ILLINOIS POLLUTION CONTROL BOARD

June 9, 1971

In the Matter of	)	
	)	# R 70-2
THERMAL STANDARDS,	)	
LAKE MICHIGAN	)	

Opinion of the Board (by Mr. Currie):

We have before us a variety of proposals concerning standards governing the introduction of heat into Lake Michigan. The subject has attracted an extraordinary degree of public interest. We have held four days of public hearings on our own, and we have also participated in two multiple-day workshops on the subject sponsored by the Federal Water Quality Administration and its successor under the umbrella of the Lake Michigan Enforcement Conference. We have accumulated mountains of scientific testimony as to the physical fate of heat discharged into the lake, as to the effects of heated discharges upon lake ecology, and as to methods of reducing heat discharges. On May 3 we published a proposed final draft regulation, together with a detailed summary of the facts and arguments supporting that draft. After allowing another month for additional comments, we have today adopted the final regulation. This opinion gives our reasons.

The present regulations applicable to Lake Michigan (SWB-7 and SWB-15) prescribe an absolute maximum lake temperature of 85° and forbid an increase of more than 5° F. above natural temperature. Technical Release 20-22, never adopted as a regulation, provides for a mixing zone of 600 feet from the point of discharge; we have held in the analogous case of the Illinois River (SWB-8) that the technical release states the implicit understanding of the prior Board in adopting the water quality standard. See Application of Commonwealth Edison Co. (Dresden #3), # 70-21 (March 3, 1971).

With the start of construction of several large nuclear generating stations along Lake Michigan, considerable public concern was expressed lest the addition of large inputs of waste heat cause harm to lake ecology. In response to this concern Assistant Secretaries of the Interior Klein and Glasgow, in 1970, proposed to the Lake Michigan Conference -- composed of the water pollution agencies of Illinois, Indiana, Michigan, Wisconsin, and the federal government -- that a new standard be adopted forbidding discharges more than 1° above normal lake temperatures.

Shortly thereafter, the Illinois Environmental Protection Agency submitted to the Board three alternative proposals regarding thermal standards for the Lake. The first would preserve the present 85° and 5°-rise standard, presumably outside a 600 feet mixing zone; the second would impose a set of monthly maximum lake temperatures and a 3° rise limit outside a mixing zone varying with the volume of the discharge; the third would impose the Klein-Glasgow 1° effluent standard.

We scheduled and held extensive hearings, which were largely duplicated in a conference workshop also held in the Fall of 1970. The Federal agencies presented detailed written documentation of their case for a strict effluent standard, which was by then phrased so as to forbid any significant heated discharge. In the Conference workshop the federal agency also submitted its witnesses for questioning. Extensive testimony in support of the federal position was presented by numerous citizens, conservation groups, and elected officials, including the Attorney General of Illinois. During our hearings and the workshop the Illinois Environmental Protection Agency refused to take a position on any of the three proposals it had made, or to offer any evidence. Later, however, the Agency came out in favor of a ban on all heated discharges larger than those from motorboats. Extensive evidence was presented by power companies and by other witnesses, on our hearings and in the workshop, in opposition to the federal proposal.

The Conference appointed a technical committee to draft a recommended standard on the basis of the evidence. The committee report, received in January, 1971, essentially found the evidence inconclusive and recommended that cooling devices to reduce heated discharges be required on all sources unless proof was made, by a date to be set by the Conference, that no significant harm was caused or would be caused by the discharge. This proposal would have had the effect of shifting the burden of proof and of postponing the decision.

Another session of the Conference was held in March, 1971, ostensibly to discuss the committee report. In preparation for this session the Board prepared detailed findings of fact and a tentative statement of position, which were distributed to other Conference members in advance. On the evening before the Conference reconvened, we were called into private session by the federal conferee and for the first time given another new federal position statement, together with detailed proposed regulations for implementing it. The essence of this position was that cooling towers or the equivalent would be required on large heat sources under construction as well as on those to be built in the future, and that restrictions were to be placed on some existing sources as well. It was made clear that the federal government intended to attempt to enforce its proposal whether or not the States went along.

The March session of the Conference elicited a large quantity of repetitive testimony and a new blast of objections from the power companies. At the close of testimony the Conference adopted virtually all of the Board's suggested findings of fact. With Illinois dissenting alone, the latest federal position was adopted. The position of the Board, representing Illinois, was that the addition of significant new heat sources not yet in operation or under construction should be prohibited. The regulation adopted today embodies this position.

The difference between our position and the federal is an important one, but it should not be exaggerated. As is evident from the unanimous Conference adoption of the essence of our fact findings, there is no substantial disagreement as to the facts. Our conclusion from these facts is that a few nuclear plants can be expected to have minor and local adverse effects, but, unless they are placed so as to interfere with significant spawning grounds, are not likely to affect the lake as a whole. Most significantly, the fear of an artificially warmed breeding ground for undesirable algae, so far as a single well-designed plant is concerned, is essentially ruled out by the evidence. Moreover, the costs of backfitting alternative cooling devices are in the tens of millions of dollars for an individual large plant, and the possibilities that such devices themselves--such as cooling towers--might have adverse affects of their own has been raised and not disproved. On the other hand, it is clear that the unlimited proliferation of such plants could have a very serious adverse effect on the lake, and it is this threat of proliferation that forms the backbone of the case presented by the federal agencies.

Reasonable men can differ as to the proper course of action to take on the basis of the essentially undisputed facts. The federal position is that, since we do not know for sure that plants under construction will not significantly harm the lake, they should be backfitted with cooling devices. Our view is that the record tells us enough to make the danger of serious harm from these few sources quite small, and that it would not be a wise use of resources to require the expenditure of large sums of money in order to avoid the relatively insignifcant harm that is likely to result from a few instances of once-through cooling, especially in light of the possible adverse effects of the cooling towers themselves. We think the most significant fact is that all four states and the federal government are now firmly on record as opposing proliferation of once-through-cooled plants beyond those now under construction. Proliferation is the problem, and Illinois by the present proposed final regulation will outlaw proliferation. It is our sincere hope that the other states will follow suit. Moreover, we are committed to requiring backfitting at any time that significant ecological harm is in fact shown.

It should be added that the Board is required by statute to base its decisions on an objective assessment of facts presented on the record. We have not the latitude to decide on the basis of the preferences of the most vocal of our constituents. One result of our proceedings has been the compilation of an extensive record and detailed findings of fact. The General Assembly, which has the last word, will be free to take those findings and come to some other conclusion on the basis of factors beyond the cognizance of this Board.

I. The Record.

1. Sources and Fate of Heat Discharges.

Lake Michigan receives enormous natural heat inputs from the sun and substantial ones from its tributaries, which commonly exceed lake temperatures by as much as seven to twelve degrees (R. 732). In addition, existing man-made sources in 1968 were estimated by the Fish and Wildlife Service (U.S. Department of the Interior) to contribute about 40 billion BTU's per hour. By far the largest single category of man-made heat sources is the electric power industry; nearly 30 billion BTU's per hour were said to be added in 1968 by plants totalling 7,600 megawatts capacity. The steel industry is said to account for over half the rest, and municipal sewage effluent is listed as a significant source as well. Over one third of the input from power generation and most of that from steel are found in the southwestern part of the lake shore, including the Illinois shoreline. Additional generating plants under construction and scheduled for operation by 1974 would increase the total shoreline capacity to 15,626 megawatts--nearly twice what it was in 1968 (see Ex.11, USDI Fish & Wildlife Service, Physical & Ecological Effects of Waste Heat on Lake Michigan, pp. 27-34). These facts are not disputed.

