Environmental Problem Solving

And the Dangers of Junk Science:

The Case of Ore Lake, Michigan

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Treatment of sanitary sewage for removal of diseasing-causing organisms and noxious chemicals is an important part of public health and environmental protection programs. Most people assume that environmental protection is best served when treatment technology is pushed to its limit in efforts to remove as much material from wastewater as community finances can afford. Conventional wisdom holds that a principle of zero discharge is the ideal goal, to the extent that the goal is attainable. This case illustrates an example where conventional wisdom would lead to environmental consequences that are exactly opposite to those desired. It also illustrates how a scientifically unsophisticated but well-intentioned public is susceptible to flawed science that is promoted for specific economic or political agendas.

Introduction

The City of Brighton and the Township of Hamburg are situated within the watershed of the upper Huron River in southeastern Michigan. Stream drainage relationships are such that Hamburg lies downstream from Brighton along a tributary to the Huron River known as South Ore Creek (Figure 1.1).

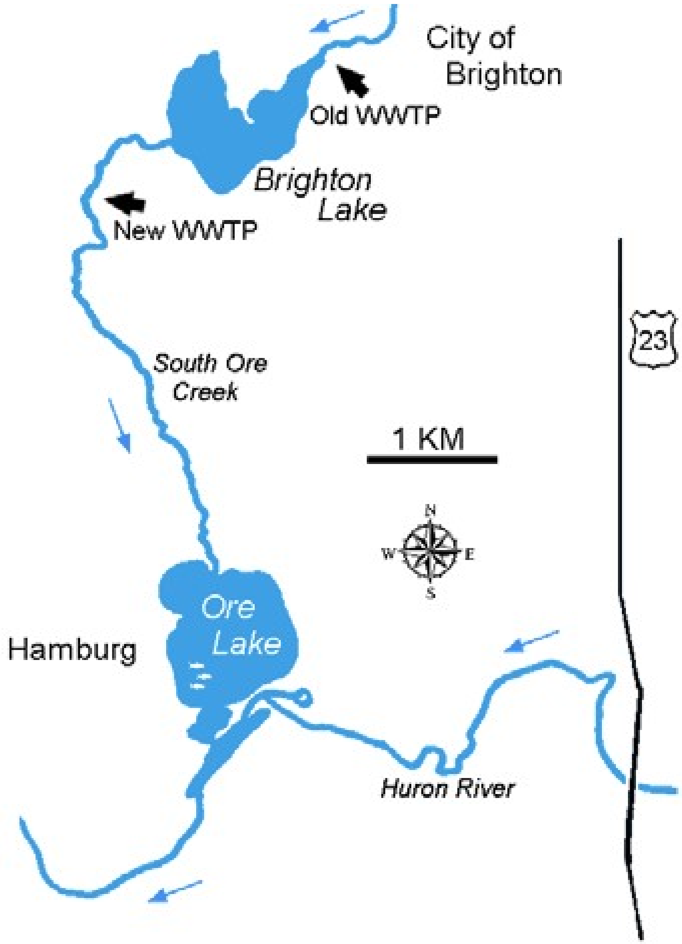

Figure 1.1. Geographic relationships of the City of Brighton and the Township of Hamburg, with stream drainage directions indicated.

The two municipalities have a history of disputes argued before local and state courts over water quality issues. Until the 1980s, Brighton had relied on an archaic wastewater treatment facility built in 1939. The facility was situated at the head of Brighton Lake, which is a man-made impoundment. The old facility practiced secondary treatment of sanitary wastes, which means that it processed raw sewage to decompose organic matter and to eliminate disease-causing bacteria. It released a discharge into Brighton Lake that was rich in chemical nutrients, including phosphate and nitrate. As a result of these fertilizing nutrient discharges, Brighton Lake as well as Ore Lake further downstream developed nuisance growths of algae each summer. Rich crops of algae formed floating scums and turned the lake waters blue-green. Rotting algae rafted to shore, causing foul odors and turning the lakes into eyesores.

As early as the mid-1960s, lakeshore residents of Ore Lake organized a lake association and tried to improve conditions in the lake. But in that era before the advent of federal clean-up grants, the costs and political mechanisms for action proved insurmountable. By the late 1970s, however, environmental awareness had heightened, and growing population in the County was compounding both the problems and the community sense of mission. The Michigan Department of Natural Resources, moreover, undertook a scientific study (Grant 1978) that confirmed through measurement and analysis that the cause of the unsatisfactory lake conditions was the Brighton wastewater treatment plant. The offending pollutant, according to the report, was phosphorus. Released in liberal quantities from the wastewater treatment plant, phosphorus served as rich fertilizer for the nuisance crops of algae. Although Brighton's facility was old, it nonetheless operated well within existing legal phosphorus discharge limits.

Concerned citizens of Hamburg Township organized a grass-roots action committee with a specific goal in mind. They formed S.T.O.P.P., the Society to Oppose Phosphorus Pollution, and they sought to convince the state Water Resource Commission to lower Brighton's phosphorus discharge limit below the existing state legal limits. In 1981 S.T.O.P.P. contested the National Pollutant Discharge Elimination System (NPDES) permit issued to Brighton. S.T.O.P.P. based its objections on the opinion that discharge of phosphorus from the Brighton Wastewater Treatment Plant (WWTP) was creating a public nuisance to the waters and property of citizens in the receiving community. S.T.O.P.P. accused Brighton of causing *cultural eutrophication*, or artificial nutrient enrichment of the lake waters by human activities. S.T.O.P.P. sought to force Brighton to implement new practices and technology to reduce its discharge of phosphorus. S.T.O.P.P. was joined in its arguments by the Michigan Department of Natural Resources, whose scientific evidence weighed heavily in the case.

After two years of arguments and hearings, the state commission agreed to lower the discharge limits for Brighton to a level that was lower than its old existing plant could achieve. Brighton appealed the decision administratively in Lansing, the state capitol, but lost. It then fought the decision in state district court, but S.T.O.P.P. and state officials prevailed again. Brighton was compelled to dismantle its old WWTP and to build a new facility with state of the art phosphorus removal technology. Brighton nonetheless continued to resist the edict, by essentially pleading that the new construction was an unfunded mandate imposed upon the City by the courts. The State of Michigan responded with a grant to Brighton to enable it to finance the new $16 million dollar construction project. The City of Brighton built its new plant downstream from Brighton Lake outside the city limits of Brighton and inside the township limits of Hamburg according to mutual agreement and contract with the adjoining municipality. Brighton agreed to receive and process a limited amount of sewage waste from Hamburg Township in exchange for the ability to situate its new facility on a large plot of land suitable for the phosphate removal technology that would be applied.

Significance of Phosphorus

Why did the founders of S.T.O.P.P. target phosphorus in their campaign to improve water quality? Phosphorus is one of many chemical elements that are essential components of all living protoplasm. It is part of the chemical backbone of DNA, and it is necessary for life processes, but other chemical elements are necessary, as well. Phosphorus in fact is not even a major chemical constituent of plant and animal tissues; it composes only about one percent of cell contents not counting water. Living organisms contain far more carbon, oxygen, hydrogen, and nitrogen than phosphorus. The key to understanding the significance of phosphorus in cultural eutrophication is to understand first that essential elements like phosphorus or carbon are used in relatively fixed proportions to one another when new organic matter is being produced.

Alfred Redfield, a scientist at Woods Hole Oceanographic Institution in the middle of the 20th Century, was first to point out that for every atom of phosphorus in algal cells there are on average 16 atoms of nitrogen and 106 atoms of carbon. The "Redfield Ratio" among chemical elements became known as the assembly rule for making algal cells in nature. Just as assembly of a passenger sedan calls for 4 tires and 2 windshield wipers in proportion to each steering wheel or transmission, living protoplasm needs its building blocks in the right proportions, too. If the automobile parts in an inventory included only 3 times as many brake parts as steering wheels, we could predict that automobile construction would more likely be limited by brakes than by steering wheels. So it is with the chemical elements that are needed to make up algal cells.

Phosphorus is a chemical element that occurs environmentally in the molecular form known as phosphate. Phosphate exists in combinations with both inorganic minerals and with organic material, and can be found as solids, gels, or in dissolved states. Phosphorus is not found naturally as a gas at environmental temperatures and pressures. So when algae take up phosphate in order to make new cells, they get their phosphate from dissolved substances in the water.

When algae need to get carbon, which they need in much greater amounts than phosphate, they also take it up from chemical forms in the water. Algae use dissolved carbon dioxide and sometimes bicarbonate as their carbon source. Carbon dioxide is also present as a gas in the atmosphere. When algae take the carbon dioxide out of the water to use it in the carbon of their own protoplasm, more carbon dioxide gas diffuses into the water from the air and replaces what was consumed. The reservoir of carbon available to algae in a lake is therefore effectively inexhaustible. This is not so with phosphate, which has no atmospheric reservoir. It makes sense to try to limit the amount of phosphate flowing into a lake because its limitation can eventually stifle the production of new algae. Production of algae can be halted even though they have unlimited access to carbon, and even though carbon is something they use in hundred-fold proportion to phosphorus.

Features of the Brighton Wastewater Treatment Facility

The new facility constructed by Brighton during the 1980s incorporated design features that are remarkably effective in curbing its discharge of phosphorus. Both chemical and biological methods are used to achieve the desired objectives. Beyond the standard secondary treatment of waste by means of biological oxidation (aerobic decomposition) of organic waste inside oxidation ditches, the Brighton facility includes four additional steps. Effluent water from the oxidation step (step 1) is low in organic matter but rich in phosphate and nitrate. This nutrient rich water is exposed to two stages of phosphorus removal by chemical precipitation in large tanks (steps 2 and 3).

The chemical principle at work in steps 2 and 3 is that phosphate forms insoluble mineral complexes with iron salts in the presence of plenty of oxygen. Substantial fractions of the phosphorus in the waste water are removed by these chemical means, although the process generates solid waste that must be hauled away and disposed of in landfill sites.

