocked by temperature increase, and the fishes which are normal inhabitants of the habitat close to shore during the summer will be unaffected, in my opinion.

Now, one of the things that people like to talk about is the subtle effects in putting fishes under stress. Well, most fishes most of the time are under one kind of stress or another and, as one of the speakers this afternoon mentioned 12 or 13 kinds of things that, if these things happen bang, bang, bang, you will have no more fishes. Well, you would have to have that happen over and over and over again. In the Connecticut River, in the Hudson River and the Delaware River -- and I can take you places in the Delaware River where this has happened now 150 years, where you get 100 species of fish.

So that my point is that even under very critical conditions, near the Zion plant, I predict that the fishes will not be put under stress, that will make them more susceptible to the predations of gulls or other predators that might be present, with very few exceptions.

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The area near Zion, in summary, is not a unique spawning ground for anything; it is not an important spawning ground for any of the large salmonid fishes, and except for a few acres, if it were, if by chance fishes chose to spawn there, they can do so seasonally without interruption. I predict that there will be no permanent reduction in species diversity by reason of having these heated plumes in the lake, including that at Zion. As a matter of fact, you are going to increase the diversity of fishes because you are going to increase the potential number of habitats that you will have. And as far as down-to-earth utilization of resources, if you believe in using these things for the good of man, I think that things will be improved.

One of the kind of things that you must always realize when we are dealing with fishes is that they are subject to great variations in year-class strata. You may get one yellow perch year-class, which might arise from very few spawners, which would produce enough young to practically fill the lake. These fluctuations in year-class are a natural phenomenon. They will always be with us. We are going to get variations from year to year. This is one of the reasons that it makes base line studies so hard to do; this is the reason they need to be done over such a long period of time.

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I am asked quite often by utility executives and others: How long do you need to study it? As long as you can; 10 years or more. There are a lot of young biologists at work.

One of the concerns that has been expressed from time to time is that the heated plume from Zion might have an effect on the pier fishing for yellow perch in Lake Michigan, and pier fishing in other areas. This is utter nonsense. As compared with the year-class fluctuations, the natural occurrence in the Delaware River, any possible effect from the Zion plant would be miniscule.

Few eggs and larvae of fishes have been found in the area. However, even with the utilization of this area as it might sometime be, as a spawning ground, most of the fishes will spawn in this area -- all of the salmonid fishes, all of the centrarchid fishes, sunfishes and bass, lay adhesive eggs that are emersive -- that is heavier than water -- and it is highly unlikely that these fishes would pass through a condenser system.

All right. What if they do? Fishes vary in their capacity to stand this trip not only as far as the temperature is concerned but because of turbulence, abrasion, and pressure changes. Some are more sensitive than others.

One of the speakers this afternoon, without

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knowing very much about the background of the study, indicated that at the end of a long canal, the Connecticut River, all of the alewives and blueback herring were basically dead -- and these were larval herring, basically a half an inch long. This is absolutely true. But immediately after the passage through the condenser, only about 30 to 35 percent of them were killed in various tribes. And we find in our experiments on the Delaware that this is one of the most sensitive of all larvae -- the clupeid larvae.

Now I assume that the alewife larvae will be there, and I assume that in many cases this will probably be a blessing. I mean I would regard this as a plus if some of these alewife larvae were so locked; they will be utilized in the plume as food providing fishes are there.

Now what about fishes that are a little bit bigger? Well, we hope that the chinook salmon will spawn in the lake by the third year, but there isn't much chance that this will come about, but we will assume that they do.

Now chinook salmon were tested back in 1950 out on the Pacific Coast condenser passage, and it was found that they pass through a condenser system which is not unlike that one at Zion, with 95 percent or more survival 10 days after the trials were over. They actually were passed through the condenser system. These were not simulated experiments.

Two final points, in summary: Sudden changes in temperature when Zion drops load in the winter will not because of the jet discharge cause mortalities of fishes. This has occurred in other places like Oyster Creek, which I mentioned.

Finally, because of the heated plume, the sport fishery is expected to be extended in the fall and spring.

Now, many speakers today have talked about intakes and the proper design of intakes is a very serious matter. I have been involved in consulting on intake structures for some years. I have had a chance to look at what has been designed in connection with Zion.

A net is going to be placed in such a position around the intake that the velocity will only be 0.29 f.p.s. -- a very low velocity. This, I predict, will keep the large fish out. It is a one-inch mesh net.

Smaller fish will no doubt pass in and go into the forebay. Now the problem of what to do with the fish that get in there is under study. There are various types of screening systems that are being studied. We know that a product can be developed which will guide these fish to a given place where they can be lifted out using an elevator, or they can be pumped out in a food-handling

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pump.

Commonwealth Edison will be on top of this problem; we are studying it. They are aware of what is going on in the rest of the country, and if there is a problem here, I feel confident that we can solve it.

One final remark has to do with some of the data that we heard about this afternoon, taken out of context: Does a fish kill damage the population?

Now, I think that some of my colleagues in biology would say: Well, you know, if the bass bluegills get out of balance in my farm pond, what do I do? I go in and drain the pond; I kill them all off, and I start all over again.

The same thing happens in rivers. Now, a speaker this afternoon referred to the fact that 100,000 white perch would be killed in a day in the Hudson River on the screens at Indian Point, and this is true. It did happen. That situation is being improved by new structures that are going to be -- that are being developed and will be put in there.

However, and in my opinion -- and I worked on the Hudson River for more than 25 years -- I think if it would kill 100 million white perch, that the other 100 million that are in there -- a 100 million plus or minus -- would do a lot better. Why? Those that are in there now don't do anything. In other words, they are stunted; they are runts; they are stinkin' small fish that at an age of 7 or 8 years are only 5 inches long. These are good for nothing; they are good to nobody; they compete with the striped bass which is a noble fish. So please remember when you are talking about fish kills, these should be avoided at all costs because of public relations, but not necessarily because of the good of "a" population.

I see my counselor is giving me the signal. (Laughter) He warned me long ago, and I speak too long.

MR. FELDMAN: Mr. Mayo, the last two presentations deal with cooling towers and their blowdown and both Mr. Butler and Dr. Lee are prepared to summarize their statements. I think it will not be long.

(Dr. Raney's presentation follows in its entirety.)

REMARKS ON HEATED DISCHARGES AND FISHES IN SOUTHWESTERN LAKE MICHIGAN IN THE VICINITY OF THE ZION NUCLEAR POWER STATION

by

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This document was prepared for presentation to a meeting of the Four State Conference to be held in Chicago, Illinois September 19-22, 1972. This statement is presented on invitation by the Commonwealth Edison Company, Chicago, Illinois. The observations, opinions and conclusions presented herein are mine and do not necessarily represent the views of Commonwealth Edison Company.

QUALIFICATIONS AND EXPERIENCE

My name is Edward C. Raney. I am Professor of Zoology, Emeritus, Cornell University, Ithaca, New York and Director of Ichthyological Associates, Ithaca, New York. I hold the Ph.D. degree in zoology (1938) from Cornell University. My scientific specialty is the study of ecology, behavior and systematics of fishes. Details of my qualifications in the field of ichthyology and aquatic ecology were submitted to the Four State Conference held September 1970 when I made a presentation entitled "Heated Discharges and Fishes in Lake Michigan."

Since I appeared before this conference in 1970, I have continued to make and direct literature and field studies related to heated discharges and fishes. In I.A. we have continued the review of literature which appeared as a published bibliography in 1969 as "Heated Effluents and Effects on Aquatic Life and Emphasis on Fishes" (Ichthyological Associates Bulletin No. 2, 1969, 470 pages, 1870 references). Continued search has produced more than 2,200 additional references which will be available shortly as a computer print-out. Field studies of aquatic habitats(reservoirs, rivers and ocean)with reference to present or potential heated plumes have continued in the eastern United States. I have either advised or have acted as director of projects on the Connecticut, Hudson, Delaware and Susquehanna rivers, the upper Chesapeake Bay, the Chesapeake and

Delaware Canal and the Atlantic Ocean off New Jersey. Personnel of Ichthyological Associates have undertaken a series of experimental studies which include determination of swim speed and stamina of fishes, swim speed and guidence capacity of ocean fishes off southern California, laboratory experiments dealing with temperature preference of fishes and their temperature avoidance or attraction, and shock experiments. Similar experiments on preference, avoidance and attraction for a number of chemicals and chemical bioassays are continuing. The results of these have furnished insight with regard to the potential problems in Lake Michigan near Zion.

During the past two years I have conferred with biologists and others associated with Commonwealth Edison, and have had an opportunity to make suggestions and read progress reports of studies being done off the Zion and Waukegan plants by Industrial Bio-Tests Laboratories, Inc. Particularly I have consulted with Peter H. Howe, Biologist , Commonwealth Edison, Dr. Robert G. Otto who has been doing experiments on temperature preference of fishes found in Lake Michigan and have seen reports by and conferred with Michael C. Cochran of Bio-Tests who has studied fish populations in southwestern Lake Michigan.

PREVIOUS PRESENTATION

In my presentation made before this conference in September 1970, I discussed the history of the fish populations of Lake Michigan and generally discussed temperature requirements of fishes, preferred temperature, lethel temperature, winter temperature, avoidance temperature, and made a number of predictions regarding behavior of fishes and the effects on fish populations in reference to the Zion plume. In this presentation I will attempt to bring you up-to-date with regard to the studies which have been made which will help in explaining my position in regard to what some environmentalists have thought would be a serious problem.

FISHES OF LAKE MICHIGAN

Great changes have occurred in Lake Michigan fisheries over the past 25 years. Many of the changes accompanied the introduction of the landlocked form of the sea lamprey, the alewife and the smelt. The major changes in fish populations were not associated particularly with the industrial activities of man but were mainly as a result of interaction of fish species. At times and with some species commercial overfishing may have been important. Monumental efforts appear to have brought the populations of lamprey under control. Recently other species such as the coho, chinook and kokanee salmon, which are native to the Pacific Coast, were introduced and in 1972 the Atlantic salmon was introduced. The stocking programs also involve the lake trout and other trouts.

FISH STOCKING IN 1972

Information supplied by the Great Lakes Fishery Commission (Commercial Fisheries Review for May-June 1972, Nos. 5 and 6, pages 6-7), indicates some 18.5 million hatchery-reared fish will be placed in the Great Lakes in 1972. This will be about a million fewer than the 1970 stocking. Salmon will be released in all Great Lakes. The 9.7 million smolts or young salmon will include 4.3 million chinook, about 4.1 million coho salmon, over 1.3 million kokanee (which are lacustrine stocks of the sockeye salmon, Oncorhynchus nerka) and about 39,000 Atlantic salmon. The latter came from Quebec and were released in the Boyne and Ausable rivers in Michigan and in PikesCreek at Bayfield, Wisconsin. Nearly 5 million lake trout (the most since 1968) were planted in Lakes Superior and Michigan during the spring of 1972. The planting of lake trout began in 1958 in Lake Superior and at the same time, tributary streams began to receive lampricide treatment. Including those stocked in 1972 the 15 year total for Lake Superior will exceed 32 million. Most of the stock is yearling lake trout and is largely from U. S. hatcheries. Also stocked in the Great Lakes in the spring of 1972 were 3.8 million other trout which included brown, rainbow, steel and splake, The splake is a hybrid(lake trout-brook)trout. The rehabilitation of the lake trout fishery in Lake Michigan started in 1965 and plantings to date total more than 16 million.

Lake Michigan received nearly 10.3 million stocked fish in 1972. This included 2.9 million lake trout supplied by the U.S. Bureau of Sport Fisheries and Wildlife. The state of Michigan released nearly 5.3 million game fish in Lake Michigan. Wisconsin released about 1.8 million fish into Lake Michigan during the same period.

RECENT FISHING IN LAKE MICHIGAN

The following comments are modified after those attributed to Dr. Wayne H. Tody, Chief of the Michigan Department of Natural Resources, Fisheries Division. (See release of the Great Lakes Basin Commission entitled "New Developments in the Great Lakes Fisheries"). In Lake Michigan in 1972 the lake trout dominated the open water sports fishing catch during May and early June. Catches of lake trout 7 pounds or more were reported. The coho salmon fishing was exceptionally good in early spring. The peak is usually about Labor Day near the parent streams. The chinook salmon which is a species which is notably difficult to catch during its life in the lake, entered the southern Lake Michigan fisheries in markedly increased numbers in 1972. Specimens weighing 15 to more than 25 pounds were caught in the early summer and those of more than 40 pounds are expected in the fall runs. Runs of steelhead trout (rainbow) are entering suitable Michigan streams and Tody reports that rainbow and brown trout are found in many of the inshore bays. The yellow perch is increasing in numbers. It declined after the decrease in numbers of the alewife was observed after 1968. None of the above generalizations may be specifically applicable to the Zion area, but fishery biologists hope that salmonid fishes will utilize the alewife and other forage fishes such as the smelt. The expectation is that the sport or recreational fisheries will continue to improve but that commercial fishing, at least in southern Lake Michigan, will be greatly limited or non-existent except possibly for the alewife.

FISH FAUNA IN THE ZION AREA

Studies were made by personnel of Industrial Bio-Tests Laboratories, Inc. of fishes which occur in the Waukegan-Zion area. During the period from April through December 1971, those captured include the alewife (66.8%) by weight, lake trout (12.4%), smelt (10.8%), bloater (6.1%). Those taken occasionally included brown trout, lake whitefish, yellow perch, carp, white sucker, chinook salmon and coho salmon. Those which were considered scarce were slimy sculpin, lake herring, goldfish, spottail shiner, rainbow trout, brook trout, longnose sucker, emerald shiner, trout-perch, golden shiner, longnose dace, ninespine stickleback, mud minnow and johnny darter. Other species taken in the area at other times include spoonhead sculpin, mottled sculpin, emerald shiner, lake sturgeon and white fish.

I pointed out in my 1970 presentation that a section of Lake Michigan cannot be all things to all fishes at all times. The distribution of species changes daily and with season. Much of this change appears to be associated with the preferred temperature of the species, but other variables are involved such as daily migrations, either vertically or inshore-offshore, the presence and abundance of food organisms and the necessity for finding suitable spawning substrate.

The inshore waters (up to possibly 20 feet) is an inhospitable environment in the winter when water temperatures approach 32 F and other factors such as bottom scour with high winds are adverse.

Off the Waukegan-Zion area the alewife has been found all months except December. Smelt have been found during all months. However the abundance may vary with species from month to month and place to place within the study area. The lake trout is usually found in water 30 feet or deeper. The coho salmon appears to be in the area mostly in June. Alewife, smelt and carp seem to spawn to a moderate extent in the area. For Lake Michigan there is no lack of suitable spawning substrate and nursery for these species. The yellow perch has been scarce in recent years. Ultimately it may be found to spawn in the Zion area, but this remains to be demonstrated. None of the large important fishes appear to spawn in the area. For some such as the lake trout the type of spawning substrate (hard bottom) required is absent or very limited.

Fishes which are known to overwinter in the deeper water off shore, such as alewife, bloater, smelt, salmon and trout, undertake spring migrations into the shallows. The reverse was noted for the slimy sculpin.

The heated plume from the Waukegan discharge attracted young alewives and several species of minnow, including the carp.

Water temperature in the depths offshore was more stable than those of inshore waters during the period from April through December 1971. However in the deeper water fluctuations during a month maybe as much as 5.4 F (August to September at 90-foot depth in the Zion zone).

Water temperature at comparable depths at three north to south zones were similar and differences were normally 3.6 F or less. I reemphasize my 1970 testimony that small differences in temperature, including those up to 5 F, have little or no ecological significance to fishes found in Temperate regions.

THERMAL PLUME AT ZION AND FISHES

The design of the cooling water system with a submerged jet as described by Dr. Pritchard (April 1970) is such that at the area inside the 5 F isotherm is less than six acres. The jet is designed so that within the 6 F isotherm, the velocity approaches 4 fps. It is obvious that only a few acres would be denied to fishes by this combination of high temperature and high velocity. An advantage of the jet system is that no kills are predicted to occur because of high temperatures alone -- the so-called heat kills. Indeed such kills are a rarity in nature with reference to cooling water at any power plants except in situations with long discharge canals in which sudden and substantial decreases in winter temperature occur. Such a situation does not occur at Zion and indeed the time of entrainment of an organism as it passes into the condenser until it reaches the 5 degree isotherm is short (approximately four minutes). Because of the relative high velocity of the water within the 5 degree isotherm and because few fishes are predicted to be present in this area close to the jet, sudden shutdowns in winter will not cause mortalities (winter kill) of fishes. The maximum temperature decrease would be 6 F or less. Even if it were a 10 F decrease the experimental evidence with fishes indicates that this will not cause mortalities or undue stress. Under the jet conditions even if stressed a fish would quickly be carried out of the area of maximum temperature.

MOVEMENT OF FISHES IN RELATION TO PLUMES

Field observations and experimental data indicate that a species of fish which is acclimated to a given water temperature may move toward or away from a higher or lower temperature, depending upon its preferred temperature. This has been illustrated by the results of many experiments done since my last presentation.

Fishes found in Lake Michigan may be grouped with regard to temperature preferences into three groups. The so-called cold water fishes include the trouts, salmons, smelt, bloater, whitefish, ninespine stickleback and slimy sculpin. The contrast are those which prefer warm water such as large mouth bass, spottail shiner, central mudminnow, carp, mottled sculpin and white sucker. An intermediate group which prefer cool water include the alewife and yellow perch. The smallmouth bass and burbot may be classified with cool water fishes. However the smallmouth is somewhat intermediate in preference toward warm water while the burbot is intermediate in preference toward cold water.

All of the fishes listed above live, in some part of its range, in water where the winter temperature may vary between 32 and 40 F. or, all can tolerate this temperature range, but none prefer it.

In Lake Michigan during the summer, the inshore waters and the upper layers (epilimnion and thermocline) are warmer than is the deep water (hypolimnion) which is essentially 40 F.

The distribution of the various fishes in spring and fall depends in large part on the preferred temperature. They usually are found fairly within a range of temperature close to their preferred temperature. The position within this range may be modified to some extent by the previous temperature to which the fish had been acclimated, and other factors such as availability of water current, oxygen, food, and suitable spawning areas.

The behavior of the fishes of Lake Michigan toward a heated plume is predicted to be basically the same as their reactions to the water in the lake as it changes with season. Because they are able to discern small differences in temperature, they move toward their preferred temperature. However, if the change in water temperature is too great they may stop or move away from a higher or lower temperature until a degree of acclimation is reached. These reactions have been noted in nature and have been demonstrated by experiments by Drs. John W. Meldrim and James J. Gift (Ichthological Associates Bulletin 7).

For example, specimens of the largemouth bass which is classified as a warm water fish, were acclimated to 77 F on July 8, avoided a temperature of 87 F, while on July 16 at the same acclimation temperature they avoided 91 F.

The yellow perch which may be classified as a cool water fish, after being acclimated to 77 F on July 13 it avoid 93 F and on July 21 when acclimated to 77 F avoided 92 F.

Experiments with the alewife, which is classified as preferring cool water, show that the avoidance temperature may vary with the acclimation temperature. For example on 5 August specimens of the alewife acclimated to 77 F avoided water of 86 F. On 21 October those acclimated to 64 F avoided water at 76 F. On 3 November those acclimated to 63 F avoided 79 F.

A closer look at the same experiments illustrates attraction to a higher temperature. In August, six specimens of alewife were acclimated at 77 F for 48 hours. They were introduced into an experimental apparatus where the water temperature was 74 F, and they were offered two alternatives, 74 F or 82 F. They proceeded to the area and occupied water of 82 F. After a short period, these same six specimens were introduced into a similar experimental tank where the water temperature was 80 F, but where the alternative temperature of 86 F was available. The latter temperature was avoided.

In another experiment in August, the results were similar. Six specimens were acclimated at 77 F, introduced into water of 75 F, and were attracted to water 83 F. A short time later the same fishes were placed in water of 80 F. They avoided the alternative temperature which was 86 F. In the above experiments the water temperatures exceeded those generally expected in Lake Michigan. However, it illustrates the expected reaction of a species, such as the alewife, if and when it comes close to a heated plume. Anxiety with regard to an expected large mortality of the alewife near heated plumes is unfounded and except under unusual conditions such as crowding little mortality is expected.

Knowledge of the final preferendum temperature, which is the temperature to which a fish will go when given an unlimited time to acclimate , enables predictions of what will happen near a heated plume in Lake Michigan.

Table 1.-- The final Preferred Temperature in degrees F for various Species of Fishes Found in Lake Michigan. Modified after Ferguson, 1958.

Species	Final Preferendum	Authority
Carp	89	Pitt, Garside and Hepburn (1956)
Smallmouth Bass	82	Fry (Ms., 1950)
Yellow Perch	75	Ferguson (1958)
Muskellunge	75	Jackson and Price (Ms., 1949)
Burbot	70	Crossman, *et al*. (Ms., 1953)
Yellow Perch	70	McCracken and Sparkman (Ms., 1948)
Brown Trout	54-63	Tait (Ms., 1958)
Brook Trout	57-61	Graham (1948), Fisher and Elson (1950
Sockeye Salmon	58	Brett (1951)
Rainbow Trout	56	Garside and Tait (Ms., 1958)
Whitefish	55	Tompkins and Fraser (Ms., 1950)
Lake Trout	54	McCauley and Tait (Ms., 1956)
Chinook Salmon	53	Brett (1951)

The plume will vary in temperature with the seasons. During the summer it will be attractive to warm water fishes provided they come into contact with a gradient at the edge of the plume. In the plume adjacent to the Waukegan discharge during the summer fishes classified as warm water and some cool water species have been found.

During late fall, winter and early spring when the warmest natural water in Lake Michigan is close to 40 F, the so-called coldwater fishes which prefer water in the 53 - 63 F range (see Table 1) may be found around the periphery of a heated plume. However, they would be found there only if their inshore-offshore migrations were such that they had an opportunity to sense the gradient leading to the plume.

In summer the alewife, yellow perch and other fishes which prefer warm water would be found in the outer part of the plume.

It is predicted that the heated plumes from all large plants on Lake Michigan will produce plume conditions which will concentrate game fishes in areas where they may be more readily taken by anglers. This has been the almost universal experience with heated plumes in temperate regions of the world.

AVOIDANCE OF PLUMES

Lethal maximum temperatures for motile organisms such as fishes are inappropriate to predict the effects when such species encounter higher temperatures (plumes), because such a measure ignores the behavior of the organisms and the period of time which an organism might be in contact with such a temperature. It is proper to use such a measure only for organisms which cannot avoid, and which remain, in the increased temperatures. A far more appropriate measure for fishes is the upper avoidance temperature.

Recent observations at large power stations discharging relatively large volumes of heated water confirm the absence or rarity of thermal fish kills or of serious biological change.

The effect of the heated reactor effluent at Hanford on the Columbia River was observed on salmon and trout over a 25 year period. No thermal kills of any significance were observed according to the review by Nakatani (1969). Live box tests in the Columbia River by Coutant et al, (1968) with young chinook salmon in a heated effluent produced no direct or latent mortalities, but the temperature rises did not exceed the lethal limit for this salmon (77 F).

In England, Alabaster (1969) made studies of fish mortalities, both in the laboratory and in the field, and reported that kills under field conditions are extremely rare and insignificant in a populational sense.

Neither have thermal kills or other harmful ecological effects been observed on the lower Connecticut River in connection with the operations of the Connecticut Yankee Power Plant, as reported by Merriman (1970).

Field observations on young american shad in the Connecticut River have been confirmed by experimental work done by Moss (1970). Variations in temperature up to 5 F elicit little or no response in young shad. Temperature changes greater than 5 F are avoided.

Other extensive studies by Meldrim and Gift (1971) and Gift and Westman (1971) indicate similar behavior for fishes.

SUMMARY

1. Much of the present sport fishery for large species is based on stocking.

2. There is no or little spawning of lake trout and other large sport fishes in the Zion area.

3. No tributaries which serve as a spawning area for large salmonid fishes occur in the Zion area.

4. Most organisms including fishes will be denied a very small area close to the heated outfall at Zion.

5. Even during the worst summer conditions the isotherms produced by using a jet effluent indicated that outside a small mixing zone of approximately 4 - 5 acres near the effluent most summer water temperatures would be below the upper lethal temperatures for the fishes and associated organisms normally found near the Zion plant in the summer.

6. The shallow shore area located near the Zion plant will not be blocked by temperature, and the fishes which are normal inhabitants of the habitat close to shore during the warmer summer months will be unaffected.

7. Even under the most critical summer conditions it is predicted that the fishes or other biota will not be placed under serious stress, which would affect the size or the quality of the populations.

8. The area near Zion is not a unique or important spawning ground but, except for a few acres, the seasonal temperature requirements for reproduction and other aspects of the life history of the fishes which are seasonally present in the Zion area are predicted to be satisfactory.

9. Fishes which normally live in the Zion area are adapted to the changes in temperature which occurs in the environment at the several seasons and may avoid, be attracted to or not react to temperatures in various parts of the plume.

10. No permanent reduction in species diversity in fishes or associated biota is predicted either in the vicinity of the plant or in the Lake in general due to the operation Zion.

11. Compared to natural changes including year class fluctuations, any change in fish populations which might be attributed to the effect of heated effluents would be miniscule and insignificant to a commercial or sport fishery.

12. The heated effluents from nuclear power plants will not affect the "pier" fishing for yellow perch in Lake Michigan. The fishery has fluctuated greatly over the years and is expected to continue to do so.

13. Few eggs and larvae of fishes have been found in the area. The fast passage through the condenser system is expected to cause little mortality to larvae.

14. Young fishes may pass through the condenser with a relatively high rise (20 F) but fast passage (approximately 4 minutes) with little mortality. In experiments with chinook salmon, 95% or more survived for ten days after the trials.

15. Sudden temperature changes when Zion suddenly drops load in winter will not because of the jet discharge cause mortalities of fishes.

16. Because of the heated plume the sport fishery is expected to be extended in fall and early spring.

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STATEMENT OF OLIVER D. BUTLER

GLEN ELLYN, ILLINOIS

MR. BUTLER: Mr. Chairman, conferees, ladies and gentlemen. My name is Oliver D. Butler. I reside at 912 Waverly Road, Glen Ellyn, Illinois.

I appeared before this conference in September 1970 for the purpose of presenting cost estimates for closed cooling system alternatives for Commonwealth Edison's Zion station.

During the October 1970 and March 1971 conference proceedings, cost estimates were also presented by Dr. Tichenor of the Pacific Northwest Water Laboratory which he had prepared at the request of the Federal Water Quality Administration.

Subsequent to Dr. Tichenor's first appearance, we contacted him to obtain the detailed cost breakdown used in the Federal Water Quality Administration report. This information was carefully analyzed and a comparison of the Federal Water Quality Administration and Commonwealth Edison figures was prepared. This cost comparison was forwarded to the conference in April 1971 for incorporation into the conference record. This incorporation did not occur -- at least not in our copy of the proceedings. I have come back to put that material before you. I also want to update those estimates.

The first comparison I want to make is shown on Exhibit A and is a cost comparison relating to dry mechanical draft cooling towers. (See p. 846) Our figures are about 8 times higher than the Federal Water Quality Administration estimates. I can give you the reasons for that in detail, but I have a strong feeling that there is now general agreement that dry towers are out of the picture.

The prepared paper lists some of the reasons of why our estimate is higher. In the interest of time, I will omit reading that and go on to the other estimate.

We have also prepared a cost estimate for round wet mechanical draft cooling towers. That is shown in Exhibit B to my paper. (See p. 847) It shows a total cost of $124 million. This compares with the estimate that was submitted for the record in April 1971 of $116 million. The difference is inflation and some relatively minor changes each way in certain cost elements. The following factors are relevant to the comparison of FWQA's results and ours:

1. Our costs are based on backfitting the existing Zion installation. Theirs were for optimum design

Exhibit A
Dated 9-72

COST COMPARISON

ALTERNATE MEANS OF COOLING

Costs (In Excess of Once-Through)	Dry Mechanical Draft Cooling Towers					
	Interior Dept. Report[1,7]			C.E.Co. Studies[2]		
I. Capital Investment Costs	Dollars	$/KW	Mills/KWHR	Dollars	$/KW	Mills/KWHR
a. Pumps & Recovery turbines	1,360,000	1.36	.03	Included in e. below		
b. Basic Tower Units	10,200,000	10.20	.20	150,000,000	68.18	1.79
c. Footings	Included in b. above			3,300,000	1.50	.04
d. Controls	510,000	.51	.01	1,750,000	0.80	.02
e. Piping, Valves & Tanks	1,700,000	1.70	.03	29,200,000	13.27	.35
1) Backfitting Piping[6]	-	-	-	23,230,000	10.56	.28
f. Land Costs[4]	-	-	-	6,400,000	2.91	.08
g. Road & Track Work[5]	-	-	-	2,450,000	1.11	.03
h. Earthwork[3]	-	-	-	31,000,000	14.09	.37
i. Yard drainage, underground interference, & fence-work	-	-	-	790,000	.36	.01
j. Electrical	Included in a,b,d,&e above			49,201,000	22.36	.59
k. Contingencies	3,230,000	3.23	.06	7,125,000	3.24	.08
l. Top Charges	Included in k. above			38,056,000	17.30	.45
Subtotal	17,000,000	17.0	.33	342,502,000	155.68	4.09
II. Operating & Maintenance Costs[8]						
a. Loss of Capability	7,000,000	7.0	.14	90,043,000	40.93	1.07
b. Increased fuel costs	12,827,500	12.83	.25	22,294,000	10.13	0.27
c. Maintenance	Included in b. above			9,043,000	4.11	0.11
Subtotal	19,827,500	19.83	.39	121,380,000	55.17	1.44
II. Total Cost (Capital Inv. & Oper. & Maint.)	36,827,500	36.83	.72	463,882,000	210.85	5.54

Notes:
1. Estimates based on 1,000 mw - fossil unit
2. Estimates based on 2,200 mw - nuclear unit (Zion)
3. Earthwork includes items such as overburden removal, dewatering, excavation for circulating water piping & tower footings, and compacted fill for roads & towers
4. Land cost estimated at $10,000/acre
5. Road & track work includes relocation of existing roads, protection of circulating water piping at road crossings & alteration of track spur
6. Backfitting piping includes such items as modification to existing service water system, alteration of existing submerged circulating water intake piping, and new booster pumping stations
7. Cost breakdown reference - October 16, 1970, Letter-Bruce Tichenor, Pacific Northwest Laboratory to O. D. Butler, C.E.Co.
8. Costs are listed in equivalent investment dollars.

Exhibit B
Dated 9-72

COST COMPARISON

ALTERNATE MEANS OF COOLING

Costs (In Excess of Once-Through)	Wet Mechanical Draft Cooling Towers					
	Case II Interior Dept. Report[1]			C.E.Co. Studies[2,6]		
	Dollars	$/KW	Mills/KWHR	Dollars	$/KW	Mills/KWHR
I. Capital Investment Costs						
a. Condensers & Pumps	3,100,000	1.41	.027	Included in d. below		
b. Basic Tower Units	8,100,000	3.67	.072	18,000,000	8.18	0.236
c. Footings	Included in b. above			Included in b. above		
d. Piping & Valves	Included in a. above			11,700,000	5.32	0.153
1) Backfitting piping[3]	-	-	-	21,138,000	9.61	0.277
e. Earthwork[4]	-	-	-	12,950,000	5.89	0.170
f. Road & Trackwork[5]	-	-	-	365,000	0.17	0.005
g. Yard drainage, underground interferences & fencing	-	-	-	260,000	0.12	0.003
h. Electrical	Included in a.&b. above			1,950,000	0.89	0.026
i. Contingencies	Included in a.&b. above			1,835,000	0.88	0.024
j. Top-charges	Included in a.&b. above			10,222,000	4.65	0.134
Subtotal	11,200,000	5.08	.099	78,420,000	35.65	1.028
II. Operating & Maintenance Costs						
a. Loss of Capability	-	-	-	34,105,000	15.50	0.45
b. Increased fuel costs[7]	1,010,000	0.46	.009	11,037,000	5.02	0.14
c. Maintenance[7]	Included in b. above			464,000	0.21	0.01
Subtotal	1,010,000	0.46	.009	45,606,000	20.73	0.60
III. Total Costs (Capital Inv. & Oper. & Maint.)	12,210,000	5.54	.108	124,026,000	56.38	1.63

Notes:
1. Based on a 1000 mw nuclear unit - 82% cap. fact. 33% eff. (2.2 scale-up) (new site)
2. Based on Zion 2200 mw nuclear 72% cap. factor 33% eff. (backfit)
3. Backfitting piping includes such items as modification to existing service water system, changing of existing submerged circulating water intake piping, and new booster pumping stations
4. Earthwork includes such items as overburden removal, dewatering, excavation for circulating water piping and tower footings, and compacted fill for roadways and towers
5. Road & trackwork includes relocation of existing roads, protection of circulating water piping at road crossings and railroad spur alterations
6. C.E.Co. study is based on use of a hybrid round mechanical draft tower with 250' hyperbolic discharge stack for plume dispersal
7. Costs are listed in equivalent investment dollars.

of a new plant.

2. We have calculated costs on the basis of using 250-feet high, round, wet, mechanical draft cooling towers. These towers have been considered because of the airport height problem at Zion which I discussed in my 1970 testimony. The tower manufacturer does not predict satisfactory performance of a 250-foot natural draft tower at the Zion location. We and the manufacturer feel that the new design concept offers a better solution to fogging and height restriction problems at the Zion location than either conventional mechanical draft or natural draft towers. This design also disfigures the site less than the tall towers would.

The 250-foot mechanical draft towers, which would use fans in a hyperbolic shell, are considerably more expensive than conventional mechanical draft cooling towers but not appreciably different in cost than our estimate for natural draft towers. The soil conditions and ground loading requirements of these structures increase the cost of their installation over conventional mechanical draft towers at the Zion location. It should be noted that although we have compared to Federal Water Quality Administration figures for conventional wet mechanical draft towers, our cost estimate considerably exceeds the Federal Water Quality

O. Butler

Administration's natural draft tower cost estimates.

3. The Federal Water Quality Administration report does not consider a charge for loss of capability for any of the "wet" cooling alternatives. Compared to once-through cooling on Lake Michigan, this charge is substantial and should be considered. Our turbines at Zion were specifically designed to fully utilize the effect of the relatively cool Lake Michigan water.

4. Our charges for loss of capacity utilize the average cost of Zion, which is $207 per kilowatt. It seems clear to me that the real cost, when you lose part of a base load plant, is in base load, rather than peaking capacity, and that the Zion cost is the one that we should use. Later plants have had much higher costs per kilowatt of capacity and to replace base load nuclear capacity lost by a cooling tower installation, starting today, it would cost nearly twice the cost I have used.

We originally pointed out that it was necessary to recognize the substantial extra costs of backfitting when adding a closed cooling system to an existing plant. Our original estimate of $116,855,000, which is now $124,026,000, has been confirmed by estimates and actual experience of other utilities which are in the process of trying to backfit stations on Lake Michigan. I refer to pages 108 and 109

O. Butler

in the "Summary of Recent Technical Information Concerning Thermal Discharges to Lake Michigan," which is part of the Environmental Protection Agency presentation to you. I read that actual cost experience is indicating that the estimates I have just given you may be low, and are unlikely to be high.

I would also point out that Dr. Tichenor is quoted in that report as now agreeing that backfitting will cost three times as much as building a plant designed for towers. He has increased his original estimate from 0.2 mill per kilowatt hour in October 1970 to 0.6 mills per kilowatt hour (referring to page 105 of the previously referenced report). His old estimate for an optimized plant designed for cooling towers was 12 times less than my estimate. He is now only one time less -- i.e., just about half of our figure. I am pleased to see that he has become more realistic, and I am sure that if he could take up the invitation we have repeatedly extended to EPA to come see the Zion site, and to determine with us just how hard it is to turn a plant entirely around in order to cool it by different means, he would take the last step and raise his estimate one more multiple. We would, then, be in agreement.

In the interest of time, I will confine my discussion of Exhibit B to point out some of the significant differences between the FWQA estimates and the estimates that I submit:

1. Referring to Exhibit B, the costs in dollars in column 1 are taken from Dr. Tichenor's 1970 figures. His figures, however, were costs for a 1,000 MW nuclear unit. The fourth column is for Zion station, a 2,200 MW nuclear unit. Because Zion is 2.2 times the size of the plant estimated by Dr. Tichenor, we have multiplied Dr. Tichenor's costs by 2.2 to make the figures more easily comparable. I do not know if he would agree that a straight multiplication was the way to do it. One can also compare the two estimates by looking at the last line entry at the bottom of the page, where both dollar costs are converted to mills per kilowatt hour. That figure has not been multiplied by 2.2.

2. Item I(b) is the cost of the basic tower unit. We are less far apart here than in some other areas, and, as I said earlier, the actual figures coming in on other plants are roughly like our figures, not the Federal Water Quality Administration's.

3. Items I(c), (d), and (e) represent backfitting and site work not included in the Federal Water Quality Administration estimates. They come to somewhat more than

twice the basic tower cost, a figure not too far removed from Dr. Tichenor's estimate, quoted by the Argonne Laboratory, that backfitting triples the cost.

4. Finally, Item II(a) gives our cost estimate for loss of capacity, a factor which the Federal Water Quality Administration omitted. This loss is $34 million in the case of Zion. That is a factor which would largely not occur in a plant originally designed for cooling towers. It is both a very large dollar amount and one we feel strongly about.

I hope that this data will help you make your judgments based on the real costs to a real plant.

That is the end of my prepared testimony.

MR. MAYO: Thank you, Mr. Butler.

(Mr. Butler's presentation follows in its entirety.)

September 1972

STATEMENT OF OLIVER D. BUTLER

My name is Oliver D. Butler. I reside at 912 Waverly Road, Glen Ellyn, Illinois.

I appeared before this conference in September 1970 for the purpose of presenting cost estimates for closed-cooling system alternatives for Commonwealth Edison's Zion Station. In April 1971 cost estimates for back-fitting closed-cooling systems to our Waukegan and State Line generating stations was submitted to the conference for the record. During the October 1970 and March 1971 conference proceedings, cost estimates were presented by Dr. Tichenor of the Pacific Northwest Water Laboratory which he had prepared at the request of the Federal Water Quality Administration.

Subsequent to his first appearance, we contacted Dr. Tichenor to obtain the detailed cost breakdown used in the Federal Water Quality Administration report. This information was carefully analyzed and a comparison of the Federal Water Quality Administration and Commonwealth Edison figures was prepared. This cost comparison was forwarded to the conference in April 1971 for incorporation into the conference record. This incorporation did not occur, at least not in our copy of the proceedings. I have come back to put that material before you. I also want to update those estimates.

The first comparison I want to make is shown on Exhibit A and is a cost comparision relating to dry mechanical draft cooling towers. Our figures are about 8 times higher than the Federal Water Quality Administration estimates. I can give you the reasons for that in detail, but I have a strong feeling that there is now general agreement that dry towers are out of the picture. I would point out that dry towers really need a direct contact condenser. We would have to delay operation for about two years in order to tear out our present condensers and obtain new ones of the direct contact type - if some manufacturer is willing to undertake ones of this size. For the record, our cost estimate, in equivalent investment dollars, is $463,882,000. Exhibit A shows the breakdown of those costs. These cost estimates have not been updated from the April 1971 data submission.

Let me emphasize that, except for capacity losses, our cost estimates are still design estimates. These are not shelf items, and it is difficult to know the cost of building a one of a kind item until the project is completed. This is especially true if nothing comparable in size has ever been built before.

We have also prepared a cost comparison for round wet mechanical draft cooling towers. It is shown in Exhibit B. It shows a total cost of $124 million dollars. This compares with the estimate that was submitted for the record in April 1971 of $116 million. The difference is inflation and some relatively minor changes each way in certain cost elements. The following factors are relevant to the comparison of FWQA's results and ours:

1. Our costs are based on back-fitting the existing Zion installation. Theirs were for optimum design of a new plant.
2. We have calculated costs on the basis of using 250 ft. high, round, wet, mechanical draft cooling towers. These towers have been considered because of the airport height problem at Zion which

I discussed in my 1970 testimony. The tower manufacturer does not predict satisfactory performance of a 250 ft. natural draft tower at the Zion location. We and the manufacturer feel that the new design concept offers a better solution to fogging and height restriction problems at the Zion location than either conventional mechanical draft or natural draft towers. This design also disfigures the site less than the tall towers would.

The 250 ft. mechanical draft towers, which would use fans in a hyperbolic shell, are considerably more expensive than conventional mechanical draft cooling towers but not appreciably different in cost than our estimate for natural draft towers. The soil conditions and ground loading requirements of these structures increase the cost of their installation over conventional mechanical draft towers at the Zion location. It should be noted that although we have compared to Federal Water Quality Administration figures for conventional wet mechanical draft towers, our cost estimate considerably exceeds the Federal Water Quality Administration's natural draft tower cost estimates.

3. The Federal Water Quality Administration report does not consider a charge for loss of capability for any of the "wet" cooling alternatives. Compared to once-through cooling on Lake Michigan, this charge is substantial and should be considered. Our turbines at Zion were specifically designed to

fully utilize the effect of the relatively cool Lake Michigan water.

4. Our charges for loss of capacity utilize the average cost of Zion, which is $207 per kilowatt. It seems clear to me that the real cost, when you lose part of a base load plant, is in base load, rather than peaking capacity, and that the Zion cost is the one to use. Later plants have had much higher costs per kilowatt of capacity and to replace base load nuclear capacity lost by a cooling tower installation, starting today, would cost nearly twice the cost I have used.

We originally pointed out that it was necessary to recognize the substantial extra costs of backfitting when adding a closed cooling system to an existing plant. Our original estimate of $116,855,000 which is now $124,026,000 has been confirmed by estimates and actual experience of other utilities which are in the process of trying to backfit stations on Lake Michigan. I refer to pages 108 and 109 in the Summary of Recent Technical Information Concerning Thermal Discharges to Lake Michigan, which is part of the Environmental Protection Agency presentation to you. I read that actual cost experience is indicating that the estimates I have just given you may be low, and are unlikely to be high.

I would also point out that Dr. Tichenor is quoted in that report as now agreeing that back-fitting will cost three times as much as building a plant designed for towers. He has increased his original estimate from 0.2 mill kw/hour (October 1970) to 0.6 mills/kw hour (p. 105 of the previously referenced report). His old estimate for an optimized plant designed for cooling towers was 12 times less than my estimate. He is now only one time less - that is, just about half of our figure. I am pleased to see that he has become more realistic, and I am sure that if he could take up the invitation we have repeatedly extended to EPA to come see the Zion site, and determine with us just how hard it is to turn a plant entirely around in order to cool it by different means, he would take the last step and raise his estimate one more multiple. We would then be in agreement.

I suspect I should take you through the cost comparison shown on Exhibit B line by line, because it is complicated. I am willing to take you through the detail behind each of those entries. Perhaps it is appropriate, however, if I point out some major differences.

(1) Referring to Exhibit B, the costs in dollars in column 1, are taken from Dr. Tichenor's 1970 figures. Those, however, were costs for a 1000 mw nuclear unit. The fourth column is for Zion station, a 2200 mw nuclear unit. Because Zion is 2.2 times the size of the plant estimated by Dr. Tichenor we have multiplied Dr. Tichenor's costs by 2.2, to make the figures more easily comparable. I do not know if he would agree that a straight multiplication was the way to do it. One can also compare the two estimates by looking at the last line entry at the bottom of the page, where both dollar costs are converted to mills per kilowatt hour. That figure has not been multiplied by 2.2.

(2) Item I(b) is the cost of the basic tower unit. We are less far apart here than in some other areas, and as I said earlier, the actual figures coming in on other plants are roughly like our figures, not the Federal Water Quality Administration's.

(3) Items I(c) (d) and (e) represent back-fitting and site work not included in the Federal Water Quality Administration estimates. They come to somewhat more than twice the basic tower cost, a figure not too far removed from Dr. Tichenor's estimate, quoted by Argonne Laboratory, that back-fitting triples the cost.

(4) Finally, Item II (a) gives our cost estimate for loss of capacity, a factor which the Federal Water Quality Administration omitted. The loss is $34 million. That is a factor which would largely not occur in a plant originally designed for cooling towers. It is both a very large dollar amount, and one we feel strongly about.

I hope that this data will help you make your judgments based on the real costs to a real plant.

Exhibit A
Dated 9-72

COST COMPARISON

ALTERNATE MEANS OF COOLING

Costs (In Excess of Once-Through)	Dry Mechanical Draft Cooling Towers					
	Interior Dept. Report[1,7]			C.E.Co. Studies[2]		
I. Capital Investment Costs	Dollars	$/KW	Mills/KWHR	Dollars	$/KW	Mills/KWHR
a. Pumps & Recovery turbines	1,360,000	1.36	.03	Included in e. below		
b. Basic Tower Units	10,200,000	10.20	.20	150,000,000	68.18	1.79
c. Footings	Included in b. above			3,300,000	1.50	.04
d. Controls	510,000	.51	.01	1,750,000	0.80	.02
e. Piping, Valves & Tanks	1,700,000	1.70	.03	29,200,000	13.27	.35
1) Backfitting Piping[6]	-	-	-	23,230,000	10.56	.28
f. Land Costs[4]	-	-	-	6,400,000	2.91	.08
g. Road & Track Work[5]	-	-	-	2,450,000	1.11	.03
h. Earthwork[3]	-	-	-	31,000,000	14.09	.37
i. Yard drainage, underground interference, & fence-work	-	-	-	790,000	.36	.01
j. Electrical	Included in a,b,d,&e above			49,201,000	22.36	.59
k. Contingencies	3,230,000	3.23	.06	7,125,000	3.24	.08
l. Top Charges	Included in k. above			38,056,000	17.30	.45
Subtotal	17,000,000	17.0	.33	342,502,000	155.68	4.09
II. Operating & Maintenance Costs[8]						
a. Loss of Capability	7,000,000	7.0	.14	90,043,000	40.93	1.07
b. Increased fuel costs	12,827,500	12.83	.25	22,294,000	10.13	0.27
c. Maintenance	Included in b. above			9,043,000	4.11	0.11
Subtotal	19,827,500	19.83	.39	121,380,000	55.17	1.44
III. Total Cost (Capital Inv. & Oper. & Maint.)	36,827,500	36.83	.72	463,882,000	210.85	5.54

Notes:
1. Estimates based on 1,000 mw - fossil unit
2. Estimates based on 2,200 mw - nuclear unit (Zion)
3. Earthwork includes items such as overburden removal, dewatering, excavation for circulating water piping & tower footings, and compacted fill for roads & towers
4. Land cost estimated at $10,000/acre
5. Road & track work includes relocation of existing roads, protection of circulating water piping at road crossings & alteration of track spur
6. Backfitting piping includes such items as modification to existing service water system, alteration of existing submerged circulating water intake piping, and new booster pumping stations
7. Cost breakdown reference - October 16, 1970, Letter-Bruce Tichenor, Pacific Northwest Laboratory to O. D. Butler, C.E.Co.
8. Costs are listed in equivalent investment dollars.