Among the generating stations now under construction are two 1100 megawatt nuclear units of Commonwealth Edison Company at Zion, Illinois, with respective completion dates of 1972 and 1973 (Byron Lee, R. 249, 254). Because they are less efficient, nuclear plants produce more waste heat per unit of electricity produced than do conventional fossil fuel plants, and much less of the waste heat is discharged directly to the atmosphere from a nuclear plant than through the stacks of a conventional one. Consequently a nuclear unit discharges from twenty to fifty per cent more heat to its cooling water than does a conventional plant of the same capacity (Philip Gustafson, R. 605-06). Commonwealth Edison's principal witness on the physical aspects of heat based his calculations on the premise that a 1000 megawatt nuclear unit -- or a 1700 megawatt fossil unit -- would discharge to the water 6.8 billion BTU's per hour, or "six one-thousandths of one per cent of the average rate of heat input to the surface layers of the Lake due to solar radiation and atmospheric radiation" (D. W. Prichard, R. 362). Each unit at Zion will be ten per cent larger than this, so that the heat rejected will be on the order of seven and one half billion BTU's per hour for each unit, or fifteen billion in total. It is anticipated that cooling water for Zion will be taken in about 2600 feet from shore, will be raised in temperature as much as 20° F. as it passes through the condensers, and will be discharged about 760 feet from shore, and that each unit will require 1670 cubic feet per second, or 750,000 gallons per minute[1] (See Ex. 14, Pritchard-Carpenter report on Predictions of the Distribution of Excess Temperature in Lake Michigan etc., p. 1). These facts, too, are not disputed.

Water temperatures near the shores of Lake Michigan range from 32° to 82° F. (Ex. 11, supra, p. 10), and there are substantial short-term and short-distance fluctuations in temperatures (Philip Gustafson, R. 608).

Predictions by the Fish and Wildlife Service that electric generating capacity along the lake, if unchecked, would multiply by the year 2000 to ten times 1968 levels (Ex. 11, supra, p. 28) were not denied.

The volume of the Lake is estimated at 1,170 cubic miles (Ex. 11, p. 2). Nobody took issue with the conclusion that, if the heat input from all new sources projected for the year 2000 were evenly distributed throughout the entire Lake, water temperatures would be raised by less than one tenth of one degree (D.W. Prichard, R. 365). No one argued that such a rise would have any detectable effect. On the other hand, all witnesses agreed that such complete mixing was impossible and that areas in the proximity of heated discharges would bear a disproportionate share of the heat burden.

1. This compares with an average flow in the Grand River, largest tributary of the Lake, that ranges from 1500 to 7700 cfs depending upon the time of year (Philip Gustafson, R. 612).

It is also agreed that all substantial heat inputs that are contemplated will be discharged rather near the shoreline. The Fish and Wildlife Service, arguing for a strict limitation on heated discharges, attempted to show that the effect of heat additions will be essentially confined to a narrow (3 mile) strip of inshore waters of less than 100 feet depth as a result of currents that force effluents to parallel the shore and of a thermal barrier that develops chiefly during the spring and inhibits mixing with deeper water (Ex. 11. pp. 11, 13, 48). On these premises, and on the further assumption that a heated plume in contact with the shore will be diluted only on one side and thus more slowly, the Fish and Wildlife Service predicts the following:

1. that a single plume from a large power plant discharging at 18° above ambient lake temperature could raise lake temperature 2° or more over an area of twenty-eight square miles (p. 83);

2. that year-2000 discharges might be "so close together that their effects would merge" (p. 86) and might cause "warming of a large proportion of the beach water zone and certain adjacent waters" (p. 88); and

3. that 4.4% of the water in the "beach zone" (up to thirty feet in depth) in the Chicago-Gary sector of the lake would be drawn through power-plant condensers each day in the year 2000 (p. 90).

The impression conveyed by this presentation is that concentration of predicted heat effects in the inshore waters of the southwest corner of the lake may warm a substantial portion of those waters by two or more degrees in another thirty years.

Power industry testimony attempted to discredit the notion of the thermal bar. Dr. D. W. Pritchard testified as to experiments suggesting that there was considerable mixing across the thermal gradient, amounting to 1.83% of the inshore volume each day, about seventy times the quantity expected to be used for cooling in 1980 (R. 427, 889-90). He also testified that a properly designed plant (such as Zion) would assure dilution on both sides of the plume by directing the discharge sufficiently away from shore; would avoid intermingling of plumes by directing the two discharges at forty-five degree angles from the perpendicular, or at right angles to each other (R. 373, 414-15); would minimize contact with the bottom and affect only the top ten to fifteen feet of water (368, 439); and would minimize the surface area raised by more than one degree F. by discharging at a high velocity in order to maximize rapid dilution (R. 372). On the basis of mathematical calculations (modeling) he estimated that the discharge of water 20° above ambient from a 1000 megawatt nuclear facility (10% smaller than either Zion unit) so designed would raise the temperature ten degrees in six-tenths of an acre; five degrees in ten acres; two degrees in 99 acres; and one degree in 391 acres (R. 380).[2] On the same basis he predicted that heated discharges from power plants five-sixths as large as those predicted by the Fish and Wildlife Service for the year 2000 would raise the temperature ten degrees in 30.9 acres; five degrees in 525; two degrees in 5100; and one degree in 20,000 (R. 387). Twenty thousand acres, he pointed out, are fourteen hundredths of one per cent of the total area of the lake (id).

Dr. Prichard also attempted to show that the length of time any one molecule of water--and hence any microorganism in the water--would be exposed to measurably elevated temperatures would be much shorter than if the area affected were a discrete body rather than part of a very large lake. The time of transit from condensers to outfall at Zion is predicted to be two minutes; an organism discharged from the outfall would remain ten degrees above ambient temperature for forty-seven seconds, five degrees above for six minutes, and two degrees above for one and a half hours (R. 390).

Dr. Pritchard's conclusion respecting the thermal bar was hotly disputed (see Dr. John Carr, in Ex. 10, transcript of Conference Workshop, pp. 1235, 1238), and his estimates of both the areas affected by elevated temperatures and the exposure time of any given particle were questioned by federal witnesses on the basis of insufficient empirical verification of his model and because his conclusions could not be evaluated without knowledge of the equations on which they were based (Richard Callaway, Ex. 10, pp. 1320, 1331, 1380, 1393-84). No one, however, presented any contrary time exposure estimates or any alternative affected-area tables based upon similar design assumptions, and a brief independent review of Pritchard's work by an Argonne National Laboratory scientist engaged in similar work failed to disclose any obvious flaws (Barton Hoglund, R. 869-70), although the reviewer disclosed considerable uncertainty as to the accuracy of one assumption employed by Pritchard; whether this uncertainty would result in a larger or a smaller plume he could not say (Letter of Barton Hoglund to Hearing Officer Kissel, Nov. 30, 1970).

2. By doubling the volume of flow, Dr. Prichard testified, one could cut the discharge temperature to ten degrees above ambient and significantly reduce the area raised more than 2°. E.g., the area raised 5° would be reduced from ten acres to 2.6. The area raised 1° to 2° would be very slightly increased (R. 871-72).