After two-stage chemical treatment, additional phosphate is removed through outdoor application of the treated effluent to soil and vegetation. First, the treated effluent is pumped over the dirt surface of large earthen filter cells that were excavated and packed with mineral soil in a field adjoining the WWTP buildings (Figure 1.2). The dirt filling these cells has the capacity to adsorb phosphate from the effluent as it percolates through the soil particles. The earthen filters are perched high above the local water table, so that the flow of effluent water is downward.

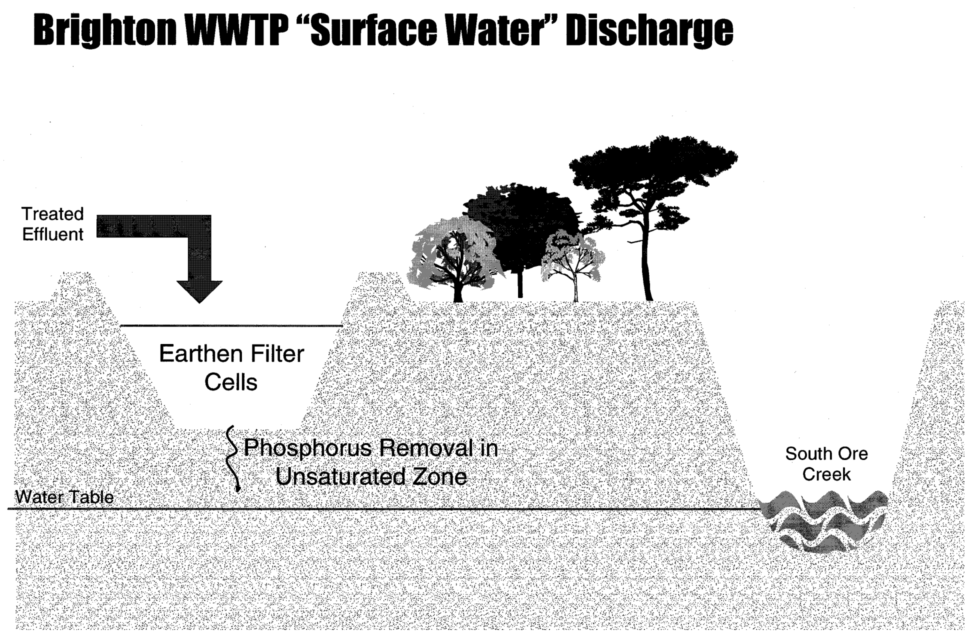

Figure 1.2. Cross-section of Brighton WWTP site demonstrating application of chemically treated effluent to soil filters. Courtesy D. E. Lund (McNamee, Porter & Seeley, Inc).

Before the effluent can percolate all the way down to the local water table, underground drains intercept the water and it is pumped back to the surface (Figure 1.3). There it is applied as irrigation water to surface vegetation on the WWTP grounds.

Brighton WWTP "Surface Water" Discharge

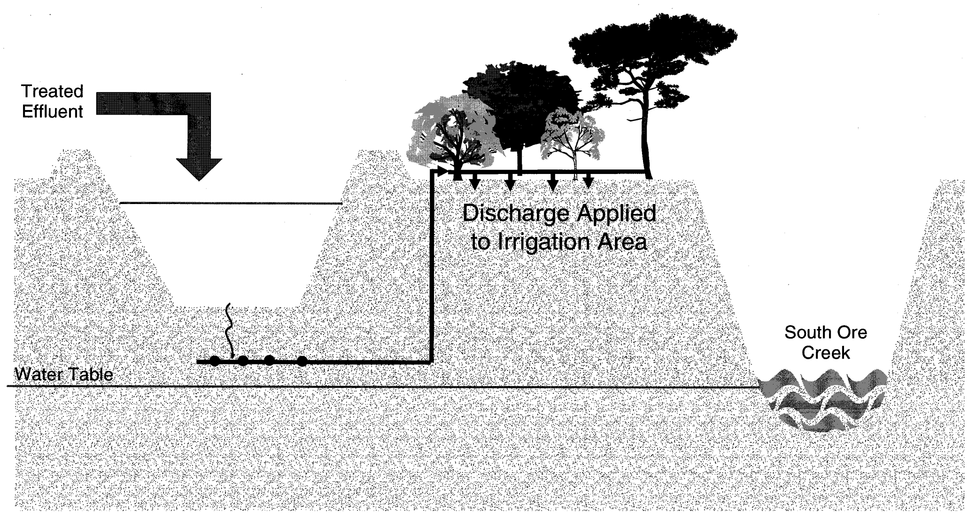

Figure1.3. Interception of soil-filtered water and return to surface for irrigation. Effluent is applied to natural community of trees, shrubs, and grasses. Courtesy D. E. Lund (McNamee, Porter & Seeley, Inc).

Some of the irrigation water evaporates as the result of the plant growth process known as *evapotranspiration*. Residual phosphate is absorbed by the plants and the soil (Figure 1.4).

Brighton WWTP "Surface Water" Discharge

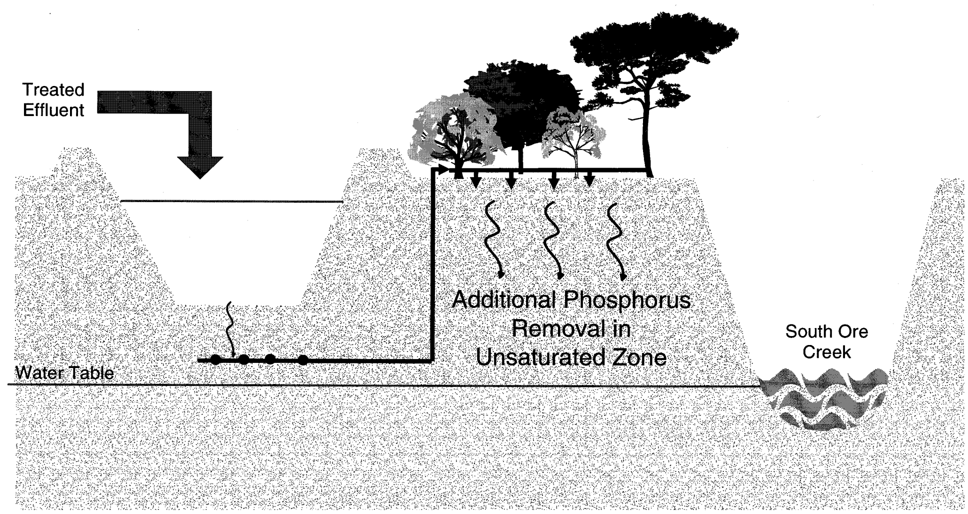

Figure 1.4. Irrigation water percolates through soil, and some residual phosphate is absorbed by plants. Courtesy D. E. Lund (McNamee, Porter & Seeley, Inc).

Brighton WWTP "Surface Water" Discharge

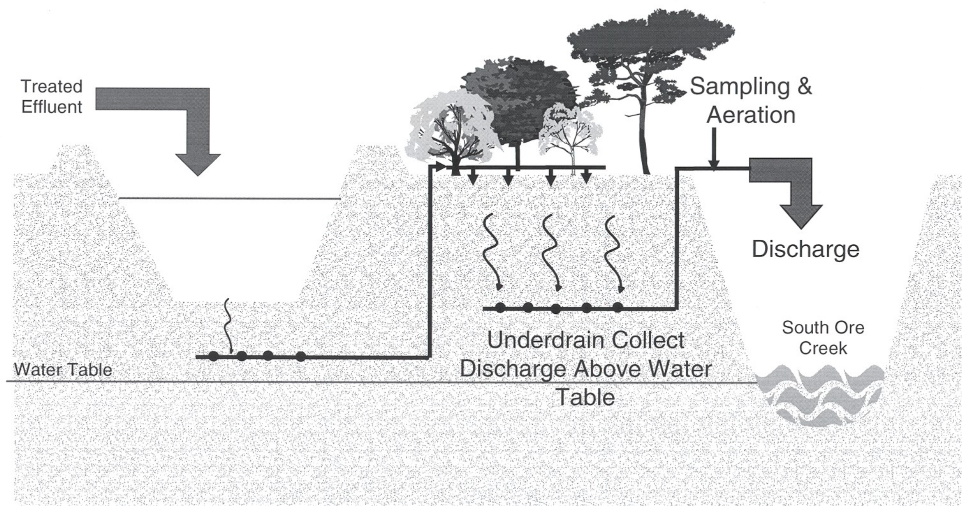

Figure 1.5. Effluent is intercepted, pumped to the surface and discharged to South Ore Creek after aeration. Courtesy D. E. Lund (McNamee, Porter & Seeley, Inc).

Once again a system of underdrains intercepts the irrigation water before it reaches the water table and pumps it to the surface. Finally, the water is bubbled with air to bring its oxygen content into equilibrium with the atmosphere, samples are collected for chemical analysis, and it is discharged into South Ore Creek (Figure 1.5). The discharge site is about one kilometer downstream from Brighton Lake and about 7 kilometers upstream from Ore Lake.

Roots of Controversy

Owing to its location adjacent to major east-west and north-south highways, the City of Brighton had become the fastest growing city in the fastest growing county in the State of Michigan. The growth strained many municipal services, and in particular the demands on its wastewater treatment facility increased. In 1997 the City of Brighton applied to the Michigan Department of Environmental Quality (MDEQ) for a Permit to increase the discharge volume from its WWTP. The Permit application provoked opposition by residents of Ore Lake and by representatives of the Township of Hamburg.

Coincident with news that Brighton was seeking a permit to expand its WWTP, residents of Ore Lake reported that they had observed what they regarded to be an algal bloom in late August 1997. The Ore Lake Preservation Association subsequently contracted with a private consultant to make measurements of the lake during 1998. The consultant operated a fee-based service for lake associations by which he performed a set of analyses on lake water samples. He provided his clients with a "lake water quality index" of unique personal design that purports to characterize "water quality" on a scale of 0 to 100. The consultant had advised

Hamburg that his water quality index for Ore Lake was unsatisfactorily low, and that the reason for the bad score was that nitrate levels were too high.