Exhibit B
Dated 9-72

COST COMPARISON

ALTERNATE MEANS OF COOLING

Costs (In Excess of Once-Through)	Wet Mechanical Draft Cooling Towers					
	Case II Interior Dept. Report[1]			C.E.Co. Studies[2,6]		
	Dollars	$/KW	Mills/KWHR	Dollars	$/KW	Mills/KWHR
I. Capital Investment Costs						
a. Condensers & Pumps	3,100,000	1.41	.027	Included in d. below		
b. Basic Tower Units	8,100,000	3.67	.072	18,000,000	8.18	0.236
c. Footings	Included in b. above			Included in b. above		
d. Piping & Valves	Included in a. above			11,700,000	5.32	0.153
1) Backfitting piping[3]	-	-	-	21,138,000	9.61	0.277
e. Earthwork[4]	-	-	-	12,950,000	5.89	0.170
f. Road & Trackwork[5]	-	-	-	365,000	0.17	0.005
g. Yard drainage, underground interferences & fencing	-	-	-	260,000	0.12	0.003
h. Electrical	Included in a.&b. above			1,950,000	0.89	0.026
i. Contingencies	Included in a.&b. above			1,835,000	0.88	0.024
j. Top-charges	Included in a.&b. above			10,222,000	4.65	0.134
Subtotal	11,200,000	5.08	.099	78,420,000	35.65	1.028
II. Operating & Maintenance Costs						
a. Loss of Capability	-	-	-	34,105,000	15.50	0.45
b. Increased fuel costs[7]	1,010,000	0.46	.009	11,037,000	5.02	0.14
c. Maintenance[7]	Included in b. above			464,000	0.21	0.01
Subtotal	1,010,000	0.46	.009	45,606,000	20.73	0.60
III. Total Costs (Capital Inv. & Oper. & Maint.)	12,210,000	5.54	.108	124,026,000	56.38	1.63

Notes:
1. Based on a 1000 mw nuclear unit - 82% cap. fact. 33% eff. (2.2 scale-up) (new site)
2. Based on Zion 2200 mw nuclear 72% cap. factor 33% eff. (backfit)
3. Backfitting piping includes such items as modification to existing service water system, changing of existing submerged circulating water intake piping, and new booster pumping stations
4. Earthwork includes such items as overburden removal, dewatering, excavation for circulating water piping and tower footings, and compacted fill for roadways and towers
5. Road & trackwork includes relocation of existing roads, protection of circulating water piping at road crossings and railroad spur alterations
6. C.E.Co. study is based on use of a hybrid round mechanical draft tower with 250' hyperbolic discharge stack for plume dispersal
7. Costs are listed in equivalent investment dollars.

MR. FELDMAN: The last statement, Mr. Mayo, is by Dr. G. Fred Lee.

MR. MAYO: Thank you.

STATEMENT OF DR. G. FRED LEE,
PROFESSOR OF WATER CHEMISTRY,
UNIVERSITY OF WISCONSIN,
MADISON, WISCONSIN

DR. LEE: My name is G. Fred Lee. I am Professor of Water Chemistry at the University of Wisconsin in Madison. I am also a consultant to the Commonwealth Edison Company.

Thus far this afternoon and this evening, we have heard about the rather minimal effects that the Zion plant once-through cooling will have on water quality in the region of Zion.

We have just heard about the cost of backfitting cooling towers. Now I want to return to the question of water quality and look specifically at what might be the effects of cooling tower blowdown on water quality in the region of Zion.

A report by the FWQA presented at the workshop back in 1970 concluded that cooling tower blowdown from towers located at Zion would not cause water quality problems in Lake Michigan. However, if you examine their report you see that there is real questions to be raised about the basis for their conclusions.

First, the FWQA assume that the makeup water at Zion would be equal to the average composition of the water in the open lake. Well, it is well known that the water near shore often has much higher concentration of chemicals than the open lake water and, in fact, the composition of the water near shore today in the Zion area exceeds the current Illinois Pollution Control Board standards for some chemicals.

The FWQA, in their 1970 report, assumed that the criteria to judge adverse effects was the drinking water standards of the U.S. Public Health Service of 1962.

Generally, it is well known that the aquatic life standards for fish and aquatic life are much stricter than drinking water standards. In other words, if a fish can swim in it and reproduce in it, generally man can drink it.

The FWQA assumed that the only process determining the chemical composition in the blowdown is a fivefold evaporative concentration of this water.

Actually there are a number of other processes that lead to chemicals in cooling tower blowdown, such

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processes as the addition of chemicals for water conditioning. Also you have the fact that a cooling tower of the wet evaporative type is a very efficient air scrubbing device, so you will scrub certain chemicals from the atmosphere.

Further you have the leaching of chemicals and the corrosion of the structure itself to consider in any cooling tower situation.

Since I feel that the FWQA assumptions are unrealistic with respect to the potential effects of blowdown from a Zion cooling tower system, I have undertaken to prepare a review of the potential effects of this blowdown on the water quality in the region of Zion.

This review consists of two parts, both of which have been given to the conferees. One of them is a 50-page literature review, in which I have tried to put together what I have found over the past year, in the area of: What do we know about blowdown from cooling towers?

The second is a summary of the specific effects that I predict for the Zion plant should cooling towers be required.

Now, I will summarize a summary of the summary this evening. The other materials, I assume, can be entered into the record without having to read them.

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Now, the differences between my approach to this situation of blowdown at Zion and the previous approach is that I will actually use water quality for the region of Zion based on the chemical studies of Bio-Test Laboratories, where a 16-month study has been completed and we do have data now on the chemical composition of the water in this region, and this is water that would be the makeup water for a cooling tower at Zion.

Further, I will judge the significance of chemicals in the blowdown, based on the State of Illinois Water Quality Standards applicable to that region.

Also, I will assume that the cooling towers at Zion will operate with evaporative concentration factors of 4.24. This is the design engineers' criteria. And that the only chemicals used for conditioning water at Zion will be sulfuric acid or neutralization of alkalinity and chlorine as a biocide.

The blowdown from cooling towers at Zion will be in the order of 16 c.f.s., which is a pretty fair stream of water.

Now, let's take a look briefly at the various chemicals which will be at or near the critical concentrations in the blowdown from Zion.

First, the ammonia content of blowdown from the

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cooling towers located at Zion would likely exceed the Illinois Pollution Control Board standard for lake water at the point of discharge.

<u>Boron</u>. The boron concentration in the blowdown will be about one-half of the Illinois Pollution Control Board for the lake water standards.

<u>Cadmium</u>. Cadmium in the blowdown will meet the Illinois Pollution Control Board lake water standard but it is expected to be much higher than the cadmium standards that have been recommended for other waters of the Great Lakes.

<u>Chromium</u>. Blowdown will meet the chromium standard at Zion. It should be noted, however, that many cooling towers located throughout the State of Illinois will not meet this standard.

<u>Chloride</u>. The blowdown will likely exceed the Illinois Pollution Control Board lake water standard at the point of discharge for chloride.

<u>Copper and Iron</u>. Copper and iron in the blowdown will be approximately equal to the Illinois Pollution Control Board lake water standard.

<u>Mercury</u>. The mercury content of lake water from the Zion area of Lake Michigan is already above the Illinois Pollution Control Board standards. Evaporative

concentration of that water by 4.24 would cause the mercury in the blowdown to exceed the Illinois Pollution Control Board standard by 6 times.

Oil. Oils in the blowdown due to the evaporative concentration of the makeup water are expected to be about equal to the Illinois Pollution Control Board standard.

Phosphorus. Evaporative concentration of the makeup water by 4.24 results in a phosphorus blowdown of approximately 20 percent of the Illinois Pollution Control Board lake standard without any use of phosphorus in the cooling tower as a corrosion or scale-controlled chemical. The blowdown from Zion would stimulate algal growth in the region of Zion due to the phosphorus present as the result of simple evaporation of the water.

Sulfate. The sulfate in the makeup water at Zion, when concentrated by evaporation, will exceed the Illinos Pollution Control Board standard by 4- to 5-fold. Further, since sulfuric acid will be needed to neutralize the alkalinity to prevent scale, it is expected that the blowdown from a cooling tower at Zion would have a sulfate concentration 7 times the Illinois Pollution Control Board standard.

Suspended Solids. The makeup water at Zion already exceeds the Illinois Pollution Control Board standard for an effluent discharge to Lake Michigan with respect to suspended solids.

Evaporative concentration of cooling water will cause the blowdown to greatly exceed the effluent standard.

Zinc. The concentration of zinc in blowdown will be expected to be less than the Illinois Pollution Control Board standard. However, a recent EPA study has shown that zinc in cooling tower blowdown is toxic to aquatic life at levels considerably less than the current Illinois Pollution Control Board standard and the expected concentration of zinc in the blowdown from Zion.

Conclusions. The expected composition of blowdown from a cooling tower at Zion, without any direct addition of chemicals for water conditioning will exceed the Illinois Pollution Control Board standard for many chemicals.

Contrary to the statement made by the FWQA in 1970, cooling tower blowdown at Zion will have adverse effect on water quality in the region of Zion.

Further, it is reasonable to predict that as a result of new water quality criteria that are being developed today, where we are emphasizing the chronic sublethal effects of chemicals on aquatic organisms, that the current water quality standards will be even made more

G. Lee

strict in the future, will become, say, smaller in number, due to the fact that we realize today that many of these chemical standards are simply too high.

Another conclusion: With respect to the possibility of treating this water, it is true that the technology exists today to treat the blowdown water to meet the Illinois Pollution Control Board standard. However, for many of the chemicals we are talking about -- especially something like sulfate -- we do not have inexpensive treatment methods available, and the cost of removing something like sulfate will be very expensive. Certainly costs of this type have to be taken into account when you consider the economics of installing cooling towers at Zion.

Well, from an overall point of view, I feel that there are situations where we have to use cooling towers, where we have large amounts of heat which must be discharged to relatively small bodies of water. In the case of Lake Michigan, however, I question whether it is in the best interest of the public and in the wise use of resources to install cooling towers. It certainly seems more appropriate to me to make use of some of the heat assimilative capacity of Lake Michigan, utilizing once-through cooling for a limited number of thermal electric generating stations. In this way, we would avoid the potential damage associated with discharging large volumes of concentrated chemicals from cooling tower blowdown into the lake.

Thank you.

MR. MAYO: Thank you, Dr. Lee.

(Dr. Lee's presentation follows in its entirety.)

The University of Wisconsin

WATER CHEMISTRY LABORATORY
MADISON, WISCONSIN 53706
262-2470
AREA CODE 608

September 27, 1972

Francis Mayo
U.S. Environmental Protection Agency
Region V
33 East Congress Parkway
Chicago, Illinois 60605

Dear Mr. Mayo:

On Thursday, September 21, I testified before the Lake Michigan Enforcement Conference on the effects of cooling tower blowdown on receiving water quality. Subsequent to this testimony, I found several minor editorial changes that should be made in the material incorporated into the record. For example, when the tables on page 8 were typed, the "less than" signs were omitted. These corrections, however, do not change the conclusions in the paper.

I suggest that you incorporate the enclosed copy of the "Estimated Potential Problems with Cooling Tower Blowdown at Zion Thermal Electric Generating Station" into the record rather than the material that I submitted previously.

Sincerely yours,

G. Fred Lee
Professor of Water Chemistry

GFL/lm
Enclosure

Estimated Potential Problems with Cooling Tower Blowdown at Zion Thermal Electric Generating Station*

G. Fred Lee[1] and Charles Stratton[2]
Water Chemistry Program
University of Wisconsin
Madison, Wisconsin

A report published by the Federal Water Quality Administration (1970) concluded that cooling tower blowdown water from a thermoelectric plant such as the Zion plant of the Commonwealth-Edison Company, located on Lake Michigan, would not cause water quality problems. However, careful examination of this report raises questions about the basis for this conclusion. For example, the average composition of southern Lake Michigan offshore water was used as an approximation of the composition of the makeup water that would be used in a cooling tower at Zion. Commonwealth-Edison's data (Bio-Test Industrial Laboratories, 1971) for nearshore waters off Zion indicated somewhat different values. The concentrations of certain chemicals in the makeup waters is close to and occasionally exceeds some of the water quality criteria that have recently been adopted by states bordering on Lake Michigan.

The authors of the FWQA report also assumed that the only process leading to increased concentrations of chemicals in the blowdown water is a five-fold evaporation concentration. No corrections were attempted for such factors as chemicals added for water conditioning, chemicals derived from air scrubbing, or chemicals derived from corrosion or leaching from the structure of the tower.

The most serious objection to the FWQA conclusion is based on the fact that the authors of this report have assumed that the criteria by which cooling tower blowdown water could be judged objectionable is the 1962 Drinking Water Standards of the U.S. Public Health Service. In most cases, water quality criteria for aqua-

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[1] Professor of Water Chemistry
[2] Graduate student in Water Chemistry
*Presented in essentially the same form at the Lake Michigan Enforcement Conference, September, 1972.

tic life are much more stringent than the criteria for drinking water. It is interesting that a federal agency uses aquatic life criteria when it wishes to show that the current or proposed method of discharge is not acceptable, i.e., once-through cooling. The same federal agency, however, uses drinking water criteria when they wish to show that the alternative methods, proposed by the agency, are satisfactory.

This paper presents the expected chemical composition of cooling tower blowdown water from a thermoelectric plant similar to the proposed Zion installation, and potential water quality problems that may exist, should cooling towers be required to meet the thermal effluent standards. Data gathered for Commonwealth-Edison from the waters near Zion will be used as representative of the cooling tower makeup water. Consideration will also be given to chemicals added for treatment of the cooling tower water, to corrosion products from the system, to leaching of chemicals from the structure, and to scrubbing of chemicals from the air passing through the tower. It will be further assumed that a concentration of the makeup water constituents by a factor of 4.24 according to the cooling tower design represents the minimum expected concentration of chemicals in the blowdown water. This assumption will be somewhat in error as a result of the loss of chemicals by drift from the tower.

Lee and Stratton (1972) have recently completed a literature review on the general aspects of the expected effects of cooling tower blowdown water on receiving water quality. This review should be consulted for further information on this topic.

Although it is impossible to make a precise estimate of the blowdown water chemical composition, it should be possible to make a much more reasonable estimate by the above approach than that taken by the FWQA (1970).

The expected characteristics of the cooling towers that may be installed at the Zion Station of the Commonwealth Edison Company are listed in Table 1.

TABLE 1

Characteristics of Cooling Towers at Zion Station
of Commonwealth Edison

	Amount	
	Percent*	GPM**
Evaporation	1.9	28,600
Blowdown	0.5	7.400
Drift	0.1	1.470
Makeup	2.5	37,470

*percent of total flow rate
**gallons per minute
(Sargent and Lundy, 1971)

The cooling towers would be operating on a 1,470,000 gpm per unit circulating water flow rate and a temperature of 24.2°F. for both units at Zion. An attempt will be made to maintain 700 mg/l total dissolved solids in the recirculating water, which results in a concentration of the makeup water by a factor of 4.24. It is expected that 1 mg/l of chlorine for a 30-minute duration three times a day will be fed to the recirculating water. Further, it is expected that sulfuric acid will be needed to neutralize 90% of the bicarbonate alkalinity. It is assumed for the purposes of this paper that it will not be necessary to add other chemicals such as phosphates, zinc, etc. that are normally used in cooling tower water conditioning. Should any of these chemicals be needed at the Zion plant cooling towers, their respective concentrations would be increased significantly over those predicted in this paper.

The volumes presented in Table 1 are based on both nuclear units operating at Zion. It is estimated that the drift from the Zion cooling towers would be in the order of 1,470 gpm, which amounts to about 0.1% of the recirculating water flow. The blowdown will be 7,400 gpm or 16 cfs from the two units.

In order to judge the potential significance of the blowdown water, the estimated concentration of those chemicals that are considered to be potential problems will be compared to the State of Illinois Water Pollution Regulations, adopted by the Illinois Pollution Control Board (1972). These standards are listed in Table 2. Both effluent and lake standards have been established.

Table 3 presents the average and maximum chemical composition of the nearshore waters in the region of the Zion thermoelectric generating station, based on a 16-month study conducted by Bio-Test Industrial Laboratories (1971) on behalf of the Commonwealth-Edison Company. These data are based on studies conducted on the Lake County water supply intake in the period January, 1970, through April, 1971. During this period, samples were obtained at approximately bi-weekly intervals.

Ammonia. The Illinois Pollution Control Board (IPCB) has not adopted an effluent standard for ammonia. However, a lake standard of 0.02 mg/l as nitrogen has been adopted. The studies by Bio-Test Laboratories (1971) show that the average content of ammonia in the waters in the region of Zion is 0.04 mg/l ammonia nitrogen. An evaporative concentration by a factor of 4.24, as proposed for the Zion plant, results in 0.17 mg/l ammonia nitrogen. However, studies have shown (Lee and Stratton, 1972) that evaporative type cooling towers tend to promote nitrification reactions in which the ammonia present is converted to nitrate. Further, the chlorination of the recirculation water will tend to reduce the ammonia content through oxidation by chlorine. To counter this, precipitation in the Midwest typically contains 0.5-1 mg/l of ammonia nitrogen. Studies currently being conducted by the authors show that cooling towers tend to scrub ammonia from the atmosphere, showing a higher concentration in the recirculation water than in the makeup water. Therefore, even though the exact ammonia content of the blowdown water is impossible to estimate at this time, it is reasonable to expect that the concentration at the point of discharge would be in excess of the IPCB lake standard.

Boron. Bio-Test Laboratories (1971) found that the average boron content of the waters in the region of Zion was 0.10 mg/l. The IPCB established a total boron lake concentration of 1.0 mg/l. It is evident that the evaporative concentration of

TABLE 2

Water Quality Standards Applicable to Blowdown Water From
A Cooling Tower at Zion Commonwealth Edison Plant

Parameter	Effluent Standard	Lake Standard*
Ammonia as N	none**	0.02
Arsenic (total)	0.25	0.01
Barium (total)	2.0	1.0
Boron (total)	none	1.0
Cadmium (total)	0.15	0.01
Chromium (total hexavalent)	0.3	0.05
Chormium (total trivalent)	1.0	1.0
Chloride	none	12.0
Copper (total)	1.0	0.02
Cyanide (total)	0.025	0.01
Fluoride	2.5	1.4
Iron(total)	2.0	0.3
Iron (dissolved)	0.5	0.3
Lead (total)	0.1	0.05
Manganese (total)	1.0	0.05
Mercury	0.0005	0.0005
Nickel	1.0	1.0
Nitrate plus Nitrite Nitrogen	none	10.0
Oil (hexane soluble)	15	0.1
Oxygen	none	not less than 90% saturation except due to natural causes
pH	5 to 10	7 to 9
Phenols	0.3	0.001

Parameter	Effluent Standard	Lake Standard
Phosphorus	1.0	0.007
Selenium (total)	1.0	0.01
Silver (total)	0.1	0.005
Sulfate	none	24.0
Suspended Solids (Inorganic)	15	none
Suspended Solids (Organic)	5	none
Total Dissolved Solids	3500	180
Zinc (total)	1.0	1.0

All concentrations expressed in mg/l

*mixing zone permitted, not to exceed area of circle with 600 ft. radius
**No effluent standard established for this parameter

TABLE 3

Chemical Composition of the Water in the
Area of Zion Thermoelectric Generating Station for
Commonwealth-Edison Company

Parameter	Average*	Maximum*
DO	11.8	8.8 (min.)
BOD	2.0	4.0
COD	8	13
TOC	9	24
NH_3-N	0.04	0.08
NO_3^--N	0.23	0.52
NO_2^--N	0.007	0.02
Turbidity	11	39
Total Phosphate as P	0.038	0.068
Total Dissolved Solids	174	211
Total Suspended Solids	18	73
Specific Conductance at 25°C umhos/cm	282	321
Total Hardness as $CaCO_3$	138	155
Total Alkalinity as $CaCO_3$	110	123
Total Coliforms/100 ml	74	267
Fecal Coliforms/100 ml	12	68
Fecal Streptococci/100 ml	3	9
Ca	36	39
Mg	12	12.4
Na	5	7
K	1.1	1.4
Cl^-	8.7	11.6

Parameter	Average*	Maximum*
$SO_4^{=}$	20.7	24.7
F^-	0.15	0.29
SiO_2	1.1	2.2
pH	8.1	8.2
Total organic Carbon	10	20
Oil (hexane soluble)	2.3	5.3
Color (true)	3	6
MBAS	<0.025	<0.025
Phenols	<0.001	<0.001
Cyanide	<0.005	<0.005
Hg	0.00075	0.0026
As	0.0014	0.0031
Cd	<0.001	<0.001
B	0.10	0.16
Fe	0.24	0.45
Cu	0.003	0.007
Cr	0.002	0.009
Zn	0.04	0.1
Ni	0.002	0.004
Pb	0.003	0.006
Mn	0.0062	0.024

*all concentrations in mg/l

After Bio-Test Industrial Laboratories (1971)

Lake Michigan water in the region of Zion would cause the boron content of the effluent blowdown to be approximately half of the lake water standard.

Cadmium. The IPCB has established a total effluent cadmium concentration of 0.15 mg/l and a lake cadmium limit of 0.01 mg/l. These limits are considerably higher than the limits which have been proposed by the FWQA (1969) for Lake Superior, where it has been found that cadmium levels in excess of 0.0005 mg/l have an adverse effect on some aquatic organism reproduction. The Bio-Test studies have shown that the cadmium content of the waters in the region of Zion is less than 0.001 mg/l. If it is assumed that the concentrations of cadmium in Lake Michigan are similar to those of Lake Superior, that is 0.0002 to 0.0004 mg/l, then the expected evaporative concentration of this water could lead to the cadmium content in the blowdown being in excess of the recommended limit for Lake Superior. However, it would meet the IPCB criteria for Lake Michigan.

Chromium. Bio-Test Laboratories reported the average total chromium content of the waters near Zion to be 0.002 mg/l. The IPCB established a total hexavalent chromium standard for effluent of 0.3 mg/l and a total trivalent chromium standard for the effluent of 1.0 mg/l. If the IPCB standards are compared to the data from various Illinois state institutional cooling tower effluents (Illinois State Water Survey, 1971, see Lee and Stratton, 1972), it is seen that the chromium content of these blowdown waters is often 12 to 60 mg/l. Of course, all of these plants are using a chromate treatment for corrosion control. While it is doubtful that any chromium would be used in the treatment of an evaporative type cooling tower at the Zion plant, such use would necessitate the installation of facilities to remove chromium from the blowdown water.

Chloride. The IPCB established a 12 mg/l chloride limit for lake water. The average content of chloride in the region of Zion is 8.7 mg/l, with a maximum value of 11.6 mg/l. Evaporative concentration of this water by a factor of 4.24 would cause the chloride content of the blowdown to exceed the established lake criteria and would necessitate rapid dilution of this water in order to meet these criteria. The chlorine used as a biocide in the cooling tower recirculating water would tend to increase the chloride content of the blowdown water to a small but measureable degree; however, it could also cause other detrimental effects in the blowdown water. Recent studies by the EPA Duluth laboratory have shown that chloramines which would be formed upon the reaction of chlorine and ammonia are toxic to aquatic organisms at concentrations of a few ug/l. While a large part of the added chlorine would be consumed as chlorine demand, it is possible that some of the chloramines would be present in the blowdown water.

Copper. The survey by Bio-Test Laboratories indicates the average copper content of the water near Zion is in the order of 0.003 mg/l. The IPCB has established a total copper limit in the effluent of 1.0 mg/l and a lake limit of 0.02 mg/l. A concentration of the makeup water by a factor of 4.24 would result in the copper content in the blowdown approaching that of the lake water limit. Many of the cooling towers examined by the Illinois State Water Survey (1971) show copper concentrations on the order of 0.01 mg/l or greater. Since most makeup waters generally contain copper in amounts considerably less than this value, there is an indication that copper is accumulated within the recirculating system, possibly derived either from corrosion of the system or from scrubbing of copper from the atmosphere. Available data show that copper exists at levels of 27 ug/l in precipitation across Canada (Thompson, 1971). This indicates that scrubbing of copper from the air may be a significant factor in cooling towers.

Iron. The IPCB established a total iron standard in the effluent of 2.0 mg/l. Bio-Test Laboratories has found that the average total iron in this region is 0.24 mg/l. This is very near the IPCB lake standard of 0.3 mg/l. Examination of the data obtained from Betz Laboratories (1971; See Lee and Stratton, 1972) shows that some of the cooling towers examined had iron concentrations in excess of the IPCB standard. It is, therefore, possible that the iron content of the blowdown water from a cooling tower located at Zion would approach the IPCB standard for this element and might on occasion exceed this standard. Studies currently in progress by the authors indicate total iron levels well in excess of 2 mg/l from the cooling towers under study.

Mercury. An effluent and a lake standard of 0.0005 mg/l total mercury have been set. Lake water in the Zion region is reported to contain 0.00075 mg/l mercury and is therefore currently in excess of both the effluent and lake standards. The blowdown would be concentrated to a level of about 0.003 mg/l mercury.

Nitrate. The lake standard for nitrate plus nitrite nitrogen is 10.0 mg N/l. Nitrites and nitrate compounds are occasionally used as corrosion inhibitors in cooling towers. When these compounds are used, the blowdown nitrate concentration can be quite high (62 mg/l for one tower studied by Fisher and Jeter as reported by Savinelli and Beecher, 1966), hence it must be assumed that the permitted mixing zone is sufficient to accomodate the necessary dilution of the blowdown effluent.

Oil, hexane soluble. A limit of 15 mg/l in the effluent and 0.1 mg/l in the lake has been set for hexane soluble oils. The hexane soluble material in the region of the Zion intake has been found by Bio-Test Laboratories to be in the order of 2 mg/l, with some values as high as 5 mg/l. Therefore, it is possible that at times the amount of hexane soluble material in the blowdown from a cooling tower would approach the IPCB effluent standard, based on an evaporative concentration of 4.24 times the intake waters of Lake Michigan. It should be further noted that the increasing tendency to substitute organic chemicals for potentially toxic inorganic chemicals such as zinc and chromium in cooling towers for corrosion control may significantly increase the amount of hexane soluble material present in blowdown.

Phenols. The IPCB has established an effluent standard of 0.3 mg/l for phenols and a lake water standard of 0.001 mg/l. Existing phenol levels in the region of Zion are less than 0.001 mg/l. However, chlorophenols are used in many cooling towers as biocides. Such practice leads to the presence of these compounds in the blowdown water. Chlorophenols at ug/l concentrations are known to cause taste and odors in drinking water and the tainting of fish flesh.

Phosphorus. A maximum phosphate concentration of effluent waters of 1.0 mg/l and a lake concentration of 0.007 mg/l as phosphorus has been established. Bio-Test Laboratories found that the total phosphate in the region of Zion intake is approximately 0.04 mg P/l. An evaporative concentration by a factor of 4.24 would result in the phosphate concentration in the blowdown being approximately 20 percent of IPCB effluent standard. Available evidence indicates that the algae growth in the region of the Zion plant is most likely limited by the phosphorus content of the water. Therefore, the discharge of large volumes of blowdown water which contained phosphate in order of a few tenths of a mg/l would tend to stimulate algal growth in the region of the discharge. Phosphates are used in many cooling towers for control of corrosion and scale. For example, several of the cooling towers analyzed by the Illinois State Water Survey (1971) have a phosphate content in the blowdown water of 3-8 mg P/l. Many of the cooling tower blowdown waters shown in data compiled by Betz Laboratories have phosphate concentrations of 0.2-2.0 mg/l. These levels are such that the blowdown from cooling towers of such a size as those required for the Zion plant would likely stimulate algal growth in the region of the discharge if any form of phosphate, including polyphosphate, phosphonates or polyol-esters, are used in the treatment program, even if this discharge met the IPCB limit of 1.0 mg P/l.

Sulfate. A maximum sulfate content in the receiving lake water of 24 mg/l has been established by the IPCB. Bio-Test Laboratories found an average sulfate concentration of 21 mg/l with a maximum of 25 mg/l in the lake water near Zion. An evaporative concentration of the makeup water by a factor of 4.24 would cause the blowdown water to exceed the lake water standard by approximately four to fivefold. Further, it is expected that sulfuric acid would be added to the recirculation water to neutralize about 90 percent of the bicarbonate alkalinity. This would result in a 75 to 100 mg/l increase in the sulfate content of the makeup water. There can, therefore, be little doubt that the waters in the region of the discharge of blowdown would greatly exceed the IPCB standard for Lake Michigan water and would have to be diluted by diffusion or treated. As I will show later, neither technique will work here.

Suspended Solids. Bio-Test Laboratories found that the water in the region of Zion has an average suspended solids concentration of 18 mg/l. IPCB allows an effluent suspended solids concentration of 15 mg/l for inorganic solids. This means that the makeup water does not presently meet the IPCB effluent standards. An evaporative concentration coupled with atmospheric scrubbing and possible precipitation within the system will certainly cause the blowdown water to exceed the IPCB standards for inorganic suspended solids. Treatment of the blowdown to remove suspended solids will, therefore, be required.

Zinc. The IPCB limit for total zinc is 1.0 mg/l in the effluent. The zinc concentration in the region of Zion averages 0.04 mg/l which would still be considerably less than the 1.0 mg/l after evaporative concentration. Many cooling towers, however, discharge zinc at concentrations considerably in excess of the

IPCB standard because it is added for corrosion inhibition. Further, there may be a significant uptake of zinc from the atmosphere. Relatively large concentrations are present in precipitation. Also, it should be mentioned that the IPCB standard of 1.0 mg/l is considerably in excess of the standard which has been proposed by the FWQA (1969) for Lake Superior. A study recently conducted at the Corvallis EPA Laboratory concerning biological effects of cooling tower blowdown indicates that zinc may be toxic to young trout at 0.09 mg/l (Garton, 1972). The zinc content of influent water and its effect on the amount of zinc present in Lake Michigan waters is currently under study by the senior author.

CONCLUSION AND OVERALL APPRAISAL

In this paper, the nature of chemicals that may be present in cooling tower blowdown water and the possible effect of these chemicals on the quality of the receiving water have been briefly discussed. The Zion nuclear power plant has been used as a discussion model. This evaluation has been prompted by the fact that the use of cooling towers may be greatly increased in the near future in order to meet proposed thermal discharge criteria.

This investigation has been conducted in light of the fact that the concepts of the critical concentrations of chemicals in natural waters have changed significantly during the past few years. In the past, the primary focus of water quality standards has been on the concentrations of chemicals in natural waters which would have a deleterious effect on aquatic life, as measured by the acute toxicity of the chemical to a particular organism.

Recently adopted IPCB standards which are used for evaluation of the Zion plant reflect, to some extent, the much stricter water quality standards necessary for protection of aquatic life against sub-lethal effects. It is likely that within a few years the critical levels of chemicals which have been established today will have to be revised downward even more in order to protect aquatic life as more information on chronic toxicity becomes available. Such revisions will result in the necessity of large expenditures by users of cooling towers to meet the new criteria.

It is clear that many of the chemicals present in the blowdown which would have expected concentrations slightly less than the IPCB effluent standards would not meet IPCB or other water quality criteria for the lake. Therefore, there will be a region in the vicinity of the discharge of the blowdown where excessive concentrations of these chemicals will occur. The FWQA (1970) proposes an approach that it is proper to dilute toxic chemicals in order to meet a standard, but it is not proper to dilute heat on a similar basis. This appears to be a somewhat contradictory approach in that the deleterious effects of heat are short-lived, reversible, and only affect the water in the immediate region of discharge. On the other hand, chemicals can have effects that extend over considerable distances. This is especially true today when the concepts of the critical concentrations of chemicals are being revised drastically downward as additional information becomes available.

It should be obvious from the above review that the conclusion drawn by the FWQA (1970) that blowdown from an evaporative type cooling tower at Zion would not cause any water quality problems is in error. It could be argued that such problems can be readily corrected by treatment of the blowdown water. While treatment is technically possible, some of the materials of concern, such as sulfate, are not being removed from waste waters at any location in the U.S. today. The only feasible methods for removal of such species are the very expensive techniques associated with saline water conversion (viz. ion exchange, reverse osmosis, evaporation). The relatively large volume of blowdown at Zion of 16 cfs would entail enormous cost to treat this blowdown so it would meet IPCB standards and not cause any adverse effects on water quality in the region of the discharge or in the lake itself. Certainly, the cost of this treatment must be included in any appraisal of the potential economic aspects of using cooling towers versus once-through cooling at large electric generating stations located on the shores of Lake Michigan.

In situations such as the Commonwealth-Edison Zion plant where the design of the discharge works effects very rapid cooling of the water within a minimum area and has a minimal effect on the ecology of the region, it is somewhat diffucult to understand why anyone would propose to trade a problem of a heated discharge which is rapidly cooled for one involving the discharge of a large volume of chemicals which are known to have adverse effects. Cooling towers must be used in many installations where large amounts of heat are to be dissipated to relatively small bodies of water. In the case of Lake Michigan, however, it appears to be in the best interest of the public and a sound ecological practice to utilize the heat assimilative capacity of Lake Michigan by allowing a limited number of thermal electric generating stations to use this lake for once-through cooling purposes rather than accept damage by discharging large volumes of chemicals.

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EFFECT OF COOLING TOWER BLOWDOWN WATER ON RECEIVING WATER QUALITY - A LITERATURE REVIEW*

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INTRODUCTION

In the past few years, federal and state regulatory agencies have been adopting thermal discharge standards which prohibit direct discharge of large volumes of cooling water to natural waters. These regulations will force the installation of a large number of the evaporative type cooling towers in order to dissipate the heat directly to the atmosphere. The nature of the evaporative type cooling tower is such that approximately one percent evaporation is necessary to achieve a 10°F temperature reduction. This evaporation results in the build-up of large concentrations of salts and other chemicals in the recirculation water.

The cooling tower heat exchange system has five basic problems associated with the recirculation water. These are: (1) scaling of heat transfer surfaces and recirculation piping, which decreases system efficiency; (2) corrosion, which results in shortening the useful life of the materials of construction; (3) general fouling of the system and components by precipitation and sedimentation from the water; (4) biological fouling, which results in accelerated corrosion and interference with heat transfer and flow; and (5) deterioration of wood structure by chemical and biological attack. In order to attempt to

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minimize these problems, the amount of evaporative concentration that normally takes place in a cooling tower is held to a minimum. In addition, various chemicals are added to the recirculation water in order to reduce the magnitude of these problems. Eventually, however, evaporative type cooling towers must discharge a substantial volume of the recirculation water to the environment if they are to continue to operate effectively. This discharged water is called blowdown. This paper considers the potential detrimental effects of cooling tower blowdown water on the receiving waters.

The volume of blowdown is highly variable and depends on many things including: makeup water quality, design and construction material, location and size of the tower and heat exchangers. The volume can be very large. For example, the installation of evaporative type cooling towers at the Commonwealth Edison Zion 2200 MW nuclear electric generating plant would result in a blowdown water volume of approximately 16 cfs. It is possible that under certain conditions, the chemicals present in cooling tower blowdown water could have a much more significant deleterious effect on water quality in a receiving water than the use of the water for direct once-thorugh cooling without chemical addition.

The chemical composition of cooling tower blowdown water is also highly variable depending on the chemical characteristics of the makeup water, the degree of evaporative concentration, the amount of drift (atmospheric loss of salts), the amount of corrosion of the cooling system, types and amounts of chemicals added to minimize water quality problems within the recirculating water system, amounts of materials scrubbed from the air passing through the tower, and biological activity within the tower and recirculation system.

Even if good data is available on the chemical composition of the makeup water and the amounts and types of chemicals added to the tower, it is still very difficult to predict the concentrations of many potentially significant chemicals in the blowdown water due to the inability to estimate the contributions from corrosion products, chemical and bio-chemical reactions that occur within the heat exchange system, fractional loss of chemicals in drift, air scrubbing, and leaching from construction materials. A review of the cooling tower literature will show that very little information is available on the chemical composition of cooling tower blowdown water. Generally, where data is available it is restricted to those chemicals such as calcium, magnesium, chloride, sulfate, bicarbonate, etc. which have, in general, very little effect on water quality except at very high concentrations. Little, if any data is available on the concentrations of some of the more significant chemicals which are known to have adverse effects on water quality at levels near a ug/l.

A few years ago, generally the only water quality problem that was thought to exist with cooling tower blowdown water was the toxicity of excessive amounts of chromate present in the blowdown which had been added to the tower for corrosion control purposes. In the past five to ten years, it has become generally recognized that other corrosion inhibitors must be used or the blowdown water must be treated for chromium removal prior to discharge to the environment. Today, however, coincident with the increased use of cooling towers, especially the anticipated use at large electric generating stations, it has become realized that many of the chemicals which were once thought to be safe at mg/l levels are actually toxic to aquatic organisms at ug/l levels. Serious questions are therefore raised about the advisability of switching from once-through cooling operations in those instances where little or no harm is anticipated to the environment by the discharge of heated natural water to evaporative type cooling towers where large volumes of blowdown water would be discharged to the environment.

A review of the cooling tower literature shows that, in general, zinc salts have been added to supplement or replace chromates as corrosion inhibitors in many cooling towers. The justification for this is generally that zinc at several mg/l is safe to discharge to the environment. However, this "safe concentration" is based on a short-term acute toxicity of zinc to fish. It is now realized that zinc at a few ug/l may have a sublethal chronic effect on fish which prevents them from reproducing. The fish or other aquatic organisms are not killed from the zinc. They simply do not reproduce, or reproduce as well, and therefore, in the end, it has the same detrimental effect as the higher levels of zinc. Today, a complete reappraisal is being made of the significant concentrations of many chemicals in waste waters. Generally, it is being found that the chronic sublethal effects of many chemicals occur at concentrations ten to a thousand times less than the acute lethal effects for fish and fish food organisms. Before discussing this point in further detail, it is appropriate to review the factors influencing the composition of blowdown water and the expected composition of that water.

FACTORS INFLUENCING CHEMICAL COMPOSITION OF BLOWDOWN WATER

Drift (Aerial Blowdown)

Another problem of the evaporative type cooling tower that can result in environmental degradation is drift. Drift is the formation of small droplets of the recirculating water that are carried from the tower and spread on the nearby landscape. Drift represents a form of aerial blowdown. Under severe conditions, these droplets or the evaporated salts that are formed in the atmosphere can lead to serious corrosion of metal, especially aluminum such as that used in house trailers, aluminum siding, etc. Depending on the types of salts present and the amounts, there can be a severe problem with respect to effects on terrestrial plants.

The potential significance of the drift problem is demonstrated by several comments in the cooling tower literature. Dalton (1962) states that the chromates in drift tend to discolor the landscape. Waselkow (1969) relates the experience of one electric utility company that relocated their entire main transmission line due to problems with flashover resulting from drift. This company then established a rule that transmission lines would no longer be located nearer than 500 ft. to a cooling tower. Thornley (1968) comments on the drift problem by stating, "Don't place tower near a parking lot where drift may spot paint on automobiles or adjacent to a taller building where drift may stain the building." Ford (1969) indicates concern for the total solids discharged to the air by drift. Crutchfield (1970) has mentioned that the Southern California Edison electric generating station is being placed on the Colorado River. Cooling towers for this station are designed for maximum aerial blowdown since, "by agreement with the Department of the Interior, no blowdown water can be returned to the Colorado River. The remainder of the blowdown water must go into evaporating basins," according to Crutchfield. In order to achieve a no blowdown condition at this plant, extensive makeup water pretreatment is necessary. Christiansen and Colman (1970) discuss how this is achieved by cold lime-soda ash softening pretreatment of the makeup water. They further discuss the reduction in water consumption effected by makeup pretreatment and consequent increased concentration ratios in the cooling tower.

The Atomic Energy Commission, in their evaluation of potential effects of cooling towers at the Palisades Plant of Consumers Power Company (AEC, 1972), noted that there are several sand dunes in the proposed area of cooling towers which are over 100 feet high, while the cooling towers which are proposed for this plant will be only 50 feet high. Further, many of the trees on the site reach 50-80 feet. Much of the time the plume from the cooling towers will impinge and spread over the nearby sand dunes. This could have a significant effect on the terrestrial vegetation near the plant. It is expected that the types of vegetation in the area of impingement of the cooling tower plume with the sand dunes would revert to shrubs and grasses and may even result in the complete loss of all vegetation due to blowout areas. Another potential problem with the cooling towers cited by the AEC (1972) is the presence of zinc and other toxic elements in the drift which would tend to accumulate on the ground and in vegetation. The AEC feels that the concentrations and total losses of certain chemicals such as sulfate and zinc could have a severe impact on plant and animal communities in the areas surrounding the cooling towers.

The Federal Water Quality Administration (FWQA, 1970) stated that drift is a normal problem that can be solved by the purchase of additional land to provide a greater degree of separation of the cooling tower and other activities of man. While these statements are correct with respect to suggesting a method to eliminate the problems of drift, namely, purchase additional land, clearly such land purchases must be considered part of the initial capital and operating cost of evaporative type cooling towers due to the loss of revenue fo more productive land use.

From a water chemistry point of view, it would be expected that the amount of drift would be highly dependent on the design of the cooling tower. The chemical composition of drift should relfect to some degree the chemical composition of the recirculating water. However, it has been shown that the chemical composition of ocean spray arising from wind over the open ocean results in a fractionation of the dissolved salts present in the spray which form air-borne salt crystals that have a different composition than the sea water from which they were derived. To some extent, a similar preferential fractionation should occur in the formation of drift in an evaporative type cooling tower.

Pretreatment of Makeup Water

Often, cooling tower makeup water is used with little or no pretreatment, however, in some installations, pretreatment is practiced. This pretreatment generally consists of softening to remove hardness. Occasionally, statements will be made that water quality in a cooling tower is not a critical factor, citing as evidence for this the fact that sewage effluent has been used in some cooling towers for the recirculating waters. However, a careful review of the literature will show that the use of domestic waste water effluents in cooling towers is not without significant problems.

Cummings (1964) discusses this situation with respect to the use of the municipal sewage effluent in cooling towers in several installations in Texas. He notes that extensive pretreatment of the water is necessary in order to remove phosphates, hardness and other materials which cause scale, corrosion and biological fouling. Furthermore, continuous side stream filtration is necessary in the cooling tower recirculating system to minimize the build-up of excessive amounts of precipitates. He notes that prior to the time of the conversion from the slowly degradable detergents to the readily biodegradable detergents that took place in the mid-1960's, the cooling towers using sewage effluent had severe foaming problems.

Terry (1966) reports on his experiences in the use of sewage plant effluent as makeup water for cooling towers. He also cites other instances where domestic waste water effluents have been used for this purpose. It was found that in order to avoid excessive scale problems due to phosphates and silica, a cold lime treatment of waste water was necessary. Also, it was necessary to add sulfuric acid to prevent calcium carbonate precipitation in the cooling tower system. He noted that relatively large concentrations of chlorine must be added to the system at various times in order to control excessive accumulation of slime forming organisms in the system. The organisms would tend to accelerate the rate of corrosion of metals in the cooling tower system. Smith (1964) discusses case histories of towers using municipal and industrial wastes, and mentions the pretreatment necessary for this type of makeup water. The Mohave Generating Station located on the Colorado River was mentioned earlier to have a cooling tower system designed for no blowdown. As discussed above this is achieved by extensive pretreatment of the makeup water.

It should be noted, however, that at most installations the makeup water is used without any pretreatment and that most of the water conditioning is accomplished by the addition of chemicals directly to the recirculating water. It is likely that side stream filtration will be used with increasing frequency on cooling towers where there is a tendency to build up excessive amounts of precipitates and particles scrubbed from the atmosphere in the recirculating water. Side stream filtration involves taking a small part of the recirculating water and passing it through sand or diatomaceous earth filters designed to remove small particles from the water and returning this filtered water to the recirculating system.

Chemical Additions

The primary method of water treatment for cooling tower recirculating water is by the addition of chemicals to minimize scale, fouling, corrosion, biological growths, and wood deterioration. Generally, these waters are treated by the addition of sulfuric acid and chlorine as the minimum treatment. Other treatments extend to mixtures of highly toxic metallic salts, complex phosphates, and biocides. Table 1 lists many of the identified compounds which are used. There are few general rules on the types and amounts of chemicals used in cooling tower recirculation water treatment. A large number of proprietary compounds are in common use. The exact composition of these compounds is not known; very few of them, if any, have been tested with respect to the long-term, sublethal, chronic toxicity on fish and other aquatic organisms. Cooling tower recirculation water treatment is usually described by professional companies that specialize in industrial water conditioning, many of which have their own proprietary compounds which are used in their treatment specifications. While it is not possible at this time to discuss in detail the many chemicals that are added to cooling tower recirculation water, it is possible to discuss the general nature of these compounds. The various types of chemicals used in cooling tower recirculation waters are briefly discussed below. It should be emphasized, however, that this is a highly changing field today, in which new chemicals are being introduced for this purpose by firms that specialize in cooling tower water treatment.

TABLE 1

Various Identified Chemical Compounds Used in the Treatment of Cooling Tower Water

Scale and/or Corrosion Control

Sulfuric acid	Organic esters
Chromate salts	Carboxylic acids
Dichromate salts	Molybdate
Zinc salts	Fluoride
Polyphosphate	Ferrocyanide
Hexametaphosphate	Copper
Pyrophosphate	Mercaptobenzothiazole
Polyol-esters	Polyacrylamide
Phosphonates	Carboxy methyl cellulose
Silicates	Aminomethylene phosphonic acid
Polymeric silicates	Borax
Nitrites	Potassium hydroxide
Amines	Sodium Hydroxide
Amides	Manganese
Pyridines	Nickel
Sulfamic Acid	Trivalent chromium
Polyelectrolytes	Benzotriazole
	Aromatic nitrogen compounds

General Fouling Control

Lignins	EDTA
Tannins	Citric acid
Lignosulfonates	Gluconic acid
Starch	Polyacrylate
Sodium silicofluoride	Polyethyleneimine

Biocides

Chlorine	Thiocyanates
Hypochlorite	Bromides
Chlorocyanurate	Creosote
Polychlorophenols	Cupric chromate
Dichloro-naphthoquinone	Zinc chromate
Mercury compounds	Bolinden
Acrolein	Erdalith
Copper sulfate	Quaternary ammonium sompounds
Arsenic acid	Chloromethylsulfones
Tri-butyltin oxide	Tertiary butyl hydrogen peroxide

Sulfuric acid. Generally, the conditioning of cooling tower makeup water for large industrial cooling towers involves the adjustment of the alkalinity (carbonate content) of the water with sulfuric acid in order to achieve a certain degree of calcium carbonate solubility in the recirculating water. Normally, the degree of calcium carbonate solubility or saturation is determined based on the calcium content that builds up in the recirculation water due to evaporative concentration and that added in the makeup water; the pH of the recirculating water; and the carbonate concentration, which is determined by the alkalinity and pH. This adjustment is generally made to some value on either the Langelier or Ryznar index. Normally, an attempt is made to achieve an index value which is near the point where the ion activity product of calcium and carbonate are just about equal to the solubility product of these species. The theory behind this approach is one of maintaining a thin film of calcium carbonate in order to reduce corrosion, yet at the same time, adjust the composition of the water such that large amounts of calcium carbonate scale do not form. While this is the generally accepted approach for cooling towers, there are questions about the validity of this approach for some waters since a number of investigators have shown that the corrosion tendency of a water may be independent of the stability index of the water with respect to calcium carbonate solubility. The operator of a cooling tower should conduct *in situ* tests on the corrosiveness of the recirculation water to try to condition this water in such a way as to minimize scale formation and corrosion based on empirical testing rather than on the somewhat arbitrary saturation indices that are frequently used. The addition of sulfuric acid is usually made in sufficient amounts to achieve a recirculation water pH near neutral. This addition converts carbonate and bicarbonate to CO_2 which is scrubbed from the tower by air. Therefore, carbonate salts are replaced by sulfate salts. Sulfates may have an adverse effect on water quality as discussed later. Furthermore, the operator of the cooling tower must operate it in such a manner as to avoid sulfate scale problems that might arise from the use of H_2SO_4 in the tower.