Measurements of the thermal plume from the existing 1047 megawatt fossil-fueled generating station at Waukegan (R. 456), which discharges at about twelve degrees F. above ambient (R. 334), indicate that the plume is hard to detect at temperatures less than two or three degrees above ambient and that the plume is recognizable about 4000 feet from the outfall at the surface and 1600 feet at the bottom (Lawrence Beer, R. 484).

2. The Effects of Heat Discharges

The two types of possible heat damage most stressed in the evidence are adverse effects on fish and the encouragement of undesirable algae growths.

The following summary of heat effects on fish, which is not contradicted, is taken from the paper Physical and Ecological Effects of Waste Heat on Lake Michigan, prepared by the Fish and Wildlife Service (Ex. 11).

Excessive temperatures can kill fish; different species have different tolerance limits. Adult coho salmon, for example, die after 60 minutes' exposure to 77° F.; when they pass through the beach waters in late summer to spawn, average normal temperatures are as high as 69°; a rise of 8° F. in mid-August would raise temperatures beyond the lethal limit(p. 51). Fish acclimated to high temperatures, moreover, are susceptible to being killed in sudden upwellings of cold water such as often occur in Lake Michigan (pp. 53-54).

Outright fish kills, however, are not the only adverse effect of excess heat: "less well known but equally important are the temperature limits for successful survival in other situations where unfavorable temperatures reduce the ability of the organisms to move about, escape predation, compete with other species for food, and otherwise successfully complete all of the vital life processes and stages (including reproduction)" (p. 50). For example, a heat dose only 25% as large as that required to cause loss of equilibrium (which in turn is less than that required to cause death) "measurably increases the susceptibility of juvenile chinook salmon and rainbow trout to predation" (p. 55). The growth rate of coho salmon is most rapid at 59° and is calculated to decrease to zero at 69-70°; the efficiency of food conversion falls below 80% of maximum at 62°, and consequently "temperatures higher than 62° F. during the growth phase of the coho salmon can be expected to reduce the population success of this species" (p. 56).

Temperatures must be below 43° for five months to assure normal maturation of yellow perch eggs, and only five months average that cold in Lake Michigan now; "any delay in cooling in the fall or acceleration of warming in the spring will shorten the time available for maturation to a period less than that required" (p. 59). Whitefish spawn in November and December, and a drop to 42° is required; lake herring spawn somewhat later and require temperatures as low as 37-39°; yellow perch spawn in spring at optimum temperatures of 46-54°, and "one year in three, the addition of heat to the spawning areas at the start of the spawning season (May 15) would cause the optimum temperature for spawning to be exceeded" (pp. 61-62). On the other hand, spawning of the undesirable alewife, whose massive die-offs have caused severe beach nuisances, would be promoted by increased temperatures (p. 62).

Above 43.2° the yield from whitefish eggs is under 50%, and thus too low to sustain a successful population; "lake temperatures are already at the maximum tolerable for the successful incubation of whitefish and cisco eggs and the addition of heat to the lake in the fall in areas where the eggs of whitefish or ciscoes are incubating will reduce the viable hatch below the 50 percent level" (pp. 63-64). A 3.6° rise over normal temperatures would "shorten the incubation period of lake herring by at least 29 days . . ., causing the fish to hatch in a potentially hostile environment in which light may not be of the right intensity, or food may not be of the proper kind (species), size, or density to ensure survival" (p. 64).

No one disputed these arguments, although there was a considerable stress on the fact that the Fish and Wildlife Service conclusions were based on laboratory studies and on the difficulty of transposing laboratory results to actual field conditions. Dr. Edward C. Raney, an ichthyologist testifying at the request of Commonwealth Edison Co., agreed that no large heat sources should be constructed on or near spawning streams or where migratory paths would be affected (pp. 551, 582). He agreed also that large structures such as power plants "will cause some changes in the local environment" (p. 557). He agreed that at a plant such as Zion "most organisms including fishes will be denied some living space"--"a matter of acres"--in the vicinity of the heated outfall; that within "a small mixing zone" summer water temperatures would exceed lethal temperatures for organisms normally found in the area; that "seasonal temperature requirements for reproduction and other aspects of the life history of the fishes. . . are predicted to be satisfactory" "except for a few acres near the base of the plume;" and that the question for decision was "are you going to give up a few acres in order to make the best use of the resource?" (R. 554-55, 595). His argument was that the area affected would be so small in relation to the whole lake that no significant changes in lake ecology or injury to recreational uses would be expected to result from construction of the plant at Zion (R. 555, 557-58).

The response of the Fish and Wildlife Service is that the proliferation of plants projected for the next thirty years threatens to affect a significant portion of the inshore waters of the lake (Ex. 11, pp. 86-87), with consequent significant adverse effects on the ecology of the lake as a whole.

A related issue is the thermal and physical damage to organisms drawn through the condensers of power plants along with water used for cooling (Ex. 11, pp. 74-75). For example, the Fish and Wildlife Service argues that studies have shown whitefish larvae will not survive in the hottest part of a thermal plume from a power plant, and therefore they will not survive passage through the condensers, where temperatures are at least as high (T.A. Edsall, Ex. 10, pp. 1290-91). Mr. Edsall's conclusion is that "all or nearly all of the organisms in this intake water would be, in fact, killed" (id, p. 1292). Dr. Raney, for Edison, countered with results of a California power plant experiment showing that 95% or more of young chinook salmon survived for ten days after five minutes' passage through condensers with a 25° rise (R. 556-57). With respect to algae drawn through the condensers, Dr. Andrew Robertson (also for Edison) believed it "unlikely" that all would be killed and said that "any cells killed will be replaced quite rapidly as these materials are made available to other cells as part of this natural cycle", so that "it seems extremely unlikely that any noticeable effect on the ecology of the lake will result" (R. 523-24).

The Fish and Wildlife Service referred also to laboratory studies showing that when water is supersaturated with oxygen and other gases (as can occur when saturated water is warmed so as to decrease gas solubility), fish can be killed by emboli (E. 10 p. 1357); (Ex. 11 p. 76).

The growth of undesirable types and quantities of algae and other aquatic plants has been an increasingly serious problem in Lake Michigan. A report by Stoermer and Yang in 1969 (Ex. 11 p. 79) reported that "Lake Michigan is probably at the present time about at the 'break point' between rather moderate and transient algal nuisances, largely confined to the inshore waters, and drastic and most likely irreversible changes in the entire ecosystem". It is the position of the Fish and Wilflife Service, and a fear expressed by numerous witnesses, that "temperature increases, whatever the amount, will tend to promote these undesirable changes, especially in inshore waters"(ibid).

The principal argument in support of this position is that increased temperatures will tend to favor growth of the less desirable algal species, such as the so-called blue-green algae, which have a preference for high temperatures and which have a tendency to accumulate in large smelly decaying masses along the beach. The Fish and Wildlife Service points to the annual succession of algal species in Lake Erie as an example of what might happen in Lake

Michigan as nutrient supplies increase: "Diatoms appear first in late winter or early spring when temperatures begin to rise above freezing, following the winter period of relatively little algal activity. Diatoms reach their maximum at temperatures of 35° F. When the temperature rises above 50° F, green algae become dominant and remain dominant until the temperature nears its maximum of about 75° F. Above 75° blue-green appear, and as the lake begins to cool, very large blooms frequently occur". Thus it is argued that a rise in lake temperature would cause this succession to occur earlier in the year and would "lengthen the period of dominance of blue-green algae by simply sustaining temperatures above 70° for a longer period" (id., pp. 77-78).