A report from this consultant to the Hamburg Township Supervisor, dated 21 September 1998, set the stage for the contest that would begin. The consultant reported:

> *In the spring of 1987, the average Lake Water Quality Index was 80, with a range of 77 to 85, or in the C to B range.*
>
> *In the spring of 1998, the average LWQI for Ore Lake was 82, with a range of 80 to 84, so the spring water quality was slightly better in 1998 than it was in 1987.*
>
> *However, in summer the story is quite a bit different.*
>
> *In the summer of 1986, the average Lake Water Quality index was 84, with a range of 80 to 87, or in the solid B range.*
>
> *In the summer of 1998, the average Lake Water Quality Index was 77, and the range was from 73 to 80, or in the C range.*

The consultant listed his recommendation:

> *Based on the above, I feel it is absolutely necessary that Hamburg Township ask for a public hearing on the Brighton Sewage Treatment Plant expansion. We need to let the DEQ know about the problems in Ore Lake.*

The consultant's report was appended to a letter from the Hamburg Township Board of Trustees, dated 22 September 1998 and sent to the Permits Section of the MDEQ Surface Water Quality Division. In its letter, the Board of Trustees declared that "Hamburg Township strongly objects to the proposed reissue of the Brighton Township Wastewater Treatment Discharge Permit" and the letter further made the claim that "water quality indicators are showing further degradation—not improvement—of water quality" in Ore Lake.

The opponents of proposed expansion argued that a different chemical element from their old nemesis, phosphorus, had now become the new villain of pollution. They cited nitrate, another nutrient chemical released by the WWTP as being detrimental to the water quality of Ore Lake. The contesting parties urged that Brighton be compelled to remove nitrate from its effluent by installing a chemical process called *denitrification*. Denitrification converts nitrate into nitrogen gas and vents it to the atmosphere. They also urged that the Permit discharge limit for phosphorus should be further reduced, even though Brighton had never come close to exceeding its existing permit limit.

The City of Brighton refused to accede to Hamburg's demands. The City Engineer for Brighton had estimated that the capital cost of installing denitrification would be $1.3 million, that it would necessitate increased electrical and labor operation costs, and that its environmental value was unproven. Hamburg responded by adopting a local ordinance that mandated denitrification. The Township asserted jurisdiction over Brighton's WWTP because the facility had been constructed within the geographic limits of the Township. The stipulated discharge concentration limits for nitrate imposed by Hamburg were at least 5-fold lower than existing technology could produce, according to the City Engineer for Brighton. The City of Brighton filed a lawsuit in the State Circuit Court claiming that Hamburg did not have legal authority to supercede the government of the State in regulating discharge limits from WWTPs.

Meanwhile, the Ore Lake Association revived the letter writing campaign and lobbying tactics that had proven successful twenty years earlier (see Appendix). By the late spring of 2000, both the Township of Hamburg and residents of Ore Lake were pleading their common case before an administrative judge of the MDEQ in Lansing, Michigan. The issue of the administrative hearing was whether or not the State's proposed Discharge Permit limits for the City of Brighton WWTP represented proper lake management strategy.

Hamburg Township and the Lake Association relied on environmental assessments conducted by a private consultant. Not being scientists themselves, the citizens hinged their case on what they were told and what they believed were sound opinions and scientific interpretations. Brighton also enlisted scientists knowledgeable about lakes and lake organisms. The expert interpretations, however, were conflicting on fundamental issues of lake biology. The MDEQ administrative hearing room thus became a contest field for scientific knowledge and theory.

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Township can object to sewer plan, judge rules. *The Detroit News* 29 February 2000.
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APPENDIX to Ore Lake Case Study Part 1

Examples of letters directed to State officials by environmental activists of Hamburg Township opposing the proposed expansion of Brighton's wastewater treatment facility.

May 1,1999

Carla Davidson, Permits Section
Surface Water Quality Division
Department of Environmental Quality
P.O. Box 30273
Lansing, Michigan, 30273

Dear Ms. Davidson:

The Ore Lake Preservation, Association, an environmental water quality organization representing property owners in the Ore Lake watershed, is submitting the following data from consulting limnologists to support our opposition to the re-issuance of the discharge permit for the City of Brighton Environmental Control Facility as currently written.

First, Water Quality Index comparisons from 1986-87 and 1998 show a degradation in the lake water quality index from 84 in 87 to 77 in 98, a decrease in grade from a B to a C+. The index ranges from 1 to 100, with 100 indicating an excellent lake water quality. A “C+” is not the expected ranking several years after the sewering of the lake.

In addition to the degradation of the water quality, degradation has at the same time occurred in Secchi Disk readings. Secchi Disk Transparency testing data averaged 7.9 feet in 1989 and 7.9 feet in 1998. Secchi Disk readings should have improved after the new Brighton Wastewater Treatment Facility became operational.

Additionally, lake oxygen has decreased. In the summer of 1986 the lake ran out of dissolved oxygen at 30 ft. In the summer of 1995the lake ran out of dissolved oxygen at 27 ft. And in the summer of 1998 the lake ran out .of dissolved oxygen at 20 ft. An indicator of decreasing water quality is the loss of dissolved oxygen over time.

At the same time the lake has decreased in dissolved O2, it has increased in phosphorus. A comparison of surface phosphorus concentrations between summer 1987 and summer 1998 shows increased concentrations of phosphorus in 9 out the 10 sampling stations. The average increase was about 15% higher for 1998.

A comparison of nitrate nitrogen concentrations in 1986-87 and 1998 shows the most dramatic long term change in the nutrient content of Ore Lake. In the summer of 1987, all sampling stations showed nitrate nitrogen concentrations of less than 50 ug/l. In the summer of 1998, nitrate nitrogen concentrations ranged from 545 ug/l to 611 ug/l. Samples from the Brighton Sewage Treatment Plant Outfall in 10/31/98 were calculated at 9600 ug/l.

Finally, Ore Lake had a very large algae bloom that lasted for several days in the summer of 1997.

It is therefore the conclusion of the Ore Lake Preservation Association that the DNR/DEQ must look at the possibility that the Brighton Environmental Control Facility sanitary wastewater discharge is negatively affecting the water quality of Ore Lake and the Upper Huron River Watershed. Certainly the reissuance could require the denitrification of the high levels of nitrate nitrogen that are currently being discharged as well as a lowering of the current phosphate phosphorus limit of 600 pounds per year. (The current discharge is about 30 pounds per year.)

President
Ore Lake Preservation Association

DEPARTMENT OF ENVIRONMENTAL QUALITY
August 21, 1999

Dear Mr. Hamilton:

I am writing this letter in regard to the National Pollutant Discharge Elimination System (N.P.D.E.S.) permit reissue for the City of Brighton Environmental Control Facility.

I am protesting your final decision. I find it difficult to believe that the D.E.Q., protector of Michigan waterways would approve of the discontinuous use of the land-filtration treatment system in order to prolong the life of the facility. You can build new treatment plants, but you cannot bring back dead lake.

You also say you studied Ore Lake in depth from April of 1998 through April of 1999, however you only studied phosphorus contributions for the TMDL, (which is still too high). You did not study the nitrates affecting Ore Lake, and we the people have never had a chance to review any of the DEQ studies. The Ore Lake Preservation Committee shared all of their work and studies with the DEQ.

We believe your reference to Dr. Fusilier's report, saying that the MDEQ makes decisions based on sound science is an insult to everyone in the state of Michigan. What sort of sound science was used when you told the city of Brighton to turn the ammonia in human waste into nitrates and to dump it into Ore Creek? Your staff made a mistake and it is your responsibility to correct it.

It is easy to sit at a desk and take something like the Walker Model and make every lake fit into a slot. It looks good on paper, but in real life, it is a little different.

How can you say an 11% or 12% increase in the flow of water coming down Ore Creek will not impact homes in Ore Lake and in Little Ore Lake? When Kensington Lake closes their dam, and Portage Lake does the same, Ore Lake is in the middle of it. Then the Huron River backs into Little Ore and people get water in their homes. The 11% or 12% increase can make a disastrous, major change in the amount of water that will be in their homes.

Hamburg Township Supervisor Howard Dillman presented a carefully studied explanation to the DEQ. You ignored every point Mr. Dillman made.

The Ore Lake Preservation Committee gave you all of their studies in November of 1998. You have chosen to ignore those studies although the very same limnologist that did the work for the STOPP organization back in 1979 did these studies, too. During those years from 1979 through much of the 1980's, Dr. Fusilier's work was used by the DNR to take the City of Brighton to court, and force the city to build its present Wastewater Treatment Plant facility.

When that plant was built in Hamburg Township a promise by Dr. Tanner and the DNR staff was made to me personally that Ore Lake would never be polluted by the Brighton Wastewater Treatment Plant again. You are breaking that promise. We tried to meet you halfway. We asked that the new structure be built be done in such a way that it would not increase nutrients, mainly nitrates to Ore Lake. You have chosen to ignore this reasonable request, too. I am disappointed and have lost my faith in the Department. You had a chance to be a hero for once, and you failed.

Sincerely,

President of STOPP (Society to Oppose Phosphorous Pollution)
Founding Chairperson of the Hamburg Environmental Review Board (1999 - 1993) Vice President of the Ore Lake Preservation, Member of the Livingston County Board of Health

cc

John Engler, Governor	Howard Dillman Supervisor Hamburg Twp	
Russell J. Harding, Director MDEQ	Dana Foster, City of Brighton	
David Hamilton, Chief of SWQD	Editor of Ann Arbor News	Editor Brighton Argus

Environmental Problem Solving and the Dangers of Junk Science: The Case of Ore Lake, Michigan

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4 March 2005

Part 2:
Arguments claiming lake degradation and need for denitrification

Background to the scientific claims advanced by Ore Lake environmentalists and township representatives

The history of political and legal struggles during the 1970s and 1980s remained fresh in the living memories of environmental activists and lakeshore residents of Ore Lake. Immediately downstream from the outfall of Brighton's wastewater treatment facility, they were predisposed to feel threatened by expansion from their neighbor. By experience the residents of Ore Lake and Hamburg had mastered political tactics that produce success for well-designed objectives. Even more so than in the past, the City of Brighton was growing into a modern day Goliath, but this time it seemed to the residents of Hamburg and Ore Lake that the Michigan DEQ was lining up on the side of the Philistines. Once again, the residents adopted the role of modern day David and they set out to duplicate their previous triumph.