Chlorine. The second most commonly used chemical in conditioning of the cooling tower recirculation water is chlorine. It is widely used as a biocide. Motley and Hoppe (1970) mention that chlorine is an effective biocide for the control of algae and bacterial slimes at 1.5 mg/l free available chlorine on a once or twice daily shock application. They point out that concentrations higher than this level are likely to cause deterioration of tower lumber. Generally, continuous addition of chlorine is not needed, and the period of treatment is generally for the time it takes for one complete recycle of the water through the tower and heat exchange system. In those cooling towers where large amounts of hydrocarbons or other organic constituents are present, the application of chlorine may have to be increased considerably in order to satisfy the chlorine demand. It is likely that because of the concentrations of ammonia typically present in cooling tower recirculating water, chloramines would be formed with the addition of chlorine. Some of the free chlorine as well as the chloramines may be present in the cooling tower blowdown water thereby creating potential water quality problems in the receiving water.

The environmental impact statement prepared by the AEC (AEC, 1972) for the Palisades Plant of Consumers Power Company states that cooling towers at this plant would utilize chlorine which would result in a blowdown discharge of chlorine of about 1 mg/l for one hour per day. The residual chlorine discharged to the lake would be 0.022 mg/l after dilution of blowdown water by 60,000 gpm and the area affected by the chlorine will be less than that for once-through cooling. However, they note that the period of chlorine discharge will be thirty times longer than for once-through cooling.

Phosphates. Various types of phosphate compounds are widely used in cooling tower recirculation water. These compounds act to reduce corrosion and to prevent scale and sludge formation. Polymeric phosphates act as nucleation inhibitors and thereby minimize the deposition of various types of precipitates on the heat exchanger, as well as other surfaces in the cooling tower heat exchanger recirculation system. Frequently, the polyphosphates are used at the 1-10 mg/l phosphorus level. Recently, some relatively new organic phosphates, the polyol-esters and the phosphonates, have been introduced for use in cooling towers. These compounds are claimed to be highly effective for scale inhibition. The manufacturers report that these compounds, which are P-O-C bonded compounds, do not revert to orthophosphate in natural waters. However, examination of the information available on the testing that has been done on this lack of reversion shows that additional stydy is necessary to be certain that reversion does not in fact take place in natural waters at a relatively slow rate due to enzymatic processes. The situation with respect to the polyol-esters and phosphonates may be somewhat similar to that to NTA (nitrilotriacetic acid) where an acclimatized group of microorganisms was shown to be able to readily degrade NTA; however, non-acclimatized organisms could not bring about this reaction. These polyol-esters of phosphate and the phosphonates are recommended for use in the 2-100 mg/l range in the recirculation water of a cooling tower. Since there is a possibility of their reversion to orthophosphate, their use in cooling towers on a large scale basis should be preceeded by careful studies on this reversion process. These potential problems have not been investigated by the manufacturers (Zecher, 1970a).

According to Motley and Hoppe (1970), the discharge of any phosphates from cooling tower installations into the Ohio River is now prohibited. It is very likely that restrictions on phosphate discharges will be in effect throughout the country in the near future.

Chromates and Other Corrosion Inhibitors. Cone (1970) discussed the various types of chemicals that are frequently used to control corrosion in cooling towers, emphasizing some of the problems associated with the chemicals used. This review should be consulted for a fairly recent discussion of the chemicals that are likely to be present in cooling tower blowdown water from industrial type cooling towers.

Chromate salts are generally found to be the most effective inhibitors. Usually corrosion control can be secured by a 100-300 mg/l chromate content in an open recirculating system and 390-500 mg/l chromate in a closed recirculating system. Sometimes concentrations in excess of 500-1000 mg/l are necessary to prevent pitting, according to Cone (1970).

Cone notes that the addition of zinc to a chromate inhibitor results in corrosion control or minimization at lower chromate concentrations. Certain organics, such as lignosulfonates and synthetic polymers are added to the chromate-zinc-phosphate formulation to reduce pitting tendencies. Cone notes that the use of silicates for corrosion control requires fairly careful control of pH. It is reported that usually

20-40 mg/l of silicate are sufficient to obtain desired protection in the cooling system and that the addition of polyphosphates enhances corrosion inhibition.

Nitrites as anodic inhibitors for corrosion control are used at 200-500 mg/l or more. pH in the recirculation system must be alkaline in order to prevent localized decomposition of the nitrites. In some cases. fluoride is added with the zinc-chromate-phosphate system to treat waters which contain large amounts of aluminum. The fluoride complexes the aluminum to prevent it from reacting with phosphates which are added for corrosion control.

Cathodic inhibitors include various multivalent metals such as zinc, nickel, manganese, and trivalent chromium. Again the addition of phosphates to the system often allows the cathodic inhibitor to be effective at lower concentrations. Cone notes that organic inhibitors have been receiving increased use in recent years. Some of the commonly used organic inhibitors are amines, amides, pyridines, carboxylic acids, esters and macaptans.

The organic phosphorus compounds mentioned above, the polyol-esters and the phosphonates, are receiving increased use along with some of the aminomethylene phosphonic acids. Most of the formulations containing multi-component mixtures of these various compounds are proprietary and the exact composition is not readily known because of the proprietary nature of the compounds. Cone (1970) claims that the most widely used corrosion inhibitors for cooling water systems are polyphosphates, zinc-phosphates, silicates, and the zinc-chromate-phosphate combination.

Zecher (1970b) discusses the difficulties encountered in replacing chromate as a corrosion inhibitor in cooling tower systems. Other treatment programs are evaluated from the standpoint of corrosion inhibition and potential pollution of water receiving the tower blowdown.

Thornley (1968) discussed the various problems that occur in cooling towers and the commonly used methods for evaluating these problems. He notes that chromate is still one of the most satisfactory chemicals for controlling corrosion in cooling tower systems. The chromates are used in either the high chromate treatment, concentrations of 200 to 2500 mg/l of sodium chromate, or the low chromate treatment at concentrations on the order of 50 mg/l. With the latter, normally it is combined with phosphates, zinc, and other chemicals.

Donohue (1969) notes that the general tendency today in cooling tower water conditioning is to reduce the use of chromate for corrosion control and increase the zinc and phosphate use. He predicts that eventually because of the problems which are being created by zinc-phosphate systems in natural waters receiving the blowdown, many plants will go back to the chromate system coupled with the removal of chromate from the blowdown water. He discusses a system which enables the removal of chormate from the blowdown water as well as reviewing some of the applications, various types of chemicals used for water conditioning in cooling towers, and the problems associated with their use.

Kelly(1968) has reviewed the procedures that can be used to remove chromates from cooling tower blowdown. He notes that effective chromate removal can be achieved by the use of an ion exchange process; however, the cost of this process is in the order of $0.511/lb of chromate removed. He states that a very careful control of pH is essential to produce a chromate free effluent and also, an adequate feed of reducing agent is important.

Schieber (1971) has discussed the removal of chromates from cooling tower blowdown water, including consideration of the cost of various types of processes that can be used for this purpose, as well as chromate recovery. Hesler (1964) further discusses the removal of chromates by the ion exchange process noting some of the more important parameters that must be carefully controlled in order to achieve good removal. Puckorius and Farnsworth (1964) discuss a process which can be used to recover the chromate and reuse it as a corrosion inhibitor in the cooling tower. They point out the economic advantages of such a recovery process, as well as the advantages of minimizing potential water quality problems to the blowdown water discharge containing chromates.

Organics. There is an increasing tendency to use organic compounds in cooling tower water conditioning. Motley and Hoppe (1970) mention that the basic "conventional" chemical conditioning for cooling towers for electric generating stations is the use of sodium hexametaphosphate for corrosion and stabilization, sulfuric acid for control of pH and alkalinity, and chlorine as a biocide. They predict that the organic phosphate compounds will eventually supplant the sodium hexametaphosphate treatment and may reduce the amount of acid needed for alkalinity reduction.

Donohue (1967) discusses the use of organic topping agents in cooling towers for water conditioning purposes. Organic topping agents are organic based compounds added to cooling water for the purpose of supplementing corrosion inhibition, maintaining heat exchange surfaces as free of deposit as possible, and preventing scale formation.

Typical materials used for this purpose are EDTA (ethylenediamine-tetraacetic acid), citric acid, gluconic acid, as well as various types of dispersants and coagulants. He notes that many types of organic compounds are being explored today for this purpose.

Lees and Twiford (1969) have discussed the theoretical and practical aspects of the use of various types of polyelectrolytes for water conditioning in cooling towers. Their paper should be consulted for additional details on this topic. Puckorius (1971) has reported on the use of a combination of organic polymers with the more traditionally used inorganic polymer, such as phosphates and silicates in minimizing corrosion in cooling towers. The nature of the organic polymers is proprietary at this time; however, they are classified as organic polyelectrolytes. The potential effects of these compounds on water quality in natural waters is unknown at present, although similar compounds have been used for treatment of municipal water supplies. Hwa (1968) discussed the replacement of chromates with synthetic organic compounds for corrosion control. Weisstuch, et al. (1970) have discussed the use of complexing agents such as EDTA for corrosion control in cooling towers. According to these authors, there is a relatively strong bond formed between the complexing agent and the metal which forms a tenacious film and tends to inhibit further corrosion. Their paper reviews the general nature of this process.

A new series of organic nitrogen corrosion inhibitors are now being used in cooling towers. Von Koeppen, et al. (1972) describe the mode of action and the effectiveness of these aromatic compounds. They are used with a phosphate and zinc mixture. Towers using this type of treatment will discharge relatively large concentrations of organic nitrogen and perhaps nitrate.

Carter and Donohue (1972) discuss the use of nitrogen-based compounds in conjunction with phosphonates to eliminate the requirement for either chromate or zinc in certain cooling towers.

Another potential problem with some of the organic proprietary compounds used in cooling towers which eventually will be discharged to natural waters through blowdown is the fact that some of them are essentially non-biodegradable. For example, the use of complexing agents such as EDTA in cooling towers, which is sometimes recommended, could result in this compound being dispersed into the environment. Since EDTA appears at this time to be non-biodegradable, it would cause significant problems in the environment as a result of its strong complexing tendencies for potentially toxic transition metals that are present in the sediment of natural waters. The polyol-esters that were mentioned earlier may also present problems by complexation of toxic metals. This area should be thoroughly investigated.

Other Biocides. In order to minimize the delignification of cooling tower lumber by fungi, Motley and Hoppe (1970) state that normally inorganic chemicals or creosote is used as a fungicide.

Willa (1965) discusses the use of polychlorophenates as a means of controlling fungus attack on wood in cooling towers. The chlorophenates are also used to control algae and other slime growths. They may be fed continuously or intermittently. There is considerable concern today among some water chemists about the possibllity of the chlorodioxin being contaminants in the chlorophenates used in cooling towers. The chlorodioxins have been found to be one of the most toxic compounds isolated by man. These were the compounds that caused the temporary suspension of the use of the herbicide, 2,4,5-T. Based on the manufacturing conditions that led to the contamination of 2,4,5-T, it is possible that the chlorophenates may also be contaminated. This is an area of active investigation at this time. The chlorodioxins are highly mutagenic, showing toxicity at ug/l levels. Furthermore, the chlorophenols are notorious for causing tastes and odors in water supplies and the tainting of fish. Willa (1965) notes that these compounds have been used at concentrations up to 300 mg/l as a shock treatment in some cooling towers.

Thornley (1968) presents an extended discussion of the problems with various types of organisms in cooling towers and the method for their control, noting that the chlorophenates, acrolein, tri-butyltin oxide, certain thiocyanates and quaternary ammonium compounds are used as biocides in cooling towers. It should also be noted that while Thornley mentions the fact that mercury compounds are excellent biocides, they are rarely used because of toxicity in the blowdown water. Based on the authors' experience, organic mercury compounds have been discharged to surface waters and have been responsible in part for some of the buildup of mercury in aquatic food web in some areas.

Donohue (1971) mentions a new approach that may be taken to avert the problem of toxic biocide residues in the blowdown; biocides that can be detoxified. Acrolein, tertiary butyl hydrogen peroxide and bromo nitro styrene are effective and stable as biocides in the tower but they may be readily detoxified upon disposal by stoichiometric quantities of sulfite. He suggests that these may eventually replace all other non-oxidizing biocides.

Another source of chemicals that may be found in cooling tower blowdown water is the preservative chemicals leached from the wood when the tower is first operated. At the present time, little information is available on the nature of these chemicals or the rates of leaching of these chemicals from the wood. Puckorius (1970) mentions the condition known as "black water" resulting from the leaching of natural organic materials from untreated redwood in newly constructed or rebuilt towers. He also discusses the leaching of arsenic, chromium, and copper salts (at levels exceeding 40 mg/l), and the creosote "slick" that results from treated lumber early in operation of a tower.

Hoppe (1971) claims that the wood preservative salts frequently used are cupric chromate and zinc chromate Boliden or erdalith are used which are mixtures of copper chromatoarsenite and in some instances, ferris salts.

General. Marshall (1971) has presented a general review of some of the various types of chemical treatments used for conditioning cooling tower waters. Freedman and Boies (1960) have reviewed the problem of corrosion in cooling towers and the various methods that can be used to reduce corrosion rates. Parker and Krenkel (1969) have provided a general review of the potential detrimental effects that can be caused by the discharge of blowdown water on surface water quality. Troscinski and Watson (1970) have reviewed the various methods that are normally used to control deposits within cooling tower systems.

Motley and Hoppe (1970) have discussed cooling tower design criteria and water treatment. Their paper should be consulted for further discussion of this topic. They point out that much closer scrutiny of the constituents that may be used in cooling tower water conditioning will have to be given in order to meet the increasingly stringent water quality criteria that are being developed today.

Operating Practices for Cooling Tower Water Conditioning.

Kelly and Puckorius (1966) discuss the typical concentrations of various chemicals that are used for control of corrosion, scale, and microbial growth in cooling towers. It is of interest to examine some of these treatments (see Table 2) in order to possibly ascertain what might be the concentrations present in some cooling tower blowdown waters.

TABLE 2*

Treatment Type	Dosage (mg/l)
Polyphosphate-based (PO_4)	20-40
Organic-polyphosphate-based (PO_4)	10-20
Chromate-phosphate (CrO_4)	15-30
Chromate-based (CrO_4)	15-20
Organic-chromate (CrO_4)	5-15
Organic-based (Total Treatment)	50

*after Kelly and Puckorius (1966)

In an attempt to gain information on existing practices with cooling towers located at electric generating stations, T.C. Hoppe of Black and Veatch Consulting Engineers of Kansas City was contacted regarding his experiences in water conditioning in cooling towers. He (personal communication, 1971) cited five different situations at cooling tower systems for turbine generators in the range of 50-850 MW. He states that the majority of these stations use chemicals in addition to sulfuric acid and chlorine. He provided five examples and these are presented below:

Water Conditioning at Cooling Towers
for Electric Generating Stations (Hoppe, 1971)

a. Polyphosphate a -8 mg/l $(PO_3)_x$, sulfuric acid, chlorine;

b. Sodium chromate at 25-30 mg/l CrO_4, polyphosphate 4-8 mg/l $(PO_3)_x$, sulfuric acid, chlorine;

c. Organic phosphate at 25 mg/l without zinc, sulfuric acid, chlorine;

d. Organic zinc at 25 mg/l without phosphate, sulfuric acid, chlorine;

e. Sodium chromate at 5 mg/l CrO_4 without sulfuric acid.

On the other hand, T.A. Miskimen reports (personal communication, 1971) that all of the American Electric Power Company cooling towers, except one, operate with just the addition of sulfuric acid and chlorine.

A drive through the countryside of England generally reveals large numbers of cooling towers at various thermal electric generating stations. Superficially, it would appear that the use of cooling towers in England is the preferred method of disposal of water heat, based on the fact that large numbers of cooling towers are present. However, further examination of this situation reveals cooling towers are used in England only under those circumstances where once-thorugh cooling cannot be readily practiced. Even where installed, the cooling towers are generally used only on a limited basis during low flow periods.

Another important difference between the English practice in cooling towers and that of the U.S. is with respect to the use of chemicals for water conditioning. The English towers tend to operate on a 1 to 2 recycle ratio, while in the U.S., much higher recycle ratios are used. The low recycle ratio being used in England is designed to minimize the problems of scaling, corrosion, etc. that often occurs because of the chemicals present in the waters used for cooling purposes. Often, in the more industrialized areas, water quality available for use in cooling towers is such that higher recycle ratios would require extensive water conditioning. In general, the English cooling towers operate with little or no water conditioning. They tend to be used to some extent as a modified once-through cooling operation where very large volumes of water are run through the cooling tower prior to discharge. It is almost as though the cooling towers are being used as part of the once-through cooling operations. On the other hand, in the U.S., much higher recycle ratios are used, thereby minimizing the amount of water discharged from blowdown, necessitating much greater use of chemicals for cooling tower water conditioning purposes.

Air Scrubbing

An evaporative type cooling tower represents a large air scrubbing device, whereby materials which are contained in air would be washed from it as part of the heat exchange process. These various chemicals would tend to accumulate in the recirculating water and would be discharged in the blowdown. While to our knowledge no studies of this type have been conducted thus far, this problem has been noted in the past. For example, Thornley (1968) comments: "Don't place towers next to boiler smoke stacks. The stack fumes will be drawn into the tower and cause corrosive acid solutions." He goes on to comment about the fact that cooling towers should be located in a dust-free area because of the problems of contamination of the recirculating water. The data on the chemical composition of the atmosphere with respect to potentially hazardous chemicals is quite limited. Some recent studies conducted at the Canadian Centre for Inland Waters (CCIW), under the direction of Mary Thompson (1971), have shown that the concentrations of potentially significant chemicals in the air are quite large. The CCIW studies represent, in many cases, approximately 100 analyses taken at various locations in Canada, representing both urban and rural environments. Table 3 presents the results of these studies for the chemical composition of rainfall. While at this time it is almost impossible to equate the composition of rainfall and other precipitation to the composition of blowdown water that might result from evaporative type cooling towers, the rainfall water does provide an indication that there are sufficient concentrations of various trace metals, aquatic plant nutrients and other potentially toxic substances present in the atmosphere to cause problems in water quality. In fact, examination of Table 3 shows an average concentration of phosphate, inorganic nitrogen, lead, copper, zinc, and cadmium which would be considered excessive compared to the new water quality standards that are being developed by various states and the federal government. In other words, often precipitation would not meet the new standards such as those proposed for Lake Superior by the FWQA (1969) and the State of Minnesota (Minnesota, 1970).

Glover (1970) considers the air-borne contamination of cooling tower water. He presents the following formula for calculating the absorption of soluble gases and suspended solids from the air:

$$BC = RC = (AC)(WE)(SF)\frac{(AR)}{(BD)}$$

where BC = concentration of air-borne contamination in blowdown water, lb contaminant/lb water

TABLE 3

Chemical Composition of Precipitation
Data from Canada Centre for Inland Waters*

Parameter	Mean	Standard Deviation	Maximum	Minimum
Total PO_4	292.00 ug/l	542.00 ug/l	380x10 ug/l	5.00 ug/l
Soluble Re-active PO_4	180.00 ug/l	449.00 ug/l	340x10 ug/l	0.00 ug/l
Nitrate - N	1.32 mg/l	1.60 mg/l	10.80 mg/l	0.07 mg/l
Ammonia - N	1.03 mg/l	1.20 mg/l	9.25 mg/l	0.00 mg/l
Chloride	3.05 mg/l	4.72 mg/l	25.80 mg/l	0.11 mg/l
Sulfate	9.23 mg/l	5.11 mg/l	26.10 mg/l	0.80 mg/l
Sodium	3.10 mg/l	4.70 mg/l	24.20 mg/l	0.10 mg/l
Potassium	0.59 mg/l	0.78 mg/l	6.00 mg/l	0.08 mg/l
Magnesium	0.64 mg/l	0.69 mg/l	4.10 mg/l	0.00 mg/l
Calcium	4.50 mg/l	3.90 mg/l	24.00 mg/l	0.00 mg/l
Bicarbonate	6.20 mg/l	9.50 mg/l	50.10 mg/l	0.00 mg/l
Lead	25.00 ug/l	29.00 ug/l	160.00 ug/l	1.00 ug/l
Copper	27.00 ug/l	101.00 ug/l	800.00 ug/l	0.00 ug/l
Iron	58.00 ug/l	61.00 ug/l	310.00 ug/l	1.00 ug/l
Zinc	98.00 ug/l	51.00 ug/l	272.00 ug/l	10.00 ug/l
Cadmium	2.00 ug/l	3.00 ug/l	16.00 ug/l	0.00 ug/l

*After Thompson (1971)

RC = concentration of air-borne contaminants in recirculating water, lb contaminant/lb water

AC = concentration of contaminant in the atmosphere, lb contaminant/cu ft air.

WE = washing efficiency

$$= \frac{\text{lb contaminant entering water}}{\text{lb contaminant in air circulated through tower}}$$

(generally 0.95-1.0)

AR = air rate in cu ft air/lb water recirculated through the tower (generally about 10 cu ft air/lb water).

BD = blowdown fraction = lb water blowdown/lb water recirculated.

SF = suspended fraction

$$= \frac{\text{lb contaminant remaining suspended in solution}}{\text{lb contaminant washed from air}}$$

(1.0 for soluble gases and soluble dusts and 0.1-0.5 for insoluble dusts).

According to Glover, the quantity of insoluble suspended materials scrubbed from the atmosphere frequently dictates the amount of blowdown required.

Glover's formula may be used to approximate the expected degree of contamination of blowdown water from atmospheric sources. In Table 4 the calculated mean and maximum contamination of blowdown water is shown. The ambient air-borne levels of contaminants are highly variable, with generally higher values in urban areas for most contaminants. The ambient mean and maximum air-borne values shown in Table 4 were selected from two sources. The values for Pb, Cu, Ni, and V are representative of an urban particulate; those for the other species are national averages except where noted.

It is assumed for the calculations that the washing efficiency is 1.0, the air rate is 10 cu ft air/lb recirculating water, and the blowdown fraction is 0.006 which is the sum of the blowdown and drift loss expected for cooling towers designated for the Zion Nuclear Power Station of the Commonwealth Edison Company (Sargent and Lundy, 1971). Since it is not known what portion of the air-borne particulate may be soluble, a value of 0.5 is used for the suspended fraction. Hence, for the mean air-borne phosphorus value of 1.43 ug/m^3,

$$BC = (8.86 \times 10^{-11})(1)(0.5)\,\frac{10}{0.006} = 0.0715 \text{ mg/l}$$

It is evident from Table 4 that Fe, Pb, An, P, Cd, Hg, NH_4^+ or $SO_4^=$ could occur in the blowdown water at a level that would create a disposal problem solely from atmospheric sources. This would be most likely to occur for a tower located in an urban or industrial area. Ammonia could become a particular problem upon chlorination of the cooling tower for control of microorganisms. The chloramines that are formed are highly toxic to fish at ug/l levels. When ammonia is in the mg/l range in the recirculating water, extreme care must be taken to avoid fish kills from the discharge of chloramines.

Loss of Volatile Material

The stripping by air of volatile materials from cooling tower recirculating water is another effect that influences the chemical composition of the blowdown water. Ammonia and volatile organic contaminants in the recirculating water would be the principal species affected and, as such, stripping would not be expected to be of great significance unless waste waters are used as the tower makeup.

Roesler, *et al*. (1971) have devised a computer program for determining the degree of removal of ammonia from waste water by air stripping in a conventional cooling tower installation. The Georgia Kraft Company (1971) investigated

TABLE 4

Atmospheric Contamination of Cooling Tower Recirculating Water

Species	Atmospheric Concentrations of Selected Contaminants, ug/m^3		Calculated Concentrations of Contaminant in Cooling Tower Blowdown from Air, ug/l	
	Mean	Maximum	Mean	Maximum
Fe	1.54[1]	22.0	77.0	1100
Pb	1.37[2]	3.60	68.5	180
Cu	0.29[2]	1.51	14.5	75.5
Ni	0.18[2]	0.36	9.0	18.0
V	0.17[2]	0.35	8.5	17.5
Zn	0,67[3]	58.0	33.5	2900
P	1.43[4]	4.23	71.5	222
Cr	0.015[5]	0.350	0.5	17.5
Cd	0.002[6]	0.350	0.1	17.5
Hg	0.001[7]	0.01	0.05	0.5
NH_3*	1.0[8]	260	100	25800
As	0.02[9]	2.5	1.0	125

*SF = 1.0

[1]Morrow and Brief (1971)

[2]USHEW (1969a)

[3]USHEW (1969b)

[4]USHEW (1989c)

[5]USHEW (1969d)

[6]USHEW (1969e)

[7]USHEW (1969f)

[8]USHEW (1969g)

[9]USHEW (1969h)

the use of a cooling tower for the removal of biological oxygen demand (BOD) from kraft mill wastes. They found that 25-30 percent of the waste water BOD could be removed by a cooling tower. The primary mechanism of BOD removal was not biological consumption but the physical process of stripping of the volatile components in the waste water. They recommended further investigation of the impact of this process on air quality.

COMPOSITION OF BLOWDOWN WATER

Very little information exists today on the chemical composition of blowdown water in the U.S. Davies (1966) reported on the chemical composition of several cooling tower blowdown waters located on streams in England. He found that chloride and sodium sulfate concentrations build up in the blowdown water in proportion to the degree of concentration by evaporation and the concentrations in the makeup water. His discussion did not provide sufficient data to determine what concentrations of some of the more critical elements might accumulate in typical cooling towers operated in England. Hoppe (1966) discusses some of the problems associated with the use of various types of chemicals in water conditioning in cooling towers. In particular, he examines the problems of corrosion control with the chromate-zinc treatment, the zinc-polyphosphate treatment, and the zinc-organic treatment. He presents a waste treatment removal scheme for the removal of chromate and zinc from blowdown waters, as well as a system for discharge of blowdown to deep disposal wells. Hoppe presents a table in this paper for cooling tower blowdown water composition of an industrial type cooling tower which uses a zinc-organic based formulation for the cooling makeup water conditioning. This table is reproduced in this paper as Table 5 for comparison purposes.

The cooling tower literature contains several papers which present a limited amount of data on the recirculation water, blowdown water or simulated recirculation water which would be used for various types of testing for corrosion control, etc. Table 6 is a compilation of selected data from the various papers from the literature. Examination of Table 6 shows that generally pH for these various cooling tower waters is near 7 with a hardness ranging from several hundred to over a thousand mg/l as calcium carbonate. The calcium and magnesium content of the water averages about 100-300 mg/l with a total alkalinity ranging from 5-44 mg/l as calcium carbonate. The chloride content is several hundred mg/l with sulfate ranging from 250 to 1400 mg/l. The change in bicarbonate and carbonate alkalinity to sulfate is quite evident from the table. The dissolved solids content for the three samples given range from approximately 1000-2000 mg/l. The one sample shows a chromate concentration of 280 mg/l.

The rather meager data on the chemical composition of cooling tower blowdown water prompted the authors to contact several firms and associates for unpublished data. W.T. Betz Company of Trevose, Pennsylvania provided data of this type. Table 7 presents the characteristics of each of the cooling towers studied. Data is given on location, water source, and type of treatment used.

The data in Table 8 from Betz Laboratories shows approximately the same characteristics as the data presented in Table 6 for the ten different cooling towers for the common parameters such as pH, hardness, calcium, magnesium, and alkalinity. Although it is of interest to note that typically, the alkalinity values in the Betz reports are considerably

TABLE 5

Analysis of Cooling Tower Blowdown
on Zinc-Organic Treatment*

pH	8.0
Total alkalinity as calcium carbonate	146 mg/l
Total hardness as calcium carbonate	1327 mg/l
Calcium hardness as calcium carbonate	847 mg/l
Sulfate as calcium carbonate	1360 mg/l
Chloride as calcium carbonate	134 mg/l
Zinc as zinc	1.2 mg/l
Total dissolved solids	2728 mg/l
Specific conductance	3040 umho/cm
Ammonia as N	0.04 mg/l
5 day BOD	1 mg/l

The cost for such treatment was estimated by Hoppe to be in the order of $0.1275/1000 gallons of makeup.

*After Hoppe (1966)

TABLE 6

Chemical Composition of Cooling Tower Recirculation Water *

Parameter	Savinelli and Beecher	Fisher and Jeter+	Drew Corporation+	Kerst+	Sloan and Nitti (1966)
pH	7	7.2-8.2	6.8	7.4	6.9
Hardness as $CaCO_3$	400	336	400	1276	495
Ca as $CaCO_3$	250	168	300	885	395
Mg as $CaCO_3$	150	168	100	658	100
Total alkalinity as Ca CO_3	5	24	20	44	
Cl^-	302	140	500	79	390
$SO_4^=$	956	332	500	1170	250
SiO_2	-	18	-		
$NO_3^=$	-	62	-		
F^-		15			
Fe	-	0.2	0.5		
Total dissolved Solids		1090	1646	1060	
Copper	-	-	0;2		-
Turbidity		-			20-40
$CrO_4^=$					280

*all concentrations in mg/l
+in Savinelli and Beecher (1966)

TABLE 7

Identification and Characteristics of Cooling Tower Water Analyses Data

Data from Betz 1971*

Cooling Tower Number	Cooling Tower Location	Makeup Water Source	Treatment
1	Northeast	Unclarified River	pyrophosphate-phosphonate-mercaptobenzothiazole-polyacrylate
2	Great Lakes Area	Clarified River	Chromate-zinc-phosphonate-polyacrylate
3	Gulf Coast	Well Water	chromate-zinc-phosphonate-polyacrylate
4	Far West	Unclarified River	zinc-lignin-phosphonate-polyarcylamide
5	Eastern	Unclarified River	chromate-phosphonate-polyacrylate-zinc
6	Southeast	Well Water	chromate-zinc-phosphonate-polyacrylate
7	Midwest	Well Water	chromate-zinc-orthophosphate
8	Far West	Clarified River	chromate-zinc-phosphonate
9	Gulf Coast	Clarified River	chromate zinc-phosphonate
10	Southeast	Well Water	chromate-zinc-phosphonate-polyacrylate

*from W.D. Betz Company, Philadelphia, Pennsylvania (1971)

TABLE 8

Chemical Characteristics of Cooling Tower Recirculation Water*

Data from Betz (1971)

	1	2	3	4	5	6	7	8	9	10
Total hardness as $CaCO_3$	650	220	50	600	250	350	1000	500	420	320
Calcium as $CaCO_3$	500	170	40	380	180	160	700	250	300	180
Magnesium as $CaCO_3$	150	50	10	220	70	190	300	250	120	140
Total Alkalinity as $CaCO_3$	120	130	150	150	50	80	30	100	80	70
Sulfate	120	140	20	130	410	600	780	300	180	660
Chloride	500	120	10	20	50	40	200	50	90	40
SiO_2	20	1	80	10	22	90	3	75	25	120
Total Phosphate as PO_4	5	0.8	0	0.9	0.2	0.2	2.0	0.2	0.1	0.2
Orthophosphate as PO_4	3	0.8	0	0.9	0.2	0.2	2.0	0.2	0.1	0.2
pH	7.5	8.0	8.2	8.1	7.2	7.2	6.5	7.5	7.2	7.2
Specific Conductance Micromhos/cm	2000	800	300	1200	1000	1300	1600	1500	1000	1000
Chromate as CrO_4	0.0	25	6	0.0	25	16	20	12	15	16
Trivalent Chromium as Cr	0.0	0.5	0.0	0.0	0.0	0.5	0.2	0.1	0.0	0.0
Soluble Zinc as Zn	0.0	1.5	0.5	1.5	7.0	3	3.0	2.0	1.8	2.5
Aluminum as Al		0.5						6.0		
Complex Phosphate (PO_4)	8	5	2	7	5	5	0	2		3
Suspended Solids		25		60					35	
Lignosulfonate	0.0	0.0	0.0	10	0.0					
Total Iron as Fe	0.5	0.8	0.05	3.0	1.2	15	0.5	3.5	1.2	0.8

*all concentrations mg/l

higher than those reported in Table 6, it is possible that the combination of use of the various types of chemicals in treating the cooling tower enables the operator of these towers to carry higher alkalinity values without having severe scale problems. This is also noted because of the fact that the sulfate levels in the Betz data tend to be somewhat less. It is of interest that the phosphate levels of the various cooling towers for Betz range from a few tenths up to several mg/l. Chromate typically runs 6-25 mg/l. Zinc, when used, is approximately 0.5-7 mg/l.

One additional source of chemical analysis data on cooling tower blowdown water was obtained from the Illinois State Water Survey (1971). This data is presented in Table 9 where analyses from November, 1971, are presented for six different non-industrial cooling towers located in the State of Illinois. The cooling towers are located at various State of Illinois institution buildings.

Examination of the data presented in Table 9 shows that in general the chemical characteristics of these cooling tower blowdown waters are approximately the same as those presented in Table 6 from the literature. It is of interest to note that some of the Illinois State Water Survey cooling towers have several mg/l of phosphate. This data also gives an indication of the levels of trace metals, such as chromium, copper, lead, nickel, and zinc in these cooling towers. Generally, the concentrations of these various metals range from less than 50 ug/l to several hundred ug/l, except for chromium which ranges from 20-60 mg/l. It is obvious that all of these cooling towers receive a chromate treatment. The lead and nickel concentrations are uniformally less than 50 ug/l, with zinc typically ranging in the order of a few tenths of a mg/l. The cadmium levels in all samples were

TABLE 9
Chemical Composition of Cooling Tower Effluent
Data from Illinois State Water Survey, November (1971)*

	Elgin State Hospital 10-27-71	Tinley Park Mental Health 10-20-71	Dixon State School 10-6-71	Illinois State Penitentiary Building 4 Vienna 9-22-71	Refrigeration Unit, Ill., State Penitentiary 9-22-71	Manteno State Hospital 8-16-71
Iron total Fe	0.30	0.12	0.36	0.02	0.10	0.4
Calcium Ca	18	46	314	177	179	94
Magnesium Mg	9	78	196	25	22	42
Cadmium Cd						
Unfiltered	0.00	0.00	0.00	0.00	0.00	0.00
Filtered	0.00	0.00	0.00	0.00	0.00	0.00
Chromium Cr	17	16	20	12	21	66
Copper Cu						
Unfiltered	0.01	0.01	0.00	0.05	0.06	0.02
Filtered	0.01	0.01	0.00	0.04	0.04	0.02
Lead Pb						
Unfiltered	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Filtered	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel Ni						
Unfiltered	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Filtered	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc Zn						
Unfiltered	0.97	0.01	0.10	0.06	0.13	0.13
Filtered	0.85	0.01	0.08	0.03	0.05	0.13
Phosphate total PO_4	0.4	7.4	3.6	0.0	0.0	8.1
Phosphate ortho PO_4	0.2	4.4	2.4	0.0	0.0	2.8
Silica SiO	59					13
Chloride Cl^-	415	10	44	98	78	114
Sulfate $SO_4^=$	3209	414	1481	336	348	497
Alkalinity as $CaCO_3$	40	260	100	164	188	130
Hardness as $CaCO_3$	82	434	1590	544	538	406

TABLE 9
Chemical Composition of Cooling Tower Effluent
Data from Illinois State Water Survey, November (1971)*

	Elgin State Hospital 10-27-71	Tinley Park Mental Health 10-20-71	Dixon State School 10=6-71	Illinois State Penitentiary Building 4, Vienna 9-22-71	Refrigeration Unit, Ill., State Penitentiary 9-22-71	Manteno State Hospital 8-16-71
Residue	5382	812	2292	846	836	1236
Suspended Solids	34	12	16	8	4	14
pH in lab	6.99	8.42	7.71	8.18	8.29	7.39

*All concentrations expressed in mg/1

less than 10 ug/l.

Garton (1972) has assembled information on typical values for the concentration of certain chemical species commonly found in cooling tower blowdown. Table 10 is taken from Garton's paper. The values are similar to those quoted from other authors; in addition, several specific organic species are listed.

The AEC (1972) considered the possible detrimental effects of utilizing cooling towers at the Palisades Nuclear Generating Plant of Consumers Power Company. Mechanical draft wet type cooling towers would be utilized at this plant. These towers would have blowdown of 1,320 gpm. The recirculating water in the tower would be treated intermittently with sodium hypochlorite as a biocide. Also phosphate and zinc compounds were to be added to the recirculating water as corrosion inhibitors. It was estimated that the phosphate content in the blowdown would be 0.27 mg/l P and 0.036 mg/l of zinc. These concentrations were to be achieved in the water discharged to the lake after dilution with 60,000 gpm of dilution water. It was further estimated that sulfuric acid would be added to the system recirculating water to give a sulfate ion concentration of 48.9 mg/l in the discharge water.

Blowdown Water Toxicity

There is little information available concerning the toxicity of cooling tower blowdown water to aquatic organisms. The measured tolerance level values (TL_{50}) for minnows for certain selected cooling water treatment chemicals are presented by Donohue (1971). These values, which were apparently determined by Betz Laboratories, are listed in Table 11.

TABLE 10

Common Chemicals and Concentrations Found in Recirculating Cooling Tower Water After Garton, 1972

Treatment	Chemical Concentrations
Chromate-zinc	2-15 mg/l $CrO_4^=$ as Cr 1-5 mg/l Zn
Chromate-zinc-phosphate (organic or inorganic)	2-15 mg/l CrO_4 as Cr 1-15 mg/l Zn 0.3-1.5 mg/l PO_4 as P or 0.3-1.5 mg/l organic phosphate as P
Zinc-inorganic phosphate	2-10 mg/l Zn 3-10 mg/l PO_4 as P
Zinc-organic phosphate	1-10 mg/l Zn 1-5 mg/l organic phosphate as P
Organic phosphate scale inhibitor	0.3-6 mg/l organic phosphate at P
Silt control polymers	0.1-5 mg/l acrylamide, polyacrylate, polyenthyleneimine, or other synthetic organic polyelectrolytes.
Natural liquin-tannin type dispersants	1-50 mg/l as sodium liquosulfonate
Non-oxidizing organic biocides	1-25 mg/l sodium polychlorophenol, quaternary amine, organo-metallic methylene bis-thiocyanate, etc.
Specific oxygen corrosion inhibitors	1-5 mg/l sodium mercaptobenzo-thiazole or benzotriazole

TABLE 11

Toxicity of Certain Selected Cooling Water Treatment Chemicals to Minnows*

After Donohue (1971)

Chemical	TL_{50}
Phosphonate (amino trimethylene phosphonate)	$>$1000 mg/l
Mercaptobenzothiazole (MBT)	3 mg/l
Benzotriazole (BZT)	40 mg/l
Hexametaphosphate	$>$500 mg/l
Sodium nitrate	500 mg/l
Zinc sulfate	15 mg/l

*species not designated

The acute toxicity of the phosphate species is quite low. It is interesting to note, however, in Table 10 that the concentration of mercaptobenzothiazole used in some treatment programs is at the level of acute toxicity quoted in Table 11 for this compound. A "safe" level of contaminant is generally considered to be 1/100 of the TL_{50}. If the blowdown is not diluted in this case by a factor of at least 100 it may be toxic to fish.

Garton (1972) working at the Environmental Protection Agency Laboratory, Corvallis, Oregon, conducted a series of bioassays on simulated cooling tower blowdown water. The simulated blowdown water was prepared to approximate the maximum proposed chemical composition of cooling tower blowdown water from the Trojan Nuclear Power Plant of the Portland General Electric Company as reported in the company's discharge permit request. The company planned to use a chromate-zinc-phosphate treatment.

Two different organisms were used in the bioassay: a green alga, Selenastrum capricornutum Printz, and the young steelhead trout, Salmo gairdneri. Test solutions were the original strength simulated blowdown and dilution of the simulated blowdown by factors of 10, 100, and 1000.

The results of the bioassays indicate that zinc and chromate in the simulated blowdown are toxic to the alga at 0.064 mg/l and 0.14 mg/l, respectively, as measured by reduction in algal productivity. The juvenile steelhead trout showed no lethal effects in 96 hours at 31 mg/l $CrO_4^=$, but the 96 hour LC_{50} (lethal concentration for 50 percent of individuals) for zinc was 0.09 mg/l. Using the recommended application factor of 1/100 of the 96 hour TL_{50} (LC_{50}) determined by this investigation, safe stream standards become 0.0009 mg/l Zn for steelhead trout.

If zinc standards are lowered in the future to levels proposed by the EPA for Lake Superior or to levels indicated by the above report, it is unlikely that even the more conventional blowdown treatment, that is, lime or alum precipitation, can render the blowdown water as free of zinc as necessary for discharge if zinc is used in the treatment program. The removal by dispersant chemicals added to the tower. Ion exchange or other advanced treatment systems may become mandatory at a substantial increase in cost.

The AEC (1972), in their evaluation of the potential impact of cooling towers at the Palisades Nuclear Electric Generating Station, concluded that phosphate, zinc, chlorine and sulfate present in the blowdown waters may have an impact on phytoplankton in Lake Michigan. The phosphate would tend to stimulate algal growth in the region of the discharge. The zinc in the blowdown would likely enter into the food web and be concentrated to a much higher level in aquatic organisms. Further, the AEC felt that there may be a toxicity problem due to zinc on the algae where the presence of zinc would inhibit photosynthesis. The chlorine present in the blowdown water would, according to the AEC, likely cause some destruction of plankton near the point of discharge.

The AEC also stated that the zinc may have an adverse effect on fish due to chronic sublethal toxicity of the zinc to various fish species.

Treatment of Blowdown

From the rather limited data available on the chemical composition of cooling tower blowdown water, it is apparent that in some instances, the blowdown water contains chemicals which would cause significant degradation of quality in receiving waters. Further, it should be noted that some of the most potentially important parameters with respect to causing chronic sublethal effects on aquatic organisms, such as ammonia, various trace metals and chloramines have not been analyzed at the concentrations which have recently been found to cause deleterious effects to aquatic organisms. It is reasonable to predict that as a result of further study, increasing attention will have to be given to the treatment of cooling tower blowdown waters. While, in general, it is technologically possible to remove many of the chemicals present in cooling tower blowdown, the cost of such treatment should be considered in any assessment of the use of cooling towers versus once-through cooling as a means of disposal of waste heat. Unfortunately, very little information has been published on these costs. Glover (1970) presents a discussion of the cost of treatment of cooling tower blowdown water. He estimates the cost of treatment by lime/alum precipitation with sulfur dioxide reduction of chromate, when it is used, to meet some of the more stringent water quality standards in effect at the time the paper was published. He also lists the level of some of the treatment techniques that will be found in the blowdown under various treatment programs. In Table 12 Glover's table is reproduced, except that the concentration of chemical species in the blowdown water is compared to the current Illinois Pollution Control Board standards for Lake Michigan (IPCB, 1972) now in effect rather than to the Pennsylvania standards used by Glover. The ratio of the blowdown chemical concentration to the IPCB standard is listed for applicable chemical species. According to Glover, a ratio of ten or less of a particular chemical species does not require specific treatment since in-plant dilution of the blowdown may be assumed to be a factor of about ten. This may not be the case for a thermoelectric power plant using only cooling towers for condenser cooling.

The treatment costs shown in Table 12 were computed by Glover considering only chemical and sludge handling expenses. The residual levels of chromate, zinc, and phosphate after treatment are not given. The cost of removal of the organics if it is required is based on one-time-use activated carbon adsorption. Reactivation of the carbon may reduce the cost to 12¢ to 24¢/1000 gal., according to Glover.

It is evident from examination of Table 12 that large evaporative type cooling towers could require substantial amounts of funds needed for treatment of cooling tower blowdown waters in order to meet existing water quality standards.

TABLE 12
Waste Disposal Characteristics and Cost of Treating Cooling Tower Blowdown After Glover (1970).

Treatment	Chemical Concentrations in Blowdown Water	IPCB Lake Standard	Ratio of Blowdown Concentration for IPCB Standard	Disposal $ Cost per 1000 gal Blowdown
chromate only	95-225 mg/1 Cr	0.05 mg/1	5000	$0.70
zinc-chro mate	8-35 mg/1 Zn 7-30 mg/1 Cr	1.0 mg/1 0.05 mg/1	15 200	0.16
zinc-chro-mate-phos-phate	8-35 mg/1 Zn 4-7 mg/1 Cr 10-15 mg/1 P	1.0 mg/1 0.05 mg/1 0.007 mg/1	15 100 1500	0.13
phosphate only	5-20 mg/1 P	0.007 mg/1	1500	0.12
zinc-phos-phate	8-35 mg/1 Zn 5-20 mg/1 P	1.0 mg/1 0.007 mg/1	15 1000	0.14
phosphate organic	5-20 mg/1 P 3-10 mg/1 "organic"	0.007 mg/1	1000	0.13
organic only	100-200 mg/1 "organ-ic" 10 mg/1 BOD (est.) 100 mg/1 COD (est) 50 mg/1 CCl_4 extract-ed (est.) 5 mg/1 MBAS	none	-	1.25
organic bio-cide	30 mg/1 chlorophenol 5 mg/1 sulfone 1 mg/1 thiocyanate	0.1 mg/1 0.025 mg/1 as CN^-	300	0.1-1.25

SUMMARY

It is evident from the above review that a wide variety of potentially significant chemicals are used in cooling towers in an attempt to minimize scale, corrosion, wood deterioration, and general biological fouling. Further, the operating characteristics of cooling towers can lead to excessive concentrations of chemicals in blowdown which are derived from the makeup water, atmospheric sources, and the cooling tower and recirculating water structures. It is entirely plausible, based on the types and amounts of chemicals used in various types of cooling towers, that significant concentrations of these chemicals could be found in blowdown water which would cause significant deterioration of water quality in the waters receiving the blowdown.