Although one Edison witness testified that temperature changes "can change" not only the types but also "the amounts" of algae (Andrew Robertson, R. 522), another asserted that while increased temperature increases the rate at which growth takes place, "this does not mean that the total biomass, i.e., amount of algae present in the water, will be increased," since "the total amount of algae and other aquatic plants present in a given body of water is primarily dependent on the availability of aquatic plant nutrients, rather than on temperature" (Fred Lee, R. 506). Fish and Wildlife Service witnesses did not disagree with this conclusion (John Carr, Ex. 10 pp. 1245-46, 1258-59), except of course for their argument that algae might be abundant for longer periods of the year.

As for the effect of warming on species distribution, Dr. Lee (for Edison) testified that the causal relation between high temperature and blue-green species was unclear, since "some of the highest concentrations ever encountered by the author have been found under the ice in winter" (R. 510), and Dr. Robertson (also for Edison) added that the seasonal succession of blue-greens might be related to increasing light and to the presence of the thermocline--which inhibits passage of organisms into the deeper and darker parts of the lake--rather than to increasing temperatures (R. 956). Fish and Wildlife countered with the belief that temperature is causal (Charles Powers, Ex. 10 p. 1371). An Edison witness did concede that species changes "could happen" if "certain parts of the water volume" were permanently warmed above ambient" (Andrew Robertson, R. 576). However, Edison witnesses maintained, because "the exposure to increased temperatures for any particular parcel of water will be quite restricted in time", and because algae growth is slow in relation to residence time, the effect will not be the same as if a small pond the size of the affected area were heated; "there will be little time for new species, favored by the increased temperatures, to be established in a parcel of water before the water is returned to ambient temperature." For this reason, and because the area affected will be small in relation to the whole lake, they conclude that "there seems little likelihood that temperature conditions from a station like the one proposed at Zion. . .will have any appreciable effect on the ecology of the planktonic plants in the lake" (Fred Lee, R. 510; Andrew

Robertson, R. 525-27).

Fish and Wildlife did not argue against the premise that a single plant would expose algae to high temperatures too briefly to affect species distribution; its position was that "an extensive zone of thermal influence" attributable to a number of plants close together would favor the undesirable blue-greens (Ex. 11 p. 85).

Of related significance is the possibility that increased temperatures might increase the incidence of the bottom-attached plant Cladophora, which accumulates with detrimental effects along Lake Michigan beaches. Testifying that Cladophora does "cause a significant deterioration of water quality" in the lake, Edison witness Dr. Fred Lee predicted that "if a suitable substratum for the attachment of Cladophora occurred in the region of the discharge plume, Cladophora would be present at a slightly earlier date each spring as a result of heating the water in the order of a few degrees above ambient". He did not consider this possibility to represent "a significant effect on water quality" because the increase would be "barely perceptible" and since the area affected would be "completely insignificant" (R. 507-08). Dr. Robertson's testimony was similar. Recognizing the undesirability of Cladophora, agreeing that water temperature is a major factor controlling the types of attached algae, and saying that it would therefore be undesirable to have "any but a very small area of the bottom of the lake exposed to substantial temperature increases", he stated that the Zion outfalls would be "directed away from shore and in deep enough water so that little if any of the bottom would experience substantial temperature changes" (R. 518-20).

Fish and Wildlife also argued that "areas of high localized temperatures" could stimulate growth of the bacterium Clostridium botulinum type E, "which has caused dieoffs of fish-eating birds on Lake Michigan and has caused human mortalities" (Ex. 11 p. 74, Ex. 10 p. 1362). One power company witness argued that this organism is anaerobic and thus should not be found in heated plumes in Lake Michigan, where oxygen is presumably abundant (Jud Hipke, Ex. 10 p. 1360). Carlos Fetterolf of the Michigan water pollution agency observed that the most pronounced outbreaks of botulism have occurred in the fall when temperatures have begun dropping (id., p. 1366).

There is a shortage of field information on the actual effects of discharges such as are contemplated for the Zion plant upon an environment like that of Lake Michigan. The most relevant, but admittedly not wholly conclusive, study that has been made was an April 1968 survey by Drs. Wesley O. Pipes and Lawrence P. Beer of the thermal plume from Commonwealth Edison's Waukegan generating station. Dr. Pipes testified that the study failed to show "any significant difference between the Waukegan Station discharge plume and the control area on the basis of the water quality and plankton samples"; that "the benthic (bottom) organisms . . most indicative of good water quality. . .were found in reasonable numbers", and in "not greatly different" numbers than in the control area, in the area of the plume; that "gross pollutional effects as a result of condenser water discharges into Lake Michigan have not been found"; that any gross effects that might occur in the next several years "should be measurable as subtle effects now"; and that "between 500 and 1,000 samples collected over a one-year period" would be required to demonstrate such subtle effects (R. 301, 302, 306, 309, 310). The study is now under way (R. 315). Dr. Pipes acknowledged that the Waukegan study had consisted of "about a week's work on the lake"; that the Waukegan plant's capacity was about the same as either of the two units planned for Zion; that a nuclear plant rejects more heat than does a fossil fuel plant (like Waukegan) of the same capacity; that extrapolation to a situation involving numerous overlapping plumes would be dangerous; that the temperature rise across the Waukegan condensers (12°F.) is less than that (20°) planned for Zion; that he could not guarantee the effects of heat would be the same at a more advanced stage of eutrophication; that his tests did not include fish, although Conservation Department tests showed salmon, pike, and trout near the discharge; that benthic organisms are relatively scarce in the Waukegan plume because of wave action; and that there were considerably more nematodes and oligochaetes--indicators of pollution--in the Waukegan plume than in the test area. He attributed this last circumstance to organic pollution in the plume area. (R. 329, 331-39, 922-25, Ex. 11. pp. 10 31-33).

Throughout the proceedings Edison contended that any adverse effects that might occur as a result of thermal discharges in the next few years would be not only minor and local but also reversible:

> Thermal discharges, unlike other discharges, do not leave a residue in the water which must be flushed from the lake upon termination of the input. The thermal discharges continuously equilibrate with the atmosphere, there are no long term effects on water quality after the discharge is stopped. . . . It is reasonable to expect that upon termination of these discharges the affected aquatic organism will recover and repopulate the affected area with normal organisms.

(Fred Lee, R. 511-12.) Reminded that there are heat-induced changes (such as the making of toast) which are not reversed by subsequent cooling, Edison later presented several studies, none directly in point, designed to show that thermally induced changes are reversible--so long, of course, as a species is not reduced below viable numbers before heat inputs are terminated. These studies were concerned with conditions sufficiently far downstream from a thermal discharge to permit cooling of the water during passage, and with the recovery of a river after the results of of discharges of various kinds are washed away by incoming water of relative purity (see R. 910-22).

A variety of other possible heat effects were mentioned during the hearings, including a reduction in oxygen solubility concurrent with an increased rate of oxygen demand to degrade materials in the water (Rep. Robert Mann, R. 69); the possible reduction of ice that protects beaches against winter erosion (R. 1096); possible increases in corrosion of industrial cooling facilities (R. 269); more comfortable swimming temperatures (R. 275); and a longer navigation season (R. 276). Dr. Lee testified, relative to the first item in this paragraph, that Lake Michigan was sufficiently free of biochemical oxygen demand and that time-temperature doses would be sufficiently short that dissolved oxygen concentrations would not be significantly affected (R. 500-03).