The pivotal evidence in that earlier struggle against Brighton had been a scientific report produced by environmental scientists working for the State (MDNR 1978). Subsequent to construction and operation of Brighton's new WWTP beginning in 1986, however, the State had conducted three additional studies that demonstrated marked improvement in Ore Lake and identified no signs of environmental problem or deterioration (MDEQ 1996, 1998, 1999). Concentrations of phosphorus had been severely reduced. Water transparency had improved, and there were no longer any documented summer nuisance blooms of bluegreen algae. The State's own scientific evidence revealed no sign of harm from the existing WWTP, and State officials relying on in-house scientific advice were inclined to issue Brighton its permit for expansion.

The Ore Lake Preservation Association therefore sought its own scientific counsel, with independent evidence and analyses to dispute the State's experts. The individual they contracted was a self-described "consulting limnologist" who operated a sole-proprietorship business from an office and laboratory building in Dexter, Michigan. The consultant made his living by hawking to Lake Associations the product of his 1982 doctoral dissertation titled *An opinion derived nine parameter unweighted multiplicative lake water quality index: the LWQI* (Fusilier 1982). His creation assigned a single numerical score from 0 to 100 to a lake water sample. The score was based on results from questionnaires he had circulated among professional limnologists in the 1970s, asking them their opinions about the components of "water quality".

The LWQI had never been adopted by any other professional, but it had great appeal among concerned citizens, especially those who were riparian landowners with strong instincts for environmental protection. Embodied within a single number was the purported scientific essence of lake "water quality" so that clients needed only to learn if their lake had high, low, or failing marks as if it were being graded on an environmental report card. The consultant had garnered a host of clients among lake associations across the State of Michigan, and he communicated with them regularly through a newsletter from his "World Headquarters" in Dexter (http://www.inland-lakes.com).

In September 1998 the consultant informed his clients that his water quality index proved that their lake was in trouble. He encouraged them to protest the proposed expansion of the Brighton WWTP with him as their scientific ally. By August 1999 he was advocating legal actions through his newsletter:

> *Maybe I need to follow Dr. Humphry's advice, which is to go to court. He said in the past he ran into similar problems and that going to court was about the only thing he found worked. He said it works because the court system is based on reason (the scientific community is also based on reason, but the problem is the DEQ folks are not scientists, they're bureaucrats.) (I sure have no problem going to court, and attorneys I've worked with tell me I'm an excellent expert witness.)*

On 3 August 1999, after public hearings and internal departmental review, the Surface Water Quality Division (SWQD) for the State of Michigan Department of Environmental Quality (MDEQ) issued a National Pollutant Discharge Elimination System (NPDES) permit to the City of Brighton for expansion of its discharge capacity. The permit was issued under the provisions of Part 31, Point Source Pollution Control Water Resources Protection of the Michigan Natural Resources Environmental Protection Act. The administrative rules accompanying that Act allow for a Contested Case Hearing before an administrative judge of the MDEQ if petitions are filed challenging the permit. Hamburg Township and a number of private individuals filed the required petitions on 3 August 1999, the same day the permit was issued.

The petitions challenging the permit were filed against the SWQD, which had issued the permit. The SWQD was represented by the Assistant Attorney General of the State of Michigan. The City of Brighton filed a Motion to Intervene as the permitee and became a party to the case in December 1999. The case was assigned to the Chief Administrative Law Judge in the Office of Administrative Hearings, MDEQ Lansing, Michigan. By January 2000 when the two sides exchanged their pre-hearing statements, the lines were drawn for a legal battle over a scientific issue. The petitioners charged in their statement dated 11 January 2000:

> *Recent studies have shown that nitrate nitrogen is the limiting nutrient for Ore Lake. Introduction of uncontrolled amounts of nitrates into Ore Lake since the inception of the Brighton WWTP have resulted in decreased dissolved oxygen and an increase of organic material in the sediments in Ore Lake. This uncontrolled nitrate discharge has accelerated the eutrophication of the lake, and if allowed to continue, will result in a hypoxic condition in all or part of the lake, and potentially the Huron River, eliminating aquatic life in these areas. MDEQ has failed to consider the uncontrolled introduction of nitrates by the Brighton WWTP, has not promulgated a total*

maximum daily load (TMDL) for nitrates, and has not promulgated either a water quality standard or effluent limitation for nitrates as they pertain to Ore Lake.

The petitioners' consultant marshaled his scientific evidence and arguments in a report released in March 2000. That report is reproduced in the Appendix to this chapter. It presents the purported facts and interpretations that became the heart of the contested case hearing.

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Appendix to Part 2

Lake Degradation in Ore Lake, Livingston County Michigan Between 1986-7 and 1998-9

March **2000**

A REPORT ON THE CAUSES OF LAKE DEGRADATION IN ORE LAKE, LIVINGSTON COUNTY, MICHIGAN

W. E. Fusilier, Consulting Limnologist, Water Quality Investigators

LIMNOLOGY

“Biological productivity is the central, unifying feature which ties the whole subject (of limnology) into a coherent, orderly, organized field. … Inland waters differ to a striking degree in the quality and quantity of life they contain. To understand the natural circumstances responsible for this tremendous difference in such waters and to identify and evaluate the influences which govern a particular form of productivity are the aim of modem limnology” (Welch, 1952).

THE CAUSES OF POOR WATER QUALITY IN LAKES

Limnologists recognize excessive nutrients often cause highly productive conditions, and hence water quality problems in lakes. The two nutrients of greatest concern are nitrogen and phosphorus. And the main problem excessive nutrients cause are algal blooms in the 15 to 20-foot thick open-water surface layer as the lake warms. These cause other problems, such as loss of dissolved oxygen in the deep open-water portion of lakes in late summer, a buildup of organic material in the bottom sediments, shallow summer Secchi disk readings, and super-saturated late summer dissolved oxygen conditions in the 15 to 20 foot thick surface water layer.

These in turn cause other problems such as the release of phosphorus from the bottom sediments during periods of anoxic (no dissolved oxygen) conditions in the bottom water, and later recycling of this nutrient when the lake mixes in spring or fall. Eventually the lake starts recycling its own nutrients. When that happens, the cycle is very difficult to break.

The lack of dissolved oxygen in these deeper layers also limits or destroys the habitat of fishes and other aquatic organisms.

LIMITING NUTRIENTS

One of the basic principles of Limnology and lake management is the concept of “limiting nutrients”. A farmer serves as a good example. When a farmer tests his soils, he is looking for the nutrient in shortest supply, the one that is limiting the amount of crops he can produce. This nutrient in shortest supply is called the "limiting nutrient", and if he adds it to his fields, he will be able to produce more crops.

The same principal [sic] applies to lakes, except in lakes the last thing anyone would want to do is add the "limiting nutrient" because if that occurred, the lake would become more "productive" and produce more plants and algae in shallow water, and algae in the surface layer of the open-water portions of the lake. These same algal blooms can float to the surface, be pushed to the shore by wind and wave action, and wash up on shore where they decompose, causing obnoxious odors, slime and a general decline in the overall water quality of the lake.

THE NITROGEN TO PHOSPHORUS RATIO

To determine which nutrient, nitrogen or phosphorus, is the limiting nutrient in a lake causing water quality problems, limnologists use the nitrogen to phosphorus ratio. (Smith GET REFERENCE) [sic]

If the nitrogen to phosphorus ratio is greater than 17 to 1, the nutrient in shortest supply is phosphorus, and that is considered the limiting nutrient, i.e., the nutrient, which if added, will cause additional algae to grow in the surface water layer in the open-water parts of the lake.

If the nitrogen to phosphorus ratio is less than 17 to 1, the nutrient in shortest supply is nitrogen so that is considered the limiting nutrient. If more nitrogen is added to the lake, it will suffer from decreased water quality as described above.