It is difficult to obtain information on the actual chemicals used in various cooling towers because of the proprietary nature of these compounds, as well as the fact that cooling tower operators are reluctant to give out this type of information. However, based on review of the literature and extensive discussions with various individuals in the cooling tower water conditioning field, as well as those that operate the towers in various parts of the country, it can be concluded that cooling towers of the industrial type generally use a wide variety of chemicals for water conditioning purposes. The larger cooling towers, especially those at thermal electric generating stations, of the natural draft type, sometimes operate with only the addition of sulfuric acid for neutralization of alkalinity and pH control, and chlorine as a biocide. Typically mechanical draft evaporative type cooling towers tend to use somewhat larger amounts and a greater variety of chemicals than natural draft towers, although this gen-

eralization would be dependent on location of the tower, characteristics of the tower, and other factors. Therefore, as a minimum, one would expect blowdown water from electric generating stations and other cooling towers to contain increased concentrations of sulfate, chloride, chlorine, and chloramines, as well as various chemicals that may be scrubbed from the air, arise from corrosion, or leach from the tower structure. Under the worst possible conditions, with respect to the potential effect of blowdown water on receiving water quality, the blowdown water could contain a wide variety of highly toxic inorganic and organic chemicals which could have significant deleterious effects on aquatic organisms and man. It is evident from this review that much greater attention must be given to potential deleterious effects of cooling tower blowdown on receiving water quality.

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*Many of the papers which serve as the primary source of information for this review are unpublished in the technical literature. Many of them have been presented at meetings of the Cooling Tower Institute. This institute maintains a file of selected papers presented at their annual meetings. Copies of some of these papers may be obtained by contacting the institute in Houston, Texas.

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Discussion - Commonwealth Edison Testimony

MR. MAYO: We had asked, gentlemen, that you hold the questioning until the completion of these presentations.

Do you have any questions?

MR. FELDMAN: Why don't I bring them all back up, Mr. Mayo?

MR. McDONALD: At the risk of inciting a riot in this endurance contest, I am going to ask a couple of questions.

I would like to address my question to Dr. Pritchard.

Dr. Pritchard, I am interested in this sinking plume phenomenon, and I am particularly interested in your announcement of this sinking plume at this session of the conference, in that at least my understanding — and you may have to help me here because I wasn't at the previous session — that previous presentations by you indicated that the thermal plume dispersion was more of a hugging and outward flow rather than a sinking plume phenomenon. And if I understand the sinking plume phenomenon in your presentation of it, this is a fact of physics that has been there and why, at this point, is it brought up for the first time? What investigation, what set of factors led to the sinking plume not being recognized before by you?

DR. PRITCHARD: Well, the conclusions that I come to right now with respect to Zion are not different than the conclusions that I had arrived at about Zion previously in the discussion of the sinking plume. In fact, I don't think there was much recognition of a winter problem or a possibility of a winter problem in earlier considerations. I will readily admit that I did not consider winter in the early stages of my analysis of the general subject of thermal effects. I thought mostly of the warmer periods of time.

The winter situation with the possibility of -- well, with the fact that the natural temperatures of the lake dropped below the temperature maximum density, was raised during the Illinois hearings -- the second -- not the Illinois hearings on standards but the Illinois hearings related to Zion itself. And at that time I stated that my calculations at the time indicated that the excess momentum in the Zion jet would carry that plume through the critical region of having water sinking, which exceeded 3° above ambient; and that if any sinking occurred, or if there was, let's say, bottoming out -- which is really a more proper term because it isn't a diving plume, it actually reaches a stage when the momentum settles down -- there is essentially a spreading out at the bottom (indicating) that this would involve, that small temperature differences have no biological significance. Whether or not even above 3° is another question. But certainly at the temperatures that now appear and those that I felt would occur then-- we are talking about the possibility if overage of fish which overwinter do occur in the region -- we are only talking about changes in the incubation period of a matter of hours for temperatures that now appear likely at Zion.

The reason for bringing it up at this time, however, is: 1) the question was raised at the Illinois hearing; 2) Argonne has actually made some measurements of the phenomena; 3) during the course of investigation of Waukegan which involved studies during the winter -- and I might say that the winter plume, while physically there, the phenomena of having temperatures exceeding 3° on the bottom had not really been looked at before the questions were raised and before people began to look at plumes in winter. No one got out in the lake and measured plumes in the wintertime. Argonne had done some, but there had been no real serious effort made until it was deemed necessary on the basis of preliminary evidence of the observations to go out and make a very thorough study of the winter plume, and this was done.

But, in the end, the analysis of the facts that

Discussion - Commonwealth Edison Testimony

I stated previously during the Illinois hearing that, in fact, the excess momentum in the Zion plume should not make the winter conditions a problem there are verified.

MR. McDONALD: Well, since physicists have always known that water is at a maximum density at 39°, why was it necessary to make studies in the winter? Was this a fact that was just overlooked during your presentation at the earlier conference?

DR. PRITCHARD: No. The reason it was necessary to make studies during the winter is that despite the fact -- and this is what I tried to emphasize in my testimony -- that despite the fact that the temperature -- that from the standpoint of the static stability -- the plume should sink in about between 45° to 46°, it does not sink between 45° and 46° if it had excess momentum. Even Waukegan, which is not designed with a high speed discharge, still has sufficient excess momentum so that it actually cools an additional 7° to 8° before it sinks. It actually passes through the region of maximum density before it sinks. It has the same density as the surrounding water, 7° or 8° above the point that it sinks.

Now, while the physics of the fact that water in a condenser has its freezing point at 4° C. and, in fact, that water has the same density at 32° at a temperature of

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46.5° approximately -- while that was well known -- I do not know of any physics at the present time, any theory that allows us to predict at what excess momentum combined with the higher density the phenomena will occur. And what is new here, and the reason we present it is that we now have some empirical data which allows us to make predictions about this.

MR. McDONALD: Well, let me see if I understand this now.

This was the first time now that this data was presented by you publicly, today?

DR. PRITCHARD: The data, yes. It is not the first time that we have talked about the winter plume.

MR. McDONALD: Well, it is the first time you have talked about the sinking plume in this conference.

DR. PRITCHARD: That is right.

MR. McDONALD: Let me follow that point just a little bit.

What does the sinking plume mean to you in terms of the method of discharge that might be employed by the Zion plant in the event a cooling tower is not installed?

DR. PRITCHARD: As I have just said --

MR. McDONALD: At the location of the discharge; the method of discharge.

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DR. PRITCHARD: The present design of Zion will provide a discharge in which sinking of or bottoming out and spreading out of water along the bottom -- a condition which would be unfavorable to rapid mixing -- will not occur until the temperature in the worst case -- and the worst case is when the lake is essentially 32° F. ambient condition -- will not occur for temperatures higher than 34° to 35°.

I say that the possibility of the sinking plume at 34° to 35° -- I say this is -- on the basis of -- both of the observation of the fact that during winter there are natural periods in which bottom temperatures reach this situation; on the basis of the analysis of the incubation period as a function of temperature for whitefish eggs, that this has no biological significance whatsoever, and it does not exceed 3° above the ambient.

MR. McDONALD: It does not.

DR. PRITCHARD: Does not.

MR. McDONALD: At the thousand feet.

DR. PRITCHARD: When you say "at the thousand feet," the Illinois standard is "within an area equal to a circle having a radius of 1,000 feet." And I might say this -- I was rather surprised at the interpretation of the thousand foot limit because the worst kind of design is one that produces a circular dimension.

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The way to design for minimum impact on the environment produces an elongated plume with small area. Now, I can tell you that the area on the bottom at Zion, having temperatures exceeding 3° F. above ambient in the winter -- I have computed, based upon the evidence we have from Waukegan, and I might say that during a summer of 70°, there will be no area having bottom temperatures 3° or greater above ambient, but during the wintertime when the temperature is on the order of 33° F., the area of the lake for the double plume at Zion -- that is twice the area of the single plume -- having temperatures exceeding 3° will be 12.6 acres.

MR. McDONALD: 12.6 acres.

DR. PRITCHARD: I am sorry for giving it that precisely. I admit I don't know it that precisely. That is a computed value, but this will approximately be 12 acres.

The surface plume would be approximately -- well -- several times that; but the bottom plume would be about 12.6 acres. But I'm almost certain that the bottom plume would be less than the 72 acres which is the acreage enclosed by a circle having a radius of 1,000 feet. And I contend that from the standpoint of impact on the environment, while I question your conviction that there was a great deal of thought that went into that 1,000 feet, that there is certainly no more and, in fact, because of the time-temperature relationship, considerably less potential for damage from an elongated plume, having larger dimensions in one direction than 1,000 feet but having no more area than the circle of 1,000 feet area.

There has been much talk about the mixing zone and some implication that the mixing zone is a zone where damage will occur. I resist that definition.

I might say that I have spent my whole life being concerned with protection of the environment. That is my business. And I contend that the mixing zone should not be considered a zone at which damage will occur. I define the mixing zone as the zone within which water quality criteria, based on long-time exposures, do not apply. But water quality criteria based upon time exposure history do apply, and that there is no more damage within the mixing zone than there is outside, and in a properly designed plant that is zero.

MR. McDONALD: Well, that is not going to happen at Zion.

DR. PRITCHARD: I see -- your legal experience gives you that --

MR. McDONALD: Well, let me -- no, your analysis gave me that.

DR. PRITCHARD: That what? That there would be no damage?

MR. McDONALD: Yes.

DR. PRITCHARD: That there would be damage?

MR. McDONALD: Was I wrong in that?

DR. PRITCHARD: You are. I conclude that there will be no damage. No damage.

MR. McDONALD: Okay. Let me ask you another question, Dr. Pritchard. And this concerns, again, this question of how much consideration, by way of field studies and data accumulation that you have engaged in beyond the immediate zone of Zion, in coming up with your conclusion. How much beyond the area of Zion have you --

DR. PRITCHARD: Well, the major part of my work has been done elsewhere.

MR. McDONALD: I mean on Lake Michigan.

DR. PRITCHARD: I personally have not conducted research on Lake Michigan. I have, however, studied the results of the work at Waukegan and served on a consulting group that has come in and tried to direct that work so that it would be as solid scientifically as possible.

I might say that that group has not been lenient; it has been quite critical. It has pushed that work to be solid, scientific work. I have studied the results from the Waukegan study. I have also gone over most of the work

Commonwealth Edison Company
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Address Reply to
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October 3, 1972

Mr. Francis T. Mayo, Chairman
Lake Michigan Enforcement Conference
U.S. Environmental Protection Agency
Region V
One North Wacker Drive
Chicago, Illinois 60606

Dear Mr. Mayo:

On Thursday, September 21, 1972, I appeared before the Lake Michigan Enforcement Conference and presented testimony with respect to costs for alternate cooling systems for Commonwealth Edison's Zion Generating Station. Following the presentation of the above testimony, Mr. Carlos Fetterolf of the Michigan Water Resources Board asked a question of me requiring that I submit more detail with respect to the $34,105,000 figure appearing on Exhibit B Line II a. This figure represents the cost of the loss of capability of the Zion plant when wet mechanical draft cooling towers are applied as the cooling means in place of once-through cooling which is proposed. The following explanation is submitted in answer to Mr. Fetterolf's question: If wet mechanical draft cooling towers were applied to the Zion Station the maximum continuous output of the station would be reduced for the following three reasons:

1. The backpressure on the turbines would be increased due to the higher temperature of the water coming from the cooling towers to condense the steam. For the two Zion units this reduction in net output capability is 127,596 kw. Attachment 1 to this letter contains the turbine performance curves marked to illustrate the difference in performance when using Lake Michigan water for cooling vs. water returned from cooling towers and shows the method of development of the output loss.

2. Additional pumping power will be required to lift the circulating water to the cooling towers. This power requirement, in the plant, reduces the net plant output power by 21,901 kw.

3. Power will be required to operate the fans on the cooling towers. This will reduce the net plant output 9,616 kw.

The above losses in net output add to 159,113 kw directly attributable to modifying the station to utilize mechanical draft cooling towers. This loss of capacity must be replaced with nuclear generating capacity at some other location. We have been very conservative in valuing the replacement capacity at $207/kw, which is the presently estimated cost of the Zion capacity. As I testified on September 21, to replace this capacity in a plant starting today would cost in the order of $400/kw. Multiplication of the 159,113 kw times $207/kw amounts to $32,936,000. The investment in additional generating capacity to replace that lost by the application of mechanical draft cooling towers will also incur property taxes. The additional property taxes due to this investment are estimated to amount to $1,169,000. The sum of the investment cost and property taxes amount to $34,105,000.

I hope that the above explanation fully answers Mr. Fetterolf's question. If it does not, I will be pleased to hear from you.

Very truly yours,

O D Butler

O. D. Butler
Assistant Vice President

Attachments
cc: Mr. C. Fetterolf
(Michigan Water Resources Com.)
Mr. A. D. Feldman
(Isham, Lincoln & Beale)

ATTACHMENT 1

CALCULATION OF CAPABILITY LOSS

1. From curve A using once through cooling the turbine back pressure at full load is established to be 2.7 inches of mercury absolute.

2. From curve B using cooling towers the turbine back pressure at full load is established to be 5.1 inches of mercury absolute.

3. a. From curve C the 2.7 inches of mercury absolute back pressure establishes a load correction of minus 1.8% of 1,129,167 kw design for 1.5 inches of mercury absolute back pressure, or a load of 1,109,971.

3. b. From curve C the 5.1 inches of mercury absolute back pressure establishes a load correction of minus 7.35% of 1,129,167 kw design for 1.5 inches of mercury absolute back pressure, or a load of 1,046,173.

4. The difference between 3a and 3b is 63,798 kw which is the loss in capability of one unit due to increased back pressure as a result of installing cooling towers. Total loss in capability of two units is 127,596 kw.

Attachment 1 **CURVE A**

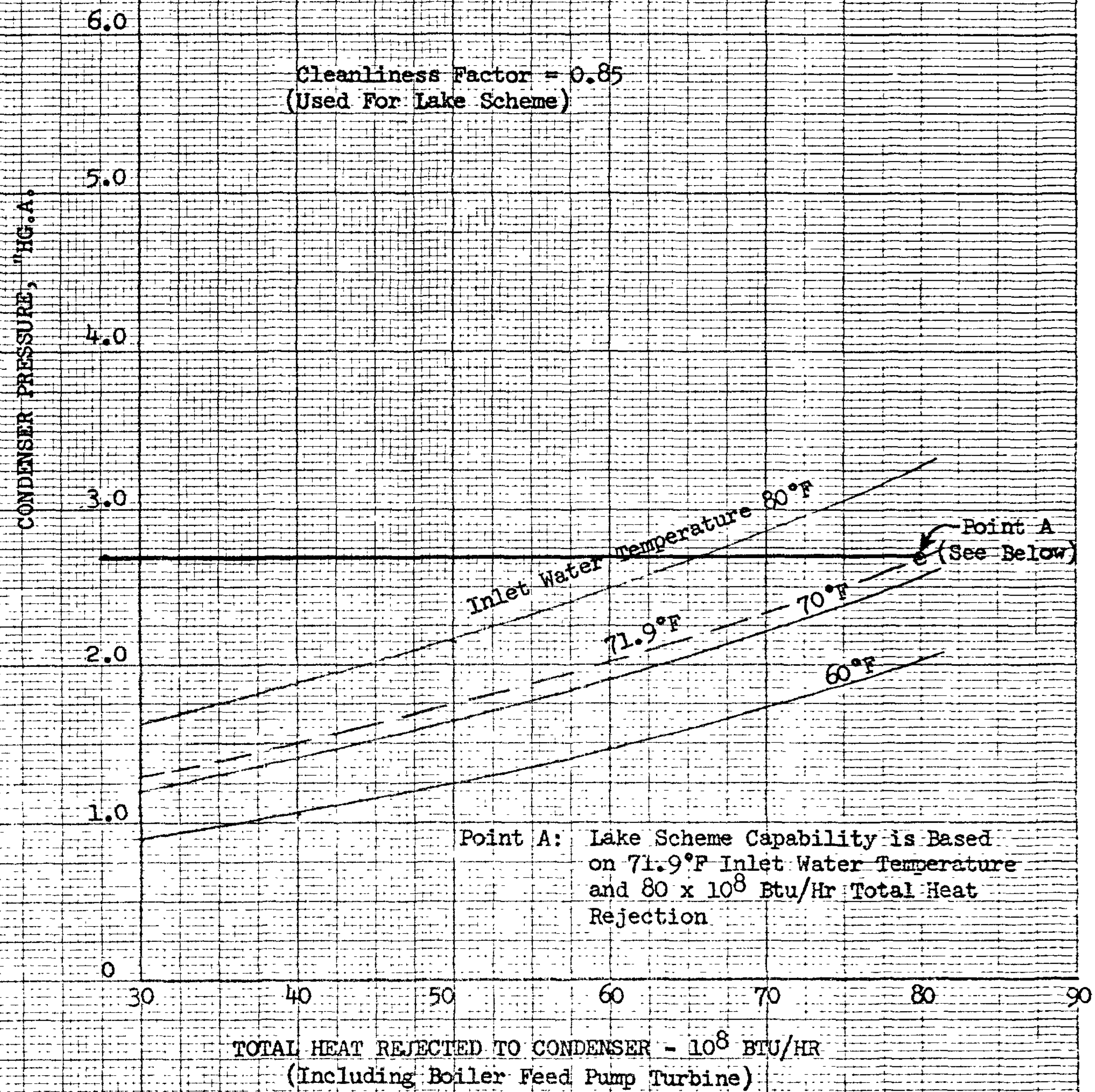
Sargent & Lundy, Engineers
Chicago, Illinois

Mechanical Analytical Div.
S. L. and R. C. H.
October 3, 1972

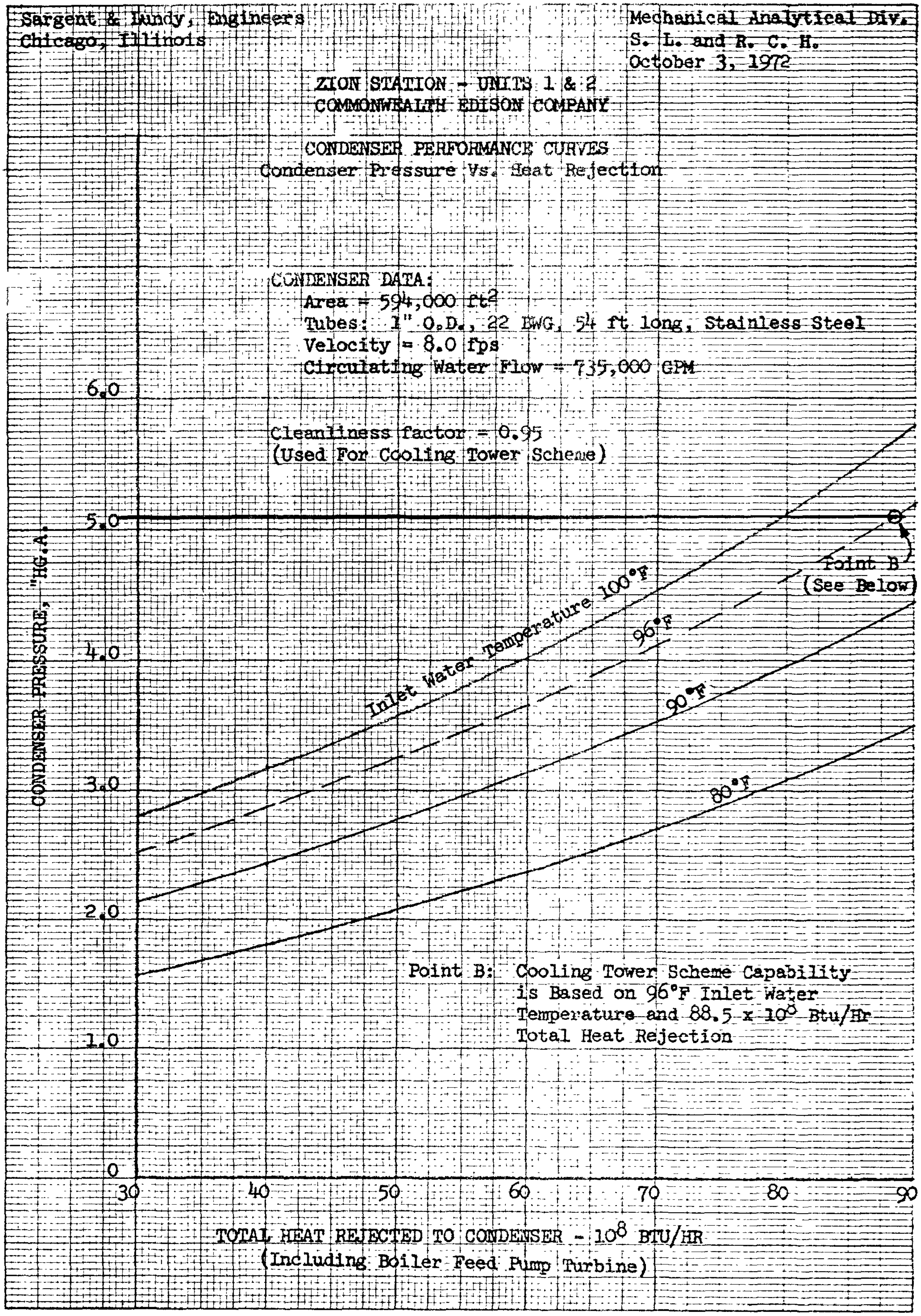
ZION STATION - UNITS 1 & 2
COMMONWEALTH EDISON COMPANY

CONDENSER PERFORMANCE CURVES
Condenser Pressure Vs. Heat Rejection

CONDENSER DATA:
- Area = 594,000 ft^2
- Tubes: 1" O.D., 22 BWG, 54 ft long, Stainless Steel
- Velocity = 8.0 fps
- Circulating Water Flow = 735,000 GPM



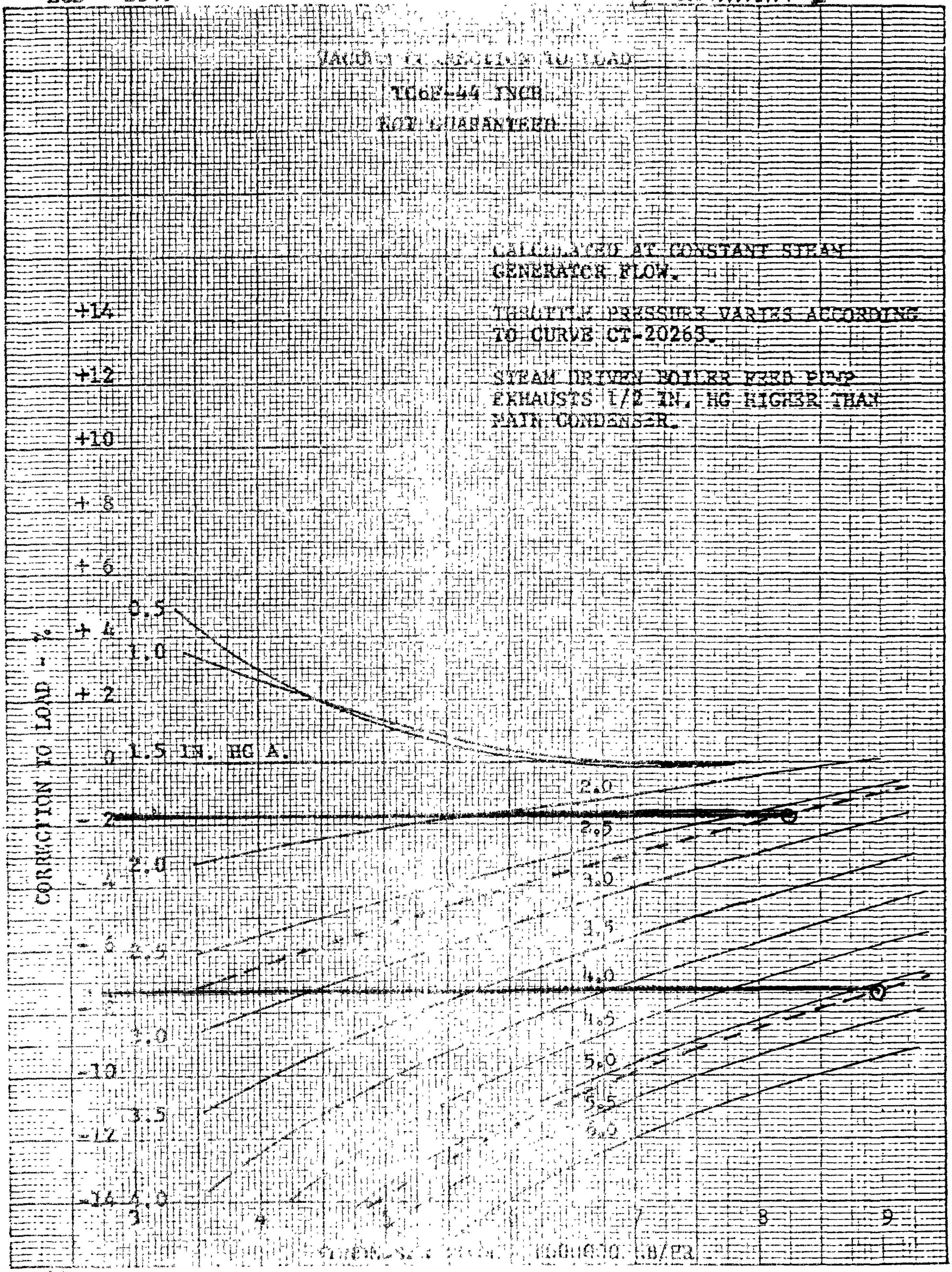
Attachment 1 CURVE B



LCD - 2345

CT-23017 *CURVE C*

Attachment 1



SIGNATURE F.M./C.M ... 3/25/69 CURVE NO. CT-23017 that has been done by Argonne in measurements of plume dimensions and have even, in fact, used their data in confirming thermal plume models that are -- I might say that this is not a static field. I consider the thermal plume modeling as a living science and the models as living models which change as we add day-to-day more information, and this is being done.

I have spent a great deal of my time in taking data that is collected not only on Lake Michigan but everywhere else in the world, and feeding that into the fund of knowledge that has gone into thermal modeling, including work done at MIT and the plume work we do, work on other Great Lakes, the Ghinna plant -- I did personally do some work on Lake Ontario in the Ghinna plant, and I have looked at the results of that design as far as the thermal plume goes.

MR. McDONALD: No, I wasn't trying to imply that you aren't interested and that you haven't done work elsewhere. The question that I really was interested in was a question that I raised with several other people, and that is the idea of getting a blueprint that would link all of the powerplants and all of the discharges into some common overall monitoring program of the lakes with participation beyond the parochial limits of Zion, Point Beach, where these very limited zones that, of necessity, you find yourself involved in.

DR. PRITCHARD: I wonder -- have you ever read the testimony that I gave at the last conference?

MR. McDONALD: I have not read it in its entirety, no.

DR. PRITCHARD: Well, I feel that quite contrary to some of the statements that were made -- and I tried to keep my testimony short so I left it out this time -- but I feel that it is a clear statement that the problem is not a lakewide problem, not even in the year 2020, not even when -- not when but if you put 10 times the amount of heat into the lake that you do now.

MR. McDONALD: Well, I am aware of that. But the question I am asking is: As a matter of insurance, whether you are convinced or not -- some people feel that it may be a lake problem—and as a matter of insurance and as a matter of investment, would it make sense?

DR. PRITHCARD: Well, I think that it makes sense to have a monitoring program which is consistent in obtaining necessary data with respect to all plants and with respect to the spaces in between them; and it doesn't necessarily have to be a centrally controlled program, but it should be one in which there is a collection of data and a review by some perhaps joint committee involving the various State agencies, the Federal agencies, and the university people who have an interest, and the companies.

I might point out that this is exactly what is being done in another part of the country, in the Chesapeake Bay. It involves two States -- not as many as you have; it involves a waterway of about the same size -- perhaps not quite the volume, but of certainly more complexity than the lake -- and there is in that region a group called the Clean Water Study Group. It is comprised of all research institutions and universities engaged in work on powerplant siting and studies of the effects of thermal discharges in the Chesapeake Bay area; it comprises representatives from all Federal agencies concerned, including your own; it comprises representatives of industry; and all of the data is available to everyone else. We have subcommittees that compare research and designs, that interchange techniques, and propose standard approaches to the studies. There are coordinated studies involving company biologists, and State biologists, and university biologists with no lack of passage of information.

I might say it wasn't always that way, and I got into this business back when there were problems with very great lack of cooperation.

But in Maryland I serve the State, and I serve on the various groups that are involved in this kind of research which in Maryland are supported by the Federal Government and the State, and I see a great deal of cooperation and study of the whole system with the intent of ultimately ending up with a -- to be sure that we stay ahead of the possibility of overloading the system.

MR. McDONALD: Thank you.

MR. FETTEROLF: A while back -- while Dr. Pritchard is still on the stand -- I think I can clarify something for you, Jim.

The Lake Michigan Technical Committee for the Study of Thermal Discharges pinpointed sinking plumes as a possible problem. As a result of that, Argonne National Laboratory established some stations off one of the plumes and did identify the fact that the plume did sink in the wintertime.

The Bureau of Sport Fisheries conducted studies on what an increase in incubation temperature for the over-wintering eggs of whitefish would result in, in the way of changes to maturation and hatching time.

They have shown that shortening of this time or that increased temperatures would result in a shortening of this period.

The Palisades Impact Statement included a consid-eration of sinking plumes. And as a result of this activity, Bio-Test then went out on these 2 days to investigate sinking plumes.

Now your question is: why did Dr. Pritchard bring this up? And the reason that he did and that you were after, he didn't give you, was that he was saying that by a jet discharge, there was enough horizontal momentum given to the plume that cooling in the surface waters occurred for an extended period and allowed the plume to cool down below the point of maximum density before it sank.

In other words, if it had been a low velocity discharge, it would have sunk when it was at a temperature of about 43° or 44° F., but because Zion has a jet discharge, it didn't sink until it reached 36° or 37° F. I think that is what his major point was.

DR. PRITCHARD: I agree with the previous lady that said that they shouldn't hold this conference without you here. Thank you very much, Carlos.

MR. McDONALD: My concern was that it appeared to be contradictory to earlier presentations by Commonwealth Edison, not by your Technical Committee. You are not representing Commonwealth Edison.

DR. PRITCHARD: Well, it is not contradictory to earlier testimony because the testimony given earlier dealt with the type of discharge which is at Zion, which we said there would not be 3° temperature water or any significant above ambient over any significant area involved during any season of the year. We did not specifically discuss the sinking plume problem, but since it has arisen and there have been considerable questions about it, I then went into the analysis and asked that the Waukegan study be done following this question that was raised in the Technical Committee and also in the Illinois hearings, that we look and see if we could obtain an estimate of the excess momentum still present in the plume at the time that the plume sank.

In other words, we went after this information --

MR. McDONALD: Okay. I think that answers it.

DR. PRITCHARD: -- to confirm what we had already said.

In a very similar way, we made use of the older model to confirm the things that we had already determined theoretically.

MR. MAYO: I have just a brief inquiry, Dr. Pritchard.

On page 9 you make reference to the fact that on both of the occasions that Bio-Test did its work that there was a strongly developed sinking plume at the Waukegan power station.

DR. PRITCHARD: Yes.

Discussion - Commonwealth Edison Testimony

MR. MAYO: I gather that if you were looking for a situation that probably represented the worst kind of an opportunity or perhaps the best kind of an opportunity for a sinking plume to develop, it would be in the Waukegan configuration for a discharge, where you have low velocities.

DR. PRITCHARD: Well, Waukegan has a 3 f.p.s. discharge at these discharge volumes and up to 3.5 f.p.s. at other times, so that, by chance, because of the nature of the natural reaches of the processes of the fill that have taken place at the discharge -- at the end of the discharge canal, actually Waukegan is a moderately high-speed discharge not a low speed. There are much lower speed discharges in the area.

MR. MAYO: So that if we did indeed have concern for the sinking plume and its impact upon organisms, the shoreside configuration for discharge with the Waukegan range of velocities or less would probably be very desirable to avoid them.

DR. PRITCHARD: Yes. I might say that -- I hope I am authorized to say this -- but I know that the State of Illinois is requiring that the Commonwealth Edison Company provide plans to bring Waukegan into conformity with the existing State standards, and the winter plume is under consideration, and I have developed and given to the company the basis for a design of the change to discharge structure at Waukegan which I feel will eliminate at Waukegan also the winter plume, at temperatures higher than 3° above ambient.

MR. MAYO: Thank you.

MR. FETTEROLF: I had one more question.

Dr. Pritchard, you alluded to the fact that a long, thin plume was more advantageous environmentally than a blob-type plume. By this, are you inferring that if a regulatory group places restrictions of an arbitrary nature on a plume size that it might not always be the most environmentally benign type of thing that could be done?

DR. PRITCHARD: I am very much -- I do that very much so, in terms of my great concern and my conviction, and also I think the biological evidence, that the pertinent biological consequences of the near field involved in the time-temperature exposure relationship is not specifically distance from the discharge.

And when one designs a discharge to have a small time of exposure of an organism either entrained through the condenser and discharged out into the plume or entrained in the plume -- that design will naturally produce an elongated plume. That is, you are striving towards a high Densimetric Froude number and that is an elongated plume.

Now, if you strive for a circular -- essentially a blob, either through some widespread diffuser pattern, you are going to essentially have a very much longer exposure of the organisms entrained into the system, and to temperatures which may be detrimental. And every organism that has been studied -- and now there are literally hundreds of aquatic and marine organisms in which measurements have been made of the stress of a given temperature rise as a function of time, and it is clear that the temperature tolerance of an organism when exposed to 48 hours, 24 hours, or an hour, is quite different than to 15 minutes, 5 minutes, or 30 seconds. And these are order of magnitude differences, in effect. And I am not just talking about depth, I am talking about the large amount of measurements that have been made on some of the organisms that are pertinent here in the lake -- the salmonid fishes, on fish fry -- as far as escaping predation -- a very solid kind of test in which you take a group of control, of salmon fry, or salmon fingerlings you have acclimated to some temperature; you take half of them, mark them some way so that you identify them from the control group, and raise their temperature; keep them at an elevated temperature until a certain time, and put both groups into a tank of hungry predators; and after a standard length of time, catch the predators, catch the remaining control and experimental group and count the number of survivors from each group. And this tells you whether or not thermal shock -- which is not observable in any other way -- has, in fact, increased the predation rate.

Such subtle events as this are clearly related to the time-temperature exposure, and if you design a plume which is related to a high velocity discharge, you are going to cut down the time of exposure of such organisms. They can't stay in the plume; they have got to be carried with it.

MR. ZAR: I have a brief question.

Dr. Pritchard, do you believe that the 1.2 f.p.s. velocity is well established at this point, or that perhaps some sort of Froude number formulas might be utilized? How much more data would you need in order to handle that now?

DR. PRITCHARD: Well, I think that probably that I took a somewhat higher number -- on one of those examples it was less than 1 f.p.s. -- and if I used a Densimetric Froude number at that point I would come out with the same number because we are talking about essentially only slight differences in the density difference between the 37° and the 35° water. So the Densimetric Froude number would be very much the same in the two cases.

So I am just using the velocity essentially as a measurement. I took 1.2, and in one case it was 0.7. We didn't observe temperatures above 37° on the bottom.

In the other case, I took 39, which raised the velocity to 1.17. On the other hand, there was only one measurement out of 140 bottom measurements which was 39° outside the immediate area of the discharge. So that I really used a rather -- I was conservative in just taking a high number. So I think that is reasonably well established.

MR. ZAR: The calculation you drew for the 2.6° F. temperature in the Zion --

DR. PRITCHARD: Yes.

MR. ZAR: -- plume -- was that based on the plume analysis that we saw back in October of 1970, or has there been some more recent plume analysis been done on the lower temperatures, and so on?

DR. PRITCHARD: I have -- since that time, I say I have what I consider to be a living model and the model has improved, I feel. I have literally 10 times as much data as I had then on the plumes to confirm the model. The model now includes the Densimetric Froude number, includes the prediction of depth thickness, vertical thickness, etc., and this has been applied to Zion. And I guess -- and I might say from some standpoint somewhat gratuitously -- the choice of a two-dimensional model, which was used in the early work, was done because of the lack of complete data on the vertical growth. But it also was conservative in that it eliminated any vertical entrainment. There is evidence that vertical entrainment will take place restricted by the increased density gradient there but that some vertical entrainment does take place.

MR. ZAR: Has that work been written up in a form that would be useful to the conferees?

DR. PRITCHARD: I am in the process of writing it. I owe it to AEC and to a number of other agencies to get the new thermal model out. But essentially it contains as much of elements of some of the other sophisticated models such as the MIT model, which I think is more consistent with data -- even their own -- than that model.

And I would just say that the results are essentially similar as far as the Zion 3° isotherm.

MR. ZAR: In relation to the thermal bio- -- I'm in trouble already. I did have several questions, but I will only ask one.

There were a few references noted in the Argonne report, which I presume you have read, some of which seem to suggest that the thermal bar is indeed inhibiting.

I presume you looked at those references and I wonder if you could comment just briefly on those.

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DR. PRITCHARD: Well, I have looked at, I think, most of the references on the thermal bar, and I don't remember precisely the details of those that suggested that it was inhibiting. The ones that I feel are the best ones on these studies have indicated that the thermal bar is a region of vertical convection. It clearly has to be a region of vertical convection. It is not like a thermocline if it is a region of maximum density difference or density stability, but it is a region of minimum stability. And you cannot have essentially the creation of water of maximum density without it sinking and causing convective overturn. It is just a physical impossibility.

So that -- I don't remember the details of the specific statement that suggested this, except the "white paper," which I think just misunderstood the physics completely. They have referred to it as a region of stability which it is not.

MR. ZAR: I have some other questions, but I will get you some other time.

MR. MAYO: Any questions, gentlemen? Any questions of any of the other Commonwealth Edison representatives?

MR. FETTEROLF: I am going to be very brief.

Mr. Butler, on page 6 you said your loss of capacity -- generating capacity -- the loss is $34 million.

Per what, sir?

MR. BUTLER: That is $34 million for the entire plant.

MR. FETTEROLF: Per what? For the year? For the life of the plant per year, or what?

MR. BUTLER: That is a difficult question.

MR. FETTEROLF: Well, if it is a difficult question, maybe you could answer it in writing, in the interest of time.

(Mr. Butler's reply to this question, submitted following the conference, follows in its entirety.)

Discussion - Commonwealth Edison Testimony

MR. FETTEROLF: For Dr. McNaught, on page 2, isn't your finding on the mortality of zooplankton in the raising of those temperatures from different acclimation temperatures something new in the zoological literature?

DR. McNAUGHT: As I said, I think we are about a magnitude below some of this weakly supported evidence that we have heard.

MR. FETTEROLF: This does not not conform with Fisheries information on increased temperatures and mortalities of fish over certain time periods.

DR. McNAUGHT: But look at the size of organism we are dealing with. I think that this is going to be a clue.

MR. FETTEROLF: This is a new concept, isn't it?

And, Dr. Raney -- I know you are not bashful, sir, (Laughter) -- very frankly, aren't you considered the country's leading expert on intake design as far as precluding fish?

DR. RANEY: Well, I can only say that I have been interested in it and I think I know all of the methods, and over the last 5 years I have spent a good many thousands of dollars trying to improve the kinds of intake structures that we now have.

MR. FETTEROLF: This is your reputation as the country's leading expert; you are a consultant for Commonwealth. Have you been consulted as far as intake design and problems by other utilities on Lake Michigan?

DR. RANEY: Yes, sir.

MR. FETTEROLF: And are they following your advice?

DR. RANEY: I think in some cases.

You can't be sure until the structures are built.

(Laughter)

MR. FETTEROLF: Well, we will look into that.

MR. MAYO: I think you were extremely complimentary to Commonwealth Edison, Dr. Raney, when you commented on the fact that at the intake facility for Zion, when they put up nets with 1-inch mesh and that you felt very confident that for any of the organisms, fishes that would pass that 1-inch mesh, that Zion was going to find a way that they could gather them up some way and find a way to keep them from going into the intake. When you consider, I think, that the intake is 2,500 feet from shore, I think that is a challenge indeed.

DR. RANEY: Yes, it is a challenge. And we back up this challenge by actually doing experimental work in a situation that is much, much worse, and that is off southern California where we have similar intakes, and where millions of fish actually are brought in. And after about a year's hard work with experimental plumes, we have reached the point where we can make recommendations, and we are confident that we are going to be able to cut those mortalities by 99.9 percent.

MR. FRANGOS: Could I ask a question?

Is there any way that you can generalize, on the basis of the reports that we have had of these large kills at intake structures, the primary cause?

DR. RANEY: Yes. There are -- basically, due to originally poor design, where you have vertical trapping screens located in the far end of an intake canal, what happens: Fish get in there and they turn and face the current; they swim sometimes for weeks until they get tired, and they come up on the screen and go into the bins.

Now we worked out a system that we can put into these situations. It is what we call a Murphey basket lift, and what this basket does is sweeps up in advance of the stream, dips gently -- just like pouring water out of a pitcher -- into a sluice. This sluice then goes back into the lake or the sea. So that there are lifts available or sluices where the original design was bad.

MR. FRANGOS: Thank you.

MR. ZAR: May I ask a question of Dr. McNaught?

As to your Figure 1 which includes some 1972 zooplankton data, as I understand Dr. McNaught's answer to a question we asked earlier about the data availability, much of this data has not yet been made available, and a number of our scientists have indicated an interest in getting it.

DR. McNAUGHT: To be truthful, I stole that figure from a Bio-Test report, so I think it is on the way.

MR. ZAR: The second thing, on page 4 you referred to upper lethal temperatures, but you don't indicate what they are or what you found them to be for those organisms or whether you have actually done that.

DR. McNAUGHT: Yes, that was by personal communication with some of the Bio-Test people. They told me that they were much higher than some of the work that had been done in the Mihurski group, and I have not seen the data report yet. I only have it by personal communication.

MR. ZAR: So you don't know if the numbers are --

DR. McNAUGHT: I don't think it would be fair to put the numbers in the record at this time until I have a chance to personally examine the data report.

MR. ZAR: Then there are two other questions that I have been asked to put to you. One is: Can you place an importance on the killing of a million pounds of zooplankton, or 500,000 pounds or 2 million pounds, or whatever?

DR. McNAUGHT: That is a difficult question. I think that, as Mr. McDonald has repeatedly stated tonight, we should place this in a total ecosystem context.

Now, we are talking about 7 percent of the standing crop passing through the condensers. This is not, of course, the total lake standing crop; this is the portion of the standing crop that passes through the condenser. And it is my feeling, from my own personal studies on the Great Lakes, that these subpopulations, as you will have it, that suffer this mortality, will very rapidly come back to carrying capacity once they are back in the open lake again. Detailed studies in the future in the plume areas will tell us where this return in carrying capacity indeed will occur.

MR. ZAR: Have you looked at the Bio-Test data with respect to zooplankton or does your work on Lake Ontario give you a feel for this?

DR. McNAUGHT: I was referring passively to my work on Lake Ontario. I think when the animals first come back into the plume that they probably overshoot to a slight degree the carrying capacity that they once held. The plume is going to make up for this condenser mortality.

MR. ZAR: I have one last question. Comparison was drawn between Waukegan and Zion. What was done was that Waukegan condensers that were used were unusually high

△ T's?

DR. McNAUGHT: Right.

MR. ZAR: Because of the longer intake and the different plumbing that is in the Zion system, would there be any differences expected as to mechanical damage that would occur? I am thinking in part of the Grosse Ile in the EPA report which seemed to indicate some additional effects at the Big Rock plant.

DR. McNAUGHT: I can't remember the data to bear out the mechanical damage. I can say that I think that the Waukegan experiment was unusually conservative and severe because the organisms were exposed to something like 5 minutes instead of 3 minutes as they were exposed to at Zion. Timing is so extremely important in the shortshot, I think the Waukegan data for heat are conservative. As far as the types of banging around that we get in the two plants I can't say at this time.

MR. FETTEROLF: As a last thing, I have got to even the score up just a little.

This morning I chided the U.S. Bureau of Sport Fisheries a little bit for not including all of Marcy's information on the significance of those fish kills.

Dr. Raney, when you discussed Dr. Coutant's work on the Columbia River, you said that the heated effluent produced no direct or latent mortalities, but the real significance of his work was that he showed that these fish were in thermal shock and they were much more subject to predation, and that there were losses due to predation by squaw fish in that river. Isn't that correct?

DR. RANEY: Yes. And these losses were, in my opinion, insignificant.

MR. FETTEROLF: Now we are even. Thank you.

MR. MAYO: Is there any more to the Illinois presentation?

MR. CURRIE: Let me ask the audience.

Are there other persons from Illinois who would like to be heard at this time? I see two hands. Mr. Muchmore first, and then the gentleman in the back, Dr. Gustafson.

MR. MAYO: These two gentlemen should receive medals.

MR. FELDMAN: I might thank you and your conferees, Mr. Mayo, for having sat through this rather long thing. We are not apologizing for having done it, but we do appreciate your willingness to hear it.

MR. MAYO: Well, there is no need for you to apologize, the invitation was there.

C. Muchmore

STATEMENT OF CHARLES MUCHMORE, P.E.,
MEMBER OF THE DEPARTMENT OF THERMAL
AND ENVIRONMENTAL ENGINEERING,
SOUTHERN ILLINOIS UNIVERSITY,
CARBONDALE, ILLINOIS

MR. MUCHMORE: Chairman Mayo, conferees, ladies and gentlemen. I will make this very brief. I know the hour is late.

I am Charles B. Muchmore, a member of the Department of Thermal and Environmental Engineering at Southern Illinois University, Carbondale, and currently I am Chairman of the Environmental Quality Committee of the Illinois Society of Professional Engineers, who I am representing here today.

I am here to reemphasize the position of the Illinois Society with respect to the threat of thermal pollution to Lake Michigan.

In April of 1970, the Society proclaimed its position on this issue. Reexamination of subsequent data and events has not altered the Society's basic position on this very important environmental matter.

I would like to quote, therefore, from an ISPE

C. Muchmore

statement issued 2 and a half years ago that we feel adequately expresses our concern and recommendations concerning the current and future development of Lake Michigan as a valuable and irreplaceable natural resource for recreational as well as power supply needs.