3. Methods of Controlling Thermal Discharges

The Federal Water Quality Administration (predecessor to the present Water Quality Office of the federal Environmental Protection Agency) prepared a study entitled Feasibility of Alternative Means of Cooling for Thermal Power Plants near Lake Michigan (Ex. 12), which discusses four possible methods for minimizing heat discharges to Lake Michigan: evaporative cooling towers, dry cooling towers, cooling ponds, and spray canals. Some witnesses urged that waste heat be put to beneficial use (e.g., Rep. Robert Mann, R. 64), but there was no evidence that this laudable goal is practicable in the immediate future. Emphasis in the hearings was placed primarily on cooling towers, and to a lesser extent on cooling ponds.

No one denies that in appropriate cases all these alternatives are technically feasible. Edison's witnesses acknowledged that wet cooling towers have been rather extensively used elsewhere (George E. McVehil, R. 1036) and stated that the company was "by no means opposed to cooling towers or cooling ponds as a general matter" (O.D. Butler, R. 991-92). Moreover, no one denies that wet towers can be backfitted onto existing power plants, so long as adequate land is available. This capability in fact forms the basis of Edison's promise that if permitted to complete Zion with once-through cooling, it will install cooling devices later if harm to the lake ecology is shown (Byron Lee, R. 256-57), and Edison has prepared detailed esiimates of the cost of such backfitting with the clear implication that this is feasible (O.D. Butler, R. 996). The arguments over wet cooling towers have rather to do with their costs and their possible adverse effects, as well as whether there is any justification for requiring their use. It is also conceded that dry towers have been employed in sizes up to 150 mw; Edison argues that there may be danger in extrapolating design and cost figures to a plant the size of Zion, and FWQA does not argue that it is reasonable to backfit dry towers (R. 988, 991)

FWQA presented the following estimates of the impact of alternative cooling means upon busbar costs of electricity (which include both capital and operating costs of generation but not the costs of transmission or distribution) from new large power plants along Lake Michigan, in mills per kilowatt-hour:

	Fossil Plants	Nuclear Plants
Once-through cooling	4.57 to 7.53	4.37 to 7.60
Wet mech draft tower	4.65 to 7.65	4.46 to 7.74
Wet natural draft tower	4.71 to 7.75	4.51 to 7.82
Cooling pond	4.58 to 7.57	4.39 to 7.66
Spray canal	4.62 to 7.60	---- -- ----
Dry mech draft tower	5.03 to 8.23	---- -- ----
Dry natural draft tower	5.00 to 8.17	---- -- ----

(Ex. 12, p. V-22 and Supplement A, p. 13).

On the basis of these estimates FWQA states that the maximum economic penalty associated with a wet cooling tower system on either fossil or nuclear plants is on the order of 0.2 mills per kilowatt-hour, less than 3% of total busbar cost (ex. 12, p. VII-2; Supplement A, p. 14). Cost estimates were not made for spray canals or dry towers on nuclear plants, but FWQA states that "one would not expect any constraints upon their application to nuclear plants" (Supp. A, p. 14). Capital costs alone for wet towers FWQA estimates at from $3.49 per kilowatt of generating capacity (for a mechanical draft tower on a fossil plant) to $6.91 (for a natural draft tower on a nuclear plant) (Ex. 12, p. V-21; Supp. A, p. 13). Dry tower capital costs (for fossil plants) are estimated by FWQA in the range of $20 per kilowatt. On these figures the cost of wet natural draft towers for the two 1100-mw units at Zion would be $15,200,000. FWQA estimated that in the case of a new fossil plant the addition of wet mechanical towers would increase the average residential electric bill by five cents per month (O.D. Butler, R. 997).

Edison argued that FWQA's estimates were lower than manufacturers' quotations it had received even for new plants; but its principal argument was that the FWQA estimates were not applicable to the situation at Zion, largely because "more than 80% of the structural work" at Zion has already been completed. Consequently, Edison maintains, "the costs of applying wet or dry cooling towers at the present stage of construction of Zion station are in the order of 5 to 6 times the cost estimates in the report" (O.D. Butler, R. 982-83). FWQA conceded that its estimates did not take into account the peculiarities of individual sites (Ex. 12, p. VII-1).

Edison's figures contemplate a hybrid wet tower with mechanical draft but with a tall(250') hyperbolic shell, in order to minimize ground fog problems while avoiding heights that would interfere with nearby aircraft operations (O.D. Butler, R. 996-97). Largely because of backfitting, Edison's figure for the capital cost of such towers to serve the entire Zion capacity (2200 mw) is $116,855,000, as compared with FWQA's $15,200,000 for a natural draft tower, for capital costs of $53.72 per kilowatt as compared with FWQA's $6.91. (Ex. 36, p. 2). The increased cost of such a tower to the average residential consumer Edison estimates at sixty-nine cents per month, assuming an average present bill of $11.44.[3] (R. 998) To backfit dry towers at Zion, Edison says, would require the plant to be substantially rebuilt at a cost of half a billion dollars, increasing the average monthly residential bill by $2.95, or 25% (See Exhibits C, D, and E to the testimony of O.D. Butler; R. 990, 997-98). As for cooling ponds, Edison contends that FWQA ignored the cost of construction; that ponding is not a feasible alternative at Zion because "adequate land is not available"; and that to build a pond at Zion would add ninety-seven cents per month--not the two or three cents predicted by FWQA--to the average consumer bill (R. 990, 999; Ex. E to testimony of O.D. Butler). FWQA, since our hearings, has submitted a particularized critique of the company's Zion cost estimates, concluding for numerous reasons that the estimates are too high (Ex. 28). A report recently prepared for the Illinois Institute for Environmental Quality by Datagraphics, Inc., reviewing the conflicting estimates, concludes that "of the two estimates, the FWQA data are more believable, probably accurate for wet towers and 50 percent low for dry towers. The power company's estimates are probably high by factors of 2 to 4." (Ex. 34 , p. 107).

Edison argues that cooling towers themselves--especially wet towers--can have substantial adverse effects on the environment. Towers are massive--up to 500 feet tall and up to a half a mile long; they are "almost certain to be considered undesirable additions to the aesthetics of the Lake Michigan landscape" (R. 984, 1008). To be tornado-proof, Edison contends, towers must withstand 300 m.p.h. winds, but the strongest now designed can withstand only 170 (R. 984, 1003). The noise from fans in mechanical towers would be a "very serious" problems at Zion and other existing sites, "due to the limited size of the sites and the proximity of populous areas" (R. 985).

3. These estimates and those below include the indirect costs passed on to the consumer by industrial and commercial users of electricity.

Wet towers cool largely by evaporation, so that considerable volumes of water vapor are emitted into the air. This raises the possibility, Edison observes, that evaporative losses may be charged against Illinois' limited authority to divert water form Lake Michigan (R. 986-97 and Memorandum Regarding Consumptive Uses Under the Lake Diversion Decree, filed by Isham, Lincoln & Beale, attorneys for Edison). It also suggests the possibility, much stressed by Edison, of fogging and related effects on the atmosphere.