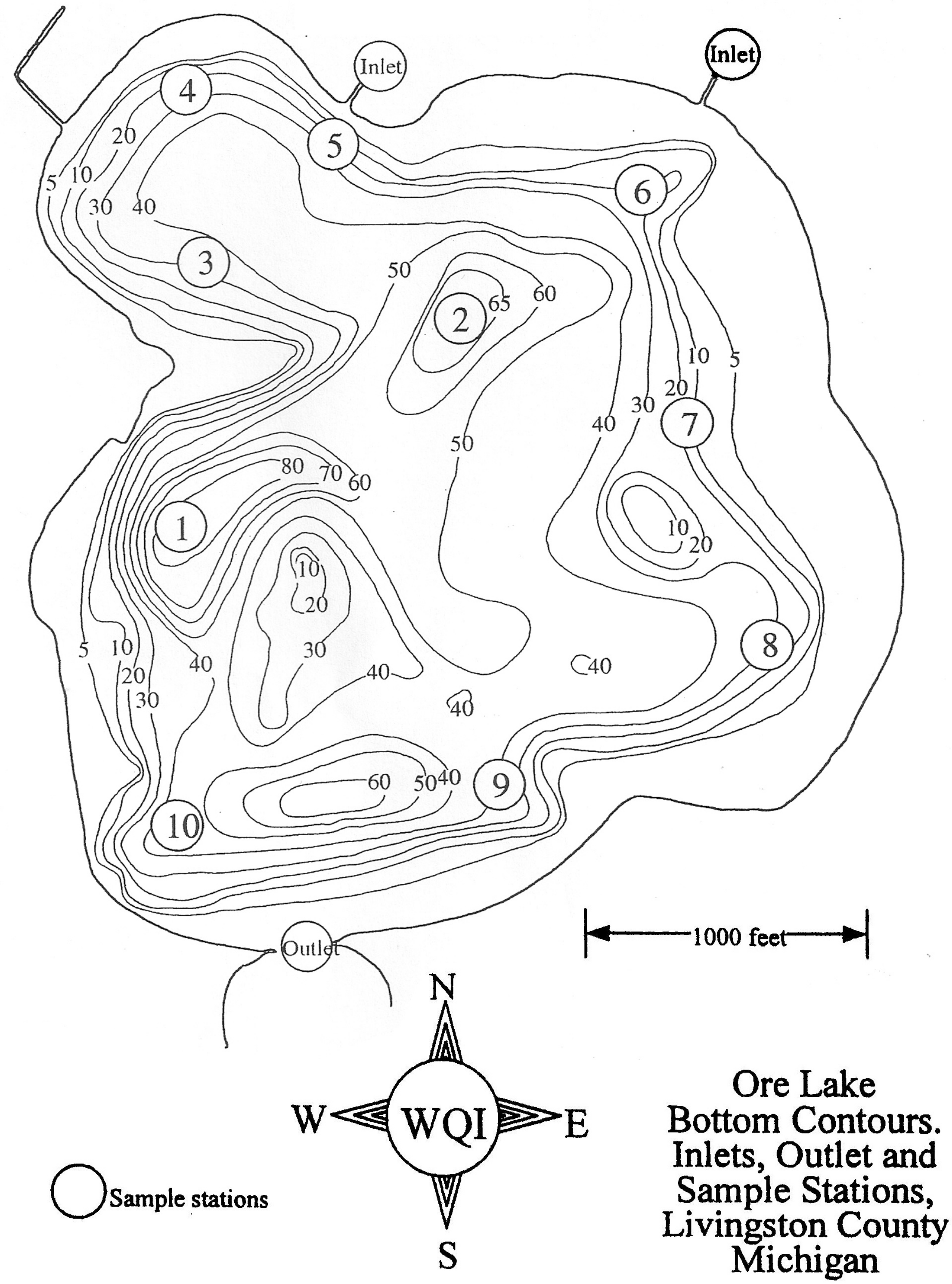
A SHORT HISTORY

Ore Lake was formed by an ice-block that broke off the retreating glacier. Debris from the melting glacier surrounded the ice block, preventing it from melting rapidly. Finally the ice block melted and the debris surrounding it fell into the hole, creating the lake basin. Lakes formed in this fashion are called kettle lakes.

Ore Lake is a 192-acre natural hard-water to moderately hard-water kettle lake located in Section 13, T1N R5E and Section 18, TlN R6E, Livingston County, Michigan. The lake has a maximum depth of 84 feet, a mean depth of 33.3 feet, a water volume of 6387-acre feet and flushes once every 0.32 years (or once every 117 days) on an average. The lake has 13,328 feet of shoreline. (See map below.)

There are two inlets; both located on the north side, South Ore Creek and the Dibrova Lake outlet. The Ore Lake outlet is located on the south side where it flows through Little Ore Lake and into the Huron River.

The area of the watershed, which is the land area that contributes water to the lake, (but does not include the lake surface) is large, 25,216 acres. Hence the watershed to lake ratio is also large, 131 to 1. (Most watershed to lake ratios are in the range of 3 to 1 to 8 to 1.) Large watershed to lake ratios like the one Ore Lake has, generally provide ample supplies of water so that even during dry periods, the lake level remains fairly constant. In fact, the large watershed, and because Ore Lake is closely connected to the Huron River, plus 1200+ acre Kent Lake is located upstream on the main stem of the Huron River (and drops its level 3 feet every fall) fall flooding on Ore Lake often occurs.



Several lakes are found in the upstream South Ore Creek watershed, among them: Maxfield Lake, Long Lake, Bitten Lake, Woodland Lake, the Brighton millpond, and Brighton Lake. Three were created by impounding the creek (Woodland Lake, Brighton millpond and Brighton Lake) and two are natural lakes. However since Woodland Lake has a deep basin originally called Gay Lake, it is considered a natural lake with a dam. Brighton Lake has a single deep hole and in all probability also had a small lake prior to construction of the dam, so it too should be considered a natural lake with a dam. The elevation of Ore Lake is 853 feet above sea level. The location of the 69-foot deep hole in the middle of the lake (Sample station 2) is 42º 26.871N latitude and 82º 48.007W longitude.

ORE LAKE SEWERS

In an effort to improve and preserve the water quality of Ore Lake, a decision was made to install public sewers around the lake, and in the late 1980s the sewers were installed. Sewage from that system was delivered to and treated by the newly constructed Brighton sewage treatment plant. This in and of itself should have caused the water quality of Ore Lake to improve.

THE NEW BRIGHTON SEWAGE TREATMENT PLANT

In 1988, when the new Brighton sewage treatment plant went on line, the effluent discharge location was changed from the top end of Brighton Lake, to South Ore Creek below Brighton Lake (but above Ore Lake). This new sewage treatment plant was well operated and should also have caused the water quality of Ore Lake to improve.

ORE LAKE WATER QUALITY STUDIES

Several studies of the water quality of Ore Lake were conducted by Water Quality Investigators (WQI), beginning in the fall of 1986. The most meaningful studies were the ones conducted in the fall of 1986-spring of 1987 and the ones in 1998 and 1999. The reason for this is the design of both the early (86-87) and later (98-99) studies were the same and included samples for water quality testing collected in both spring and summer from 10 in-lake surface stations, plus top to bottom samples every 10 feet at Station 2, the 69-foot deep-hole in the middle of the lake. Ten bottom sediment samples were also collected in both studies.

HOW IS THE WATER QUALITY OF LAKES DEFINED?

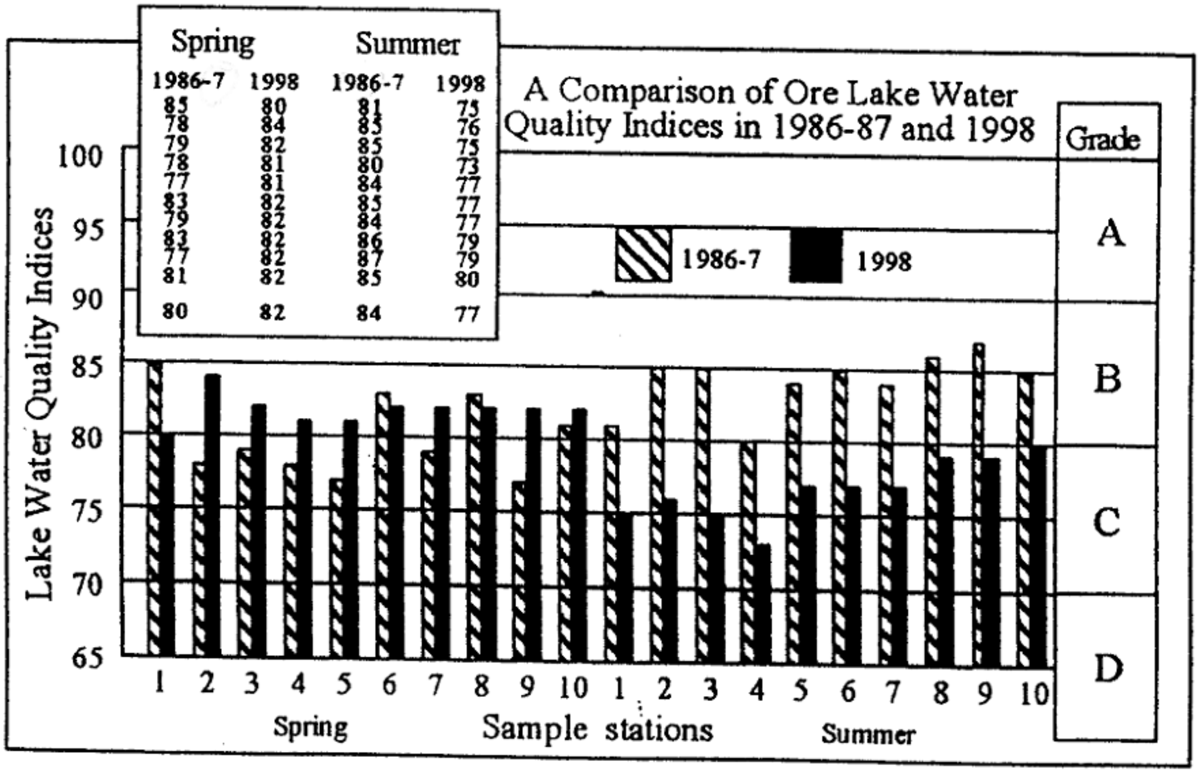
The concept of lake water quality is something this author has been interested in for some time. Because there were so many different methods used by various investigators to define the water quality of lakes, a Lake Water Quality Index was developed (Fusilier, 1982), using the opinions of a panel of 555 American Society of Limnology and Oceanography scientists specifically selected because they had advanced degrees and were chemists and biologists who studied lake water quality.

This panel of experts indicated the following tests should be used to determine the water quality of lakes: temperature, dissolved oxygen, total phosphorus, total nitrate nitrogen, pH, total alkalinity, conductivity, chlorophyll a and Secchi disk depth. (As an added note, several of the same tests, including nitrates and phosphorus were also included in the river water quality index developed by the National Sanitation Foundation. Brown, 1970).

The Lake Water Quality Index tests (and Lake Water Quality Index) were used in both the early and later studies of Ore Lake.

The index rates lakes about the same way professors rate students: 90-lOO=A, 80-9O=B, 70-8O=C, 60-7O=D, and below 60=E.

The graph below shows the spring and summer 1986-7 and 1998 Lake Water Quality Indices.