"The Great Lakes are an important natural resource that provide great benefits to the people of this region. These benefits are both industrial and recreational. One of the important industrial uses of the water in the lakes is to provide the cooling required in the generation of electric power. Electric power is extremely important to all of us and our need for power is increasing at a tremendous rate.

"The Illinois Society of Professional Engineers shares in the public concern for the well-being of the lake. However, we believe that the current standards set up and administered by the Illinois Pollution Control Board provide adequate protection. These are responsible standards that provide for the greatest benefits to all without impairing the long-term recreational use of the lake. Actually we know a great deal about the assimilation and dissipation of heat in the lake. We, as engineers, can and will design the facilities that will make it possible to use Lake Michigan without damaging it. Our health, safety, and welfare require that we continue with construction of

C. Muchmore

powerplants. Some of these have to be on Lake Michigan. We should proceed cautiously but we should and must proceed now."

As I say, this statement is essentially the stand made 2 and a half years ago.

Of major concern to the Illinois Society of Professional Engineers, which represents over 5,000 registered engineers from varied areas of employment -- private practice, industry, government, and education -- is that actions taken to cope with potential environmental dangers be kept in perspective. First, let us review some basic facts.

It has been pointed out in previous hearings that the thermal pollution danger to Lake Michigan is not one of significantly increasing the average temperature of the lake. Straightforward calculations assuming complete mixing and adiabatic conditions indicate that heat loads projected to 1980 would result, over a year's operation, in a temperature increase of less than 0.1° F. The potential danger due to thermal pollution is, therefore, definitely local in character. I think this has been well documented.

The extent and nature of thermal effects on aquatic biota is not fully understood. As additional knowledge is gained, changes in recommended methods of discharge and

C. Muchmore

areas of mixing zones may well be justified. Consideration must always be given, of course, to the trade-off between increased heat dissipation to a lower temperature atmosphere by maintaining a smaller, higher temperature mixing zone, compared to environmental effects in a lower temperature, larger one.

Comparison of the anticipated or unknown results of the following two alternatives to continued and expanded use of Lake Michigan as a cooling source results in the following conclusions:

Alternative 1: Prohibit powerplant construction at the lake. The obvious needs for greater power production to match future needs does not make this an attractive alternative.

Alternative 2: Require cooling tower construction to satisfy heat dissipation needs. The uncertain environmental impact of cooling towers does not at this time justify the expense of their substitution for the lake as a heat sink.

Thus, we do not feel that the above alternatives to use of Lake Michigan as a cooling source are acceptable solutions to the problem. We advocate continued use of the lake for this purpose, and encourage more extensive studies to determine significant effects on the aquatic biota. Should current and future studies clearly demonstrate undesirable thermal effects to a significant extent, backfitting of cooling towers to existing power generating stations would be possible.

It is likely that aquatic environmental effects due to slight temperature changes would be relatively reversible in nature, compared to those resulting from chemical contamination. Overemphasizing potential harmful effects of thermal pollution may tend to diminish our efforts on preventing deterioration of the lake quality as a result of other pollutional sources, an inherently more irreversible danger to future generations' enjoyment of Lake Michigan waters.

And to point out specifically here, I think we could draw upon yesterday's comments concerning phosphate. I believe the economic picture came into view very clearly there, and I think that we all recognized that whether we paid for our environmental improvements through local taxes, the water bill, higher utility rates -- one way or another -- there is, of course, an upper limit to what our economy can stand.

I believe yesterday the conferees arrived at a ballpark figure of about a tenth of a cent per capita per day as the incremental cost to enable us to attain that 1 mg/l phosphorus standard compared to the 2 mg/l. I believe this figure is about in the ballpark of the additional incremental costs that we are talking on a per capita basis if we talk putting in cooling towers rather than using straight-through cooling of the lake on the current installations. And perhaps someone from the industry could clarify this. I think they are in the same ballpark.

In other words, I think we have to look carefully here at what has to be done and where the money can be spent that will have the greatest impact on the lake. And from our point of view, the case for phosphorus is a lot more clearly interpreted, better documented, than is the thermal question at this point.

I thank you.

MR. McDONALD: Mr. Muchmore.

MR. MUCHMORE: Yes.

MR. McDONALD: On that tenth of a cent added cost for cooling towers, I wouldn't expect you to develop this now, but I would be very interested in having you submit this, on how you arrived at your calculation.

MR. MUCHMORE: Well, we could rough it out here. Could we take a 3 percent --

MR. FETTEROLF: How about submitting it in writing?

MR. McDONALD: I'd rather not. But that tenth of a cent is a very interesting --

MR. MUCHMORE: My off-the-top-of-the-head guess is that is probably low. But I think it is in the same ballpark as the number you were talking about with regard to phosphorus yesterday. I think they are comparable costs.

MR. McDONALD: See if you can refine it a little and maybe you can send it in to us.

MR. MUCHMORE: Surely.

MR. McDONALD: Thank you.

(Mr. Muchmore's submission following the conference follows in its entirety.)

ENVIRONMENTAL PROTECTION AGENCY • STATE OF ILLINOIS
William L. Blaser, Director • Richard B. Ogilvie, Governor

Please reply to:
2121 West Taylor Street
Chicago, Illinois 60612
Phone 312 793-3730

Four State Lake Michigan Enforcement Conference

October 2, 1972

Francis T. Mayo,
Regional Administrator
USEPA
1 North Wacker Drive
Chicago, Illinois 60606

Dear Mr. Mayo:

During the recent session of the Four State Lake Michigan Enforcement Conference, Charles B. Muchmore representing the Illinois Society of Professional Engineers made some statements concerning the thermal standards for Lake Michigan. In his statement he related to per capita costs associated with the requirement of backfitting of cooling towers for existing power plants on Lake Michigan. He has submitted a letter dated September 28, 1972 including some data to substantiate his comments. I am including six copies of his documents and request that it be included in the record of these proceedings and if you deem necessary, forward it on to the other conferees.

Thank you for your consideration of this matter.

Very truly yours,

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

Carl T. Blomgren

Carl T. Blomgren, Manager
Standards Section, DWPC

CTB:dk
Enclosure

Southern Illinois
University

CARBONDALE, ILLINOIS 62901

School of Engineering and Technology
DEPARTMENT OF THERMAL AND ENVIRONMENTAL ENGINEERING

September 28, 1972

Conferees, Lake Michigan Enforcement Conference
September 19-21, 1972

Gentlemen:

Enclosed find the information requested by Mr. James O. McDonald concerning the estimated economic impact, on a per capita basis, associated with the requirement that backfitting of cooling towers be required for existing power plants on Lake Michigan.

I did obtain a more accurate figure on current per capita electric service expenditures (I used my own electric bill for an approximation at the time of my statement at the Conference) by contacting Mr. Joseph McCluskey, Director of Environmental Affairs for Commonwealth Edison. The calculated result is not significantly different from the order of magnitude estimate that I stated at the Conference.

I hope this clarifies the intent and basis for my statement at the Conference. At the time of my testimony, the hour was late and detailed discussion at that time seemed inappropriate.

Yours truly,

Charles B. Muchmore, P.E.

Charles B. Muchmore, P.E.

CBM/dk
cc: Mr. J. McCluskey, Director of Environmental Affairs
Commonwealth Edison
Mr. W. Dart, Executive Director, Illinois Society of Professional Engineers

Supplemental Testimony at Lake Michigan

Enforcement Conference, September 19-21, 1972

by Charles B. Muchmore, P.E.,
Chairman of the Environmental Quality Committee
of the Illinois Society of Professional Engineers

My comments following presentation of my written statement were intended to emphasize our concern that in setting regulations governing the use of Lake Michigan water, full recognition be given to the relative costs involved and potential benefits to be gained.

At the Conference the previous day, the question of additional cost associated with attaining a 1 mg/1 phosphate effluent standard, rather than the previously suggested figure of 2 mg/1, was discussed. An approximate figure of 0.1¢/capita-day was mentioned. Computed on a similar basis, the cost associated with backfitting cooling towers to existing power plants on Lake Michigan gives a figure of 0.34¢/capita-day (see calculation below).

Considerable concern was expressed by several of the conferees over the expense of the more stringent phosphate removal requirement. Clearly, the cost associated with backfitting of cooling towers is in the same order of magnitude. When one considers the relatively well-documented evidence indicating the need to keep as much phosphorous as possible out of the Lake, compared to the contradictory and, in my opinion, insufficient evidence concerning potential harm due to thermal effects, it seems reasonable to question the desirability of requiring backfitting of cooling towers.

Of significance, too, is the fact that the increased cost of phosphorus removal is principally a chemical cost. Should future studies of the Lake or new technology dictate that the removal of phosphorus by precipitation techniques is no longer justified, there would be no problem in changing the requirement. Not so with cooling towers. The financial committment resulting from a requirement to back-fit cooling towers is a long term one.

CALCULATION:

Basis:

Average annual residential billing, Commonwealth Edison, 1971 (Source: Telephone conversation 9/22/72 with Mr. J. McCluskey, Director of Environmental Affairs, Commonwealth Edison)	$159.00
Cost of backfitting with an evaporative tower system: (Source: Mr. Tichenor's testimony given at the three state hearings, as reported in Summary of Recent Technical Information Concerning Thermal Discharges Into Lake Michigan, Argonne National Laboratory, U.S. EPA Contract Report 72-1, p. 105)	Nominally a 3% residential rate increase

Assuming an average family size of 4 (perhaps a bit optimistic for the future, but current reports are encouraging), the average per capita daily billing is 11¢.

Applying the 3% increase that would result from backfitting cooling towers gives a daily per capita increase of 0.34¢.

C. Muchmore

MR. MAYO: Mr. Currie.

MR. CURRIE: Dr. Gustafson.

While he is coming up, I have written statements I have been asked to have entered into the record as if read. They are from Paul R. Harrison, from Ann Chellman, from Mrs. Catherine T. Quigg, from Dr. James E. Carson, and from Arthur Pancoe.

(The documents above referred to follow in their entirety.)

Statement Before the Atomic Energy Commission Hearing on
Effects of Thermal Discharge on Lake Michigan

September 19, 1972

Gentlemen:

The purpose of the Chicago Technical Society Council Ecological and Environmental Committee at this hearing is to attempt to provide objective criticism of the past, present and future assessments of the effect of thermal discharges on Lake Michigan and surrounding environs.

It is obviously difficult to predict with certainty the effect of these new, large energy inputs into the local biosphere when they have not occurred under like conditions at any other location. However, it is not difficult to say that there will be ecological effects for certain-no matter how or where this massive amount of energy is released in such small physical scales. The basic concept of entropy states that there is a minimum amount of energy that can be recovered in any energy conversion process. It must be, at the very least, the primary resolve of any controlling agency to minimize any excess above this basic physical principle. Conversion of nuclear energy into steam energy, and finally into electrical energy, and the transportation of that electrical energy to inefficient electrical devices does not in any way maximize energy use. This is especially true when one sees that the majority of the steam energy is wasted by cooling by large amounts of water and then this excess energy dumped into a small area creating sure changes in the local ecology. There have been many arguments brought forth concerning the use of atomic power plants, dumping of waste energy (which we do not consider useless), and subsequently using that electricity in extremely inefficient ways. We feel that this Committee cannot ignore this inefficiency because the subject of today's discussion is a prime example of that inefficiency and lack of creative ability and resolve to use this thermal energy in a productive way. We are reminded of the Ruler in Adu Duabi in the Middle East who spent millions of dollars, indeed billions of dollars, in securing atomic power plants, not for the sake of creating electricity, but to use the heat and the steam process in an atomic power plant to create pure water and to create heated water for irrigation in large areas of greenhouses in order to produce fruit year-around. In other words, a creative use of what is considered in our country as waste heat. It is apparent that the primary concern of the power company and AEC has been the production of power rather than the efficient use of energy. Likewise, it requires creativity and larger assessments of the total problem, which seemingly, bewilders both the Atomic Energy Commission and the American Power Company consortiums. The remaining possible reason for this lack of concern could be that they truly do not care about the environment. But, as a modern day Will Rogers, I only know what I see on television. These advertisements tell me that the electric companies do, indeed, care about our "total environment".

Assuming we are stuck with this "waste" energy, why is it then that the controversy still reigns as to the environmental impact of these monsterous energy generators?

In our opinion, the causes can be summed up in that there is a lack of basic foundation to make proper decisions. As is the case in most ecological problems currently in vogue, there are many computer massagers and modelers who take very questionable data, take data out of context, and mis-apply basic concepts so that the final result after much computation and brilliance in mathematics come out with a very nice conclusion which "remains to be shown". The record shows that this is the past case and also the present case.

Gentlemen, it is very difficult to make decisions using models based upon scant and inadequate, and in some cases, incompetent data. To be creative, we would like to highly recommend that a thorough oceanographic study be undertaken and properly reviewed before a license is given for the building, let alone the operation of these power producers. This study should be intra-disciplinary in nature and consider the following:

1. Models should fit field data - not the data - the model ~~wherever this is necessary and/or desirable~~.

2. a) Can a model be fitted to all important variables?

b) What are the important variables?

c) To what extent do variables interact to produce automatically what may be best described as a complex polynomial?

d) How valid are simplistic models compared to the higher order reactions which may actually occur?

e) If any one site data must be modeled specifically for that site - is it best to construct a limited model <u>or</u> obtain definitive data for each site? We think each site is unique.

Some variables that need to be adequately monitored concerning thermal plume are:

1. <u>Geology</u>

a) Bed rock

b) Sedimentation

c) Geologic processes (Chem. & phys.) e.g., Analytical reaction with heat, acids, etc. Current rate and carrying capacity.

d) Ground water inflow (hydrology)

Bathymetry

a) Geomorphology

2. Geochemistry

e.g. Carbonate balance; reaction rates

3. Climatology

a) Heat and vapor affects on the local environment

b) Winds and currents

c) Pressure systems

4. Biology (per se and in response to water quality)

a) Phyto and zooplankton within and beyond the thermal plume

b) Speciation of fish (birds)

c) Effects on N. S. & C. cycles - as heat input may influence microflora present

d) Biochemistry of water relative to biota present

5. Engineering

a) Design of site in accord with the above

b) Physical, thermal and pressure shock characteristics on biota

6. Monitoring of plant effluents on the environment

Some of the above parameters are already considered but are not measured adequately or given proper weight in decision making.

It is obvious that the local current measurements are entirely inadequate. In fact, many of the assumptions as to current directions are completely wrong. I point to the Michigan City breakwater and the Traverse City situations as primary examples on Lake Michigan. These current studies must be conducted over six months at the minimum and a year or more, as desirable.

We cannot understand, or at all agree, with the statement that geological measurements are not necessary. I point to outfall erosion problems and other geo-chemical considerations carving away at other locations on Lake Michigan, both nuclear and fossil fuel plants.

Much of the lake shore has not been properly mapped in order to show before and after situations due to the discharge of water, let alone its temperature considerations. It has been shown by Miss Edith McKee that a detailed one-foot interval map of the lake bottom within a few miles of an outfall can adequately describe much of the currents. Laminar and turbulent flows are easily discerned in these mappings.

A study should be made of the chemistry of the water and the effect of the reactor on the chemical equlibrium which has been established.

We must determine the interaction between the various parameters measured.

The above parameters are the ones which seem of current concern. However, as in the case of all dynamic problems, the parameters being assessed must be continuously reviewed and may change with time.

It is required that two years of climatological data be made before a license is granted to atomic power plants. We ask simply, - why not an equal amount of time for oceanographic studies (or oceanographic climatology, if you will) to be conducted for two years prior to issuance of a license? To our knowledge, these types of studies have been only in a peripheral and cursory manner. I am sure none of the persons in this room would like to live next to a reactor in which the safety research was done in a similar inadequate manner.

All of the above considerations and suggestions are not at all prohibitively expensive, especially considering the back fitting and possible future damages and reparations that may be necessary due to the fact that these studies were not made.

It is our recommendation that adequate studies be made as soon as possible of the above parameters, as well as those currently under study.

It is recommended that no new facilities be built until new guidelines and adequate basic, physical studies are made in order to obtain adequate input data to these sophisticated models. Without this basic data they are full of brilliant sound and fury and signify nothing, or at the best, signify the wrong decisions, which are not only dangerous to the health and well being of Lake Michigan, but our own enjoyment and guarantee of adequate fresh water supplies for other activities, both recreational and industrial.

If Lake Michigan, or any other lake, be it large or small, turns into a eutrophicated cess pool other industries and users of this large heat sink will be severely restricted and will pay a dear price, as well as the civilian sector.

Gentlemen, in summation, it is our opinion that the following basic criticisms can be made:

(1) Proper use of energy is not and will not be a reality until a re-assessment of the basic thinking of the Atomic Energy Commission comes about so that they may assess the entire enrgy cycle of nuclear reactors and the energy produced from them.

(2) There is much too much reliance upon computer modeling without obtaining basic physical measurements.

We would humbly recommend that those who earn their living or supplement as the case may be, by consulting with both your agency and/or the utilities, should obtain more detailed and more pertinent physical measurements in the field and get their "tail feathers wet" in order to make these models and mathematical gyrations more meaningful. We would suggest that they spend as much time in the field as they do on the models and the amount of time on the models as they would usually spend in the field. I think that all of us would be much more capable of making good decisions and designs by the proper use of this "waste energy" dumped in our increasingly fragile environment.

Thank you for your attention.

Paul R. Harrison, Ph.D.
Chairman
Ecology and Environmental Comm.
Chicago Technical Society Council

PRH:hsl
9/20/72

Lake Michigan is the single major natural resource in the Chicago area. One of the basic attributes of the lake is its large volumn of relatively cold water and its attendant populations of cold water flora and fauna.

Ecologists consider temperature the primary control of life on earth and fish, which are unable to regulate their body temperature, are particularly sensitive to changes in the thermal environment.

Elevated water temperatures present a real threat to the aquatic ecosystem of the lake. Temperature levels that fall short of lethal, but may be considered unfavorable, can aversely affect the animals' metabolism, feeding, growth and reproduction. Even though a single game-fish species may be able to adapt to the temperature variations, the food chain envolving smaller fish, invertebrates, plants and dissolved nutrients is more sensitive. Any environmental change that seriously affects the proliferation of any link in the chain can affect the harvest of game fish.

Thermal discharges add stress to the lake already polluted by chemical wastes of shoreline industries. The capacity of water to carry dissolved oxygen necessary to support useful forms of aquatic life diminishes as temperature rises. Higher temperatures cause reduced solubility of oxygen and, if this is combined with an organic load, the temperature increase will unbalance a mixed algae population to blue green algae, the species found in organic or chemical pollution.

Because of the rate of increase projected for future electric power production, we cannot continue to add waste to the environment in the form of heat. We must cure the disease rather than treat the symptoms, by reducing heat pollution at it's source.

Ann Chellman
136 S. Hickory St.
Palatine, Illinois 60067

POLLUTION &
ENVIRONMENTAL
PROBLEMS

49 SOUTH GREELEY STREET
PALATINE, ILLINOIS 60067

LAKE MICHIGAN ENFORCEMENT CONFERENCE
SEPTEMBER 20, 1972

Statement by: Mrs. Catherine T. Quigg
Vice President
Pollution & Environmental Problems

How many of you are aware that Commonwealth Edison is "concerned for your total environment"? How much do you think it costs Commonwealth Edison every year to get that message across to the public... on television...in newspapers...magazines...and even on cardboard lightbulb holders. It must be millions!

We think that Commonwealth Edison would spend that money on cooling towers at the Zion plants--if they were <u>really</u> concerned for our total environment.

Who else but an enormously wealthy company--aided and abetted by the Atomic Energy Commission--would have the gall to use our valuable Lake Michigan as a daily waste dump for billions of gallons of heated water ...and then tell us it's protecting our environment?

Who else but a combine like this could supply this and every other environmental conference with scientists, lawyers and PR men extolling its virtues.

It's not easy for scientists or citizens to fight the political-utility nuclear power claque. We don't have their power -- or money. It could make a big difference in getting the message to the public -- that their lake will die from the kind of concern it's getting from Commonwealth Edison.

How will we know when our lake is dying from thermal pollution? We will know.

Its fish will die from temperature lethality...not immediately but eventually. Because we see fish in heated discharges does not mean these effluents are desirable for that species. Many organisms, including man, are at times and under certain conditions attracted to environments that are clearly not optimal. A critical look at the fish found near effluents frequently shows that these dense populations are not of desirable game species but are less desirable, rough fish species.

We will know our lake is dying of thermal pollution when we go fishing and catch a string of algae instead of fish. We'll know when we see windrows of rotting algaes on our shorelines and beaches.

By the green in our drinking water--we will know. We'll add more chlorine to our water to control the bacteria and slime. And then we'll know by the unpleasantness of drinking highly chlorinated water.

We will find fish mysteriously dead on our shores. And some will know that they have died from toxicity. Because they know that the toxicity of most materials -- whether pesticides, solvents, heavy metals, or others -- increases at higher temperatures. Water quality criteria can be determined for materials toxic to aquatic life under desirable temperatures, but when temperatures are elevated above optimum, toxicity is increased and these criteria may no longer protect aquatic life.

Yes, by these and other signs, we will know when our lake is dying.

I say -- kill our lake if you must -- because you can afford to convince most of us that you "mean well." But please don't add insult to injury by making us listen to the constant rendition of "Commonwealth Edison -- concern for your total environment."

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Reprint from Annual report of the Radiological Physics Division for 1971.

ANL-7860 Part III, August 1972

THE ATMOSPHERIC CONSEQUENCES OF THERMAL DISCHARGES FROM POWER GENERATING STATIONS

James E. Carson

Concern for the biological and ecological effects of heated water has resulted in legal actions that will prevent power companies from dumping the waste heat from the majority of their new generating units into rivers and lakes. Many nuclear- and fossil-fueled plants now under construction, and even some now on-line, are being required to change from once-through cooling systems to other methods, such as wet cooling towers, cooling ponds and spray canals, despite higher costs and lower themal efficiencies. Yet, these alternate cooling procedures are not without their own environmental problems.

The primary weather change due to once-through cooling on a large water body is a local increase in fogginess at the plant outfall. But the relative probability of significant local meteorological effects is much higher with alternate cooling procedures, since these reduce the area of heat and moisture transfer. It is, therefore, concluded that, from a meteorological point of view, the least undesirable way to dispose of waste heat is by using once-through cooling on large water bodies.

Introduction

The peak demand for electrical power in the United States is increasing at a rate of 7% per year.[1] This increase is due both to increasing population and to increasing per capita consumption. According to the Federal Power Commission, the installed capacity in 1970 was about 340,000 MW, while the estimated requirement for 1990 will be 1,260,000 MW.[1] Almost all of the new capacity will consist of thermal (steam) units, both nuclear- and fossil-fueled, with marked trends toward larger capacity units and more units on a given site. Despite their lower thermal efficiencies, an increasing fraction of the new plants will be nuclear, this choice being made in part to reduce emissions of atmospheric pollutants such as fly ash and sulfur dioxide.

Large quantities of reject heat are not unique to nuclear electrical generating stations since all heat engines release heat to the environment. In other words, what is frequently called "waste heat" is really a necessary part of the energy conversion process.

Almost all of the energy produced by electrical power stations, both the waste heat and the useful power generated, is eventually dissipated to the atmosphere. In this paper the potential meteorological effects of the waste heat are explored. While studies of the effect of thermal discharges on the atmosphere are relevant to all types of power generation, they are particularly significant to water-cooled nuclear power plants which produce 40 to 50% more waste heat per unit of electricity than modern fossil-fueled plants. Part of the difference in cooling requirements is caused by the loss of heat up the chimney in conventional power plants (10 to 12% of the total). It should be noted that most fossil-fueled plants now on-line operate at efficiencies comparable to those of the new nuclear plants.

Utilities use large amounts of water to cool the condensers in the plants; the cooler this water is, the more efficient the process will be. Until recently, most plants used once-through cooling, drawing water from lakes, rivers, or the ocean, heating it 10° to 25° F as it passes through the plant, and returning it to the source. Because of concern for both the effects of increased temperatures on the biota of the receiving water body and shortages of cooling water, many power generating stations now under construction will use cooling towers or cooling ponds to dissipate much of the heat to the atmosphere before recycling the cooling water or returning it to the source. Lower costs of operation and installation dictate the use of "wet" or evaporative supplemental cooling systems except in areas of very limited water supplies.

The state of the art is such that meteorologists are not able to predict quantitatively how the atmosphere will react to the large amounts of heat energy and water vapor that it will be forced to absorb as the result of the disposal of waste heat from power plants. Conceivably, critical heat release rates may exist for particularly sensitive sites which, when exceeded, may lead to significant meteorological effects, such as the generation of thunderstorms in convectively unstable, subtropical conditions.

To date only a limited number of research and field studies on the atmospheric aspects of thermal pollution have been conducted and reported in the literature. Published papers include those of Aynsley,[2] Stockham,[3] Overcamp and Hoult,[4] Decker,[5] Colbaugh et al.,[6] Huff et al.,[7] Hosler,[8] Hanna and Swisher,[9] EG & G,[10] Altomare,[12] and Carson.[13] Most reports dealing with thermal discharges into rivers, ponds, lakes, or from cooling towers, indicate that changes in weather near the outfall might occur, but few contain data to support or quantify this conclusion.

As a result of the National Environmental Protection Act, utilities are now required to file statements anticipating the environmental impact of their new plants, including the atmospheric effects of their proposed cooling systems. Most of these statements have been prepared by meteorological consultants, and many include forecasts of the frequency of plant-induced fogs and icing. Unfortunately, the majority of these analyses have not been made part of the public record and, therefore, are not available for quotation. One of several reports that have been made public is a study of possible cooling tower plume effects at the Zion (Illinois) Nuclear Generating Station by McVehil.[14]

In September, 1971, the National Science Foundation sponsored a workshop to prepare a list of the areas of ignorance in the field of environmental aspects of thermal discharges from large sources and to suggest research projects to improve our knowledge.[15] This conference covered many topics in addition to the atmospheric aspects of wast heat discharges.

One-through Cooling on a Large Lake

An important problem in mid-western U.S. concerns the possible atmospheric effects of waste heat discharged from nuclear power plants around Lake Michigan. Two fossil-fueled plants (capacity 616 MWe) and five nuclear units (6,732 MWe) are now being installed along the shores of Lake Michigan.[16] These units are scheduled to be operational in 1974; the total power plant load will then be 15,625 MWe. Originally, each of these units was designed for once-through cooling; but recent actions of regulating agencies will force most, if not all, of the new plants to use other cooling techniques, such as cooling towers.

Except for a small amount advected through the Straits of Mackinac into Lake Huron, all of the power plant waste heat discharged into the lake will eventually enter the atmosphere through radiation, evaporation, and conduction from the lake surface. Except for an increase in fogginess near the individual thermal outfalls, it is expected that atmospheric modifications attributable to once-through cooling installations will be insignificant, as the energy will enter the atmosphere slowly over a large area. The reactor heat will warm the lake a small fraction of one degree.

While the total quantity of heat put into the lake by these power plants is very small compared to that exchanged by natural processes (solar radiation, evaporation, conduction, and long-wave radiation), it does not immediately follow that the meteorological consequences will also be small. It is possible that the frequency and severity of the lake snows, fog, and freezing fog around the south and east shorelines of the lake could be increased somewhat as a result of a small increase in lake surface temperature. In any event, such meteorological and climatological changes would be very difficult to isolate in the noise of natural variability of weather elements.

Thermal plumes introduced into large bodies of water are dissipated by two processes: through direct surface losses to the atmosphere by evaporation, radiation, and conduction, and through dilution by mixing with the cooler main body of water. Unfortunately, the relative magnitudes of these two temperature-lowering processes are not known for various weather and lake conditions. Meteorologists are not able to measure directly the locally-increased vertical fluxes of radiation, heat, and water vapor over a thermal plume with the accuracy required because of the small size and meander of the thermal plume itself. Direct measurements of plume temperature reduction by mixing with ambient lake water presents experimental difficulties. Csanady[17] has concluded from a theoretical analysis that only a small part (on the order of 5%) of the plume's heat is lost to the atmosphere before mixing lowers the plume's surface temperature excess to 1°F. More recently, Csanady et al.[18] measured the heat balance of a thermal plume from a nuclear power plant on Lake Huron and found that "the direct heat flux to the atmosphere from the detectable plume was 1/3 of the total heat flux." Ayers[19] concludes that there is a "significant loss of excess heat to air, and an insignificant loss of heat to the underlying cold water." Clearly, more field measurements are needed to determine rates of heat loss from thermal plumes over a range of weather conditions. The relative importance of the two temperature-lowering processes will vary as lake and atmospheric conditions change. When the lake is rough, mixing will be rapid. When it is smooth, the warm water will tend to float with little mixing and present a larger area of greater temperature excess, and hence increased heat transfer to the atmosphere.

Except for that advected into Lake Huron, the heat energy mixed into the main body of Lake Michigan will eventually be returned to the atmosphere. This transfer takes place over such a large area that it is reasonable to conclude that once-through cooling will have a much smaller impact on the atmosphere than alternate cooling methods such as towers or ponds.

Lake Michigan has a natural temperature resetting mechanism due to the cooling of the entire body of the lake every winter below 4° C, the temperature of maximum density of fresh water. Twice each year the lake is observed to be vertically isothermal at the temperature of maximum density due to thermal instability and mechanical mixing resulting from storms. Thus, except for an improbable condition in which a temperature as low as 4° C is not obtained, lakes such as Lake Michigan cannot accumulate heat energy year after year. It has been observed[20] that the average temperature of Lake Michigan has actually decreased 1° to 2° F during the past two or three decades, despite its use for cooling by industry and fossil-fueled plants, and despite warmer inflow stream temperatures due to tree removal.

Two scales of weather changes can be expected from thermal discharges into the lake: local changes due to increased heat and moisture fluxes over the thermal plume, and large scale modificiations due to the accumulation of heat energy in the main water body.

Heat and water vapor are added to the atmosphere as air moves from the land over the lake surface. Owing to the local temperature excess, more heat will enter the atmosphere from the thermal plume than from the main lake surface. Thus, air with a trajectory over a thermal plume will be somewhat warmer, more humid, and less stable as a consequence of thermal discharges. Observations confirm that an increase in the frequency and density of steam fog over the immediate plume area is the primary observable effect of thermal discharges into large water bodies.

Thermal discharges from power plants also might conceivably modify the large-scale climate of an area. Much of the heat will be mixed into the main body of the lake, raising its temperature a small fraction of one degree.[13,21,22] Some of the energy added in summer will be stored until the fall cooling period is reached; increased evaporation and conduction could then increase the intensity and frequency of lake snows in late fall. It does not necessarily follow that the increase in lake snows would be directly proportional to the extra heat discharge; even a small increase in water temperature could be just sufficient to release an atmospheric instability. The amount of heat discharged by power plants is much too small to cause measurable air temperature changes on the lake shore (see below).

A review of the literature indicates that, except for fog, changes in weather and climate due to once-through cooling on lakes, rivers, and cooling ponds are too small to be observed. Numerous cases of thin fog and/or light freezing fog near thermal outfalls or cooling ponds have been reported.[23,24] These steam fogs are "wispy" thin and dissipate quickly. In no case did a statement that these plume-related fogs pose a problem to visibility and traffic on nearby land appear. If the air temperature is below freezing, these steam fogs may drift over structures and through vegetation and cause rime icing. The author has observed dense steam fog 3 to 10 m deep over a cooling pond when the air was more than 55° C (100° F) cooler than the water. Ambient air temperature was about -7° C, with low humidity. The fog drifted inland a maximum of 15 m and deposited a 2- to 3-cm layer of flaky, low-density rime ice on vegetation within 4 m of the canal edge. This ice was so light as to be no hazard to the plants. No ice had formed on either a bridge crossing the canal or on trees further inland.

Perhaps the most serious difficulty in conducting field studies at existing cooling ponds, rivers, and lakes is that the undisturbed water body itself affects weather conditions. For example, lake-effect snows and steam fogs frequently occur near Lake Michigan far from any thermal discharge. But it is very hard to say how the intensity, duration, and frequency of fogs and freezing fogs in Waukegan, for example (which has a 1,100 MWe coal plant using once-through cooling) has been altered by this local influx of additional heat.

Isolating possible long-term changes in weather and climate around the lake will be an even more difficult problem. Calculations show that the total reject heat from power plants now being built is very small compared to the meteorological input, and is also very small compared to natural variations of atmospheric processes.

Nowhere in the literature has the author found a single report of observed precipitation or significant temperature changes due to once-through cooling on a large water body.

In midwinter, ice-free areas will be formed at or near the point of discharge. Plant personnel (including a professional meteorologist) at a large fossil-fueled plant on Lake Ontario report that the plume area is too small to affect weather conditions on the shore. Steam fogs are often present over the plume, but these are rapidly dissipated by mixing with dryer air as they move inland.

Estimated Weather Effects from Once-through Cooling on Lake Michigan

Some appreciation of the relative improbability of a significant weather modification by waste heat from nuclear power stations on Lake Michigan can be obtained by comparing the amounts of heat involved in power generation with those quantities involved with natural meteorological processes.[13,21,22]

A nominal plant-year, defined as a 1,000 MWe nuclear power plant operated at full capacity for the entire period, generates 1.5×10^{16} cal of waste heat. Assuming that all of this energy stays in the lake (that is, no heat is lost to the atmosphere) and that the heat is uniformly mixed throughout the lake, the temperature rise will be only 0.0032° C per year. If all nuclear plants scheduled for operation by 1974 are on line (total capacity about 7,000 MWe) for an entire year, the maximum possible temperature rise would be only 0.022° C.[13] This temperature increase is two orders of magnitude smaller than the observed year-to-year temperature variations observed in Lake Michigan.[20]

These calculations represent an upper limit of the ability of power plants to warm the lake, since zero heat losses to the atmosphere were assumed. Longtin,[21] using a more complex model which allows for heat losses to the atmosphere, has concluded that the thermal input from all power facilities on the lake is "...crudely estimated to be 0.028° C." Asbury,[22] using a similar but more refined model, reports that the average annual temperature of the lake will increase only 0.0055° C because of the reject heat from nuclear plants totaling 7,000 MWe.

A more realistic assumption for the energy distribution within the lake is that the waste heat is confined to the epilimnion. If it is assumed that all of the reactor heat generated during the 6-month summer season is confined to a layer 20 m deep and is further restricted to the southern basin (about 1/3 of the area) of the lake, the temperature rise from nuclear plants with a capacity of 7,000 MWe will be 0.14° C.[13] Again, the value is much smaller than the observed natural variability. These calculations show that the warming of Lake Michigan by power plants, while undirectional, is too small to change measurably the average air temperature along its shore.

Carson[13] has shown that, if all of the reactor waste heat were dissipated to the atmosphere by evaporation only, the additional evaporative flux would be 0.308 cm/yr. The natural evaporation rate is not known exactly, but a value of 76 cm/yr is reasonable. Thus, the maximum additional evaporation due to reactor heat is less than 0.4% of natural. Whether such a small increase in humidity is sufficient to be observable is another question. The extra moisture should also tend to increase precipitation around the lake, but predicting how much the increase would be, or in what form, is beyond the state of the art.[25,26] If all of this water were to fall as snow with a density of 0.1 g/cm^3 over an area 500 km by 50 km, the snow depth would be 9 cm.[13]

The heat transfer rate by natural evaporation corresponds to the heat loss from nuclear plants totaling 1,730,000 MWe, showing that man's heat burden on the lake is trivial.

Natural-Draft Cooling Towers

Weather changes due to cooling towers are more severe than those related to once-through cooling; at least they are more easily and frequently observed. Towers dissipate large amounts of heat and water vapor from small areas at the same rate as power is generated.

Meteorological problems associated with both natural- and forced-draft types of cooling towers can be separated into three zones; within the tower, the water droplet plume, and the vapor plume after the droplets evaporate. Within the tower, the meteorological question is the nucleating properties, if any, of the drift or carryover. The visible plume presents the primary and most easily studied problem; predicting the position (plume rise and height of base), dimensions (length, width, and depth), and liquid water content of the visible plume from weather conditions (wind speed, wet and dry bulb temperatures, stability) and plant parameters (inlet water temperature, approach, plant load, size and type of tower, and number of units on line). Data on the frequency and areal extent of ground level fog, icing, and drizzle (mist) are also needed. In the final zone, information on the effect of the water vapor plumes on cloud formation, precipitation, and ground-level humidity is needed.

Ground-Level Fog and Icing

Practically every article on cooling towers includes a statement that natural-draft units "have the potential to cause or to increase the frequency of ground-level fog and icing." On the other hand, available observations near natural-draft towers indicate that the plumes rarely, if ever, reach the ground. For example, Mr. W. C. Colbaugh of TVA (personal communication) reports that there have been no cases of visible plumes reaching the ground during two years of operation of the Paradise, Kentucky steam plant. According to Mr. F. A. Schiermeier of the Office of Air Programs (personal communication), no surface fogs or icing have been observed in four years of operation of the Keystone, Pennsylvania Power Plant (1800 MWe). The same results have been reported in England[27] and elsewhere in the United States.[5,23,28] These observers report that the visible plumes enter the atmosphere at heights of 100 m or more and evaporate completely before reaching ground level. Hosler[8] does report one occasion on which the visible plume from a natural-draft cooling tower did reach the ground; this is the only reported case in the literature. Nevertheless, contrary to actual observations taken at tower sites, most theoretical analyses predict frequent tower-induced ground-level fog.[10,14,29]

Theoretical analyses designed to predict plume dimensions and ground-level fog from cooling towers usually contain three sections. First, a model is used to predict plume rise. This model may be one of the standard plume rise formulas[30] or a cumulus cloud model.[31] Second, a calculation of the rate of dilution of water vapor from the tower is made using one of the standard dispersion formulas. Finally, the wind direction and moisture-deficit climatology of the site are used to determine plume lengths and when and where the plume will reach the surface.

Photographs taken at cooling tower installations often show the plume leaving the towers and rising, completely separated from the surface fog of evidently independent origin, since aerodynamic downwash is not observed (for example, see Ref. 2). Of course, large orographic eddies could bring the plume down in areas of sufficiently rough terrain. Then, in any terrain, mist falling from the plume could cause or add to ground-level fog and icing. Natural ground fog is fairly frequent in the vicinity of cooling towers, since these installations are usually located near rivers and other water sources.

Dimensions of the Visible Plume

Under certain weather conditions (low temperature, high humidity, moderate wind speed, and a stable atmosphere), the visible plume from a cooling tower may extend several miles. Colbaugh et al.[6] have measured plumes extending 16 km in Tennessee. Even longer plumes have been observed but not reported in the literature. A literature search shows a lack of good data on cooling tower plumes collected on a systematic basis. The TVA is now engaged in a major field program to obtain such data, but their analysis has not been completed.[6] This program is also measuring the dispersion of the water vapor plume after the visible portion evaporates.

Bierman et al.[32] have published the only climatology of plume lengths available. They measured the length of the plume from a cooling tower complex in Pennsylvania for six months in 1969 (January 31st through July). These pictures were taken in early morning, normally the time of day with the longest visible plumes. It was found that the plumes evaporated completely on 81.5% of all days during the period of study. Of these, 87.3% disappeared within 5 stack heights or 1625 ft of the tower; only 2.6% extend more than 15 stack heights or 4875 ft. The plume merged with an existing overcast on 16.5% of all days. On the remaining days (2.0%), the plumes were classified as "special cases," such as cloud building.

Cloud and Precipitation Formation

Aynsley[2] has observed that cooling tower plumes can, if meteorological conditions are proper, create cumulus clouds. He concludes that this is a "rare occurrence," and that these man-made clouds only precede natural cloud formation. He discussed the possibility that a cooling tower plume could somehow trigger an existing atmospheric instability and create extra cumulus congestus clouds and precipitation miles downwind of the release point. As the number and size of cooling towers on a given site increase, the probability of significant alteration of cloudiness and precipitation patterns will increase.[9,15] The state of the art in cloud physics is such that we cannot say with any degree of certainty that there will be any increase in rainfall amounts due to cooling tower plumes.[7]

There are at least three reported occurrences of snow showers or ice crystals being generated by cooling towers [Culkowski,[33] FWQA,[34] and Colbaugh[6]] . In all cases, the amounts of snow were very small.

In an unpublished report, the Central Electricity Generating Board of Great Britain[27] reported its findings on the environmental effects of cooling towers. No measurable change in surface relative humidity was detected downwind. The visible plume sometimes persisted for a number of miles downwind, altering sunshine in the area. No drizzle was observed from the towers. Cumulus clouds were sometimes formed, but no cases of showers or precipitation being generated by the plume have been observed.

A small part of the cooling water (estimated to be less than 0.1 %), is carried into the plume without being evaporated. These droplets, called drift or carryover, contain whatever impurities are present in the makeup water and release these materials into the atmosphere when they evaporate. River water, containing soil erosion products, and sea water, are frequently used in cooling towers. Since certain clay materials are known to be good cloud seeding agents, these drift particles could be effective cloud nucleating agents and conceivably might modify clouds and precipitation over a large area. These drift particles evaporate as they fall to the ground and may cause surface fog and/or icing near the tower.

Mechanical-Draft Cooling Towers

The fog potential from these smaller forced-ventilation towers is much greater than for natural-draft units for the following reasons:

1. mechanical units release their water vapor at a much lower elevation (50 to 80 ft compared to 350 to 500 ft) where winds are weaker, the saturation deficit is less, and the surface nocturnal inversion frequently prevails;

2. the plumes are frequently trapped in building eddies; and

3. much higher entrainment rates are generated owing to smaller exit diameters, high (100 fps) exit speed, and additional turbulence created by the fan.

Argonne National Laboratory has several wet cooling towers. On very cold, calm days, a visible plume may extend upwards 200 ft or so before disappearing. On cold, windy days, plumes often extend 200 to 500 ft horizontally. In January 1970 during a near-record period (70 hr) of subzero temperatures, the author was not able to find icing on any of the trees 200 ft downwind of the cooling tower, even though they had been in the visible plumes for over 24 hr. The author has examined these trees on numerous occasions during the past three years; no ice has ever been detected.

The most thorough review of the effects of natural- and forced-draft cooling towers on local fogginess and cloud precipitation formation can be found in a recent paper by Huff et al.[7]

Dry Cooling Towers

In areas where water is expensive or scarce, dry cooling towers may be used.[35] It is possible that the large quantities of heat released from such cooling towers could generate sufficient convection to create cumulus clouds and precipitation,[14] but this seems unlikely in the semi-desert climates where such units are used.

Cooling Ponds

In areas where land is relatively inexpensive, cooling ponds or lakes are being constructed. Commonwealth Edison will use this method of heat dissipation at its Dresden (1,618 MWe) and LaSalle County, Illinois (2,156 MWe) plants. There is a "rule" that 1 acre of water surface is needed to cool one MWe-fossil, while 1.5 acres are needed for each MWe-nuclear.

Water losses from cooling lakes can be separated into two components: natural evaporation from an unheated lake and extra water losses due to the reactor heat. This extra evaporation is less than would be used by cooling towers of similar capacity, but the total water loss from the cooling pond is usually greater than that from a cooling tower of similar heat capacity. In most western states, the total water loss from artificial ponds may be unacceptably high (Hauser and Oleson[36]).

The frequency, intensity, and inland penetration of pond-induced fogs are items of concern in pond site selection. Observations made at existing cooling ponds indicate that the fog, except for cases of large-scale fog formation, is thin, wispy and usually does not penetrate inland more than 100 to 500 ft. It would appear that because the water vapor is released over large areas, ponds are not a major source of fog, despite the release of the water at ground level. The pond should be located so that the induced fogs (and freezing fogs) do not affect roads and bridges.

Steam fog is created whenever the air is sufficiently colder and less humid than the underlying water. Church(37) has indicated that steam fog will form if the vapor-pressure differences between the air and water is 5 millibars or more and the air temperature is at or below freezing. The air layer next to the water surface is heated and has moisture added; mixing of this air with the unmodified air just above can lead to supersaturation and condensation. Further vertical mixing tends to evaporate the steam fog.

It should be remembered that natural steam fog is fairly common in much of the nation due to the frequent passage of cold air masses over open water. Because of higher water temperatures, steam fog may form over the heated water in cooling ponds when conditions do not favor natural steam fog. Some of the water droplets will be removed by vegetation and other surfaces as they move across the nearby land areas, causing a local increase in humidity and dew. During periods of subfreezing temperatures, some of the droplets will freeze and create a layer of low-density rime ice on nearby vegetation and structures. Observations at existing ponds indicate that this rarely, if ever, causes problems with plants, power lines, etc.

Air crossing the pond will be slightly warmer and more humid than it would otherwise be. How large these changes will be at the shoreline is not known; it is reasonable to assume that the differences will be insignificant and too small to measure a short distance inland.

On a very cold winter day, January 5, 1972 (air temperature -2.5°F, relative humidity about 80%), heavy steam fog was present over the cooling pond of a nuclear power plant in northern Illinois. Light rime ice up to

1/4-in thick was observed on fences and vegetation up to 100 ft from the lake. The horizontal visibility on a highway bridge over the pond was more than 100 ft; no ice was observed on the roadbed. Ice crystals were observed floating in the atmosphere over another road about 100 ft downwind of the pond.

On January 14 and 15, 1972, the visibility on a bridge over the pond itself averaged less than 100 ft as the fog moved in patches from the pond. The air temperature during this period remained near zero, with W to NW winds 10 to 15 knots. Dense portions of this fog momentarily reduced visibility to 5 to 10 ft; a few seconds later, the fog thinned and occasionally the visibility improved to 200 ft. The bridge was quite slippery, owing mostly to 2 in of snow on January 13; the combination of poor visibility and slick roads caused two automobile accidents. Visibility on another road 200 ft from the pond never went below 200 ft.

The maximum observed inland penetration of ground-level fog from this cooling pond (period of record, November 1971 through February 18, 1972) was only 1/4 mile (400 m). The steam fogs either evaporate completely or move aloft and form a cloud deck.

A study has been made of the inland extent of steam fogs generated by other cooling ponds.[38] In four steam fogs over a cooling pond in central Illinois, the downwind fog extended 40 to 150 m. Five observations were made at the Four Corners power plant in New Mexico in December 1970 and January 1971. The reported inland extent of the fog on two days was 20 to 40 m; on another, 50 to 150 m. On January 7, 1971, when the air temperature was -12° F and the water was +51° F, the fog moved inland 3000 to 3400 m. The next day was 2° F colder, and the inland movement was 14,000 to 18,000 m. The report made no mention of the density of the fog.

Decker[24] and Zeller et al.[23] have published papers on the effects of cooling ponds on atmospheric conditions; they report no serious fogging problems at several cooling ponds in Europe and the USA.

Spray Canals and Ponds

In a spray cooling system, pumps are used to send the heated water into the atmosphere to increase the area of contact between water and air, thus increasing the rate of cooling by conduction and evaporation. Typical units now in service send the water 20 ft upwards over a 40-ft diameter circle. The primary advantage of a spray system over a cooling pond is the much smaller area needed to cool a given plant load.