Wet towers at Zion, according to Edison witness George McVehil, would evaporate 18,000 gallons of water per minute (R. 1032). Taller towers would decrease the incidence of fog; the hybrid 250-foot towers contemplated as an alternative for Zion would, according to McVehil, cause fog episodes on five to thirty days per year, mostly in winter, mostly between there and nine a.m., and mostly "to the north and over Lake Michigan" (R. 1033-34). Icing is to be expected as well as impairment of visibility, and "a significant number of occurrences are indicated west of the plant, in the town of Zion, around Waukegan Airport, and especially along highways to the northwest" (R. 1034). Moreover, plumes even from tall towers "will often be extensive and persistent," and they "should be expected to at times create appreciable increase in cloud cover over the lake shore area, possibly interfering with aircraft traffic around Waukegan Airport" (R. 1033-34). Pictures of dense visible plumes from existing towers are in the record (appended to statement of O.D. Butler); Edison also reports a survey indicating that 17 of 47 utilities surveyed reported ground fog and 20 icing problems, a result Edison deemed especially significant since "the larger plants surveyed were all in the southwest or arid plains states" (R. 1035-36). Spray canals would cause more fog because they evaporate the same quantities of water and at ground level; cooling ponds would cause less because the evaporation occurs from a much larger area (R. 1039).

Dry towers avoid fog and diversion problems, but questions have been raised--not answered--concerning the possible effects of massive installations on the weather: "It has been estimated that such dry towers could induce sufficient vertical circulation to produce cumulus clouds of extensive magnitude. . . . Changes in precipitation and other weather effects are found down wind of large cities. These are believed to be ... caused, at least in part, by heat from the city." (R. 987-88). The possibility of many of these adverse effects is adverted to as well by Dr. P. F. Gustafson of Argonne National Laboratory, who notes also the problem of blowdown in wet towers: "Solids left behind in evaporation must be removed, as must slime and algal growths, usually by back-flushing into the Lake" (R. 601-16). A witness from a downstate area in which Edison plans to construct a cooling pond reminded us that the neighbors do not always cotton to that solution either (R. 682).

FWQA's feasibility report anticipated several of these objections and sought to minimize their importance. Sites should be chosen, FWQA said, as far from highways and airports as possible, and downwind from them; in any case, studies are cited to show that fog from wet towers has proved no problem even in the foggy Appalachian region; and calculations based on emission volumes and dilution capacity of the air are said to indicate that "weather conditions in the Lake Michigan area are seldom severe enough to cause extensive fog conditions in the vicinity of wet cooling devices" (Ex. 12, pp. VI-3 - VI-20). FWQA concedes that the fog problem will vary according to local conditions.

FWQA compares evaporation losses from wet cooling devices with those induced by adding heated water to the Lake in order to show that the difference is not so great as might be supposed: Under conditions in which evaporation from a wet tower would amount to 10.6 cubic feet per second, once-through cooling would cause evaporative losses of 8.2 cfs (id., p. VI-25).

The blowdown problem, FWQA suggests, can be reduced "practically to the point of extinction by increasing the concentration multiple" because "the concentration of dissolved solids in the Lake Michigan is very low" (id., p. VI-29). This point was challenged during the federal thermal workshop, but FWQA adds that adverse effects can be minimized by chemical treatment of blowdown water (id., pp. VI-31, VI-38). Finally, FWQA adverts to the possibility of "drift": "water that is carried out of the top of a wet cooling tower or from a spray canal in liquid droplets rather than vapor." Drift, FWQA concedes, can cause problems with nearby transmission lines, but FWQA finds that drift problems have been "limited to the immediate vicinity of the tower installation" and adds that "mechanical draft towers can be purchased today with certification of drift elimination to the 0.02 percent level" (id., p. VI-27). FWQA does not comment on possible aesthetic objections to cooling towers, on noise, or on any weather effects from dry towers.

Edison points out that site-location methods of avoiding fog and drift problems are not feasible alternatives for Zion because of the advanced state of construction there (R. 979-80).

The Illinois State Water Survey, at our request, has performed a two-month investigation of the atmospheric effects of cooling towers. The Water Survey's preliminary report conveys much useful data but concludes that "meteorologists have not acquired adequate information to define in quantitative terms the meteorological consequences of the large amounts of heat energy and water vapor that are released into the atmosphere from cooling towers associated with nuclear power plants" (Ex. 32, p. 8).

4. Summary of Facts.

a. The area that would be raised in temperature more than 5° by the heated discharge from a 1000 mw nuclear plant, designed so as to maximize dilution, could be limited to the order of ten acres, and the area raised 2° to the order of 100 acres.

b. Such a plant could be built so that any given particle of water, or any organism, drawn through its condensers would be exposed to temperatures 20° above ambient for two minutes during passage, and any particle or organism discharged or entrained would be exposed thereafter to temperatures more than 10° above ambient for the order of forty-five seconds, more than 5° for six minutes, and more than 2° for one and a half hours.

c. A properly designed discharge structure can avoid any significant increase in temperature on the lake bottom or along the shore.

d. The lake as a whole would not be perceptibly warmed by even a tenfold multiplication of present generating capacity on the lake with once-through cooling, if there were perfect mixing.

e. Perfect mixing, however, is not possible. Consequently, if no limits are imposed the proliferation of electric plants along the lake may result in the warming by several degrees of a large fraction of the inshore waters, especially in the southwest portion of the lake.

f. The interaction of two or more thermal plumes may have a more than linear effect on the area affected by a rise in temperature and on the residence time of any particle at elevated temperatures.

g. A single 1000 mw nuclear plant will create a zone of a few acres uninhabitable by fish during the warmer months and unsuitable for spawning and other significant fish activities at various times.

h. Many, but an unknown percentage, of organisms passing thorugh the condensers of such a power plant will be killed or damaged by heat and by physical shock.

i. A single large plant located in a spawning ground or across a migratory route would significantly disrupt the balance of the affected species throughout the lake.

j. There is substantial agreement that the residence time of algal cells in the heated plume from a properly designed single 1000 mw plant is too short to cause any detectable shift to less desirable species, and no increase in total algal mass is to be expected.

k. Unless it is located so as to interfere with spawning or migration, a single isolated 1000 mw plant will have local effects as noted above but will not upset the balance of the lake as a whole.

l. Unlimited proliferation of electric plants along the lake could seriously worsen the problem of nuisance algae by favoring the less desirable species and could seriously alter the balance of fish and other organisms in the lake as a whole.

m. Various alternative methods of heat disposal are technically feasible, including wet and dry cooling towers, cooling ponds, and spray canals. The backfitting of all but dry towers is feasible.

n. To backfit wet towers at the 2200-mw nuclear plant now under construction at Zion, Illinois, would cost somewhere from fifteen to 117 million dollars; at a maximum this would cost residential customers each sixty-nine cents per month.

o. All alternative cooling means may have some undesirable environmental effects. Wet towers can cause fog problems; the Commonwealth Edison Company estimates fog from a wet tower on five to thirty mornings per year at Zion, usually in unpeopled areas. All towers discharge some polluted blowdown water that must be treated before release. Dry towers may cause as yet undetermined meteorological changes. Both wet and dry towers are bulky and unattractive additions to the lakefront. Evaporation from wet towers or spray canals arguably would be charged against Illinois' limited authority to divert water form Lake Michigan. Cooling ponds consume about two acres of land per megawatt, land that could be put to productive use.