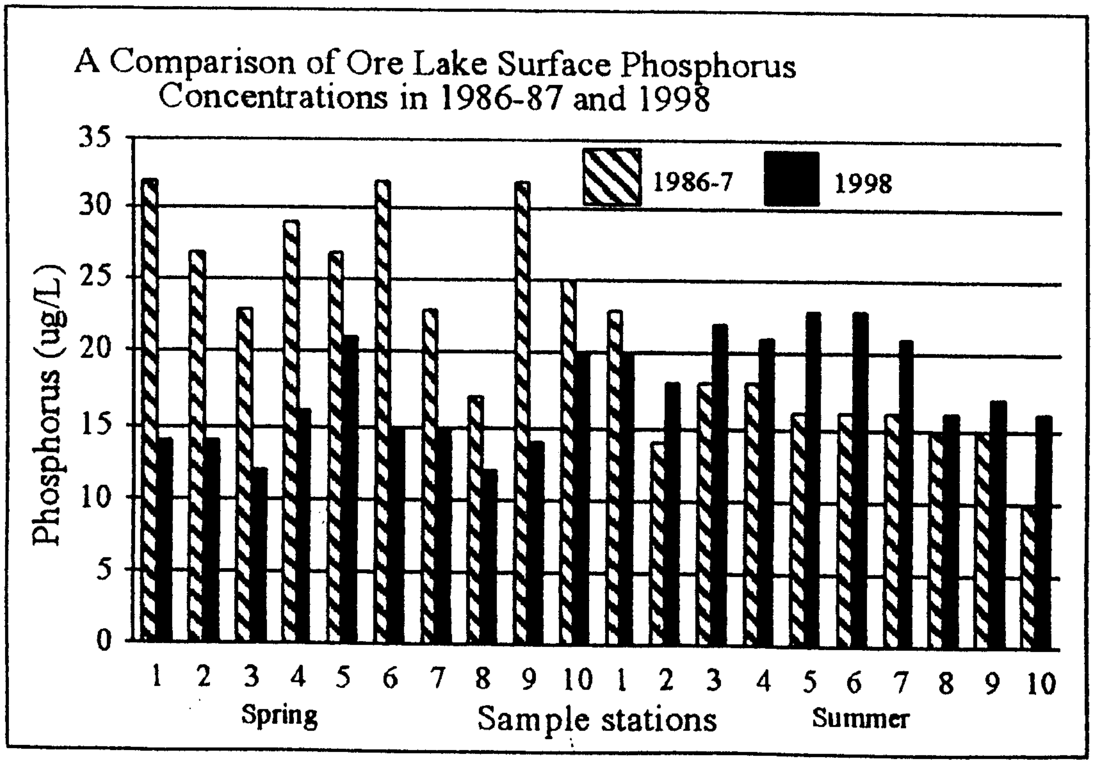
In 1987, the spring Lake Water Quality Indices of Ore Lake ranged from 77 to 85 with an average of 80. In 1998, the Lake Water Quality Indices of Ore Lake ranged from 80 to 84, and averaged 82. Hence in spring, between 1986-7 and 1998 the average LWQIs improved two points.

In 1986, the late summer LWQIs for Ore Lake ranged from 80 to 87 and averaged 84. In 1998, the late summer LWQIs ranged from 73 to 80, and averaged 77.

In late summer, the Ore Lake LWQIs dropped seven points (and went from a grade of B to a grade of C). One of the main reasons the summer LWQIs dropped in 1998 was high nitrate concentrations. They were much lower in the lake in 1986.

TOTAL PHOSPHORUS

The graph below shows the phosphorus data which can be found in the appendices.



In the spring of 1987, the 10 surface phosphorus concentrations ranged from 17 to 32 micrograms per liter, and averaged 27 micrograms per liter.

In the spring of 1998, the 10 surface phosphorus concentrations ranged from 10 to 23 micrograms per liter, and averaged 16 micrograms per liter.

The graph shows a decrease in spring phosphorus from the early to the later studies.

In the fall of 1986, the 10 surface phosphorus concentrations ranged from 12 to 21 micrograms per liter, and averaged 15 micrograms per liter.

In the fall of 1998, the 10 surface phosphorus concentrations ranged from 16 to 23 micrograms per liter and averaged 20 micrograms per liter. The graph (and data) shows an increase in summer phosphorus between 1986-7 and 1998, but in any case, the phosphorus concentration in Ore Lake is relatively low. These data indicate the Brighton sewage treatment plant is doing a good job controlling phosphorus discharges from the plant.

NITRATE NITROGEN

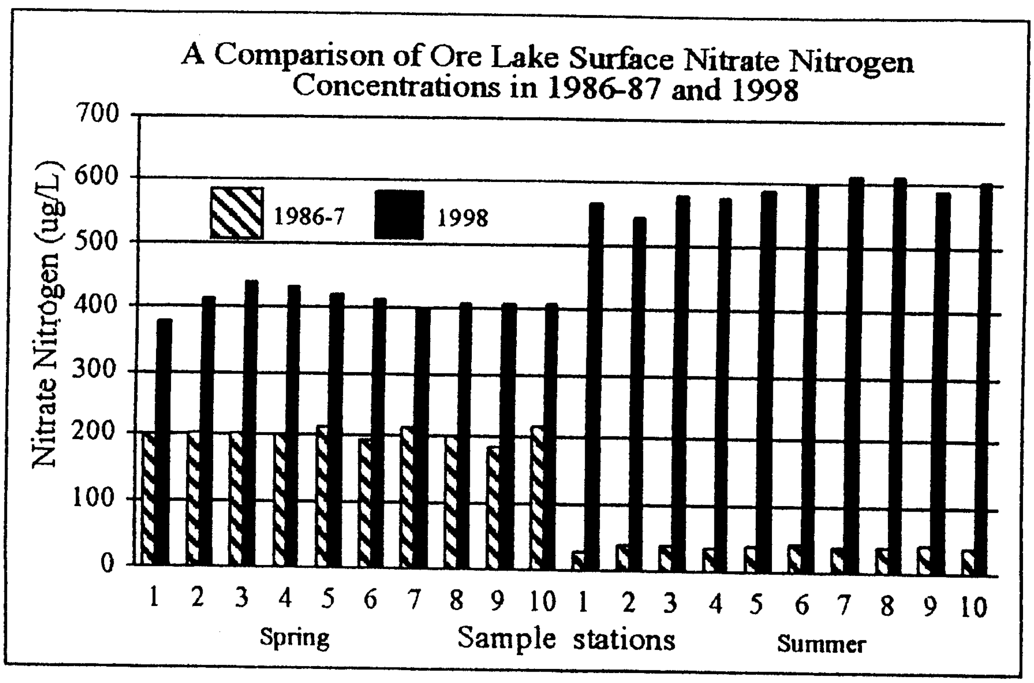
In spring 1987, the nitrate nitrogen concentrations at the ten surface stations ranged from 183 to 215 micrograms per liter and averaged 222 micrograms per liter. These are normal spring nitrate nitrogen concentrations for a Michigan inland lake.

In spring 1998, the nitrate nitrogen concentrations at the ten surface stations ranged from 378 to 439 micrograms per liter and averaged 417 micrograms per liter. These are about twice as high as we normally see in southeast Michigan inland lakes in spring.

In the fall of 1986, nitrate nitrogen concentrations at the ten surface stations ranged from 29 to 42 micrograms per liter, and averaged 37 micrograms per liter. These are normal late summer nitrogen concentrations for southeast Michigan inland lakes. Generally the nitrate nitrogen concentration in Michigan inland lakes drops rather dramatically between spring and summer, and the 1986-7 Ore Lake data demonstrate this phenomena [sic].

In the fall of 1998, nitrate nitrogen concentrations at the ten surface stations ranged from 545 to 611 micrograms per liter, and averaged 587 micrograms per liter. These are much higher nitrate nitrogen concentrations than we normally see in an southeast Michigan inland lake.

The graph below shows the nitrate nitrogen data.



As the graph shows, spring surface 1998 nitrate nitrogen concentrations were about twice the spring surface 1987 nitrate nitrogen concentrations, and late summer surface 1998 nitrate nitrogen concentrations were more than 15 times higher than the 1986 surface nitrate nitrogen concentrations.

The nitrate nitrogen data indicates nitrate nitrogen concentrations increased dramatically between 1986-7 and 1998. And the difference between the spring and summer 1998 nitrate nitrogen concentrations could be easily explained by the fact that stream flows are generally greater in spring than summer, so dilution occurred more in spring.

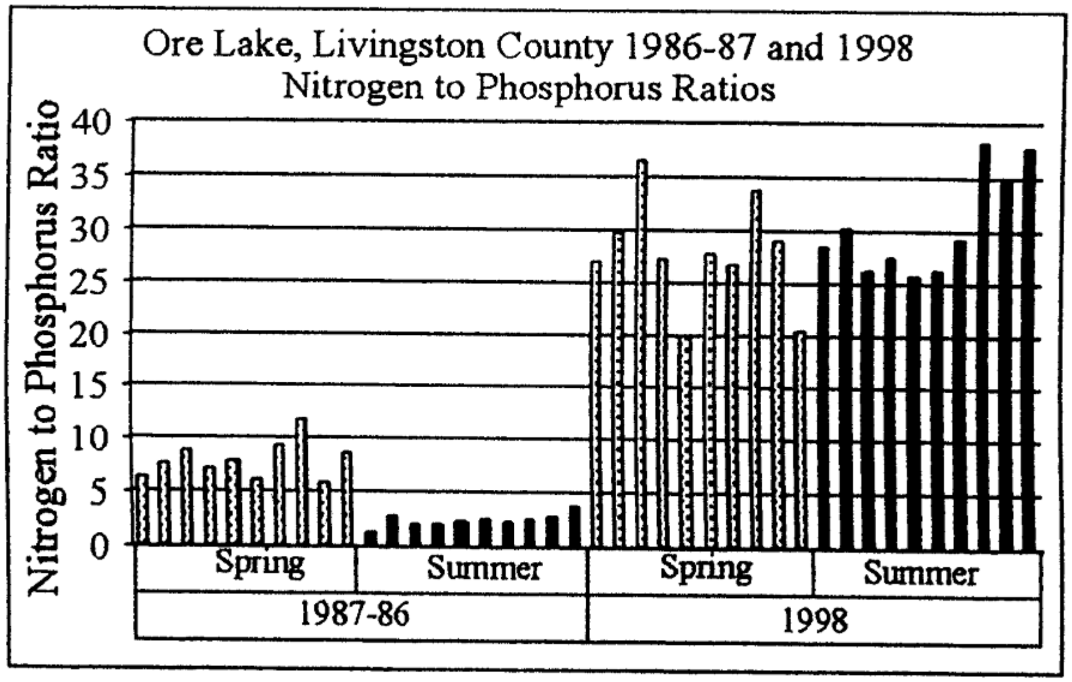
THE NITROGEN TO PHOSPHORUS RATIO

As noted above nitrogen to phosphorus ratios are used to determine which nutrient is the limiting nutrient.

In the spring of 1987 the nitrate nitrogen to phosphorus ratios at the ten surface stations ranged from 5.7 to 11.8, and averaged 7.9. Hence in spring 1987 the lake was probably nitrate limited.

In the summer of 1986, the nitrate nitrogen to phosphorus ratios at the ten surface stations ranged from 1.9 to 3.7 and averaged 2.4, well below 17, and indicates the lake was nitrate limited at that time.