Since spray canals concentrate in both space and time (when compared to once-through cooling or cooling ponds) the heat transfer to atmosphere, the atmospheric changes due to the extra heat and water vapor will be enhanced. The visible plume created by the spray canal contains drift water droplets in addition to drops of condensed vapor. These drift droplets will tend to be larger than those produced by condensation and add considerably to the wetting and icing potential of the visible atmospheric plume.

In contrast with cooling towers and ponds, there has been little operating experience with large spray cooling systems, especially in winter, the season of greatest interest. A small spray system, designed primarily as a scale or test model of a full system, has been operated for one winter in New Hampshire; no serious meteorological problems were experienced (Mr. James Parks, Public Service of New Hampshire, personal communication). This system is located in a valley which keeps wind speeds over the spray modules low; most of the drift droplets fell back into the canal and were not carried inland. Typically, the fog created by the spray units rose to a height of 200 ft before evaporating and/or moving inland. Hence, icing has not been a serious problem near the canal. On two occasions, very thin fog has been observed as far as 2 miles from the canal. Canal-produced fogs, in contrast to natural fogs in this part of New England, are thin and do not reduce visibilities over nearby highways to less than 100 ft. Since no significant environmental problems were observed during the past winter, the utility is now expanding the spray canal to dissipate the entire heat load from the power plant.

The Dresden, Illinois, Station of the Commonwealth Edison Company started operation of a spray canal system in August 1971. Experience during the summer months gave no indication of serious environmental problems due to fog from the spray canal. Commonwealth Edison is now sponsoring a full-scale investigation of the fogging and icing potential of the Dresden cooling system which contains a 1275-acre lake in addition to the spray canal. Although this observation program has just started, experience to date at Dresden can be used to predict atmospheric effects at other spray canals.

On January 5, 1972, the overnight temperature was well below zero. At 0800 C.S.T., when the first visual observation of fog and icing was made, the air temperature was -2.5°F and the relative humidity 100%. Over the spray canal, a dense plume rose to a height of 100 to 150 ft; this visible plume extended inland about 1000 ft before evaporating (R. W. McLain, Murray and Trettel, Consulting Meteorologists, personal communication). About 1-1/2 to 2-1/2 in of hard, dense rime ice was deposited on vegetation and fences next to the canal; this dense ice, with decreasing thickness, was found to extend inland 100 to 150 ft. Light rime ice formed further downwind, up to 1/2 in thick 500 to 700 ft downwind, and 1/4 in at 1000 ft. It was observed that ice formed only on vertical surfaces, such as fences, posts, and vegetation. No ice was observed on a road 600 ft downwind of the spray units.

From the limited experience to date, it is reasonable to expect that spray cooling systems will create more severe icing conditions during winter than mechanical draft cooling towers and cooling ponds, with drift being a serious problem.

Quantitative estimates of fog and icing potential from spray canals are not possible, in part because the properties of the air downwind of spray units (temperature, liquid water content, drop size distribution, etc.) are unknown functions of ambient weather conditions (wind speed, air temperature, humidity, stability), water temperature, and characteristics of the spray heads (drop size distribution, number of sprays and their location with respect to the wind direction, etc.). For most wind conditions, the air will be in contact with the water from the spray for a shorter period than it would be in a cooling tower. Thus, the heat and moisture transfer to the air will be slower, and more air will be modified to cool a given plant load.

Based on experience at the two locations mentioned above, the primary atmospheric effect will be dense fog and hard rime ice on vertical surfaces near the spray units on cold days (<+10° F) in winter, with thin fog and light rime ice extending some distance inland.

Summary and Conclusions

The amount of heat energy contained in the cooling water from the large nuclear power stations is quite small compared to the natural heat processes. Since the heat energy from these plants with once-through cooling systems will enter the atmosphere over a large area, changes in weather will be small and probably impossible to isolate in the natural variability of weather elements. An exception will be an increase of steam fog in fall and winter at the point of discharge.

Alternate cooling systems, such as cooling towers, cooling ponds, and spray canals, release the energy to the atmosphere rapidly over a small area; hence, the potential for local weather changes is greatly enhanced. Much care should be given to cooling site location so that the fog and icing do not seriously restrict road traffic, etc.

From a meteorologist's point of view, once-through cooling on a large water body is to be preferred over either cooling towers or cooling ponds.

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The Atmospheric Effects of Thermal Discharges into a Large Lake

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Concern for the biological and ecological effects of heated water has resulted in legal actions that will prevent power companies from dumping the waste heat from the majority of their new generating units into rivers and lakes. Many nuclear- and fossil-fueled plants now under construction, and even some now on-line, are being required to change from once-through cooling systems to other methods, such as wet cooling towers, cooling ponds, and spray canals, despite higher costs and lower thermal efficiencies. Yet, these alternate cooling procedures are not without their own environmental problems.

The primary weather change due to once-through cooling on a large water body is a small local increase in fogginess at the plant outfall. But the relative probability of significant local meteorological effects is much higher with alternate cooling procedures, since these reduce the area of heat and moisture transfer. It is therefore concluded that, from a meteorological point of view, the least undesirable way to dispose of waste heat is by using once-through cooling on large water bodies.

The peak demand for electrical power in the United States is increasing at a rate of 7% per year.[1] This increase is due both to increasing population and to increasing per capita consumption. Almost all of the new capacity will consist of thermal (steam) units, both nuclear- and fossil-fueled, with marked trends toward larger capacity units and more units on a given site. Despite their lower thermal efficiencies, an increasing fraction of the new plants will be nuclear, this choice being made in part to reduce emissions of atmospheric pollutants such as flyash and sulfur dioxide.

Two fossil fuel (with a capacity of 616 MWe) and five nuclear plants (6732 MWe) are now being installed along the shores of Lake Michigan[2] and are expected to be on-line with the 25 operational plants by 1974. These plants will have a total capacity of 15,626 MWe. All were originally designed for once-through cooling. Recent actions of the Environmental Protection Agency may force most, if not all, of the new plants to use alternate cooling techniques, such as cooling towers or cooling ponds.

Utilities use large amounts of water to cool the condensers in the plant; the cooler this water is, the more efficient the process will be. Until recently, most plants have used once-through cooling, drawing water from lakes, rivers, or the ocean, heating it 10°–25° F as it passes through the plant, and returning it to the source. Because of concern for both the effects of increased temperatures on the biota of the receiving water body and shortages of cooling water, many power generating stations now under construction will use cooling towers or cooling ponds to dissipate much of the heat to the atmosphere before recycling the cooling water or returning it to the source. Lower costs of operation and installation dictate the use of "wet" or evaporative supplemental cooling systems except in areas of very limited water supplies.

The state of the art is such that meteorologists are not able to predict quantitatively how the atmosphere will react to the large amounts of heat energy and water vapor that it will be forced to absorb as the result of the disposal of waste heat from power

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plants. Conceivably, critical heat release rates may exist for particularly sensitive sites which, when exceeded, may lead to significant meteorological effects, such as the generation of thunderstorms in convectively unstable, subtropical conditions.

Large quantities of reject heat are not unique to nuclear electrical generating stations since all heat engines release heat to the environment. In other words, what is frequently called "waste heat" is really a necessary part of the energy conversion process.

Almost all of the energy produced by electrical power stations, both the waste heat and the useful power generated, is eventually dissipated to the atmosphere. In this paper the potential meteorological effects of the waste heat are explored. While studies of the effect of thermal discharges on the atmosphere are relevant to all types of power generation, they are particularly significant to water-cooled nuclear power plants which produce 40 to 50% more waste heat per unit of electricity than modern fossil-fueled plants. Part of the difference in cooling requirements is caused by the loss of heat up the chimney in conventional power plants (10 to 12% of the total). It should be noted that all but the most modern of the fossil-fueled plants now on-line operate at efficiencies comparable to the new nuclear plants.

Statements made by the utilities serving the Lake Michigan area indicate that alternate cooling methods, such as cooling towers and ponds, may be used for plants now being designed. These alternate cooling methods are not without their own environmental problems, and the meteorological consequences of these procedures are briefly discussed. It is found that once-through cooling is the preferred method, meteorologically speaking.

To date only a limited number of research and field studies on the atmospheric aspects of thermal pollution have been conducted and reported in the literature. Published papers include those of Aynsley,[3] Stockham,[4] Overcamp and Hoult,[5] Decker,[6] Colbaugh, et al.,[7] Huff, et al.,[8] Hosler,[9] Hanna and Swisher,[10] EG&G,[11] Kolflat,[12] and Altomare.[13]

In September 1971, the National Science Foundation sponsored a workshop to prepare a list of the areas of ignorance in the field of environmental aspects of thermal discharges from large sources and to suggest research projects to improve our knowledge.[14] This conference covered many topics in addition to the atmospheric aspects of waste heat discharges.

This paper deals primarily with the atmospheric effects of once-through cooling on a large lake, such as Lake Michigan. It was found that the total energy released by these nuclear power plants is a very small fraction of the natural heat transfer processes on the Lake; it is concluded that the meteorological and climatological consequences will be small. Except for a small amount advected into Lake Huron, all of the power plant reject heat will eventually enter the atmosphere through radiation, evaporation, and conduction from the lake surface.

While the total quantity of heat put into the lake by these power plants is very small compared to that exchanged by natural processes (solar radiation, evaporation, conduction, and long-wave radiation), it does not immediately follow that the meteorological consequences will also be small. It is possible that the frequency and severity of the lake snows, fog, and freezing fog around the south and east shorelines of the lake could be increased somewhat as a result of a small increase in lake surface temperature. In any event, such meteorological and climatological changes would be very difficult to isolate in the noise of natural variability of weather elements.

Observed Weather Changes Caused by Thermal Enrichment

Thermal plumes introduced into large bodies of water are dissipated by two processes: through direct surface losses to the atmosphere by evaporation, radiation, and conduction, and through dilution by mixing with the cooler, main body of water. Unfortunately, the relative magnitudes of these two temperature-lowering processes are not known for various weather and lake conditions. Meteorologists are not able to measure directly the locally-increased vertical fluxes of radiation, heat, and water vapor over a thermal plume with the accuracy required due to the small size and meander of the thermal plume itself. Direct measurement of plume temperature reduction by mixing with ambient lake water presents experimental difficulties. Csanady[15] has concluded from a theoretical analysis that only a small part (on the order of 5%) of the plume's heat is lost to the atmosphere before mixing lowers the plume's surface temperature-excess to 1°F. More recently, Csanady, et al.[16] measured the heat balance of a thermal plume from a nuclear power plant on Lake Huron and found that "the direct heat flux to the atmosphere from the detectable plume was 1/3 of the total heat flux." Ayers[17] concludes that there is a "significant loss of excess heat to air, and an insignificant loss of heat to the underlying cold water." Clearly, more field measurements are needed to determine rates of heat loss from thermal plumes over a range of weather conditions. The relative importance of the two temperature-lowering processes will vary as lake and atmospheric conditions change. When the lake is rough, mixing will be rapid. When it is smooth, the warm water will tend to float with little mixing and present a larger area of greater temperature excess, and hence increased heat transfer to the atmosphere.

Except for that advected into Lake Huron, the heat energy mixed into the main body of Lake Michigan will eventually be returned to the atmosphere. This transfer takes place over such a large area that it is reasonable to conclude that once-through cooling will have a much smaller impact on the atmosphere than alternate cooling methods such as towers or ponds.

Lake Michigan has a natural temperature resetting mechanism due to the cooling of the entire body of the lake every winter below 4°C, the temperature of maximum density of fresh water. Twice each year the lake is observed to be vertically isothermal at the temperature of maximum density due to thermal instability and mechanical mixing due to storms. Thus, up to an improbable condition in which a temperature as low as 4°C is not obtained, lakes such as Lake Michigan cannot accumulate heat energy year after year. It has been observed[18] that the average temperature of Lake Michigan has actually decreased 1°–2°F during the past two or three decades despite its use for cooling by industry and fossil-fueled plants, and despite warmer inflow-stream temperatures due to tree removal.

Two scales of weather changes can be expected from thermal discharges into the lake: local changes due to increased heat and moisture fluxes over the thermal plume, and large-scale modifications due to the accumulation of heat energy in the main water body.

Heat and water vapor are added to the atmosphere as air moves from the land over the lake surface. Due to the local temperature excess, more heat will enter the atmosphere from the thermal plume than from the main lake surface. Thus, air with a trajectory over a thermal plume will be somewhat warmer, more humid, and less stable as a consequence of thermal discharges. Observations confirm that an increase in the frequency and density of steam fog over the immediate plume area is the primary observable effect of thermal discharges into large water bodies.

Thermal discharges from power plants also might conceivably modify the large-scale climate of an area. Much of the heat will be mixed into the main body of the lake, raising its temperature a small fraction of one degree.[19,20] Some of the energy added in summer will be stored until the fall cooling period is reached; increased evaporation and conduction could then increase the intensity and frequency of lake snows in late fall. It does not necessarily follow that the increase in lake snows would be directly proportional to the extra heat discharge; even a small increase in water temperature could be just sufficient to release an atmospheric instability. The amount of heat discharged by power plants is much too small to cause measurable air temperature changes on the lake shore (see below).

A review of the literature indicates that, except for fog, changes in weather and climate due to once-through cooling on lakes, rivers, and cooling ponds are too small to be observed. Numerous cases of thin fog and/or light freezing fog near thermal outfalls or cooling ponds have been reported.[21,22] These steam fogs are "wispy", thin and dissipate quickly. In no case did a statement that these plume-related fogs pose a problem to visibility and traffic on nearby land appear. If the air temperature is below freezing, these steam fogs may drift over structures and through vegetation and cause rime icing. The author has observed dense steam fog 3 to 10 meters deep over a cooling pond when the air was more than 55°C (100°F) cooler than the water. Ambient air temperature was about −7°C, with low humidity. The fog drifted inland a maximum of 15 m and deposited a 2 to 3 cm layer of flaky, low-density rime ice on vegetation within 4 m of the canal edge. This ice was so light as to be no hazard to the plants. No ice had formed on either a bridge crossing the canal or on trees further inland.

Perhaps the most serious difficulty in conducting field studies at existing cooling ponds, rivers, and lakes is that the undisturbed water body itself affects weather conditions. For example, lake-effect snows and steam fogs frequently occur near Lake Michigan far from any thermal discharge. But it is very hard to say how the intensity, duration, and frequency of fogs and freezing fogs in Waukegan, for example (which has a 1100 MWe coal plant using once-through cooling), has been altered by this local influx of additional heat.

Isolating possible long-term changes in weather and climate around the lake will be an even more difficult problem. Calculations show that the total reject heat from power plants now being built is very small compared to the meteorological input, and is also very small compared to natural variations of atmospheric processes.

Nowhere in the literature has the author found a single report of observed precipitation or significant temperature change due to once-through cooling on a large water body.

In midwinter, ice-free areas will be formed at or near the point of discharge. Plant personnel (including a professional meteorologist) at a large fossil-fueled plant on Lake Ontario report that the plume area is too small to affect weather conditions on the shore. Steam fogs are often present over the plume, but these are rapidly dissipated by mixing with drier air as they move inland.

The power plant heat in Lake Michigan will act to reduce the ice cover by delaying its formation in fall and to advance its melting in spring. Thus, the shipping season will be slightly increased; how many minutes or hours per year is a valid but unanswered question.

Estimated Weather Effects from Once-Through Cooling on Lake Michigan

Some appreciation of the relative improbability of a significant weather modification by waste heat from nuclear power stations on Lake Michigan can be obtained by comparing the amounts of heat involved in power generation with those quantities involved with natural meteorological processes.

The following assumptions, all conservative (that is, yielding a maximum value for the meteorological change being considered), were made in the following calculations:

a. Each reactor is operated at full capacity for the entire year.
b. The thermal efficiency of the plant is 33%, and all of the waste heat enters the lake (in nuclear power plants, about 5% of the energy is lost to the atmosphere inside the plant).
c. No heat is lost from cooling water to the atmosphere before it enters the lake.
d. Only one heat dissipation process is operating at any one time.
e. Nuclear plants with a capacity of 7000 MWe will be on line.

Data on the volume, surface area, and other features of Lake Michigan are listed in the Appendix.

Annual Temperature Rise

A quantitative estimate of the amount of temperature rise possible in Lake Michigan because of nuclear waste heat can be obtained from the following simple calculation. A nominal plant-year, defined as a 1000 MWe nuclear operated at full capacity for the entire period, generates 1.5×10^{16} calories of waste heat. If we assume that *all* of this energy stays in the lake (that is, there are no losses to the atmosphere by evaporation, radiation, or conduction), the temperature rise is given by

$$\Delta T = \frac{H}{ms}$$

where H is the heat added, m is the mass of water warmed, and s the specific heat of water (=1 cal/g/°C). If this heat were uniformly mixed throughout the lake (horizontally and vertically), then for a 1000-MWe plant,

$$\Delta T = \frac{1.5 \times 10^{16}\ \text{cal}}{4.65 \times 10^{18}\ \text{g} \times 1\ \text{cal/g/deg}}$$

$$\Delta T = 0.0032°\text{C/yr}$$

For 7000 MWe,

$$\Delta T = 0.022°\text{C/yr}$$

Both are two orders of magnitude smaller than the observed year-to-year temperature variations in Lake Michigan.[18] It should also be remembered that Ayers has found that the Lake has cooled about 2°F in the past 40 years despite its use as a thermal sink for existing power plants and industry, and warmer stream temperatures due to forest removal.

These calculations represent an upper limit of the ability of power plants to warm the lake, since zero heat losses to the atmosphere were assumed. Longtin,[19] using a more complex model which allows for heat losses to the atmosphere, has concluded that the thermal input from all power facilities on the Lake is "...crudely estimated to be 0.028°C." Asbury,[20] using a similar but more refined model reports that the average annual temperature of the Lake will increase only 0.0055°C due to the reject heat from nuclear plants totaling 7000 MWe.

Summer Surface Temperature Changes

A more realistic assumption for the heat distribution within the lake is that the energy is confined to the epilimnion. If it is assumed that all of the reactor heat generated during the 6-mo summer season is confined to a layer 20 m deep and is further restricted to the southern basin (about ⅓ of the area) of the lake, the temperature rise is

$$\Delta T = H/ms = H/\rho Ads$$

where ρ is water density, A is the area, and d the depth of the mixed zone. For a 1000-MWe nuclear plant,

$$\Delta T = \frac{7.5 \times 10^{15} \text{ cal}}{1 \text{ g/cm}^3 \times 1.93 \times 10^{14} \text{ cm}^2 \times 2 \times 10^3 \text{ cm} \times 1 \text{ cal/g/}^\circ\text{C}}$$

$$= \frac{7.5 \times 10^{15}}{3.86 \times 10^{17}} = 0.0194^\circ\text{C}$$

For 7000 MWe,

$$\Delta T = 0.14^\circ\text{C}$$

This value is again much smaller than the observed natural variability.

These calculations show that the warming of Lake Michigan, while unidirectional, is much too small to change measurably the average air temperature along its shore.

Warming Inside the Thermal Bar

In spring, the waters of the lake near the shore warm faster than the deeper waters, and a "thermal bar" is created.[23] This "bar" acts to reduce lateral mixing, and confines heated effluents to the shore-line.

Two of the nuclear installations now under construction will have a total capacity of 2200 MWe. The maximum heat discharge rate into the lake will be 2.1×10^9 cal/sec. It is assumed that the thermal bar is only 2 km from the shore (a conservative estimate), that the water at this point is 10 m deep, and the coastal current is 0.5 m/sec (about 1 mph). The water transported past the discharge point will be 5×10^9 cm³/sec. If the water inside the thermal bar is completely mixed, the temperature rise will be

$$\Delta T = \frac{H/t}{m/t \times s} =$$

$$\frac{2.1 \times 10^9 \text{ cal/sec}}{5 \times 10^9 \text{ g/sec} \times 1 \text{ cal/g/}^\circ\text{C}} = 0.42^\circ\text{C}$$

This temperature rise is small compared to measured hour-to-hour changes in lake temperature observed near the shore.

Evaporation

In the above calculations, it was assumed that no heat was lost to the atmosphere by evaporation, conduction, or radiation.

If we now assume that all of the nuclear waste heat is used to evaporate water (again, a conservative assumption), the amount of additional evaporation is given by

$$H = mL = L\rho Ad$$

where ρ, A, and d are density, area and depth as before, and L is latent heat. For a 1000-MWe plant,

$$d = \frac{H}{\rho AL} =$$

$$\frac{1.5 \times 10^{16} \text{ cal/yr}}{1 \text{ g/cm}^3 \times 5.8 \times 10^{14} \text{ cm}^2 \times 590 \text{ cal/g}}$$

$$= \frac{1.5 \times 10^{16}}{3.42 \times 10^{17}} = 0.044 \text{ cm/yr}$$

For 7000 MWe,

$$d = 0.308 \text{ cm/yr or } 0.12 \text{ in./yr}$$

The natural evaporation rate is not known exactly, but a depth of 76 cm/yr (30 in./year) is reasonable. Thus, the additional evaporation due to reactor heat is less than 0.4% of natural. This extra moisture should act to increase slightly humidity in the area; whether the increase is sufficient to be observable is another question. The extra vapor should also act to increase precipitation around the lake, but predicting how much the increase would be, and in what form, is beyond the state of the art.[24,25]

The heat transfer rate of the natural evaporation (76 cm/yr) corresponds to the heat loss from nuclear plants totaling 1,730,000 MWe, showing again that man's heat burden on the lake is trivial compared to nature's.

Water Budget

It is estimated that the flow of water from Lake Michigan into Lake Huron lies somewhere between 40,000 and 55,000 cfs (1133 to 1560 m³/sec). An additional 3200 cfs (91 m³/sec) is diverted into the Mississippi River Basin. The water lost by evaporation per unit time, V/t, is given by

$$V/t = H/t/L\rho$$

For a 1000-MWe plant,

$$V/t = H/t/L\rho$$

$$= \frac{4.8 \times 10^8 \text{ cal/sec}}{590 \text{ cal/g} \times 1 \text{ g/cm}^3}$$

$$= 8.1 \times 10^5 \text{ cm}^3\text{/sec or } 28.6 \text{ cfs}$$

For 7000 MWe,

$$\text{vol/sec} = 210 \text{ cfs}$$

This number represents the upper limit of water loss by evaporation by any cooling technique used. Because of heat losses by radiation and conduction, once-through cooling would evaporate less water than a cooling pond, and both would use less than cooling towers.

Net Radiation

Long-wave radiation from the water surface is another heat dissipation process. The Brunt[26] formula for net heat loss for clear conditions at night is

$$R_n = \sigma T^4(1 - a - b\sqrt{e})$$

where σ, a, and b are constants, T is surface temperature in degrees absolute, and e is the atmospheric water vapor pressure (mb). Using the usual values for the constants ($a = 0.44$, $b = 0.08$) and a reasonable value for vapor pressure, the additional net radiation loss from water heated 5°C is about 8 watts/m². If the area of the thermal plume whose temperature is 5°C above ambient is 20,000 m² (100 × 200 m), the heat loss by this process is 0.16 mW.

The capacity of the lake to lose heat by long-wave radiation is very large: if the lake surface temperature were increased from 4° to 5°C, the extra net radiation would be 1.8 watts/m² or 104,000 MW for the entire lake.

Change of Heat Storage from Year to Year

It is observed that the lake overturns each spring and fall as a result of the peculiar change in the density of water with temperature at +4°C. As a result of this overturning, it is observed that the lake is vertically isothermal at this temperature twice per year, and the heat content of the lake is "reset" to this datum level twice annually. Thus, Lake Michigan will not accumulate nuclear heat energy from one year to the next. What will happen is that the time of the fall overturn will be delayed, the time of the spring overturn advanced, and the average water temperature in both winter and summer will be increased slightly.

Church[27] reports that the heat lost to the atmosphere during these turnover periods averages about 300 cal/cm²/day. Over the entire area of the lake, this amounts to 1.74×10^{17} cal/day. Nuclear plants with 7000-MWe capacity generate 1.05×10^{17} cal/year. It would appear that the change in the time of overturning will be of the order of one day, or much less than the observed variability, about one month. Church measured daily heat losses to the atmosphere as large as 600 cal/cm²/day, or 3.5×10^{17} cal/day over the entire lake.

Church[27] reports that the annual heat budget of the south basin of Lake Michigan is 52,000 cal/cm². That is, this amount of energy is absorbed during the summer and returned to the atmosphere the following winter. If all of the reactor heat were used in a similar manner, the extra annual heat exchange would be (from 7000 MWe) 181 cal/cm². For comparison on an average daily basis, the observed solar energy received at the Argonne site is 348 cal/cm²/day. In December, the month with the least insolation, the average over 15 years is 135 units.

Reactor Heat *vs* Sunshine

Solar radiation reaching the ground at noon on a clear day at Argonne averages about 1.5 cal/cm²/min in June, 0.7 units in December. A 1000-MWe reactor generates 28.6×10^9 cal/min of reject heat. This corresponds to noon sunshine on a 477-acre area in June, 1000 acres in December. The observed plume from 1100-MWe coal plant on Lake Michigan covers an area somewhat less than a square mile. Thus, the heat generated by the plant is about equal to the solar load on the plume at noon in summer, doubling the thermal input to that body of water.

A 1000-MWe reactor puts 28.6×10^9 cal/min into the cooling water, 7000 MWe places 2×10^{11} units. The solar constant is 2.00 cal/cm²/min. Over an area equal to that of Lake Michigan, this amounts to 1.16×10^{15} cal/min. That is, the reactor heat load on the lake is only 0.02% of the solar constant on the same area.

The Argonne sunshine data show a value of about 800 cal/cm² on a clear day in June, 300 units on a clear day in December. Very cloudy days in June can receive as little as 80 units, and only 1 in December. These are record single days in a 15-yr period. If all of the heat energy from 7000 MWe reactors operating at capacity for a full *year* were stored in the water and released during one *day*, the heat flux would be 181 cal/cm²/day. This value is equivalent to a few extra hours of clear skies in summer, and is less than one additional clear day in winter, and is also small compared to year-to-year variations in cloudiness in the area.

Snowfall

It is assumed that all of the heat from a 1000-MWe reactor is used to evaporate water. In one day, this amounts to 7.0×10^{10} grams. If all of this water were to fall as snow (density = 0.1) over a 10- × 30-km area, the snow depth from this water would be

$$h = \frac{\text{mass}}{\text{area} \times \text{density}} = \frac{7.0 \times 10^{10}\ \text{g}}{0.1\ \text{g/cm}^3 \times 3 \times 10^{12}\ \text{cm}^2} = 0.233\ \text{cm or } 0.1\ \text{in.}$$

If all the reactor heat for a full year were converted into snow over a belt 500 × 40 km, the snow depth would be

$$h = \frac{(7.0 \times 10^{10}\ \text{g/GWe/day})(7\ \text{GWe})\ (365\ \text{days/yr})}{(0.1\ \text{g/cm}^3)(2 \times 10^{14}\ \text{cm}^2)} = 8.94\ \text{cm or } 3.5\ \text{in.}$$

Average depths in the snow belt of the State of Michigan run from 40 to 100 in./yr, with the lower value near the site of the power plant now under construction.[28]

It should be remembered that lake-effect snows are the result of convection created by intense surface heating by the relatively warm water. It is entirely possible that increases in snow amounts could be considerably greater than suggested by the above calculations due to a greater release of convective instability.

Meteorological Effects of Cooling Towers

Weather changes due to cooling towers are more severe than those related to once-through cooling; at least they are more easily and frequently observed. Towers dissipate large amounts of heat and water vapor from small areas, and at the same rate as power is generated.

In once-through cooling systems, the heat releases to the atmosphere may occur over large areas days or weeks after being generated and long after the thermal plume has disappeared.

Most reports dealing with the meteorological consequences of natural draft cooling towers state that they have the "potential" to cause ground-level fog: observations at towers indicated that they rarely if ever do.[2,3,6–9,21] The warm, moist plume enters the atmosphere at heights of 100 m or more, and evaporate before reaching ground level.

Cooling tower vapor releases could reach the ground in hilly terrain areas. An inversion aloft plus radiative and evaporative cooling from the top of the plume could create a negative buoyancy and cause the plume to descend to ground level; this has not been observed in England but may occur in hilly terrain. The extra heat and water vapor does under proper meteorological conditions create cumulus clouds. The possibility that the cooling tower plume somehow triggers an existing atmospheric instability and creates extra cumulus congestus clouds and precipitation miles downwind of the release point must be considered. There are at least three reported occurrences of snow showers or ice crystals being generated by cooling towers.[7,29,30]

Aynsley[3] has observed that cooling tower plumes can, if meteorological conditions are proper, create cumulus clouds. He concludes that this is a "rare occurrence," and that these man-made clouds only precede natural cloud formation. He also speculates that extra heat and water vapor could increase downwind rainfall.

Photographs taken at cooling tower sites frequently show ground level fog completely separate from the rising plume from the towers.[3] The surface fog is caused by natural processes, such as nocturnal radiation; the rivers and reservoirs used to supply makeup water to the towers aid in the formation of fog.

In an unpublished report (date June 1968), the Central Electricity Generating Board of Great Britain reported its findings on the environmental effects of cooling towers. No measurable change in relative humidity was detected downwind. The visible plume sometimes persisted for a number of miles downwind, altering sunshine in the area. No drizzle was observed from the towers. They reported that cumulus clouds were sometimes formed but that no cases of showers or precipitation being generated by the plumes have been observed.

A small part of the cooling water (estimated to be less than 0.1% of the cooling water) is carried into the plume without being evaporated. These droplets, called drift, will contain whatever impurities are in the makeup water, and release these materials into the atmosphere when they evaporate. River water, containing soil erosion products, and sea water are common sources of this water. Some clay materials are known to be good seeding agents. The resulting particles may be effective nucleating agents, and thus could modify clouds and precipitation over a large area.

Many nuclear plants will use mechanical draft cooling towers. These towers, with their low level of release (20–30 m) and more rapid entrainment, do cause ground-level fog. The plumes mix rapidly with ambient air (due to their small diameters, higher exit speeds, and greater internal turbulence) and are often caught in the building wake. Also, the saturation deficit is lower at this height than for natural draft towers.

Therefore, more attention must be paid to site selection to minimize fog over highways if forced draft towers are used.[31]

The Argonne National Laboratory has several small wet cooling towers. On very cold, calm days, a visible plume may extend upwards 100 m or so before disappearing. On cold, windy days, they often extend a similar distance horizontally. Last winter, during a near-record period (70 hr) of sub-zero temperatures, the author was not able to find icing on any of the trees just downwind of the Zero Gradient Synchrotron cooling tower, even though they had been in the visible plume for over 24 hr.

The most thorough review of the effects of cooling towers on local fogginess, and cloud and precipitation formation can be found in the recent paper by Huff, et al.[8] There are several references in the literature on observed weather changes due to wet cooling towers.[2,6,7,9,21,31,32]

Summary and Conclusions

The amount of heat energy contained in the cooling water from the large nuclear power stations is quite small compared to the natural heat processes. Since the heat energy from these plants with once-through cooling systems will enter the atmosphere over a large area, changes in weather will be small and probably impossible to isolate in the natural variability of weather elements. An exception will be an increase of steam fog in fall and winter at the point of discharge.

Alternate cooling systems, such as cooling towers, cooling ponds, and spray canals, release their energy to the atmosphere rapidly over a small area; hence, the potential for local weather changes is greatly enhanced. Much care should be given to cooling site location so that the fog and icing do not seriously restrict road traffic, etc.

From a meteorologist's point of view, once-through cooling on a large water body is to be preferred over either cooling towers or cooling ponds. Because of the large heat capacity of the lake, this heat rejection procedure will not cause any significant changes in the weather and climate of the area.

APPENDIX

The following data for Lake Michigan were used:

Area	= 22,400 sq mi = 6.25×10^{12} sq ft
	= 5.80×10^4 km² = 5.80×10^{11} cm²
Volume	= 1.64×10^{14} ft³ = 1.23×10^{15} gal = 1116 mi³
	= 4,652 km³ = 4.652×10^{15} cm³
Mass	= 1.02×10^{16} lb
	= 4.65×10^{18} g
Average depth	= 276 ft = 81.4 m
Outflow	= 40 to 55 × 10³ cfs (1133 to 1560 m³/sec) into Lake Huron
	= 3.2 × 10³ cfs into the Mississippi River Basin (91 m³/sec)

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SHOULD THERMAL DISCHARGE INTO LAKE MICHIGAN BE ALLOWED?

BY

ARTHUR PANCOE

SCIENTIFIC DIRECTOR OF:

SOCIETY AGAINST VIOLENCE TO THE ENVIRONMENT

FOR PRESENTATION BEFORE THE RECONVENING OF THE LAKE MICHIGAN ENFORCEMENT CONFERENCE ON SEPTEMBER 19TH, 1972 IN CHICAGO, ILLINOIS.

I am appearing before this Board to tell you why I believe it is inadvisable to allow thermal infusion into Lake Michigan from electric generating plants. At this time I will bring before this Board five major dangers, amongst others, that have not at any time in previous testimony been accounted for satisfactorily.

One: The first peril I wish to emphasize is the inability of plankton to withstand the rapid temperature rise across the condenser. In Dr. Donald W. Pritchard's paper of September, 1970 before the Lake Michigan Enforcement Conference, supporting the use of Lake Michigan for cooling water used in generation of power, he discusses in detail various aspects of the problem, with the ultimate conclusion that presently proposed plants will have no measurable effect on the overall Lake temperature. In this I concur. But the subject Dr. Pritchard deals with in most detail is how to discharge the cooling water in a way which will allow the most rapid dilution of the thermal plume. Why is this the major concern of his presentation? I suggest the answer may be found on the bottom of Page 20 of Dr. Pritchard's report.

"For example, in the case of the Zion Power Station, the time of transit of the condenser cooling water from the condensers to the point of discharge will be approximately two minutes. In order to minimize any possible biological effects of using the surface waters of Lake

Michigan for cooling, the condenser cooling water flow system should be designed to minimize the time of transit of the heated effluent from the condensers to the point of discharge." Note: Dr. Pritchard even though a proponent of using the Lake for once through cooling purpose, and a Commonwealth Edison witness at the last Conference, uses the words "minimize any possible biological effects." This means there is a problem here, and at the very basic level of the food chain. Since only 10% of the energy radiated to the Lake is available to man and is manifest at this microscopic level of the food chain, as we move up the food chain, each level is at most 10% efficient. We can readily see that we are taking a risk at the most basic level of life, and the dangers, if we are wrong, are not insignificant.

On March 21, 1971, during the reconvening of The Lake Michigan Enforcement Conference, I received a call from Dr. Thomas Roos, the Biologist of Dartmouth College, who expressed deep concern over the use of Lake Michigan water for once through cooling. He said that the sudden rise of 20° F. across the condenser, in his opinion, will kill most, if not all, the Phyto and zoo plankton. He stated that the two minutes of anticipated time that this plankton is exposed to the extremely warm water may not seem much in the life of an individual, but must be correlated to the one and a half or two day life span of the form of life in question.

He reiterated the danger to the entire Lake's life if harm comes to this primary level of the Lake's food chain. For further amplification of this and other concerns of Dr. Ross see letter attached (3)

I might point out that Professor Roos formerly lived on the North Shore and has an overall familiarity with the Lake.

In their detailed article on waste heat in "Technology Review" December, 1971, Professor Donald Harleman and Professor Ralph Parsons of M. I. T. Laboratory for Water Resources dealt with this problem with the following statement: "Smaller organisms such as zooplankton pass through the intake - condenser - discharge system. The effect of their passage depend upon both temperature rise and the time of exposure. Water temperature increases which approach the sub-lethal range of impaired biological activity should be avoided. Most states therefor limit both maximum temperatures and allowable temperature rises, from 1½ to $5^{o}F$."

It should be noted here that it is estimated that all inshore water will flow through, on the average, one of those plants three times per year. To the extent that the Palisades and Bailly Station Plants are intending to use cooling towers, the magnitude of this problem may be reduced. It is recognized that the inshore water is biologically the most productive portion of the Lake, and the biota being drawn through these plants is the base upon which all fishes, and to some extent fowl, depend upon for life.

Two: According to Dr. P. F. Gustafson of Argonne National Laboratory in a paper also presented before The Lake Michigan Enforcement Conference, little, if any,environmental changes can be detected about the discharge areas from existing fossil plants operating about the Lake.[(2)] But he goes on to say "but secondary, more subtle, effects at some distance from the point of input may take place." But can it be denied that there is an ideal optimum temperature for the growth of blue-green algae, and such an ideal environment will be created artificially and rather permanently in a boundary area about the mixing zone?

This algae has some species which multiply most profusely at 95°F.[(2)] and other species that prefer temperature in the range of 86° F. This algae is already found in abundance at the Southern end of Lake Michigan. It is very adaptable and will even grow well within the plants' cooling systems where the water is at its highest temperature.

Three: Mr. George E. McVehil on behalf of Commonwealth Edison Company testified before the Illinois Pollution Control Board on November 7, 1970 that if cooling towers were installed at Zion, fog conditions would exist in the Zion area, as the result, various number of days per year, depending upon the type of towers installed.

I concur in this prediction, but I believe he failed to mention that similar fogging conditions may very well occur over the Lake in the area of discharge. That is, a large amount of the heat loss from the area of thermal plume will be due to increased surface evaporation, as a result of increased heat. You will note in Dr. Pritchard's testimony mentioned earlier (1) he specifies that approximately 15% of the heat lost from the Lake is due to evaporation. While he was discussing this figure in a different context, its application to my point is obvious. Also, Dr. Gustafson mentions this problem in a very peripheral way in his report. (2)

Heat is dissipated from water surface by evaporation, radiation and conduction, and the percentage of the total heat dissipation by evaporation increases as the temperature of the water surface increases above its natural state. For a water surface at 5° F. above equilibrium, the heat lost by evaporation is about one-third of total. Naturally, in winter the percent of heat lost by evaporation will be radically higher than this figure.

Should the fogging over the Lake be less intense than above towers, but cover more area, the total effect on the environment of say, Zion, might be more extreme than in the case of towers.

Four: In lakes and ponds (lentic environments) the biota is synchronized in its life cycles by changes in water temperatures. If man in a major way distorts this very finally turned gradual and sequential mechanism of the inshore waters in the spring of the year, the consequence may be far more dramatic than we can even envision. For a detailed description of this possible danger, I refer you to a previous paper I presented before The Lake Michigan Enforcement Conference, September, 1970, with special reference to a paper attached to that report, by J. J. Resia of the Department of Biological Sciences, Northwestern University.(4)

Five: The last point I wish to bring up is what I believe to be an erroneous idea that now, or in the future, will it be possible to isolate, for example, heat alone, as a specific contributor to the death of Lake Michigan.

Synergism: The detrimental effects of heat, chemical fertilizers, chemical pollutants, sewage, bacteria, and solid wastes being discharged into the Lake may very well in combination be far more disastrous to the Lake than the study of any one of the perils alone might suggest.

If damage does occur from the heat, it will be subtle at first and may not make itself manifest for years or even decades into the future. Damage will be accumulative, as Lake Michigan does not have a rapid changeover of water. I also suggest that at no time will it be provable that heat alone is responsible for the damage.

In a statement to me on March 21, 1971 Professor Arthur D. Hasler, of the University of Wisconsin, one of the world's outstanding limnologists, expressed deep concern over the direction we are going with regard to disposing large amounts of heat into the Lake. He stated to me that he would much prefer to see this heat disposed of into the atmosphere at this time.

I would like to conclude by requesting that this Board adapt a standard allowing no thermal discharge into Lake Michigan from new electric generating plants, either under construction now, or planned for the future, since alternative means of distribution of the heat are available.

Arthur Pancoe
Scientific Director

Reference (1) Title: Statement on Temperature Standards for Lake Michigan by Dr. Donald W. Pritchard, September, 1970 before The Lake Michigan Enforcement Conference.

Reference (2) Title: Thermal Discharges and Lake Michigan by Dr. P. F. Gustafson, September, 1970, also before The Lake Michigan Enforcement Conference.

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22 March 1971

Reconvened Third Session of Lake Michigan Enforcement Conference
c/o Mr. Arthur Pancoe
1030 South Wabash Avenue
Chicago, Illinois 60605

Gentlemen:

The proposed use of Lake Michigan on-shore surface water as a coolant for power-generating nuclear reactors poses a potential threat to the lake for at least two reasons: damage to surface plankton and long-term thermal disturbance.

Constant cycling of virtually all on-shore surface waters through the reactors will expose sensitive planktonic organisms, both plant and animal, to a profound thermal shock. Although their duration at elevated temperatures will be short in terms of a human life, even two to five minutes is long in the life of a single-cell organism. The process of cell division, necessary for cell continuity requires only five to thirty minutes, depending on the species. Planktonic organisms have evolved in a relatively stable environment, in which temperature changes are slow or absent. Indeed, many minute plants and animals use small (less than two degree) fluctuations in temperature as signals for developmental change. Brief exposure to elevated temperatures is sufficiently likely to produce change in organism physiology and maturation to warrant a detailed study of the effects of temperature on all of the organisms involved in the specific waters to be affected. I know of no such detailed study on Lake Michigan plankton, but one whould be done before risking major, permanent damage. It should be emphasized that the surface algae are the sole base of the food chain on which all lake animal life depends: a reduction in available fixed carbon (i. e. starch and cellulose) will propagate proportionally through the entire ecological pyramid.

Thermal pollution itself poses a special problem for the Lake Michigan basin. The V-shaped profile of the lake favors a high thermocline, with a shallow layer of warm water overlying a deep mass of cold water: mixing between these two water masses is slow. Complete turnover requires 10,000 years in Lake Michigan. Calculations of heat dissipation must take into account only this limited mass of available diluent water, and not the entire water volume. It is even possible that adding to the heat of the surface layer will slow doen water turnover, intensify thermal stratification, and spedd the process of deoxygenation of the lake bottom.

I hope that this letter expresses the basis of my concern as a biologist for the planned use of Lake Michigan. The potential damage is great and irreversible. I doubt that adequate information is available to prove that the changes will be benign: such changes ought not be made until their safety is ascertained.

Sincerely yours,

Thomas B. Roos

Thomas B. Roos, Associate Professor

Ref. 5

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"One thing which definitely is not needed in the current debates over effects of waste heat from nuclear power plants on Lake Michigan is another biologist who takes the position of an advocate. I therefore must preface my following remarks with a brief bit of philosophy.

With few significant exceptions, predictions of resultant harm to the Lake's biota are honestly debatable. When specialists in pertinent fields disagree, the issues become quite clouded and confusing to the public. The clouds part a bit, though, if the layman keeps two things in mind.

First, the empirical, inductive method to which modern science is wedded never "proves" or disproves" anything. No matter how dogmatically some scientific "truths" often are taught, it must be remembered that at the philosophical foundation of scientific method is a rule which says that the most an investigator can hope to accomplish by his experimental results and interpretations is to cause one hypothesis or another to seem more or less likely to be true. Hence, competent scientists, honestly attempting to be objective, can and often do disagree.

This brings us to the second point. The current environmental quality crusades in general and the nuclear power plant controversies in particular have seen too many scientists showing too little regard for objectivity. Abuses of this nature seem to come from both sides of almost every confrontation. It can be maddening for a scientist to try to refute a less idealistic oponent's "absolute certainties" with wishy-washy "it appears thats" and "the data suggest thats." Nevertheless, scientists and engineers who myopically pander either to their employers' vested interests on the one hand or to crowd response on the other do service to no one and, I fear, are going to learn that in the long run, their credibility and that of their profession is as fragile as it is valuable.

Granted the above, I would like to describe a problem which I feel has not yet been given any real attention by those about to decid what can and can not be done with waste heat in Lake Michigan.

In the temperate latitudes in which we live, organisms are forced to adjust their life cycles to the rigors of changing seasons. Mother Nature has been very fussy about compliance, and those species which failed to synchronize became evolutionary drop-outs. One well-known environmental cue that is widely used by plants and animals as a season-indicator is photoperiod, the changing length of the day. Thus, many birds, for example, are "told" when their gonads should ripen, when they should mate, and when t[illegible] should fatten up and migrate by the lengthening or shortening daylight hours.

For terrestrial organisms, as well as for those which are found in rivers and streams (lotic environments), photoperiod

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is a cue far more trustworthy than temperature. For the biota of lakes and ponds (lentic environments), however, seasonal temperature changes usually are pretty consistent (especially in large lakes), and it is well-known that for many lentic species (notably, fishes), water temperature plays the principal role in seasonal synchronization.

Since the effects of thermal discharges, present and proposed, on the overall temperatures of Lake Michigan can be considered insignificant (which, possibly, is why Commonwealth Edison spokesmen have mentioned them so often), and since the plumes of heated water will be small in relation to total Lake area, it is not immediately evident that a significant proportion of any population in the Lake could be affected adversely.

There is more to the story, however. In the first place, the littoral (nearshore) areas of any large body of water are by far the most biologically important. In these littoral areas, Nature provides light and nutrients in relative abundance, and productivity is high. Since populations always produce more offspring than the environment can support, and since the principal limiting factor in the survival of offspring of most aquatic animals is food availability, natural selection has "taught" the great majority of species to reproduce in littoral waters. Thus, these nearshore areas, into which the nuclear plant effluents are to be directed, see a lot more biological traffic than comparable offshore areas. Included in this relatively congested situation are those fishes which are spawning, those which have been spawned, and those predators desirous of eating spawner or spawnee.

We understand, then, that biomass is relatively large in the general vicinity of the proposed heated effluents, but the story goes further. Most animals have preferred temperatures. This means that their activity is less at one temperature than at any other. In fishes, for example, an individual's preferred temperature depends on such factors as species, previous thermal history, age, physiological state, time of day and year, and many other things known and unknown, but it may be generalized that if a group of similar fish are placed in a thermal gradient, they will tend to congregate at their preferred temperature in a sore of "gapers' block" effect.

I have heard the advocates of "thermal enrichment" speak enthusiastically of fishing "hot spots" produced by power plant discharges. Such phenomena are produced when ambient water temperatures are below the preferred temperature of fish in the general vicinity of a heated plume. When the fish congregate at their preferred temperature in the gradient caused by the plume, a fisherman's bonanza results.

But there may be a catch to this. I have already discussed why fishes tend to be in the general vicinity of the thermal plumes, and how they can tend to move to positions in the plumes where temperatures are above ambient. Such situations already exist on small scale in Lake Michigan. But if to these considerations we add the proposals for a growing number of large discharges from nuclear plants, we must conclude that greater percentages of the Lake's fish populations would be spending greater amounts of time at temperatures above ambient.