II. Alternatives Open to the Board.

On the record we see the following possibilities for action:

1. Impose no limit on heated discharges to the lake. This alternative is wholly unacceptable, since unlimited proliferation of heat sources could very well have a very substantial detrimental effect on the ecology of the lake as a whole.

2. Outlaw all heated discharges to the lake, or all discharges above a given temperature (e.g., 1° or 5° above ambient), or above a given volume (e.g., 50 gallons per hour), with or without a grandfather clause. Such an approach would have the virtue of avoiding a later difficult and uncertain decision as to when the point of serious ecological risk is reached by a firm and early declaration that no significant thermal sources are to be allowed, and it would establish the position that not even a small percentage of the lake is to be sacrificed in the interest of inexpensive cooling.

3. Attempt to determine today the approximate thermal input that can be tolerated without harming the lake as a whole and without sacrificing undue percentages of the lake in the interest of inexpensive cooling, for example by limiting inputs to fifteen billion btu per hour within each twenty-mile stretch of lakeshore. This approach, while necessarily arbitrary in the same sense as is setting the voting age at 18 or at 21 years, has the advantage of attempting to avoid overall lake damage while accepting the argument that it is not worth millions of dollars to avoid making perhaps twenty acres uninhibitable by fish, and while allowing considerable use of a valuable natural resource, the cooling capacity of Lake Michigan.

4. Accept the federal Committee proposal to defer decision a few years in the hope that more complete information will be obtained, by placing the burden of proof on those discharging or planning to discharge heated effluents to show that their action will not cause ecological damage. This alternative preserves maximum flexibility to accommodate new knowledge, with a concomitant increase in uncertainty.

III. Reasons for Our Decision

There are two arguments for forbidding any new thermal sources to Lake Michigan. The first is that the people should not be asked to sacrifice even a few acres of the Lake in the interest of inexpensive cooling, that the exclusion of fish from a few acres near the outfall and the damaging of the organisms drawn through the plant condensers are in themselves intolerable even though the effects are entirely local. The second is that the only logical place to draw the line is at the beginning, that it is likely to be as impossible in any future case as it is today to find that any particular plant will cause harm to the lake as a whole, and therefore that unless all future discharges are forbidden there will be a proliferation of heat sources that will have serious effects on the whole lake. The analogy is to the slow acre-by-acre filling of San Francisco Bay: Each few acres may be insignificant, but the net effect after a few years is to diminish radically the area and utility of the Bay.

One difficulty with the first argument is that it may not be worth fifteen million dollars (to use the lowest estimate), or about 117 million (to use the highest), to prevent the bruising or broiling of a number of organisms of no significance to the overall lake ecology and to assure fish a few more acres to inhabit. A second difficulty is that to order an end to further heat discharges is to forbid the use of a valuable natural resource, the cooling capacity of the lake water, in order to prevent a rather minor injury to the Lake. A third is that there may be environmental disadvantages from alternative cooling methods as well: fogging (and possible accidents) from wet towers and possible meteorological effects from dry; the displacement of worthy land uses by cooling ponds; the unattractive and bulky insults to the lakeshore from any type of tower; and the added power that must be generated, with its own environmental problems, in order to drive fans in mechanical draft towers. It is not altogether clear that, given the existence of a power plant on the lakeshore in a more or less populated area (as at Zion), once-through cooling really would be worse for the environment than would any of its alternatives. The plain fact is that there is no known means of producing electricity without some degradation of the environment. The villain of the piece is our apparently insatiable demand for electric power, which doubles every ten years. Some day we may have to ask ourselves whether we are not producing enough power, in light of the environmental costs of producing more. In the meantime we must recognize that to keep the heat out of the lake is not to avoid all harm to the environment, and that the environmental costs of alternative cooling means must be considered before we require enormous expenditures to avoid relatively minor damage to the lake.

In other words, to allow once-through cooling at any new site is to allow some degradation of the Lake, and thus it must be viewed with distaste. But we cannot ignore the costs of avoiding that degradation, and we cannot ignore the fact that some other part of the environment will be degraded if we attempt to give the Lake absolute protection.

Perhaps the strongest argument for the second theory for forbidding all new sources today--that the line must be drawn at the beginning to avoid proliferation--is that the above argument against strict regulation will apply equally to the second proposed plant, and to the third, and so on. It is unlikely that our information will ever be complete enough to permit us to identify which straw will break the camel's back. Shifting the burden of proof to the power companies to demonstrate the lack of harm seems not an answer to the real problem; depending on what is accepted as sufficient proof, this solution seems likely either to be the equivalent of a ban on future sources (since no one will be able to prove there will be no harm) or to result in very considerable proliferation (because the same showing of localized effect can be made of the two hundredth plant, assuming it does not interact with other plumes, as of the first).

We are therefore confronted with a situation in which an absolute ban would impose costs--in money, in secondary environmental effects, and in nonuse of the cooling resource--that are not justified by the benefits to be gained, while at some point in the continuum of additional sources the balance will be shifted. Where that shift takes place we do not know, and very probably we will never know. It therefore seems prudent to set a firm limit today on new heat sources to the Lake that is calculated to allow some significant use of the cooling resource and to avoid the adverse effects of alternative cooling means while at the same time providing a margin of safety to prevent either ecological damage to the lake as a whole or the sacrifice of excessive local acreages. It is proper to consider as well the built-up nature of most of the Illinois shore and the desirability of maintaining some open land for recreational purposes, as well as the general policy that Lake Michigan should be given special protection as a uniquely valuable recreational and water-supply resource. The Illinois lakefront is not the best place to put power plants, because both the land and the water are badly needed for other purposes.

It is for these reasons as well as the advanced stage of construction of the Zion plant that it seems appropriate to draw the line so as to allow operation of that one facility--with its twin 1100 megawatt units--without requiring cooling devices, so long as certain design precautions are taken, as the company has agreed to do, but to forbid any additional new heat discharges to the Illinois portion of the Lake. While the Edison company has no vested right to begin operating its plant as designed, the advanced stage of construction is a fact that must be considered. It means that alternative cooling schemes would be more expensive than if they were being built into a plant at the design stage. It means we are stuck with a power plant on the Lake whether or n t we forbid once-through cooling. And it means that alternative devices such as cooling towers are also likely to be located right at the lakefront, where they will be at their most objectionable. We can and will require backfitting of such devices if serious harm occurs after once-through cooling has commenced, and with reasonable assurance that any harm done will be local and reversible.

The question naturally arises how we can justify permitting even one large new thermal input to Lake Michigan, which could be avoided by existing technology, in light of our much sterner approach to inputs such as mercury and other toxic materials. Sound policy, as well as the statute itself, requires us to consider the costs as well as the benefits of pollution control, and it is a reasonable position that a single large heat source on Lake Michigan will cause so little harm that it is not worth several million dollars to avoid it, especially since other adverse environmental effects would be likely to result if alternative means were used. This conclusion is based upon the record in this proceeding, which establishes in addition to the above facts that heat itself is not a nuisance, as is sewage; that it is not persistent or biologically concentrated, as is mercury;

and that its effects are likely to be reversible. It is perfectly consistent to make an entirely different assessment of probable costs and benefits in dealing with another pollutant with different characteristics, even though in both cases there is an inability to quantify the benefits of pollution control. Similarly, today's ruling in no way binds the Board to adopt the same thermal regulation for other bodies of water, since the relevant facts -- such as the volumes available for dilution purposes -- may differ from stream to stream.