The following graph shows these data.



In the spring of 1998 the nitrate nitrogen to phosphorus ratio ranged from 20.0 to 36.6, and averaged 27.8. Since the nitrate nitrogen to phosphorus -- ratio is now greater than 17, the lake is currently phosphorus limited.

In late summer, 1998, the nitrate nitrogen to phosphorus ratio ranged from 25.6 to 38.2 and averaged 30.4. And again, the data show the lake is phosphorus limited in 1998 while in 1986 it was nitrate limited.

Based on these nitrate nitrogen to phosphorus data, in 1986-7, Ore Lake was nitrate limited in both spring and summer, but especially in summer. Now, because of the much higher nitrate nitrogen concentrations in the lake in 1998 compared to 1986-7, the lake is now phosphorus limited.

The problem is the limiting nutrient was changed from nitrogen in 1986-7 to phosphorus in 1998, especially in summer. This caused the lake to become more productive.

One of the cardinal rules regarding limiting nutrients, is the limiting nutrient should not be added to a lake if the goal is to preserve or improve the water quality in that lake. If the limiting nutrient is added, **productivity will increase** until a different nutrient becomes limiting, and that is what happened in Ore Lake.

In this case in 1986-7 the limiting nutrient in Ore Lake, especially in summer, was nitrogen. In 1998 the limiting nutrient was phosphorus, but that was because nitrates were added to the lake in high concentrations. The concentration of nitrate nitrogen in late summer increased more than 15 times between 1986-7 and 1998.

Now phosphorus is the limiting nutrient, but in the mean time the lake is producing more algae in the open-water areas than it did when it was nitrogen limited, especially in summer, because the limiting nutrient, nitrate, was added. And this higher level of algal production will continue until nitrates again become the limiting nutrient, especially in summer.

THE SOURCE OF THE NITRATES

To determine if the source of the nitrates was South Ore Creek samples were collected at Brighton Lake (above the Brighton sewage treatment plant outfall) and at the Hamburg Road bridge (below the Brighton sewage treatment plant outfall, but above Ore Lake) seven times in September and October 1998 by Ed and Nancy Roberts and WQI limnologists.

The goal of this sampling effort was two fold. First, was to determine if the source of nitrates was South Ore Creek, and second, if the source was South Ore Creek, to determine if the nitrate concentration changed when the treated Brighton sewage effluent was added to the creek.

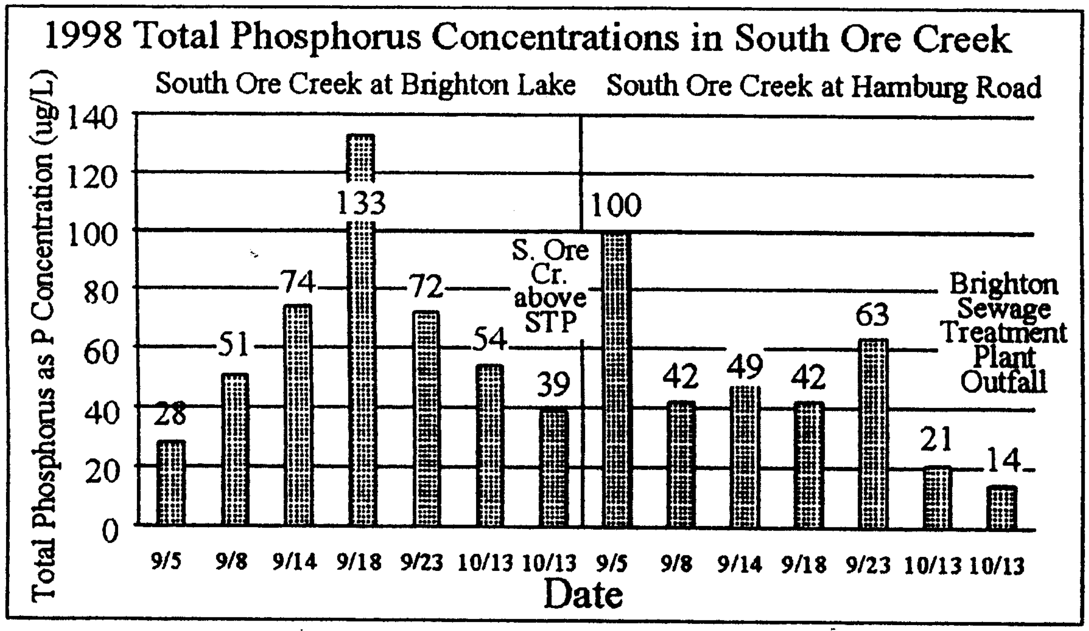
All analytical data (in micrograms per liter) are shown above the bars on the graphs.

TOTAL PHOSPHORUS

The total phosphorus concentration of the South Ore Creek samples below Brighton Lake (above the STP outfall) averaged 64 micrograms per liter (range 28-133 micrograms per liter).

The total phosphorus concentration of the South Ore Creek Hamburg Road samples (below the STP outfall) averaged 47 micrograms per liter (range = 14-100 micrograms per liter). The sample from the STP outfall in South Ore Creek was the lowest (14 micrograms per liter) of all the samples.

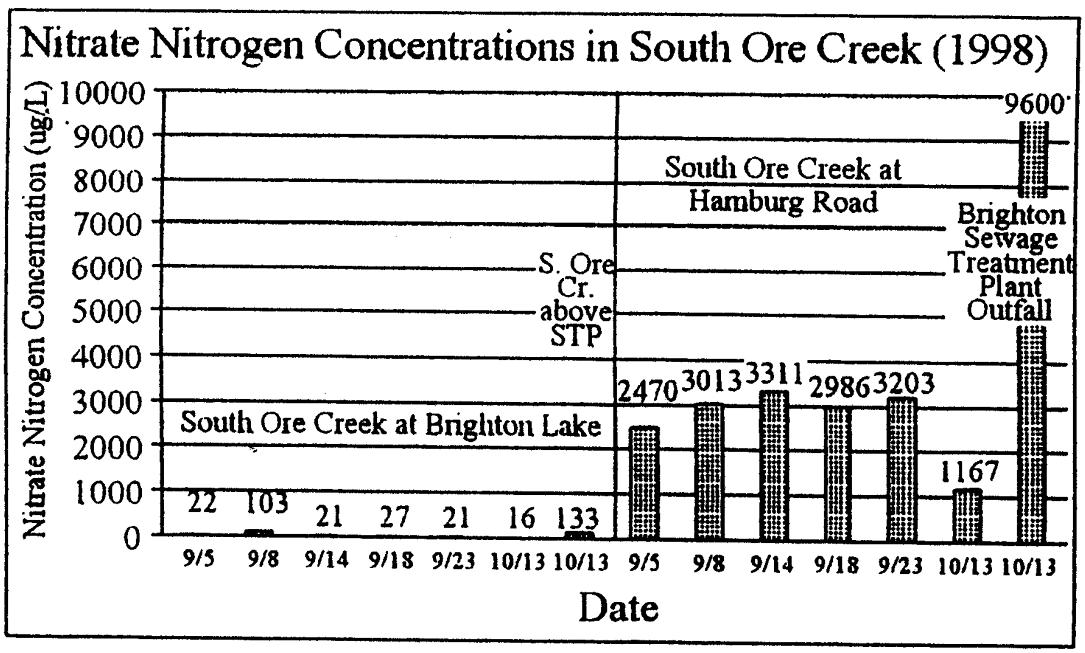
The graph below shows the phosphorus data collected in this effort.



Based on these data, it appears the Brighton STP is meeting their permit requirements. Although phosphorus does not appear to be a problem at this time, future significant increases in phosphorus, should they occur, may well alter this conclusion.

TOTAL NITRATE NITROGEN

The same samples were analyzed for nitrate nitrogen. The graph below shows these data.



The total nitrate nitrogen concentration of the seven South Ore Creek samples below Brighton Lake (above the STP outfall) averaged 47 micrograms per liter (range 16-133 micrograms per liter).

The total nitrate nitrogen concentration of six Hamburg Road samples (below the STP outfall) averaged 2692 micrograms per liter (range = 1167-3311 micrograms per liter). The sample from the STP outfall was the highest (9600 micrograms per liter) of all the samples.

Based on the South Ore Creek nitrate nitrogen data, between Brighton Lake and Hamburg Road, average nitrate nitrogen concentrations increased more than 50 times. Although just a single sample was taken at the Brighton sewage treatment plant outfall, it was high, almost 10,000 micrograms per liter. That datum, along with the nitrate nitrogen concentrations above and below the outfall indicates the source of the high nitrate nitrogen concentrations in the creek is the treated Brighton sewage treatment plant effluent.

After these data were presented to the city of Brighton, their engineers acknowledged in a letter that the data showed how well the Brighton sewage treatment plant was working, because the plant made nitrates out of ammonia so as to not remove dissolved oxygen from the receiving stream, South Ore Creek.