Besides having other, more well-known, physiological effects, water temperature (as mentioned previously) is the principal seasonal timer for many species of fish. In effect, pr[illegible]ssive changes in the ambient temperature of the Lake "tell" a fish when to begin and complete gonadal development, when to feed, when to migrate, and when to spawn. Thus, each species of fish is influenced to perform some or all of these activities at a time of the year most advantageous for survival of the population. It must be noted that the physical characteristics of the season are not the only reasons why timing is important. Spawning, for example, must be performed simultaneously by the greatest possible proportion of the population, for maximum efficiency, and the larvae must latch in synchrony with the often ephemeral availability of important food species (which also are influenced by temperature).

Add to all of these considerations the complex, seasonally-variable food-web interactions in the Lake, and one begins to understand the validity of questions raised about fishes spending time in the proposed "hot spots" rather than in waters of ambient temperatures. The temperature a fish "likes" bears no necessary resemblance to the temperature that is good for survival of its population.

I have heard attempts by some to defend calefaction on the grounds that elevated temperatures have no adverse effects on certain aquatic animals from arctic or tropical latitudes. I have also heard it mentioned that in certain fish culture practices, people spend money to heat ponds to increase yield. In answer to the latter, it should be noted that such people also have to feed the fish in those cultures. Cultures are not ecosystems. And in answer to both, we need only keep in mind that we are concerned with temperate latitude fishes trying to stay alive and obtain food in a temperate latitude lake.

Finally, I wish that discussions of ecological effects of waste heat could rise above naive considerations of what is lethal to adult fishes. There's more than one way to skin a population, and knocking out reproduction sounds to me as though it might be fairly effective."

J. J. Resia
Department of Biological Sciences
Northwestern University

P. Gustafson

MR. CURRIE: Dr. Gustafson.

STATEMENT OF DR. PHILIP F. GUSTAFSON,
ASSOCIATE DIRECTOR, DIVISION OF RADIOLOGICAL
AND ENVIRONMENTAL RESEARCH,
ARGONNE NATIONAL LABORATORY,
ARGONNE, ILLINOIS

DR. GUSTAFSON: Mr. Chairman, conferees, and remaining participants. I am Philip F. Gustafson, Argonne National Laboratory, Associate Director of the Division of Radiological and Environmental Research at the Laboratory, and coordinator of our Great Lakes Research Program.

As I think most everything that I have to say has been said already, but what I am going to say is fairly brief anyway, and having stuck it out this long, I am going to go ahead. (Laughter)

As you all know, in its past several sessions, the Lake Michigan Enforcement Conference has dealt with the problem of setting thermal effluent standards which will maintain the ecology of Lake Michigan in its present or, hopefully, even in an improved state, and yet allow the lake to be used for a multiplicity of purposes which are of benefit to mankind.

P. Gustafson

The principal obstacle to reaching agreement on thermal standards has been the question of what biological effects will occur as a result of large electrical generating stations, particularly nuclear stations, using once-through cooling on the lake. There is some feeling that until this question can be answered completely, no further discharges should be permitted. Paradoxically, the answer can only be obtained by field studies in the lake, not by laboratory studies or computer simulations.

For the past 3 years, Argonne National Laboratory has been conducting physical and biological research on thermal discharges into Lake Michigan under its Great Lakes Research Program. These thermal studies have centered about some of the large fossil-fueled stations, and have included the three nuclear plants now in operation on the lake. We have also examined the results of other researchers on Lake Michigan and the other Great Lakes as part of our total program. The conclusion that we have come to, on the basis of our own work and that of others, is that there is no evidence of unacceptable ecological effects due to present thermal discharges, even on a local scale.

This does not mean that there are not biological responses directly attributable to the warm water — attraction of fish to the thermal plume, for example. It

P. Gustafson

does not mean that fish acclimated to the higher than ambient temperatures in the thermal plume may not be injured or killed by a sudden shutdown of the plant, particularly in cold weather. It also does not mean that a substantial amount of entrained biota passing through the cooling system will not be damaged or killed; however, increased productivity due to increased temperature partially replaces this loss.

What our conclusion does mean is that the total impact of these various factors will not produce changes which are irreversible or irreparable in the physical and biological state of those portions of Lake Michigan now subject to thermal discharges. Since the local impact is tolerable, the lakewide or system impact is also acceptable. Furthermore, on the basis of present knowledge we believe that the operation of powerplants now under construction on the shores of Lake Michigan will also have an acceptable impact on the local or system ecology if operated with once-through cooling.

I think that there is, by and large, general agreement on the part of the participants in the Enforcement Conference that the real concern is not the present thermal additions to Lake Michigan, or even the incremental addition of the generating facilities now under construction; rather it is the prospect of addition upon addition which the

P. Gustafson

future may bring with our present rate of regional growth and power needs. In order to answer this concern before it becomes a reality, we must determine the present state of the lake in general and understandable terms, determine the long-term, long-range effect of present and soon-to-operate thermal discharges, and to then determine at what point the long-range effects have an unacceptable influence on the entire lake or a significant portion thereof.

Considerable research is under way on Lake Michigan to provide data which can answer these questions. Some of it is supported by Federal agencies such as AEC and EPA, some by State agencies, and an increasing amount by utility companies.

Certainly the greatest return on the money being spent on research will be attained if these efforts are coordinated-- coordinated in the sense that standardized techniques in sampling and data acquisition are employed, and standard analytical methods used so that results from one group to another or one site to another will be compatible.

Such coordination could be done through an Environmental Assessment Committee -- call it what you will -- such as was proposed by the Technical Committee at a previous session of the Enforcement Conference. I would like

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to propose that the Enforcement Conference consider sponsoring such a committee. The logical members of such a group are already active participants in the conference. The committee should include representatives from involved Federal and State agencies, the academic community, industry -- particularly the electric utilities -- environmental groups, and I would hope that Argonne might also be a participant.

In addition to the coordinating role, the committee could review and interpret results, suggest new avenues of investigation, and even engage in the development and testing of a systems model of the entire lake. Perhaps a starting point for the latter would be the preparation of a Regional Environmental Impact Statement, which would be essentially the type of impact statements that are being prepared under the National Environmental Policy Act for nuclear powerplants. Such a NEPA-type statement for the entire lake would involve the combined effects of man's activities upon the lake. This would be a most useful document with which to assess future courses of action not only in thermal but in terms of chemical pollutants as well. Working cooperatively, I think we can accomplish much more than we can ever hope to do independently.

Lake Michigan is a valuable multiple use resource which with wise management can provide perhaps even more benefit to future generations. If we use our talents properly, we can develop and conduct a regional study which will serve as a demonstration to other areas of our Nation.

MR. BRYSON: I have to ask one question.

DR. GUSTAFSON: Yes.

MR. BRYSON: Some time ago, didn't Argonne undertake to form such a group in cooperation with the various studies going on around the lake involving the various utility companies? Whatever happened to that effort?

DR. GUSTAFSON: Well, we still work cooperatively with a number of utilities and with EPA and with the university people. But it is -- well, I would say this: that cooperation, coordination -- particularly coordination -- is a fulltime job. And I find that more and more as our own work goes on we tend to lose track on a day-to-day basis, which is really, I think, very essential -- we lose this as we get further into our own work. And what we sort of need is an overseeing body that will do the coordinating more tightly than we can.

MR. BRYSON: Good point.

DR. GUSTAFSON: But I think we have -- and I am very pleased to see the use made of -- data which Argonne has acquired, and the degree to which we have, I think, in a relatively short time, become reasonably proficient in some of these things. I would hope that we could continue to do this and we have tried to -- with our still fairly limited resources, when we know that somebody is going to do an experiment somewhere -- throw our resources in, too, with the feeling, and I think the correct feeling, that we get a lot more out of it the more parameters, the more people that are looking at something.

But I would hope that this could grow and perhaps this conference is a means of promoting such growth. I know we all have this feeling that: what is the future going to bring? And how are we going to assess -- well, I have used the term -- "acceptable" damage or "unacceptable" damage, because I have gotten so tired of trying to defend what is "significant" and what is "insignificant."

So this is sort of pushing it on a stage further, I realize, but that is something we have got to determine. Is it a powerplant or is it one fish or what is it? And I think that this is -- as has been said before -- partly a social problem; it's partly a technical problem. And it is something that I think can be ironed out, but we have got to do it some way. It is sort of late for philosophy, I guess. (Laughter)

MR. FRANGOS: Dr. Gustafson.

DR. GUSTAFSON: Yes.

MR. FRANGOS: It is late for a couple of questions. But is it correct that it was your group that prepared the report that appeared in the EPA document that was distributed prior to the convening of this session?

DR. GUSTAFSON: Yes, it was some of the people from Argonne, right.

MR. FRANGOS: Were you associated with that, or was it done under your direction?

DR. GUSTAFSON: It was actually done under Bart Hogan's direction, and I looked over the document as it was being prepared but did not have a truly active role in its preparation.

MR. FRANGOS: Is this statement that you are making here this evening in any way an official position of the Argonne National Laboratory?

DR. GUSTAFSON: Essentially it is the position of the people at the Laboratory engaged in Great Lakes research.

MR. FRANGOS: Thank you.

MR. MAYO: Is that the conclusion of the Illinois presentation, Mr. Currie?

MR. CURRIE: Yes.

MR. MAYO: Mr. Frangos.

MR. FRANGOS: Thank you, Mr. Chairman, conferees, and holdouts. (Laughter)

Unaccustomed as I am to making presentations at 11:15 p.m. in the evening, I do want to make a standing request, Mr. Mayo, for the record, that in any future conferences, symposia, meetings, colloquia, or hearings that may be conducted or sponsored by your Agency, that the order of appearance of States be determined by lottery conveyance. (Laughter and applause)

Having said that, I will defer attempting to summarize the State of Wisconsin's statement but rather proceed with those who have indicated that they wish to make a statement, and then I will get back to the Wisconsin statement.

With that, I would like to call upon a representative of the Wisconsin Public Service Corporation.

STATEMENT OF EVANS W. JAMES, SENIOR VICE PRESIDENT,
WISCONSIN PUBLIC SERVICE CORPORATION,
GREEN BAY, WISCONSIN
(AS READ BY CHARLES J. MARNELL)

MR. MARNELL: Mr. Chairman, conferees, and those who have endured. My name is Charles Marnell. I am employed by Pioneer Service and Engineering, and I am here to represent

E. James

Mr. Evans James of Wisconsin Public Service. I am here to read the statement prepared by Mr. Evans James.

Wisconsin Public Service Corporation is a Wisconsin public utility engaged in the production, transmission and distribution of electricity and the purchase and distribution of natural gas. Its service area is located in northeastern Wisconsin and Menominee County, Michigan. Its principal office is located in Green Bay, Wisconsin.

This utility has an interest in three electric generating plants which are affected by rules governing thermal discharges into Lake Michigan. It wholly owns and operates the Pulliam fossil-fired steam plant at Green Bay located at the confluence of the Fox River and Green Bay. It has a minority interest with Wisconsin Power & Light Company in the Edgewater fossil-fired steam plant at Sheboygan on the shores of Lake Michigan. The Edgewater plant is operated by Wisconsin Power & Light Company. This utility together with Wisconsin Power & Light Company and Madison Gas & Electric Company shares ownership in the Kewaunee nuclear generating plant now under construction on the west shore of Lake Michigan. It is in charge of the construction of the Kewaunee plant and will operate it when it is expected to go on line in the fall of 1973.

This brief statement will be directed to the

Pulliam and Kewaunee plants only since these are or will be operated by this company.

As this conference knows, the Wisconsin Department of Natural Resources on December 8, 1971, established thermal standards for Lake Michigan, such standards to become effective on February 1, 1972. Subsequently, on March 29, 1972, the Department issued guidelines for environmental studies to be undertaken at Lake Michigan thermal discharge sites. These standards and guidelines affect both the Pulliam and Kewaunee plants.

It should first be noted that with respect to Kewaunee, Wisconsin Public Service Corporation had undertaken comprehensive studies of the environment surrounding the Kewaunee site well in advance of the establishment of standards by the Wisconsin Department of Natural Resources. As a matter of fact, these comprehensive studies have been under way the past 3 years and have encompassed extensive examination of air, water, and food sources.

Following the issuance of the standards and the guidelines, this utility has prepared and presented to the Wisconsin Department of Natural Resources study plans for both Pulliam and Kewaunee and these plans have been approved subject to continuing review by the Department. While the Kewaunee studies were begun in advance of the creation of the Department's guidelines, the future program at Kewaunee will be modified to the degree necessary to meet the guidelines. The studies at Pulliam are beginning this fall based on the approved study program.

Since the Wisconsin Department of Natural Resources has laid down specific measures for studying the effect of thermal discharges into Lake Michigan, and since this utility has invested and will continue to invest substantial sums of money in the required studies, it now urgently requests this conference to hold in abeyance any rules which would interfere with the operation of any plant now operating or under construction on Lake Michigan until the data being accumulated has been secured and studied. Only in that way can judgment based on fact rather than theory reasonably be made. To follow any other procedure would be grossly wasteful of time and money and would interfere with a well conceived and efficiently managed program which will produce a sound basis for establishing any environmental controls which may be found necessary.

I will briefly describe the programs under way at Kewaunee and Pulliam for your information.

At Kewaunee, a preoperational radiological monitoring program was begun in September 1969 by Industrial Bio-Test Laboratories, Inc. of Northbrook, Illinois for the

E. James

primary purpose of establishing baseline data for airborne radioisotopes which naturally occur from atomic testing. A meteorological program was started in August 1968 under the management of NUS of Washington, D.C. for the purpose of securing 2 years of meteorological data to satisfy the Atomic Energy Commission's licensing requirements. The company continued to gather meteorological data following the expiration of the 2-year period until in June 1972, a meteorological program was developed with Bio-Test for it to assess the best available data concerning radioactive airborne releases. A series of studies was begun in 1969 by the University of Michigan and its environmental research group to assess the normal background of radioisotopes which occur throughout Lake Michigan in plant (phytoplankton) and animal (zooplankton and fish) sediments. This study is continuing to determine the food change relationship between fish and man. Another program was begun in 1971 known as the Helgeson Nuclear Lake Bottom Study, which consisted of mapping the lake bottom at the Kewaunee site for natural occurring radionuclides in order to get appropriate baseline data. This mapping study was carried out twice in 1971. In addition to the above, Bio-Test and University of Wisconsin-Milwaukee are each performing studies to determine Kewaunee's interaction with Lake Michigan. I have available an outline of these studies which identifies the nature and frequency of them and will be glad to produce them for the conference's information if desired. I will place them in the record as A and B.

MR. MAYO: Fine.

MR. MARNELL: Thank you.

(The documents above referred to follow in their entirety.)

Environmental Studies at Kewaunee

Bio-Test Studies

	1971 Studies	1972 Studies
Frequency	Three (3) Trips One Each Vegetative Season	Four (4) Trips (2 Separate Samplings Each Trip) Twice Each Season
Profiles of the Water Column	Sixteen (16) Locations 5 at 2 meter depth: Total Alkalinity, DO & PH at Mid Depth 5 at 4 meter depth: Same at Top and Bottom 5 at 8 meter depth: Same at Top, Middle, and Bottom 1 at 16 meter depth: Same at Top, Middle & Bottom	Seventeen (17) Locations 5 at 10 feet depth - Temperature and DO 5 at 20 foot depth will be measured at the 5 at 30 foot depth surface and at each meter 1 at Discharge of depth 1 at 40 foot depth
Currents	Drogue measurements using radar and transits once each trip: three total	Two continuous recording current meters will be placed at the site; one in the intake, discharge area and one at a random spot. Drogue measurements as needed.
Water Quality[1]	Triplicate samples at 3 locations (9 total samples) BOD, COD, TOC, Total Oxygen, Specific Conductance, Silica, Total Alkalinity, pH, Dissolved Oxygen, Chloride, Total Phosphorus or Tho-phosphate, Nitrate Nitrogen, Ca, Mg, Fe, Cr.	Duplicate samples at 7 locations (24 total samples) Total organic nitrogen, ammonia, nitrate, nitrite, total phosphorus, soluble orthophosphate, TOC, Fl, Sulfate, Color Cl, TDS, pH, Alkalinity, Total Hardness, Si, Turbidity, Specific Conductance, COD, total Iron, Total Chromium, Cu, Ni, Zn, Cd, As, Boron, Pb, Mn, Hg, Na, K, DO & BOD.
Bacteriology	Triplicate samples at 3 locations (9 total samples) Total plate counts, fecal streptococci and fecal coliform	Duplicate samples at 7 locations (24 total samples) Total plate counts fecal streptococci and fecal coliform
Phytoplankton	Triplicate samples at 3 locations (9 total samples) Kemmerer sampler & analyze to species with percent abundance	Duplicate samples at 7 locations (14 total samples) Kremmeler sampler and analyze to species with percent abundance.
Zooplankton	Six vertical tows at 2 locations Percent abundance & evaluate to species	Duplicate vertical tows at five (5) locations (14 total samples) Percent abundance and evaluate to species
Periphyton	Triplicate samples from naturally occurring substrates Color, composition, abundance, and species identification	Duplicate samples from naturally occurring substrates (6 total sampl- Color, composition, abundance and species identification (Once per quarter)
Benthos	Triplicate samples at three (3) locations (9 total samples) Abundance and Species ide ification	Duplicate samples at 7 locations (14 total samples) Abundance and species identification. (Once per quarter)

Bio-Test Studies (Continued)

	1971 Studies	1972 Studies
Fish	7 periods, 2 locations Identified to species, weighed, measured	Twice each season, 6 locations (8 total trips) Species ID, weighed, measured, age and growth determined, epibenthic pump to determine larval fish and fish eggs (24 gill nets, 24 seins)

UW-Milwaukee Study

	1971 Studies	1972 Studies
Temperature	Continuous recording at 4 locations (9 month)	
Radioactivity	Gross Beta counting on sediment and algae 5 algae sites 3 slide racks 8 sediment sites Samples collected 6 - 8 times during the season	
Sediments	Determine size distribution at 8 sites Samples collected 6 - 8 times during the year	
Phytoplankton	Species identification made at 7 sites Percent abundance of each species Samples collected 6 - 8 times during the year	
Zooplankton	Samples taken at 4 sites at 2 - 4 week intervals during Spring, Summer and Fall. Identified to Genus and Percent abundance of each genus was determined.	
Currents (1970)	Nearshore currents determined using Drogues during the sampling season.	
Passage of Organisms through the Condenser		Attempt to establish mortality rates for phytoplankton and zooplankton as they pass through an unheated condenser (mechanical effects on organisms)

FMM:jan
5/19/72

TABLE I

FREQUENCY OF FIELD SAMPLING BY CATEGORY

	Category	Sampling Period - 1972			
		May	July	Sept.	Nov.
1.	Water Column Profile	XX[1/]	XX	XX	XX
2.	Lake Currents[2/]	X	X	X	X
3.	Water Quality	XX	XX	XX	XX
4.	Bacteriology	XX	XX	XX	XX
5.	Phytoplankton	XX	XX	XX	XX
6.	Zooplankton	XX	XX	XX	XX
7.	Periphyton	X	X	X	X
8.	Benthos	X	X	X	X
9.	Fish	XX	XX	XX	XX

1/ XX = Two independent samplings during the quarter.
2/ Certain aspects will be monitored on a continuous basis.

E. James

MR. MARNELL: These University of Wisconsin-Milwaukee studies began in 1969 and the Bio-Test studies began in 1971.

At the Pulliam plant, the environmental quality water studies will follow closely the Department of Natural Resources' guidelines. Temperature measurements and infrared photos of the thermal plume will be taken in order to evaluate the plume dimensions. Fish will be collected to determine the numbers, species, length, weight, and age. The benthic organisms, phytoplankton and zooplankton samples will be collected in replicate from permanent sample locations. Continuous monitoring of the intake and discharge water temperatures will be undertaken as well as continuous monitoring of the discharge for pH and dissolved oxygen. Dissolved oxygen and Biochemical Oxygen Demand (BOD) profile will be determined in conjunction with the temperature profile study. The intake and discharge will be analyzed to determine their various chemical constituents including copper, calcium, zinc, specific conductance, sodium, potassium, fluoride, sulfate, silicon, color turbidity, ammonia, total phosphorus, soluble phosphorus, chlorides, magnesium, pH, hardness, alkalinity, mercury, boron, arsenic, iron, chromium, nickel, lead, and manganese. The residual chlorine in the discharge water will be determined by using the amperometric procedure. A permanent record will be kept of a summarization of the total amounts, frequency, and volume of chemicals discharged to the water.

I believe this description of our programs emphasizes the depth and great extent of the environmental studies being undertaken. I again urge that the value of these studies not be destroyed by any change in procedures. The standards and guidelines issued by the Wisconsin Department of Natural Resources should be pursued and their results used in making a final determination.

That concludes the statement.

MR. MAYO: Any questions, gentlemen?

MR. MARNELL: Mr. Chairman, I have to defer from any questions as I am not prepared to answer them for Mr. Evans James.

MR. MAYO: Thank you.

MR. MARNELL: But I would refer any questions that you have to him.

MR. MAYO: Thank you for the statement.

MR. FRANGOS: Miss Sarah Jenkins of the Sierra Club.

S. Jenkins

STATEMENT OF SARAH JENKINS, MEMBER, EXECUTIVE COMMITTEE, JOHN MUIR CHAPTER, SIERRA CLUB, MADISON, WISCONSIN

MISS JENKINS: Mr. Chairman, conferees, and holdouts.

My name is Sarah Jenkins, and I am from Madison, Wisconsin. I am speaking for the Sierra Club national organization.

My background is that I have got a Bachelor's Degree in Physics and a Master's in Biophysics, and I have been studying energy for work on a second Master's since June of 1970. I have been on the John Muir Chapter Executive Board since January of this year.

Sierra Club is interested in problems involving nuclear powerplants on Lake Michigan because along with Businessmen for the Public Interest we have intervened on several of the plants. We have actually intervened on Palisades and on Point Beach 1, and along with Businessmen for the Public Interest we have filed to intervene on Point Beach 1, Zion 1 and 2, Donald C. Cook 1 and 2.

Sierra Club is concerned about the effect of powerplants on Lake Michigan because we feel that the evidence

S. Jenkins

from the studies being conducted on the lake is not in yet, and we don't believe that the data gathered from laboratory studies is particularly promising. It does show that there are biological effects. We do not like using the lake as a laboratory. We are unwilling to gamble with the integrity of the Lake Michigan ecosystem.

We feel that the decisions that this conference is going to make will create an important precedent and we are worried about the type of decision that will be made here.

It is extremely easy -- as Mr. McDonald was pointing out earlier today -- to say that you can go on line now, and when we see signs of damage you will have to come off line. But the problem comes: What are the signs of damage when you decide that you are going to have to put in closed-cycle cooling?

It is particularly difficult if the plant has been operating for, say, half its expected lifetime to insist that somebody spend a great deal of money to put in closed-cycle cooling because it is difficult to amortize the cost.

We are worried, as Dr. Gustafson commented, about the problem of the projected growth of powerplant use of Lake Michigan for cooling water. The base that is being doubled is getting increasingly large -- the base of electric power

S. Jenkins

generation -- and so the effects are becoming more and more serious.

We have some disagreement with the projections for growth in demand, based on data presented at a Sierra Club conference in Vermont last January -- data indicating that we may not need as much power in the future for installing mass transit and sewage treatment as some people very glibly said we might.

We believe that whatever standards are set should apply to all large powerplants, should apply to all powerplants built since January 1, 1971; that these standards should require high quality monitoring; that if closed-cycle cooling systems are to be required that the micro-meteorology surrounding where the cooling towers are being put up must be accurately surveyed. At this point, the exact effects of such cooling towers of the size projected is not known and until the studies are made it will be difficult to evaluate the actual environmental trade-offs between cooling towers and once-through cooling.

We also feel that this issue is part of broader questions that are really societal questions and not bio-technical decisions.

Three questions are basically:

1. How much power does our society and this Lake

S. Jenkins

Michigan region really need?

2. When do the environmental and societal costs of continued growth of energy use exceed the benefits?

3. Who is and who should be deciding these questions?

Members of the Sierra Club believe that these matters should be the subject of inform public debate and that the informed debate should be informed because the facts have been made public.

Thank you.

MR. MAYO: Thank you, Miss Jenkins.

MR. McDONALD: I think your point about backfitting on a plant that has been used half its life is a very good point. We run into this, and I am sure we are going to run into it more as we go after the industrial plants -- the steel mills, the oil companies -- they are all old. Hardly a plant that has been in business doesn't age very rapidly as far as treatment systems are concerned.

(The documents submitted by Ms. Jenkins following the conference follow in their entirety.)

by Ansel Adams in *This Is the American Earth*

SIERRA CLUB Mills Tower, San Francisco 94104

Midwest Office
444 West Main Street
Madison, WI 53703
(608) 257-4994

Sept. 26, 1972

Mr. Francis T. Mayo
Regional Administrator
Region V
Environmental Protection Agency
One North Wacker Drive
Chicago, IL 60606

Dear Mr. Mayo:

The enclosed is a written version of my comments last Thursday night at the Lake Michigan Enforcement Conference. It may clarify some of the points I made then.

Could these written comments be included in the written record of the conference?

Thank you for your attention.

Sincerely,

Sarah Jenkins

Sarah Jenkins
Member, Executive Committe
John Muir Chapter of the
Sierra Club

SJ:mh

by Ansel Adams in *This Is the American Earth*

SIERRA CLUB Mills Tower, San Francisco 94104

SIERRA CLUB STATEMENT

MADE TO

THE LAKE MICHIGAN ENFORCEMENT CONFERENCE
September 21, 1972

Statement made by Sarah Jenkins

Mr. Chairman, Conferees, and Holdouts.

My qualifications are a bachelor's degree in physics, a master's in biophysics, and I have been studying energy problems for the past two years in connection with writing a second master's thesis. I have been on the John Muir Chapter(Sierra Club) executive board since January 1972.

Sierra Club has been involved in the problems associated with siting electric power plants on Lake Michigan since the first intervention at Palisades. Sierra Club has been one of the intervenors in the Palisades and Point Beach II cases, and along with Businessmen for the Public Interest has filed for intervention in Point Beach I, Zion I and II, and Donald C. Cook I and II.

The Sierra Club is concerned about the effects of discharge of vast quantities of heated water into Lake Michigan. We are aware that the results of field studies of the lake are not in yet, but the evidence from laboratory studies of the effects of heat upon organisms is not very promising. It could be a long time before we notice the effects of the discharge of the heated water. Whenever there are long time delays between cause and effect, it is possible for the effects to be serious before their existence is noticed.

We do not want Lake Michigan to be treated as a laboratory. We are unwilling to gamble with the integrity of the Lake Michigan ecosystem.

We would prefer that in this case, any errors in standards be made on the side of caution.

Whatever decision is reached by the conferees will set an important precedent affecting the future uses of Lake Michigan. Because of this, we would be very worried about a decision that says that heat may be discharged into the lake until such time as signs of damage appear, at which time devices to control the discharge of heat must be backfitted. I would like to emphasize a point made earlier by Mr. McDonald it is too easy to question what constitutes evidence of damage. Will it be the first tentative signs of ecosystem change or a major change? Further, it is always possible to say that whatever changes are being seen are really due to another cause such as fertilizers being applied to crop land and washed into the lake.

The other problem with a decision requiring backfitting arises if a plant has been operating for 10-20 years and will only be in operation for a further 10 years. Then it can be argued that the cost of backfitting will be too great when amortized over the remaining life of the plant. The argument becomes - we will install control equipment in new plants but it is too costly to backfit existing plants.

Case-by-case decisions then become completely arbitrary, not based on scientific evidence. It is arbitrary to say that equipment must be built into new plants but does not have to be backfitted to existing plants.

We are concerned about this decision as a precedent because of the enormous rate of growth of the electric power industry. As the base amount of energy which is doubled by exponential growth increases, the consequences of short doubling times become more serious. We do not entirely agree with projections of demand for electricity into the future. At the Vermont Power Conference (sponsored by Sierra Club in Johnson, Vermont, January 14-15, 1972) a paper was presented which questions two of the reasons given for needing vast amounts of more power in the future - mass transit and sewage treatment. In both cases, the increased demand was two per cent once in 30 years compared with the present growth rate of seven per cent per year (which equals 800 per cent in 30 years). Residential and commercial demand for electricity will be very sensitive to changes in codes for lighting and insulation, and to the extent of further growth of electrical heating.

Whatever standards are set by this conference should include the following points: they should apply to all large power plants, and to all plants built since January 1, 1971. Further the standards should require high quality monitoring of the ecosystem adjacent to the power plant. If closed cycle cooling systems are required then the micrometeorological effects of such systems must be studied. Prediction and evaluation of the trade-offs between the effects of once-through cooling and closed cycle cooling will not be possible without better data on their actual effects.

The Sierra Club believes that the issue of discharge of heat to Lake Michigan is part of three broader questions:

1. How much power does our society and this Lake Michigan region really need?

2. When do the environmental and societal costs of continued growth of energy use exceed the benefits?

3. Who is and who should decide these questions? We in the Sierra Club believe that these matters should be the subject of informed public debate. Informed debate because the facts have been made public.

Thank you.

S. Burstein

MR. FRANGOS: Mr. Sol Burstein.

STATEMENT OF SOL BURSTEIN, SENIOR VICE PRESIDENT,
WISCONSIN ELECTRIC POWER COMPANY,
MILWAUKEE, WISCONSIN

MR. BURSTEIN: Mr. Chairman, conferees, ladies and gentlemen.

I would like to add a good bit of weight to this conference. I am sorry that this is not the forum, I believe, nor the hour, to refute some of the things that have been said concerning the Point Beach nuclear plant, the AEC licensing proceedings, and certain matters that go with that.

But if Mr. Mayo will permit me, I would like to introduce as an exhibit the eleven volumes of the transcript of the record of that proceeding which speaks for itself.

MR. MAYO: Fine.

MR. BURSTEIN: I would also like to introduce for your record as an exhibit the Environmental Impact Statements that were alluded to before and in which people like Dr. Coutant were quoted completely out of context. The conclusions of those Impact Statements, I think, are important in the analyses of the thermal effects of powerplants

S. Burstein

on Lake Michigan.

MR. MAYO: Do you have that material with you?

MR. BURSTEIN: Yes, sir.

MR. MAYO: Fine.

MR. BURSTEIN: Forgive me, Mr. Chairman.

Let me suggest that it is a very complete and competent record that was made of Point Beach. It deals with many of the questions concerning diving plumes, concerns with condenser transport. It is concerned with almost every other question that was raised here, in a public hearing in which sworn testimony was given, in which there were adversary opportunities for cross examination of witnesses, and I think as such deserves an opportunity for those who haven't to review a very important history. As my text indicates, this AEC proceeding was the first full power, full NEPA hearing on environmental issues in an operating license case, to my knowledge.

(The documents above referred to are on file at U.S. EPA Headquarters, Washington, D.C. and Region V Office, Chicago, Illinois.)

MR. BURSTEIN: I will attempt to paraphrase some of my remarks in order to conserve what litle time we may have left. But let me say first that Point Beach Unit 1 has been operating rather successfully for almost 23 months,

S. Burstein

during which time we have had an opportunity to actually monitor one of the more recent and significant nuclear plants on the lake. Unit 2, as you have heard, has had its hearing concluded, but the decision is still awaited, and is operating at 20 percent power license after many appeals and court reviews which, as you heard, are still being reviewed.

As I mentioned before to this conference, we had time between a period when it was agreed essentially that no damage to Lake Michigan exists and when it was feared by some that future additional sources of heat input might cause irreversible adverse effects. I am pleased that the Enforcement Division of this Region of EPA undertook to have Argonne provide the summary embodied under Contract Report 72-1. My copy of this valuable and exhaustive review is covered in black, which I assume is to mourn the passing of the "white paper." I believe an examination of this new Argonne report will indicate that even in the short interval between the 1971 conference and today, substantial scientific effort has been and is being expended to develop a responsible, objective body of technical knowledge concerning thermal discharges. Not all the data are in, of course, but to my knowledge none represents any confirmation of the fears expressed earlier concerning adverse effects of these thermal effects.

S. Burstein

As you know, my own State of Wisconsin passed new water quality criteria last December which were made effective in February, and following the details of rules at the end of March concerning substantial monitoring effects, all of the utilities with plants on Lake Michign undertook their implementation, including my own companies.

In the next 18 months, we will be spending in excess of $1.2 million for these studies at four of our plants, including Point Beach. I believe this work to be one of the most detailed and comprehensive programs for the monitoring of thermal discharges and the analysis of their effects. They are designed to be of the highest professional quality, and we are confident that these new studies will confirm what we have been talking about before, and I would be happy to share them with the Environmental Protection Agency and all of the conferees.

Additionally, of course, we are continuing on with the numerous other programs that we have enumerated to you before, some of which I have mentioned in detail in the text of my comments.

In my remarks to the workshop sessions of September-October of 1970, I stated that I believed no new Federal thermal standards were required for Lake Michigan, but that the adequacy of State criteria could be confirmed by actual

S. Burstein

observations at the operating steam electric generating plants. I stated that any effects of thermal discharges on sensitive localized areas could be accommodated on a case-by-case analysis. It is, of course, heartening to read carefully Mr. John Quarles' May 12, 1972, policy statement on thermal discharges and the report of the Environmental Protection Agency to this conference which I understand to specify a case-by-case analysis of all relevant facts applying to a particular site.

As I indicated before, the full record of the Point Beach nuclear plant proceeding is an excellent example of that case-by-case treatment.

At the same time that I am encouraged by the EPA policy statements, I am dismayed by two apparently contradictory matters. The first concerns Regional Administrator Mayo's letter to the Chairman of the Licensing Board in the Point Beach proceeding as recently as August 10, 1972, which states that EPA "... continues to support the recommendations of the Lake Michigan Enforcement Conference approved by the Administrator of the EPA on May 14, 1971, and continues to urge that the Point Beach Unit No. 2 have a closed-cycle cooling system in accordance with the recommendations of the Enforcement Conference."

Evidently Mr. Mayo finds himself constrained by

S. Burstein

the recommendations of the 1971 Enforcement Conference which are in conflict with present EPA case-by-case analysis policy.

The second matter concerns an item appearing in the September 18, 1972, issue of Electrical Week. The report references EPA sources as continuing to maintain their stand on requiring closed-cycle cooling for Lake Michigan power-plants rather than the case-by-case consideration, with a quote: "We [EPA] are simply viewing Lake Michigan as a single case."

Perhaps I should be even more concerned by similar statements, Mr. Chairman, that have been made on the thermal question today.

I believe that we have now gone past the point of further nonsense. I do not honestly see how we can say that there is consistency between a case-by-case policy statement and Lake Michigan as a whole.

We have been around this barn innumerable times, and there is nothing further to be gained by more evasion. The record in these conferences clearly demonstrates that insofar as thermal matters are concerned there is no technical basis for considering Lake Michigan as a single case.

There are many, many items which I have deliberately summarized in a single paragraph concerning the reasons why it is imperative that I think this conference take clear and unmistakable action to rescind the 1971 thermal recommendations. This will give the EPA Regional Administrator confirmation of the actions of the respective States and will avoid any present or potential conflict between Federal and State agencies, the Congress, and the courts.

I suggest perhaps, Mr. Chairman and conferees, that it is time for this conference, including EPA, to endorse for the Region what the conferees have accomplished individually.

MR. MAYO: Are there any questions, gentlemen?

Thank you, Mr. Burstein.

(Mr. Burstein's presentation follows in its entirety.)

STATEMENT OF SOL BURSTEIN
SENIOR VICE PRESIDENT
WISCONSIN ELECTRIC POWER COMPANY

LAKE MICHIGAN ENFORCEMENT CONFERENCE
CHICAGO, ILLINOIS
SEPTEMBER 19-22, 1972

My name is Sol Burstein. I am Senior Vice President of Wisconsin Electric Power Company. You will recall that at previous sessions of the Conference I presented details in regard to the Wisconsin Electric Power system that I represent, the territory and number of customers we serve, and the power plants we operate in the State of Wisconsin along the western shore of Lake Michigan. Among these power plants, which utilize once-through-cooling, are the Oak Creek Plant, which is presently the largest operating thermal plant on Lake Michigan, and the Point Beach Nuclear Plant, one unit of which has been operating at essentially full power for almost twenty-three months. In regard to the second unit, we have recently concluded one of the longest and most detailed public hearings on environmental effects of its operation and it is now in service at an interim 20% level.

In my remarks to this Conference on March 24, 1971, I emphasized certain observations from the proceedings and from the conclusions of the January, 1971, report of the Technical Committee on Thermal Discharges. I expressed my concurrence with the Committee recommendation and the then

Assistant Secretary of the Interior, Carl Klein, that there is a period of time between the present when no damage to Lake Michigan from thermal discharges exists - and some undefined future time when some feared additional sources of heat might cause irreversible adverse effects. I stated this period affords and, indeed, demands that we use this time to determine what we should intelligently do before we do it.

I am pleased that the Region V Enforcement Division of the Environmental Protection Agency undertook to have Argonne National Laboratory provide the summary embodied under Contract Report 72-1. My copy of this valuable and exhaustive review is covered in black which I assume is to mourn the passing of the White Papers. I believe an examination of this new Argonne report will indicate that even in the short interval between the 1971 Conferences and today, substantial scientific effort has been and is being expended to develop a responsible, objective body of technical knowledge concerning thermal discharges. Not all the data are in, of course, but to my knowledge, none represents any confirmation of the fears expressed earlier concerning adverse effects of these thermal effluents.

In my own state of Wisconsin, new thermal criteria adopted in December, 1971, and effective February 1, 1972, call for extensive monitoring of existing power plant discharges and their effects on the aquatic environment. Data and analyses are to be provided to the Wisconsin Department of Natural Resources in interim progress reports and in a final report due February 1, 1974. An advisory board of eminently qualified scientists developed a set of requirements to implement these Wisconsin criteria in March, 1972, immediately after which the utilities in my state undertook to perform the studies.

In the next eighteen months we will be spending in excess of $1,200,000 for these studies at the Oak Creek, Lakeside, Port Washington and Point Beach plants. I believe this work to be one of the most detailed and comprehensive programs for the monitoring of thermal discharges and the analysis of their effects. They are designed to be of the highest professional quality. We are confident that these new studies, together with the data observed in the past at our facilities and at other similar installations, will provide further hard scientific corroboration of our past positions before this Conference. We would be pleased to share the results of our studies with EPA and the conferees.

Additionally, the Center for Great Lakes Studies at the University of Wisconsin in Milwaukee has undertaken studies at our Oak Creek Power Plant under AEC funding with instrumentation and other services supplied by us. You will recall my having suggested such an undertaking in 1970. The other programs being conducted by the Sea Grant Program at the University of Wisconsin, Argonne National Laboratory, University of Wisconsin-Milwaukee and those being sponsored by the Lake Michigan Utility Study Group continue to receive our financial and technical support and continue to supply further information on thermal effects. More and more we are beginning to give Administrator Ruckelshaus as well as the states and the conferees that "considerable and growing body of evidence" that we did not have earlier. To date, none of these data provide any basis for any arbitrary or hasty decisions absolutely precluding thermal releases to Lake Michigan.

In my remarks to the workshop sessions of last September-October, I stated that I believed no new federal thermal standards were required for Lake Michigan but that the adequacy of state criteria could be confirmed by actual observations at operating steam-electric generating plants. I stated that any effects of thermal discharges on sensitive localized areas could be accommodated on a case-by-case analysis. It is, of course, heartening to read carefully Mr. John Quarles May 12, 1972, policy statement on thermal discharges and the report of the Environmental Protection Agency to this

Conference which I understand to specify a case-by-case analysis of all relevant facts applying to a particular site.

We have just had what I believe is the first full public hearing on environmental issues attending an AEC contested operating license proceeding in connection with our Point Beach Nuclear Plant, Unit 2. During this hearing, a major emphasis was on the effects of plant operation on the aquatic environment. I believe an objective review of the transcript of that hearing will indicate that a valid, scientifically based analysis on a case-by-case basis is the only realistic approach to an understanding and evaluation of power plant thermal effects. I would be glad to provide this Conference with a copy of that transcript.

At the same time that I am encouraged by the EPA policy statements, I am dismayed by two apparently contradictory matters. The first concerns Regional Administrator Mayo's letter to the Chairman of the Licensing Board in the Point Beach proceeding as recently as August 10, 1972, which states explicitly that EPA "continues to support the Recommendations of the Lake Michigan Enforcement Conference approved by the Administrator of the EPA on May 14, 1971, and continues to urge that the Point Beach Unit #2 have a closed cycle cooling system in accordance with the recommendations of the Enforcement Conference". Evidently, Mr. Mayo finds himself constrained by the recommendations of the 1971 Enforcement Conference which are in conflict with present EPA case-by-case analysis policy.

The second matter concerns an item appearing in the September 18, 1972, issue of Electrical Week, a McGraw-Hill utility industry newsletter. This report references EPA sources as continuing to maintain their stand on requiring closed cycle cooling for Lake Michigan power plants rather than the case-by-case consideration with the quote, "We [EPA] are simply viewing Lake Michigan as a single case".

I believe, Mr. Chairman and Conferees, that we have gone past the point of further nonsense. We have been around this barn innumerable times and there is nothing further to be gained by more evasion. The record in these Conferences clearly demonstrates that insofar as thermal matters are concerned, there is no technical basis for considering Lake Michigan as a single case.

I need notrepeat here in detail what you all know and have heard -- the separate actions of the respective states, the present events in the Congress on the new water quality legislation, the analysis and the conclusions by all the national laboratories in the environmental impact statements for all the current nuclear plants on Lake Michigan which are against closed cycle cooling, the absence of a NEPA statement on the 1971 recommendations, present litigation which records the fact that these 1971 recommendations have no legal effect, the forthcoming publication of the revised Green Book, the actual results of currently operating power plants on Lake Michigan and the extensive and high caliber additional studies currently under way to provide further information. All these matters, together with the apparent conflict between EPA present policy on thermal discharges and the 1971 recommendations of the Enforcement Conference require that this Conference take clear and unmistakable action to rescind the 1971 thermal recommendations. This action will give the EPA Regional Administrator confirmation of the actions of the respective states and will avoid any present or potential conflict between federal and state agencies, the Congress and the courts.

I believe we in Wisconsin have demonstrated that the utility industry and state agencies charged with environmental protection and enhancement can work together on a realistic timetable to determine and evaluate environmental impacts and to effect remedial actions where necessary. I believe other utilities and other state agencies around Lake Michigan have provided similar demonstrations of their capacity and intent. I suggest it is now time for this Conference, including EPA, to endorse for the region what the conferees have accomplished individually.

MR. FRANGOS: Mr. Paul Keshishian.

STATEMENT OF PAUL KESHISHIAN, DIRECTOR, POWER PRODUCTION, WISCONSIN POWER AND LIGHT COMPANY, MADISON, WISCONSIN

MR. KESHISHIAN: My name is Paul Keshishian. I am the Director of Power Production of the Wisconsin Power and Light Company.

Before I read my prepared statement, I would like to make reference to what Mr. Barber said earlier -- I think it was -- this evening. (Laughter)

I take strong exception with Mr. Barber's list of fish kills as proof of the need for cooling towers on Lake Michigan. As a point of fact, one incident he referred to occurred in December 1952 at the Glenwood Landing Station of Long Island Lighting Company, and involved their 100 MW No. 4 unit. It was a serious problem. Brown herrings were being found in their intake screens and their unit condensers so that periodic shutdowns occurred.

A noted ichthyologist was hired to determine the cause of the problem. After careful study of the incident and field investigation, he recommended that they shut off their dock lights at night as the lights were an attraction to the fish that resulted in their being sucked into the intake structures. Once the lights were shut off, they had no further problems with herrings in their intakes. For the past 20 years, they have not had any problems. And this is not a fish story. (Laughter)

I also take exception to his conclusions regarding the Indian Point station of the Consolidated Edison Company of New York. While this station apparently has a problem, there are many other stations on the Hudson River that do not have a problem. Specifically, on the Consolidated Edison system, there are 11 other stations he did not refer to. I was general superintendent of 5 of those stations between 1958 to 1969, and I never witnessed or had knowledge of any fish kill. Specifically, I was general superintendent of the 59th Street station, the 74th Street station, the Kent Avenue station, the Astoria generating station, and the Raymond generating station.

I also point out that both the latter two stations are 5 times the size of the Indian Point station. I think it is absolutely incorrect to reach a conclusion that because a small percentage of stations may have had a problem that, ergo, a thousand other stations will also have the same problem.

I won't read my complete statement. You have

P. Keshishian

that.

The Wisconsin Power and Light Company is basically in partnership with the Wisconsin Public Service Corporation and Madison Gas and Electric Company, who are building the 500 MW nuclear power station at Kewaunee. We are also building the Columbia generating station near Portage, Columbia County, and we own 40 percent of both stations.

I am pleased to have the opportunity to comment on a proposed policy for the responsible use of our water resources. We have an interest in the development of such a policy as an electric public utility charged with the responsibility under Wisconsin law of providing electric service to its customers and also reasonably adequate facilities to provide that service. Wisconsin Power and Light Company believes that its record to date in all ways establishes itself as a responsible citizen in these areas.

I will confine my remarks to the Edgewater generating station in regard to the Lake Michigan proposed standards.

At the outset, it may be helpful to discuss this question in the perspective of the cost implications involved particularly in view of the fact that there is no proven damage to Lake Michigan from the operation of the electric generating plants.

P. Keshishian

Since the last Lake Michigan conference study in Chicago, we have had an engineering report prepared for alternative cooling systems for our Edgewater generating station. The capital cost of installing a mechanical draft cooling tower at our Edgewater station is now estimated to be $7,835,000. In addition, as a result of the decrease in turbine capability and requirements for auxiliary power to operate the towers, an additional equivalent investment of $6 million would be required to replace this capability and compensate for the additional fuel requirements. Thus, the total required equivalent capital investment for the installation and operation of these towers would be $13,835,000. In addition, $200,000 per year will be required for the maintenance of these towers and their auxiliary equipment.

We should also point out that to operate these towers it is necessary to burn an additional 117 million pounds of coal per year with the resulting discharge to the atmosphere of over 7 million pounds of sulfur dioxide and large amounts of nitrogen dioxide and particulate matter. In the absence of evidence that there is significant damage to the lake, what justification is there for this magnitude of expenditures and this increase in atmospheric pollution?

The Wisconsin Department of Natural Resources determined that it would study the effects of the operations of each powerplant on Lake Michigan on a case-by-case basis. As a result, we are currently negotiating a contract for a year-long environmental study at the Edgewater generating station to determine if any damage is occurring to the lake at this site as a result of our powerplant operations. This study will obtain all the necessary information requested by the Department of Natural Resources of Wisconsin in its proposed Guidelines for Environmental Studies at Lake Michigan Thermal Discharge Sites as required under Wisconsin Administrative Code N.R. 102.04.