Accordingly, we have adopted three different standards according as the heat source is already in operation, under construction, or proposed for the future. Large future sources are forbidden to employ once-through cooling without auxiliary cooling devices because the proliferation of such sources would mean that not just insignificant portions of the Lake are being warmed. Sources under construction -- Zion -- are required to meet conditions, substantially agreed to by Edison, to assure that the area affected is small, but are not required to employ auxiliary cooling because the backfitting expense does not appear justified in light of the small area concerned. Existing sources, which are relatively small, and new sources not large enough to fall within the requirement of auxiliary cooling are required to meet a 3°-above-natural-temperature standard, and to satisfy specified monthly maximum temperatures, at the edge of a mixing zone whose area is that of a circle with a radius of 1,000 feet. The basis of this regulation, which departs somewhat from that presently in force, is that while the heating of any significant portion of the Lake would be intolerable, the considerable costs of auxiliary cooling make it unwise to outlaw small mixing zones in which temperatures may be elevated somewhat above natural. A more detailed discussion of this last provision, which applies to all sources now or to be constructed, is in order.

The standard as adopted is consistent with the recommendations of the National Technical Advisory Committee on Water Quality Criteria (NTAC) (Ex. 35, p. 43) and is essentially the same as that proposed by the federal Environmental Protection Agency at the March 1971 session of the Lake Michigan Enforcement Conference. It differs from the existing standard in a number of ways.

First, where the existing standard provides a single maximum of 85° which is never to be exceeded the new standard specifies a series of monthly maxima intended to preserve natural seasonal temperature variations. The monthly maxima presented at the conference by the federal EPA represent the dual policy that temperatures should be kept near normal at all times and that there are certain extremes that must be avoided even when normal variations are preserved. The need for a range of monthly limits to replace the existing 85° maximum was explained by Dr. Donald Mount, Director of the National Water Quality Laboratory:

> By way of introduction, I would emphasize that unlike pollutants such as DDT or lead we are not striving for a zero concentration, but rather for a range of temperatures which is best for the well-being of the aquatic biota of the Lake, and we further recognize that the temperature range is clearly different in various seasons. While toxicity levels may vary some, on the whole there is little difference in safe concentrations of DDT or lead as the seasons change. This is not so with the temperature requirements and so a single value is not enough to specify necessary temperature conditions. The problems of establishing acceptable temperature limits are further complicated because within some limits the aquatic biota has the capability of shifting critical seasons such as spawning to coincide with a faster or slower warming rate of the water, either from natural or artificial causes. On the other hand, since many of the important species require rather specific foods, particularly when they first hatch from the eggs, there is a danger of upsetting the timing of food supply of the right type with the various life stages of the desirable fishes in the Lake (Ex. 33, p. 104).

In addition, the new standard imposes a 3° rise above natural temperature limitation at all times at the edge of a 1,000 foot mixing zone as opposed to the present 5° rise limit at 600'. In terms of the relative areas affected the difference is a case of six of one and a half dozen of the other. In illustration of this Dr. Pritchard's model (Ex. 14 p. 54) of Edison's Waukegan Plant's plume indicates that 17 acres are heated 5° above natural temperature. This area is two thirds (65%) of that permitted by a circular 600' mixing zone (26 acres). For 3° the affected area is 48 acres which is still two thirds (65%) of that allowed by a 1,000' zone (72 acres). Thus the 2° decrease in permitted temperature rise is just offset by the increase in the mixing zone caused by going from 600' to 1,000'. The change, though a minor one, has been tentatively accepted by our sister Lake Michigan states and therefore to help insure the adoption of consistent lake-wide standards we modify our existing standard accordingly.

It is of course the area of the Lake subjected to a temperature increase which is the determining factor in this entire discussion. For this reason the regulation as adopted specifies an areal rather than a linear mixing zone concept. It is the amount of lake affected not an arbitrary distance from a point which is important. It is equally important, however, that the mixing area be fixed and not allowed to migrate with the vagaries of wind and current, both to afford relatively easy enforcement and to ensure that the affected area is, in fact, limited. The regulation as adopted would permit the use of discharge structures designed to minimize harmful effects even if such structures result in a fixed mixing zone of simple form other than a circle provided that the area affected is no larger than would be included in a circular zone. This provision is in keeping with the recommendation of the NTAC that: "Mixing should be accomplished as quickly as possible through the use of devices which insure that the waste is mixed with the allocated dilution water in the smallest possible area." (Ex. 35, p. 31).

The requirement that temperatures be raised no more than three degrees above natural at the edge of the newly defined mixing zone should impose no greater burden on existing dischargers than did the previous regulation. The largest such source is the Waukegan generating station of Commonwealth Edison and Edison's own testimony is that the Waukegan plume is 3° above ambient within only 46 acres, while our new mixing zone affords them about 72 (Ex. 14, [statement of D.W. Pritchard] , p. 54). The accuracy of this estimate has been questioned; an Argonne estimate is 270 acres (Ex. 38, letter from J. G. Asbury to Pollution Control Board, April 13, 1971). If the Edison estimate is right, Waukegan can easily meet this part of the new regulation; if Argonne's is right, Waukegan is in violation of both the new and the old standard, and the area affected is far too large. We trust the Agency will investigate the question.

Edison objected strenuously to the related federal proposal for existing sources, arguing that it might require the backfitting of cooling towers at Waukegan (at a cost of $12-16,000,000) and that in any event it would necessitate modifications in intake and discharge structures costing $9,000,000 (Ex. 36, Statement of O.D. Butler to Lake Michigan Enforcement Conference April 23, 1971, pp. 3-5).

It is not at all clear that our new standard will have any such effect. It will require modifications of the discharge structure if Argonne's estimate of the plume area is correct, but so would the old standard. It seems probable that the intake modifications discussed by Edison would be attributable to the federal recommendation that intakes be designed to minimize harm to entrained organisms, a requirement we have deliberately limited to facilities not yet in operation. And the effect of our monthly maxima upon Waukegan will probably be less severe than that of the federal because ours is based upon a fixed area equivalent to that of a 1,000 foot radius circle while theirs limits the linear extent of the plume in any direction. Plumes tend to be more or less cigar-shaped, skewed in the direction of the wind. In any event, a comparison between the monthly maxima and actual temperature readings in the Lake shows that only in October is there much likelihood that it will be more difficult to meet the maxima than to meet the 3°-above-natural requirement (R. 642). The October limit is 65°. In addition, Edison informs us that Waukegan temperature data indicate that there would be some difficulty in meeting the maxima on a couple of days in an average year, most likely in November (Ex. 39, p. 2). We think that if the necessity to avoid a 1° rise at the edge of the zone on one or two days each October or November imposes on Waukegan a substantial construction requirement that would not be imposed by the 3° limit the company might well apply for a variance. We do not view the possibility as justifying a change in the standard itself.

Edison has also commented that the redesign of discharge structures might be an acceptable method of preventing any ecological damage that might be shown to occur (Ex. 39, p. 2). It is not the intent of the Board to anticipate whether or not modifications of discharge structures will suffice to prevent ecological damage and the standard as written does not preclude their use.

I, Regina E. Ryan, Clerk of the Board, hereby certify that the above Opinion was entered on the 9 day of June, 1971.

Regina E. Ryan