The question of appropriate temperature limitations for waters discharged into Lake Michigan involves the balancing of all public rights in the use of Lake Michigan including the industrial use of those waters provided the industrial use does not result in significant damage. Wisconsin Power and Light Company is strongly opposed to any program such as the imposition of an effluent requirement that is not based upon actual experience that would result in substantially higher costs to Wisconsin electric rate payers without any corresponding decrease in damage to Lake Michigan.

Thank you, Mr. Chairman and conferees.

MR. MAYO: Thank you.

(Mr. Keshishian's statement follows in its entirety.)

STATEMENT OF WISCONSIN POWER AND LIGHT COMPANY

My name is Paul Keshishian. I am the Director of Power Production of the Wisconsin Power and Light Company.

Wisconsin Power and Light Company is an investor owned, electric, gas and water utility. It provides the retail electric service to 232,000 customers in over 400 communities. It provides wholesale electric service to 33 communities and 5 cooperatives. Its service area occupies 15,000 square miles in central and southern Wisconsin with a population of almost 700,000.

Wisconsin Power and Light Company owns and operates four fossil-fueled electric generating plants with a total generating capacity of 780,000 kilowatts. One of the generating plants, Edgewater, with a capacity of 458,000 kilowatts, is located on Lake Michigan at Sheboygan. Two of our plants are located in Rock County, and one is located in Grant County. It also owns hydroelectric facilities with a generating capacity of 51,200 kilowatts and gas turbine generating facilities with a capacity of 86,000 kilowatts.

Wisconsin Power and Light Company, in partnership with Wisconsin Public Service Corporation and Madison Gas and Electric Company, is in the process of constructing a 527,000 kilowatt nuclear generating plant on Lake Michigan near Kewaunee, in Kewaunee County. Operation of the Kewaunee plant is scheduled for 1973. The same three companies are also constructing a 527,000 kilowatt fossil-fueled generating plant, known as the

Columbia Generating Station, near Portage, Columbia County. Commercial operation for the Columbia Plant is scheduled for March 1, 1975.

I am pleased to have the opportunity to comment on a proposed policy for the responsible use of our water resources. We have an interest in the development of such a policy as an electric public utility charged with the responsibility under Wisconsin law of providing electric service to its customers and also reasonably adequate facilities to provide that service. Wisconsin Power and Light Company believes that its record to date in all ways establishes itself as a responsible citizen in these areas.

I will confine my remarks to the Edgewater Generating Station in regard to the Lake Michigan proposed standards.

At the outset, it may be helpful to discuss this question in the perspective of the cost implications involved particularly in view of the fact that there is no proven damage to Lake Michigan from the operation of the electric generating plants.

Since the last Lake Michigan conference study in Chicago, we have had an engineering report prepared for alternate cooling systems for our Edgewater Generating Station. The capital cost of installing a mechanical draft cooling tower at our Edgewater Station is now estimated to be $7,835,000. In addition, as a result of the decrease in turbine capability and requirements for auxiliary power to operate the towers, an additional equivalent investment of $6,000,000 would be required to replace this capability and compensate for the additional fuel requirements. Thus, the total required equivalent capital investment for the installation and operation of these towers would be $13,835,000. In addition, $200,000 per year will be required for the maintenance of these towers and their auxiliary equipment.

We should also point out that to operate these towers it is necessary to burn an additional 117,600,000 pounds of coal per year with the resulting discharge to the atmosphere of over 7,000,000 pounds of sulfur dioxide and large amounts of nitrogen dioxide and particulate matter. In the absence of evidence that there is significant damage to the Lake, what justification is there for this magnitude of expenditures and this increase in atmospheric pollution?

The Wisconsin Department of Natural Resources determined that it would study the effects of the operations of each power plant on Lake Michigan on a case by case basis. As a result, we are currently negotiating a contract for a year-long environmental study at the Edgewater Generating Station to determine if any damage is occurring to the Lake at this site as a result of our power plant operations. This study will obtain all the necessary information requested by the Department of Natural Resources of Wisconsin in its proposed Guidelines for Environmental Studies at Lake Michigan Thermal Discharges Sites as required under Wisconsin Administrative Code N.R. 102.04.

The question of appropriate temperature limitations for waters discharged into Lake Michigan involves the balancing of all public rights in the use of Lake Michigan including the industrial use of those waters provided the industrial use does not result in significant damage. Wisconsin Power and Light Company is strongly opposed to any program such as the imposition of an effluent requirement that is not based upon actual experience that would result in substantially higher costs to Wisconsin electric rate payers without any corresponding decrease in damage to Lake Michigan.

Any questions, gentlemen?

MR. FRANGOS: Mr. Keshishian, I have recently learned that Mr. Mayo is an old Brooklyn boy. Maybe you fellows can get together a little bit later and talk about the Dodgers and old times!

MR. KESHISHIAN: I would really like to.

MR. McDONALD: Maybe Mr. Mayo ought to talk about the East River because it is my understanding -- I am from upstate New York originally -- but I always thought that the East River was something like the Chicago River and Sanitary Ship Canal now as far as containing fish. Isn't it just about devoid of fish, Mr. Mayo, so it is hard to have a fish kill?

(Laughter.)

MR. FRANGOS: Mr. Chairman, I have a statement by Mr. James A. Rogers, Assistant Attorney General of Wisconsin. He asked that I read this into the record, so if you will indulge me, I will read it.

STATEMENT OF JAMES A. ROGERS,

ASSISTANT ATTORNEY GENERAL,

WISCONSIN JUSTICE DEPARTMENT,

MADISON, WISCONSIN

(AS READ BY THOMAS G. FRANGOS)

J. Rogers

MR. FRANGOS: My name is James A. Rogers and I am an Assistant Attorney General of Wisconsin. I work in a division of the State Justice Department that specializes in environmental matters, and in that capacity I have participated in a lengthy Atomic Energy Commission Safety and Licensing Board hearing on Wisconsin Electric Power Company's application to operate Unit 2 of the Point Beach nuclear powerplant. This plant is located near Manitowoc, Wisconsin. I am speaking today only in behalf of the Justice Department.

One of the major issues in those proceedings, defined most broadly, was whether the water discharged from the plant at a substantially higer temperature than ambient, would cause "pollution," and, if so, what should be done about it.

It would be improper at this time to attempt to publicly generalize as to what the evidence showed; it is proper and important, however, to ask what evidence exists that was not presented. Specifically, I feel that if the United States Environmental Protection Agency possesses information which is relevant to the environmental issues posed by the operation of a specific nuclear powerplant sited on Lake Michigan or by the operation of such plants as a group, it is desirable to have that Agency present

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this information, either as an advocate for intervenors or applicants, or as a friend of the court, so that the decision of the Atomic Energy Commission hearing panel may be more intelligently made. Even testimony to the effect that the findings are contradictory or that specialists within the Agency disagree would be valuable.

There was great frustration experienced by our office in the Point Beach hearings, and to some extent it was caused by the Environmental Protection Agency's tantalizing criticisms of the scientific approach being taken by Applicant power company, by warnings of dangers, and by the suggestion that the Agency would indeed become involved in the hearing.

In the Environmental Protection Agency's comments to Environmental Impact Statement for Point Beach, dated March 22, 1972, the Agency reiterated the position that Point Beach would not be in compliance with the recommendations of the Lake Michigan Enforcement Conference, and in detailed comments suggested several possible ways in which the thermal effluent would damage Lake Michigan's ecology. For example, the comments said that:

"Research performed at the Environmental Protection Agency's National Water Quality Laboratory in Duluth, Minnesota, indicates that reproductive ability may be

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impaired in fish exposed to elevated water temperatures. ... [T]he effluent from the Point Beach plant could significantly reduce the reproductive success of yellow perch attracted to the plume."

It was hoped by our office that such evidence would be offered by the EPA and subjected to adversary scrutiny, a hope that had been encouraged by the Agency's filing of a notice of limited appearance. But the only EPA witness who appeared at the hearing was under subpoena by the private intervenors. The confusion was heightened somewhat when, on August 10 of this year, Mr. Mayo sent a letter to the Chairman of the Atomic Energy Commission hearing panel stating:

"This Agency ... continues to urge that Point Beach Unit No. 2 have a closed-cycle cooling system in accordance with the recommendations of the [Lake Michigan] Enforcement Conference."

It also stated that EPA would forego appearance at the Point Beach hearings until after this session of the Enforcement Conference.

The point of all this is that, especially in the wake of recent court decisions broadening Atomic Energy Commission obligations in the environmental field, the licensing proceedings before the Atomic Energy Commission

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are the fora in which environmental challenges can be directly responded to with enforceable orders of the Atomic Energy Commission, either conditioning the granting of licenses or, in theory, denying the license application altogether. It is at these Atomic Energy Commission hearings that data in the possession of the Environmental Protection Agency will have its most telling impact.

While my remarks may be taken as severe criticism of EPA's role in the Lake Michigan thermal question, I would rather characterize it as a request to that broadly-based and well-funded Agency to assist those struggling State agencies to get an initial grasp of this problem. The Environmental Protection Agency has repeatedly shown an ability to make a sophisticated scientific analysis of important environmental questions and I have merely assumed that studies of this caliber have been made of the thermal question.

End of statement.

Mr. Chairman, I would also like to submit for the record a statement by Mrs. Miriam Dahl on thermal discharges into Lake Michigan.

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

IZAAK WALTON LEAGUE
WISCONSIN DIVISION

STATEMENT

SEPT.19,1972
ATOMIC ENERGY USE FOR POWER

Mr. Chairman;Conferees; Ladies and Gentlemen:

I am Miriam O.Dahl. I represent today the Wisconsin State Division of the Izaak Walton League of America which has 22 Chapters representing a grass roots opinion from the State.

The Wisconsin Division has in previous statements taken a position promoting economic health and progress. We believe the only responsible course of survival of such economic health is a much wiser approach to our past and present flagrant use of irreplaceable resources and to stop the continuing abuse of our environment.

In line with this thinking, we have previously proposed studies using new approaches and theories as well as the usual methods to find new and safe ways to use the resources we have. Concerning use of the atomic energies methods of producing electric power, testing has not been adequate to reassure, even partially, the proper methods of use,let alone the safeguards to protect from possible accidental holocaust. The word has been to go ahead and see what happens. If what happens is irreversible in destruction and/or mutations, that is too bad. Just go ahead.

Disposal of radioactive wastes have not been solved satisfactorily. So what? We are told that people want peak demands met no matter at what cost. This could hardly be interpreted as healthy economics in any sense.

The discharge of heated water into the waterways, in this case into Lake Michigan has been contested in the courts. The money spent to gain permission to go ahead with the discharge as stated at the original 20' could have been used to research methods of reducing the temperature to a lower level, but the old methods of operation still persist in the economy even though on a more sophisticated level.

In our position statement the Wisconsin Division of Izaak Walton League stated that we believe a 1' difference in temperature can be achieved and should be a goal within the near future IF the research project is pursued with the same determination as the action to preserve the 20' figure. A present 4' allowance would be adequate for present use and would not hurt the ecology according to present findings. We have been told that a 5' temperature could be achieved 2 years ago. We deplore the allowance of the 20'. This shows that progress in the last 3 years has been nil in this area. It is certainly not what we expected. The expenditures have been for a holding action, Not for the forward thrust. We have lost the precious commodities of time,money and research information.

The threatened lack of electrical energy last summer did not occur. The Wisconsin Electric Power Company, according to news releases purchased the extra power needed from another company. No curtailment or loss of power was experienced.

Policy changes in advertising of Power Companies has been useful in showing the public how it can best use electric power. This is a step in the right direction. Another great step would be to change the sliding scale rates to industrial users so that it would not pay less for using more power. More efficient use of industrial power would effect great savings This should be reviewed in every industrial plant. Waste of more than 50% in some cases can be eliminated.

Lighting up downtown areas to sunlight intensity during the night hours can be better controlled. We do NOT need to stop lighting, even display lighting, but it is now overdone and can be modified. Streets must be illuminated, some more than they are. Public buildings have overlighting of such brilliance that it is tiring, if not injurious to the eyes. The heat generated must be dissipated by more cooling energy. Recently in a convention halll I asked that only 1/2 of the UNNESCESSARY lights be extinguished. It was done. Everyone had good vision and conducted business as usual. Many people later remarked that they felt less sleepy and more comfortable. Such changes can be made immediately and would result in providing "extra power resources" when needed.

Innovative measures are needed. To continue pragmatically refusing to try some of the suggestions is to refuse healthy economic progress in proper use of our resources. Laws can, of course help, b ut laws are not needed by practical business men with some imaginative vision who want to achieve the same ecological world for which we work. We believe the power company officials are such men.

The large hurdle is the change of approach to our problems. Once over that, we can devote our energies and funds to finding the answers to safe uses of nuclea r sources and to reducing the heat discharges.

We charge this Conference with the responsibility to protect the waters from the condemnation of such high heat additions. At the same time, we charge our State of Wisconsin with the responsibility of re-evaluating its position on this same problem.

Respectfully submitted,

Chr. Water Pollution Committee
Wisconsin State Division of the
Izaak Walton League of America.

September 19,1972.

T. Frangos

STATEMENT OF THOMAS G. FRANGOS,
ADMINISTRATOR, DIVISION OF ENVIRONMENTAL PROTECTION,
WISCONSIN DEPARTMENT OF NATURAL RESOURCES,
MADISON, WISCONSIN

MR. FRANGOS: At this time, I would like to read a 2-page statement by the Department of Natural Resources, and I think at this point in time it is easier for me to read it rather than try to paraphrase it.

In the summer of 1971, the Wisconsin Department of Natural Resources held a public hearing to consider revising thermal standards for Lake Michigan to conform with the recommendations of the Lake Michigan Enforcement Conference. Following the hearing, oral agreements were presented to a quorum of the Natural Resources Board by representatives of the utilities, environmental groups, and the U.S. Environmental Protection Agency. The Environmental Quality Committee of the Board reviewed the transcript of the public hearing, took cognizance of the oral presentation, and discussed the proposed standards with staff members of the Department. The committee's conclusions reached in the fall of 1971 are as follows:

"The problem of heat discharges is complex

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involving not only the scientific data required to establish criteria, but also the social and economic considerations that must be evaluated in establishing standards and providing preventive and corrective measures. Based on our review of the information presented, we are of the opinion that much is unknown about the effects of thermal discharges and about the environmental impact of corrective works or methods that may be employed to reduce the quantity of heat discharged. However, because of the increased possibility of damage to Lake Michigan from proliferation of powerplants, the committee believes that it is sound public policy to prohibit thermal discharge from plants not now operating, operable, or under construction until questions we and others have raised have been answered. The committee holds that the financial burden to establish the impact of heated discharges rests on the industry.

"A 2-year study conducted at the various powerplant sites on Lake Michigan together with data now being obtained from several other studies, should provide data on which rational decisions as to proper corrective measures to be taken can be based. These studies will be conducted by the industry and will be designed and supervised by the Department.

"In the meantime, the Department will be

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conducting its own investigations, including further evaluation of the environmental problems associated with cooling towers or cooling ponds.

"Further, we would reserve to the Board and the Department the right to take immediate remedial action should it be determined at any time during the 2-year study period that environmental damage appears imminent or existent.

"This provision, coupled with a moratorium on the siting of additional plants on Lake Michigan, satisfies the committee that the quality of the lake can and will be maintained to best serve the public interest."

The Natural Resources Board approved the revised thermal standards on December 8, 1971. They were published in the January 1972 Register and became effective on February 1, 1972. As part of the Wisconsin Administrative Code, the standards have the force and effect of law.

The new thermal standards establish monthly maximum temperature criteria and a limit of 3° F. over the existing temperature of the receiving water at the edge of an established mixing zone. Milwaukee Harbor, Port Washington Harbor and the mouth of the Fox Fiver are exempted from the monthly maximums because of the naturally occurring higher temperatures.

For existing or soon-to-be completed facilities that exceed a discharge of 500 million B.t.u. per hour, it is required that the owners submit monthly reports of temperature and flow data, a detailed chemical analysis of blowdown waters, a preliminary engineering report for the installation of alternative cooling systems, and the findings of a 2-year study of the environmental and ecological impact of the discharges. The environmental study must be conducted in a manner approved by the Department and it will aid in the establishment of a mixing zone.

Any new facility must be designed so as to avoid significant thermal discharge to Lake Michigan, and should existing discharges appear to threaten or cause environmental damage, the Department may order the reduction of thermal input regardless of interim measures undertaken by the source owners.

The Department of Natural Resources immediately notified the affected utilities of the reporting requirements of the new thermal standards. In addition, a committee was formed to develop Guidelines for Environmental Studies at Lake Michigan Thermal Discharge Sites. Included in the committee were two representatives from UW-Madison, two representatives from UW-Milwaukee and one representative from UW-Green Bay. Copies of the guidelines, which are attached, were distributed to Wisconsin utilities and

T. Frangos

subsequent meetings were held by DNR to determine the adequacy of the utilities' proposed environmental studies.

At the present time, all of the reporting and environmental study requirements of the Wisconsin thermal standards are being complied with. An attached status report lists the involved powerplants and the dates various reports were received and preliminary study plans approved.

I would like to make the attachments also a part of the record.

MR. MAYO: Do you have copies of the attachments with you?

MR. FRANGOS: Yes. I thought those were distributed, Mr. Mayo. I have additional ones though if you would like.

MR. MAYO: I just wanted to make sure they were available for the record.

MR. FRANGOS: I believe that concludes the Wisconsin presentation.

(The documents above referred to follow in their entirety.)

STATUS OF WISCONSIN POWER PLANTS

IN MEETING LAKE MICHIGAN THERMAL STANDARDS

SEPTEMBER 5, 1972

Unit	Utility	Preliminary Eng. Report	Chemical Analysis Blowdown Waters	DNR Approval Env. Study	Monthly Operating Reports
Edgewater	WPL	8/31/72	3/9/72	7/19/72	Yes
Kewaunee	WPS	8/2/72	Nuclear Plant	6/14/72	Not in Operation
Pulliam	WPS	8/2/72	8/2/72	6/13/72	Yes
Point Beach	WEP	8/1/72	Nuclear Plant	9/5/72	Yes
Oak Creek	WEP	8/1/72	7/31/72	9/5/72	Yes
Lakeside	WEP	8/1/72	7/31/72	9/5/72	Yes
Port Washington	WEP	N/A	7/31/72	N/A	Yes
Valley	WEP	N/A	7/31/72	N/A	Yes

N/A - Not applicable since not required in administrative code.

WPL - Wisconsin Power and Light Company

WPS - Wisconsin Public Service Corporation

WEP - Wisconsin Electric Power Company

JRM:mn

102.04 Lake Michigan thermal standards. For Lake Michigan the following thermal standards are established so as to minimize effects on the aquatic biota in the receiving waters.

(1) (a) Thermal discharges shall not raise the receiving water temperature more than 3 degrees F. at the boundary of mixing zones established by the department.

(b) In addition to the limitation set forth in subsection (1) (a); but excepting the Milwaukee Harbor, Port Washington Harbor and the mouth of the Fox River, thermal discharges shall not raise the temperature of the receiving waters at the boundary of the established mixing zones above the following limits:

January	45 degrees F.
February	45 degrees F.
March	45 degrees F.
April	55 degrees F.
May	60 degrees F.
June	70 degrees F.
July	80 degrees F.
August	80 degrees F.
September	80 degrees F.
October	65 degrees F.
November	60 degrees F.
December	50 degrees F.

(2) All owners utilizing, maintaining or presently constructing sources of thermal discharges exceeding a daily average of 500 million BTU per hour shall:

(a) Submit monthly reports of temperature and flow data on forms prescribed by the department commencing 60 days after the effective date of this rule.

(b) Within 24 months of the effective date of this rule, complete an investigation and study of the environmental and ecological impact of such discharge in a manner approved by the department. After a review of the ecological and environmental impact of the discharge, mixing zones shall be established by the department.

(c) Submit to the department within 6 months of the effective date of this rule a preliminary engineering report for the installation of alternative cooling systems.

(d) Submit within 6 months of the effective date of this rule a detailed chemical analysis of blowdown waters discharged to Lake Michigan and its tributaries.

(3) Any plant or facility, the construction of which is commenced after the effective date of this rule, shall be so designed as to avoid significant thermal discharge to Lake Michigan.

(4) The department may order the reduction of thermal discharges to Lake Michigan regardless of interim measures undertaken by the source owners in compliance with this rule if environmental damage appears imminent or existent.

(5) The provisions of this rule are not applicable to municipal waste and water treatment plants and vessels.

Wisconsin Department of Natural Resources
Division of Environmental Protection

LAKE MICHIGAN - THERMAL IMPACT INVESTIGATIONS

GENERAL COMMENTS

An investigation or study of the environmental and ecological impact of thermal discharges that exceed one half billion BTU's per hour to Lake Michigan is required by the new thermal standards. Power plants which are to conduct the studies are:

Point Beach Nuclear Plant, Wisconsin Electric Power Company
Kewaunee Nuclear Plant, Wisconsin Public Service Corporation
Oak Creek Plant, Wisconsin Electric Power Company
Lakeside Plant, Wisconsin Electric Power Company
Edgewater Plant, Wisconsin Power and Light Company
Pulliam Plant, Wisconsin Public Service Corporation

The studies are to be prepared in a manner approved by the Department, and the report covering the results must be submitted within 24 months of the effective date of the thermal standards (January 31, 1974). All studies are to be conducted in a manner such that the data obtained provides an accurate and quantitative description of the phenomena under investigation. These investigations shall include studies specifically designed to evaluate the variability of the data obtained and, therefore, the expected precision with which a predicted or measured effect is estimated or determined. The analytical and other methods used for measurements shall be in accord with methods that are known to give a high degree of reliability under the conditions used in this study.

The studies should be conducted in a manner so that a quarterly review of the data collected is made by the investigator. Any particular problems indicated by this quarterly review should be brought to the Department of Natural Resources for possible advice and assistance. It is imperative that an active data review be conducted during the course of the study and adjustments of the study planned in accord with the findings of the previous period.

Attached are specific guidelines for these thermal impact investigations.

JRM:jm
3-29-72
Attachment

Guidelines for Environmental Studies
at Lake Michigan Thermal Discharge Sites

I. Predictive Model and Measurement of Existing Temperature and Velocity Structure of the Thermal Plume Under Prescribed Boundary Conditions.

At those installations where thermal discharges are in effect today, field measurements of the thermal plume should be made. At new or soon to operate facilities, mathematical models of the expected thermal discharge plume should be developed.

These studies should:

a. Present expected temperature isolines for the thermal plume from the point of discharge in the lake to the 2° F ΔT isoline (i.e. above the ambient). The isolines should be computed for at least 2° F intervals. These computations should be made for the expected temperature distribution at least eight times throughout a year, twice during each season, and should include the sinking plume conditions that may develop each winter. Consideration should be given to the potential effects of lake currents and stratification on the shape and extent of the thermal discharge plume.

b. Present velocity contours in the thermal discharge plume along with estimates or measurements of the time-temperature relationship that would exist in the discharge plume. Data should also be provided on the time from the point where the water enters the condenser until it is discharged to the lake.

c. Estimates should be made of the amount of entrainment of lake water by the discharge plume, i.e. estimate the dilution of the heated effluent that will occur.

d. Estimate the amount of recycle of water that will occur during winter operating conditions when a portion of the discharge water is returned to the intake in order to prevent freezing.

e. Measure ambient water temperature conditions in the region of the discharge in order to establish the temperature and rate of change of temperature under the normal and extreme meteorological conditions that may exist in that area.

The definition of existing plumes should include consideration of the use of drogues and aerial photography temperature imagery in order to define plume conditions. All air-borne temperature studies should be made with ground truth observations in order to check the reliability of them. During all thermal plume studies, an accurate record should be kept of the intake and discharge temperatures as well as at least hourly readings of plant load and discharge. This data should be collected for at least the period 6 hours prior to the initiation of the special purpose study. Also the meteorological conditions should be read at at least hourly intervals during the special purpose studies on the plumes. It will be important to try to define the plume characteristics as a function of plant operating conditions and meteorological conditions. All plant, lake and meteorological factors that are likely to influence the shape and extent of the plume should be monitored prior to and during any study on the characteristics of the plume.

II. Environmental Considerations

A. Sampling station locations should be established using a grid system, and each station should be marked with a permanent buoy. In lieu of this requirement, shipboard or land based navigation may be used provided that it accurately locates the sampling stations used in the study. The sampling grid should provide a sufficient number of samples to accurately describe aquatic organisms and water quality characteristics within and in the area adjacent to the thermal discharge plume. Where possible, sampling stations within the plume shall be established at the 2° FΔT isolines.

B. The parameters and frequency of sampling used in these studies shall be chosen to give a known degree of precision for each potentially significant effect of the thermal discharge on water quality in the region of discharge and Lake Michigan as a whole. The degree of precision shall be such that it is normally attainable with the best technology available today. The investigator should keep abreast of developments and new technology in this area and incorporate them into the study where it is found that the new technology may significantly improve the ability to detect the effects of thermal discharges on water quality. If a change is made in the analytical procedure during the course of this study, a limited scope study should be conducted in order to establish within a reasonable degree of certainty the relationship between the measurements made with the old and new analytical procedure.

The frequency and location of sampling shall be done in a manner so as to detect any potentially significant effect of the thermal discharge on water quality. The investigator should establish a tower in the lake for monitoring meteorological and ambient lake conditions in the region of the discharge plume. This meteorological station should be equipped with instruments for measurements, at a minimum, of, wind speed and direction, air temperature, dew point, solar radiation, net radiation, water temperature and currents at various depths, wave heights and frequencies and lake levels.

1. Fish

   (i) Sample at least eight times per year; twice during each season as a minimum.

   (ii) Fishery personnel to determine most appropriate techniques for collection.

   (iii) Record number of species, length, weight, and collect scale sample for aging.

   (iv) Spawning areas and activities: Numbers and types of juvenile fish found in the area.

The objective of the fish studies shall be to determine the numbers, types, characteristics and activities of the fish populations of existing or proposed thermal discharge plumes. Particular attention shall be given to the affect of the plume on the distributions of fish populations for each season of the year. Information on the numbers and types of fish found in the discharge plume at various times of the year is essential. Particular note should be made of the potential effects of the thermal discharge plume on fish migration. Does the plume inhibit fish migration? Are fish prevented from returning to selected areas for spawning in the region of the plume? Finally, the effects of the intake on fish populations shall be determined.

2. Benthic Macro Invertebrates

   (i) Bimonthly collections at permanent stations. Sufficient numbers of samples shall be taken at any one location to detect potentially significant changes in the numbers and types of macro invertebrates between sampling locations and sampling dates.

   (ii) Sampling equipment will be determined by bottom type, and shall provide representative samples of the bottom fauna. All benthic fauna retained in a No. 30 mesh sieve shall be enumerated and identified to genera where possible.

3. Plankton

   (i) Collections to be made over at least a one week period of intensive study in spring, summer and fall and where possible in the winter, at permanent stations.

   (ii) Utilize standard collection techniques which record volume of water sampled.

   (iii) Record percent composition and chlorophyll content.

Zooplankton may be collected by towing metering zooplankton nets, using conditions which are known to give reliable estimates of zooplankton population in the area being sampled. The phytoplankton shall be collected by discrete water sampling, i.e., do not use nets. The depth of sampling for the plankton shall be chosen to give an accurate estimate of the plankton populations in the region being sampled. The plankton shall be enumerated and identified to at least genera (identify major species) where possible with emphasis on food chain relationships.

4. Attached Algae, Macrophytes and Periphyton

The amount and types of attached algae, macrophytes and periphyton within the discharge plume and adjacent areas shall be determined during the late spring, mid-summer and early fall. This type of sampling is often best done by divers and manual collection. Record the amounts of benthic algae found in terms of mass per square meter of bottom. Sufficient numbers of samples should be taken at any one location to provide a reliable estimate with a known degree of precision in the sampling area in order to detect the high degree of reliability differences in the benthic algae biomass between sampling locations at any one sampling time and between sampling times. Consideration should be given to the use of artificial substrates which should be placed in the thermal plume discharge area and in adjacent areas in order to ascertain whether there might be a change in the periphyton as a result of the discharge.

5. Bacteriological

To be collected every month in season if appropriate. Fecal coliform, fecal streptococci and total plate count should be made.

6. Water Temperature and Currents

(i) Continuous monitoring of intake and effluent.

(ii) Profiles at one foot depth intervals at permanent stations every two weeks with due allowance for adverse weather conditions. Note that surface and subsurface drogues, coupled with aerial photography, could provide a synoptic picture of the current patterns.

7. Water Chemistry

(i) Dissolved oxygen profiles to be made every two weeks at permanent stations. Define extent of dissolved oxygen supersaturation in the thermal discharge plume. Determine area of thermal discharge plume with 110 percent or greater dissolved oxygen-dissolved nitrogen supersaturation. Estimate dissolved nitrogen supersaturation. Determine area for each season. The fish sampling should take special note of the areas with 110 percent or greater dissolved oxygen-dissolved nitrogen supersaturation. The numbers and types of fish within this area should be determined if at all possible, especially during the winter period.

(ii) Residual chlorine if used for algae control in the system. Measure total and free available chlorine in the thermal discharge plume using amperometric procedure. Determine areas where total chlorine exceeds 5 μg/l in the discharge plume at various seasons of the year.

(iii) Dissolved copper, cadmium and zinc if present in the discharge to be measured at monthly intervals. Four times a year determine mercury, boron, arsenic, iron, chromium, nickel, lead and manganese in the thermal discharge of the power plant.

(iv) A complete list of all chemicals used at the plant which could potentially be in the discharge should be provided. At quarterly intervals, the amounts of these chemicals present in the discharge should be determined.

(v) Nutrient series and other chemical parameters (total inorganic nitrogen, total organic carbon, specific conductance. sodium. potassium. fluoride. sulfate, silicon, color, turbidity, BOD, ammonia, nitrate, nitrite, total phosphorus, soluble phosphorus, pH, hardness and alkalinity) to be collected at designated permanent stations once a month. Samples should be collected one foot below the surface, mid-depth, and one foot above the bottom where appropriate.

8. Bottom and Sediments

(i) The lake bottom topography should be mapped in the vicinity of the outfall at least four times per year (once per season).

(ii) Sediment movements and the type and characteristics of the sediments should be determined in the outfall vicinity.

III. Special Studies

a. Effect on fish fry, fish eggs and plankton by passage through condenser.

All special purpose studies designed to simulate the passage of materials through the condensers should use a time-temperature relationship which is typical for that found in the discharge waters from the point of the condenser to the discernable edge of the thermal plume. Actual sampling of the condenser discharge water should be done in a manner such that it is representative of the water mass. The organisms should be held for a sufficiently long period of time to detect any substantial changes that might occur as a result of damage in passing through the condenser.

b. Effects of intake structures on aquatic life.

c. Estimate cost and potential beneficial uses of waste heated water.

d. Estimate cost and potential detrimental effects of alternate methods of cooling on environmental quality.

IV. Other Factors to Consider

Consider, and where possible, evaluate any other discharges in the region of the plant which might influence water quality in the thermal plume discharge area. An accurate record shall be kept of all discharges of chemicals to Lake Michigan in the region of the discharge plume area. This should include waters which have been in contact with ash pits for fossil fuel plants, boiler and other blowdown waters, cooling tower blowdown if they are used, discharge of sanitary waste, etc. The concentrations, total amounts, frequency of discharge, and volumes should be recorded in order to assess the total load and possible significance of the various chemicals added to the lake on water quality in the region of the plant.

JRM:jmm
3-22-72

MR. CURRIE: Mr. Chairman, there is one additional witness who wished to make a statement from Illinois. I was not aware of him when I called for additional witnesses. Four minutes, I am told.

STATEMENT OF PAUL OPPENHEIMER,
HYDE PARK-KENWOOD COMMUNITY CONFERENCE,
CHICAGO, ILLINOIS

MR. OPPENHEIMER: Mr. Chairman, members of the conference. I am Paul Oppenheimer and I am making this statement for the Hyde Park-Kenwood Community Conference. We have over 2,000 member families.

I swim in Lake Michigan almost every day from late spring to fall for the last 30 years. In the forties and early fifties the water was as clear as a mountain stream, and you could see right down to the bottom along the shore. Today when I swim under water I can hardly see my own hands.

Thanks to the fact that United States Steel and the other industrial law violators use Lake Michigan as a dump for their waste materials, we have slimy and slippery algae growing all over the rocks at the shore and on the lake bottom, announcing the high degree to which Lake Michigan has gone down the drain already. It is not unusual

P. Oppenheimer

for United States Steel to spend large sums of money for advertising, money they should spend to remove their waste materials. A number of municipalities throw their untreated or half-treated wastes into the lake, too. The poor, starving millionaires of Highland Park, for instance, could not afford to build a satisfactory treatment plant. They prefer to watch from their $200,000 mansions high up on the shore when their own excrements flow undisturbed into the lake. (Laughter)

Now, to top it all, half a dozen utilities want to build nuclear powerplants which are designed to use tremendous quantities of lake water and want to dump it back into the lake, heated up some 20°. There can be no doubt that, added to the already existing and continuing abuse of Lake Michigan, this will, in the long run, make Lake Michigan unfit to support life, destroy recreational activities along its shores, and endanger our drinking water.

Besides, these atomic reactors are not even safe. Many prominent scientists, including AEC staff members have testified to their belief that the emergency core cooling system as it exists today will not cool the core in time to prevent melting down, and consequent release of fatally high concentrations of radioactive gases.

P. Oppenheimer

If constructed at all, nuclear powerplants should be on sites away from the lake. They should never be allowed to damage the lake by returning heated water into it. The Council on Environmental Quality states in its latest report that $287 billion will be needed over the next 10 years to keep pollution under control, with a cost of $100 to every individual taxpayer. May I ask: What sense does it make to give the utilities license to misuse and damage the lake, make millions of dollars in profits in the process, and then have the taxpayers spend dollars in the billions to repair the damage done by the issue of licenses which should not have been issued in the first place? All I can say is that these utilities don't seem to hesitate to make our country the greatest welfare state on earth, and themselves the recipients of this welfare.

It is the duty of the Federal and State authorities to protect the lake. That does include the Atomic Energy Commission. Lake Michigan is the property of all the people, and no private interests have any right to use it for financial gains at the expense of the quality of its waters.

Thank you, gentlemen.

MR. MAYO: Thank you, sir. (Applause)

Are there any other presentations?

Closing Remarks - F. Mayo

The general practice of the conference at the reconvened sessions is that following the presentation of material by the interested parties, the conferees will then go into Executive Session at some appropriate time for the purpose of discussing that record and developing conclusions and recommendations.

There has been an opportunity to discuss an appropriate date for an Executive Session with the conferees. They are in general agreement that November 9 and 10 would be an appropriate time. There has been no decision so far as time and place are concerned.

I want to thank those who have endured. It has indeed been a very trying day for all of the parties involved. I want to express the appreciation of the conferees to those who have come and stayed with us in an effort to ensure that all those interested in getting statements into the record were able to do so.

Are there any comments as far as the conferees are concerned? With that, gentlemen, the Fourth Session of the Lake Michigan Enforcement Conference is adjourned.

(The Conference adjourned at 11:59 p.m.)

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(Documents received following the conference are included at the end of this volume.)

NAME OF AGENCY

EPA, REGION V
CHICAGO, ILLINOIS 60606

PRECEDENCE

ACTION

INFO

TYPE OF MESSAGE

[X] SINGLE [ ] BOOK

[ ] MULTI-ADDRESS

SECURITY CLASSIFICATION

ACCOUNTING CLASSIFICATION

STANDARD FORM 14 REV MARCH 15, 1957
GSA REGULATION 2-IX-203 04
14-303

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START MESSAGE ADDRESS HERE

HONORABLE ADLAI E. STEVENSON III
UNITED STATES SENATE
WASHINGTON, D.C. 20510

IN REGARD TO YOUR WIRE TO ME AS CHAIRMAN OF THE LAKE MICHIGAN ENFORCEMENT CONFERENCE, YOUR EXPRESSION OF CONCERN OF THE DAMAGES OF THERMAL POLLUTION IN LAKE MICHIGAN IS VERY MUCH APPRECIATED.

THE FOURTH SESSION OF THE CONFERENCE ADJOURNED ON SEPTEMBER 21, 1972 AFTER THREE DAYS OF EXTENSIVE TESTIMONY ON A NUMBER OF ISSUES INCLUDING THE THERMAL ISSUE. I SHARE YOUR CONCERN ON THE QUESTION OF THERMAL POLLUTION. TOWARD THAT END, THE CONFERENCE RECORD WILL BE STUDIED BY THE CONFERREES PRIOR TO RECONVENING IN EXECUTIVE SESSION ON NOVEMBER 9 AND 10, 1972 AT THE PICK CONGRESS HOTEL IN CHICAGO TO MAKE FURTHER RECOMMENDATIONS ON PROTECTING THE LAKE FROM ADVERSE HEAT DISCHARGES. THE CONFERENCE WILL ALSO BE RECONVENED IN EXECUTIVE SESSION ON OCTOBER 25 AND 26, 1972 AT THE SHERATON-CHICAGO HOTEL TO CONSIDER ADDITIONAL RECOMMENDATIONS ON NON-THERMAL ASPECTS OF THE CONFERENCE. YOU ARE MOST CORDIALLY WELCOME TO ATTEND BOTH SESSIONS.

DO NOT TYPE MESSAGE BEYOND THIS LINE

FRANCIS T. MAYO
REGIONAL ADMINISTRATOR
REGION V

PAGE NO 1 | NO. OF PAGES 1

NAME AND TITLE OF ORIGINATOR (Type)
JAMES O. McDONALD, DIRECTOR
ENFORCEMENT DIVISION

ORIGINATOR'S TEL NO.
353-1469

DATE AND TIME PREPARED
SEPTEMBER 25, 1972 11:00 A.M.

I certify that this message is official business, is not personal, and is in the interest of the Government.

Francis T. Mayo
(Signature)

SECURITY CLASSIFICATION
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western union **Telegram**

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526PEDT

MR FRANCIS MAYO, CHAIRMAN

LAKE MICHIGAN ENFORCEMENT CONFERENCE 1 NORTH WACKER DR /CHICAGO ILL

DELIVER DO NOT PHONE

I WOULD LIKE TO EXPRESS TO THE LAKEMICHIGAN ENFORCEMENT CONFERENCE ONCE AGAIN MY DEEP CONCERN OVER THE DANGERS OF THERMAL POLLUTION IN LAKE MICHIGAN. THE NEED FOR INCREASED RESERVES OF ELECTRICAL POWER IN THE MIDWEST MUST BE BALANCED AGAINST PRESERVATION OF THE ECOLOGY OF THE LAKE. UNTIL SUFFICIENT DATA, PROVING BEYOND ALL DOUBT THAT HEATED DISCHARGES ARE NOT THE CAUSE OF SIGNIFICANT ECOLOGICAL HARM, CAN BE GATHERED FROM THOSE FEW PLANTS PRESENTLY UNDER CONSTRUCTION, FURTHER CONSTRUCTION OF THE MANY FACILITIES CURRENTLY IN THE

SF-1201 (R5-69)

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PLANNING STAGE SHOULD NOT BE PERMITTED.

I REITERATE MY POSITION AS PRESENTED TO THE CHAIRMAN OF THE 1971 LAKE MICHIGAN ENFORCEMENT CONFERENCE THAT FUTURE CONSTRUCTION OF NUCLEAR PLANTS WITHOUT A TESTED LAKEWIDE STANDARD DERIVED FROM AND APPLIED TO THOSE PLANTS PRESENTLY UNDER CONSTRUCTION WOULD BE A GRAVE MISTAKE ENDANGERING THE FUTURE OF THE LAKE AND THE LIVES OF THOSE MILLIONS WHO DEPEND UPON IT FOR THEIR WELL- BEING

I STAND READY

READY TO WORK WITH THE CONFERENCE IN IMPLEMENTING THESE RECOMMENDATIONS IN SUCH A WAY THAT THE INTERESTS OF THE CITIZENS OF THE MIDWEST ARE BEST SERVED IN TERMS OF ADEQUATE POWER RESOURCES AND PROTECTION FOR LAKE MICHIGAN

ADLAI E. STEVENSON III UNITED STATES SENATE.

SF-1201 (R5-69)

KALAMAZOO
Nature Center INC.
FOR
ENVIRONMENTAL EDUCATION

7000 N. Westnedge Avenue
Kalamazoo, Michigan 49007
Telephone (616) 381-1574

September 21, 1972

Lake Michigan Enforcement Conference
Francis T. Mayo
1 North Wacker Drive
Chicago, Illinois 60606

Dear Sir:

The Board of Trustees of the Kalamazoo Nature Center of Kalamazoo, Michigan, were shocked and concerned about the condition of the waters of Lake Michigan as reported by the Enforcement Conference.

We urge that the Enforcement Conference adopt stringent standards to insure protection of water quality of the lake.

Please include this in the record of the Enforcement Conference proceedings.

Very truly yours,

Daniel R. Smith
President, Board of Trustees

DRS/vg

THE ROLE OF LAND USE MANAGEMENT AND ACCELERATED EUTROPHICATION OF LAKE MICHIGAN

The biosphere consists of many interacting ecosystems. There is a multitude of interacting biological and physical factors within each of these ecosystems. Mankind has greatly altered most of these natural systems, and we are now having to try and correct some of the results of these manipulations. We are just beginning to become cognizant of some of the ramifications of the changes that we have brought about in these ecosystems. One of these has been the increase in rate of eutrophication of Lake Michigan. Many of the changes in these systems involve alteration of land use patterns.

The general nature of the natural systems in the Lake Michigan watershed have been briefly examined in an attempt to determine causes for the degradation of water quality in the lake. A major input into the lake of the element phosphorous has been demonstrated to come from sedimentation in the basin. This relationship between land use and management and accelerated eutrophication of the lake is the topic of this testimony.

Forested communities which dominated the region surrounding the Lake are very effective in trapping and cycling plant nutrients. The boll of the trees contain considerable quantities of nitrogen, phosphorous, and other necessary plant nutrients. Soil erosion and sedimentation from these kinds of plant communities were insignificant. The result of these processes was a very low attrition of nutrient/ sediments into the lake.

Phosphorous is an element which is a plant nutrient frequently involved in accelerated eutrophication of waters. Ground water sources do not contain large concentrations of phosphorous because the soils in the watershed effectively filter out most of the pho...

from the percolating waters. The form in which this is held i...

dependent upon the pH or reaction of the soil system. ...nce erosion

of the soil matrix takes place, then large quantities of the phos-

phorous may enter the lake.

Two land uses will be examined in some detail to emphasize the necessity of placement of high level priorities on land use planning and implementation. The first is agricultural land use. Major technological changes have taken place in this industry duri... the last twenty years. There has been an abrupt change to much larger and more efficient farming equipment, increased uses of ... cides and fertilizers and alteration of many associated agron... cultural practices. The small diversified farm has suddenly ... large-based corporation. These alterations have res... input act of agriculture on the envi... of modern agricultur...

projects. These projects potentially remain the best ative to the "cement, steel, and large dam" philosophy of the U.S Corps of Army Engineers. The small watershed projects do include conservation planning in the basin but unfortunately many of these plans are never implemented. Agreements between Soil Conservation District Cooperators and the Soil Conservation Service are not binding. The Soil Conservation Service has drifted off into the cement and steel philosophy of the Corps of Army Engineers many times instead of dealing with the real problem of getting each acre of land used within its capability. Channelization and dam construction are not viable bstitutes for good land management. They tend to treat only the toms of man's mismanagement rather than the causes.

he second land use problem that directly dea ication process going on g from in the watershed effectively filter out most of the phosphorous from the percolating waters. The form in which this is held is dependent upon the pH or reaction of the soil system. Once erosion of the soil matrix takes place, then large quantities of the phosphorous may enter the lake.

Two land uses will be examined in some detail to emphasize the necessity of placement of high level priorities on land use planning and implementation. The first is agricultural land use. Major technological changes have taken place in this industry during the last twenty years. There has been an abrupt change to much larger and more efficient farming equipment, increased uses of pesticides and fertilizers and alteration of many associated agronomic or cultural practices. The small diversified farm has suddenly become a monoculture-based corporation. These alterations have resulted in major changes in the input act of agriculture on the environment.

The monoculture system of much of modern agriculture has increased the need for pest control and fertilizer use but perhaps the most important change has been in soil erosion control. Small fields of pasture land, small grains and row crops can be arranged in a landscape so that minimal amounts of sediment are lost from an agricultural area. This is not the case with many modern farms which are dependent upon large fields of a single crop. A tragic loss in soil erosion control practices such as contour strip cropping, grass waterways, and terraces has also resulted from these changes in land management.

The Soil Conservation Service remains the primary agency responsible for soil erosion control in this country. This federal agency does considerable conservation planning on small watersheds through the P.L. 566 projects. These projects potentially remain the best alternative to the "cement, steel, and large dam" philosophy of the U.S Corps of Army Engineers. The small watershed projects do include conservation planning in the basin but unfortunately many of these plans are never implemented. Agreements between Soil Conservation District Cooperators and the Soil Conservation Service are not binding. The Soil Conservation Service has drifted off into the cement and steel philosophy of the Corps of Army Engineers many times instead of dealing with the real problem of getting each acre of land used within its capability. Channelization and dam construction are not viable substitutes for good land management. They tend to treat only the symptoms of man's mismanagement rather than the causes.

The second land use problem that directly deals with the sediment/eutrophication process going on in Lake Michigan is the disturbance resulting from construction projects. This disturbance of soil and vegetation results in massive losses of sediment when adequate controls have not been installed. Disturbance of the vegetation and subsequent exposure of the mineral soil results in erosion. Again, this sediment becomes a major water pollutant. The technology to control these inputs of phosphorous into the lake clearly exists and the socio-economic costs are quite low.

The importance of land-use planning in the restoration or maintenance of a quality environment cannot be overstated. The soil and other associated resources are the basis upon which man survives on this planet. The capabilities of these resources should therefore be very carefully evaluated when dealing with any environmental problem. The basic planning procedures suggested here have already been developed and utilized. Ian McHarg's work in the Minneapolis and St. Paul and Baltimore areas has developed practical methods of using this kind of information.

The following are some recommendations for dealing with this problem and its solution:

1. To emphasize the importance of broad-scale land-use planning in all attempts to preserve or restore the quality of the water in Lake Michigan.

2. To work for some alteration in procedures and practices to place greater emphasis on land-use planning by the Soil Conservation Service. For example, binding agreements concerning land use could be made a part of the P.L. 566 program.

3. To recommend the establishment of regional erosion or sediment control laws--i.e., similar to the one recently passed in the State of Iowa.

4. To recognize and stress in all planning and control activities the interrelationships between natural resources.

☆U.S.Government Printing Office: 1974 — 751-197