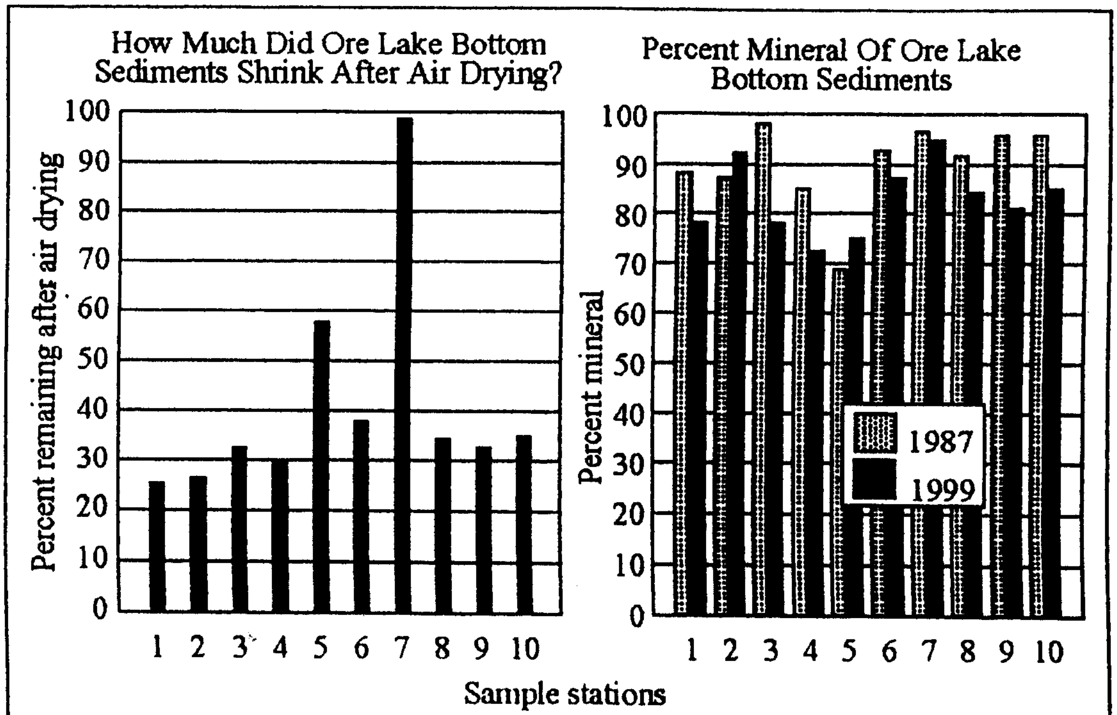
ACCUMULATION OF ORGANIC MATERIAL IN THE BOTTOM SEDIMENTS

Analysis of the bottom sediments often provides a history of what is happening in a lake in terms of productivity. Bottom sediments are collected with a Peterson dredge, placed in pint freezer containers, and allowed to air dry. The dry block of sediment is measured to determine volume, then ground, placed in ceramic dishes, dried at 100 degrees C, weighed, burned at 550 degrees C, and weighed again. The loss after burning is considered organic material. Bottom sediment data includes color after air drying, color after burning, percent shrinkage after air drying, and percent mineral after burning. The graph below shows the Ore Lake bottom sediment data in 1986-7 and 1999. No shrinkage data is available for 1986-7 because those data were not determined at that time.

In the case of Ore Lake, the amount of organic material in the bottom sediments increased from an average of 10 percent in 1986-7 to an average 17 percent in 1999, a seven percent increase in organic material in just 12 years. (It took 7,000 to 10,000 years for the first 10 percent of organic material to accumulate in the bottom sediments, so an increase of seven percent in 12 years is excessive and not attributable to natural causes.)

WHAT IS THE PROCESS THAT CAUSES ORGANIC MATERIAL TO ACCUMULATE IN THE BOTTOM SEDIMENTS?

First, a bit of limnology. As deeper lakes warm in summer, (generally) three layers of water form, the surface and bottom layers being separated by a 10 to 20 foot-thick layer called a thermocline. This layer is defined by a rapid change in temperature with depth and usually occurs from about 17 to about 25 feet. The thermocline isolates the water in the bottom of the lake from the surface water and from the air, which is the source of most dissolved oxygen in a lake (although algal blooms can add dissolved oxygen during daylight hours).



Characteristics of Ore Lake Bottom Sediments (1987 & 1999)

Sample I.D.	Percent Shrinkage	Percent Mineral		Dried at 100°C Color & Description	Color after burning at 550°C	Depth of water (feet)
	1999	1987	1999	1999	1999	1999
1	74	89	79	Tan smooth	Gray	80
2	73	88	92	Tan smooth	Gray	62
3	68	97	78	Gray smooth	Gray	28
4	70	85	72	Gray smooth	Red gray	32
5	32	69	75	Dark gray fibrous	Red gray	30
6	52	92	88	Gray smooth	Gray	30
7	1	94	93	Gray sand	Gray	27
8	65	91	84	Gray smooth	Gray	43
9	68	95	81	Gray smooth	Gray	50
10	65	95	85	Gray smooth	Gray	50
1987 = 90%		Average mineral content of bottom sediments				1999 = 83%

Algae, which grow in lakes when nutrients are available, live in the surface water (where they are exposed to sunlight which enables them to carry on photosynthetic activities). But they settle to the bottom when they die.

If just a small amount of algae is produced, there is enough oxygen dissolved in the water column of the lake to allow bacteria to decompose the dead algae.

However if too much algae is produced (the lake becomes too productive because of excessive amounts of nutrients) the dissolved oxygen in the bottom layer under the thermocline can be used up (depleted) by the bacteria trying to decompose the dead algae. When that happens, decomposition essentially stops, and the partially decomposed dead algae settle to the bottom and accumulate as organic material.

So an accumulation of organic material in the bottom sediments of a lake is an indication of the amount of algae being produced, and therefore an indicator of the amount of nutrients entering the lake over a period of years.

The data shows in 1987 the average mineral content of the bottom sediments was 90 percent. In 1999, the average mineral content of the bottom sediments dropped 7 percent to 83 percent.

Is this significant? If you consider the mineral content of Ore Lake bottom sediments decreased ten percent (to an average of 90% mineral) in 7000 to ten thousand years, and then decreased another seven percent (to an average of 83% mineral) in 12 years, it certainly appears to be.

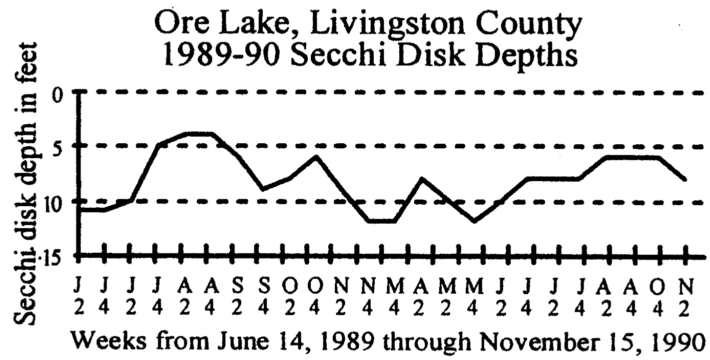
SHALLOW SECCHI DISK READINGS

A Secchi disk is an eight-inch diameter black and white disk that is lowered into the lake until it disappears. The depth where it disappears is called the Secchi disk depth. This was the first test that alerted this author to conditions in Ore Lake when some of the late summer 1998 Secchi disk readings were 4 feet or less. Those shallow readings indicated there was a problem in the lake.

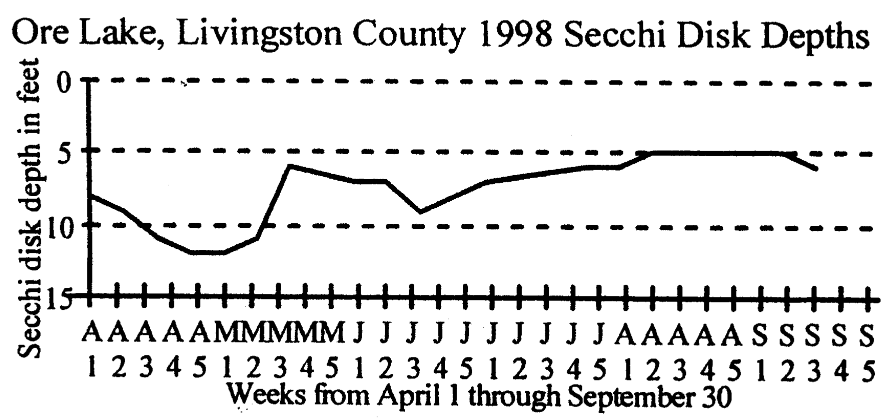
The first years good Secchi disk data is available is 1989-90 when Ore Lake Secchi disk readings' were collected every two weeks from June 14, 1989 through November 15, 1990 during the ice-free months. The graph below shows that data. The average Secchi disk depth is 8.3 feet.

In 1998 Ore Lake resident Phil Paye took Secchi disk readings during the warm months on Ore Lake. The graph below shows the data Phil collected.

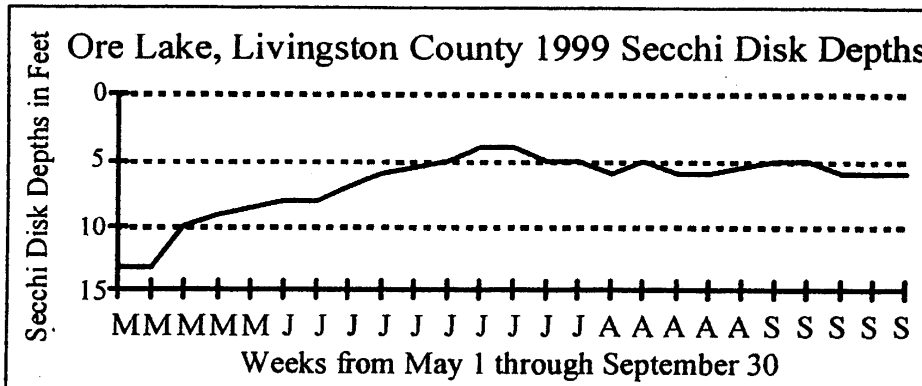
Phil Paye also took Secchi disk readings on Ore Lake in 1999. The graph below shows that data. According to DNR (DNR, 1980) data, Ore Lake had average Secchi disk readings of 9.0 feet in 1980. The 1989-90 average Ore Lake Secchi disk readings were 8.3 feet. The 1998 Ore Lake Secchi disk readings averaged 7.8 feet. And the 1999 Secchi disk data averaged 6.7 feet. These data show the average Secchi disk readings decreased (the lake became more turbid from 1980 (before sewers and before the new Brighton sewage treatment plant) to 1998 and 1999 (ten years after the installation of sewers around the lake, and after the new Brighton sewage treatment plant went on line). After the lake was sewered the lake should have become clearer.



1989		
JUN	11	11
JUL	10	5
AUG	4	4
SEP	6	9
OCT	8	6
NOV	9	12
1990		
MAR		12
APR	8	
MAY	10	12
JUN	10	8
JUL	9	8
AUG	6	6
SEP		
OCT		6
NOV	8	



MAY	8	9	11	12	12
JUN	11	6	.	7	7
JUL	9	.	7	.	.
AUG	6	6	5	5	.
SEP	.	5	6	.	.

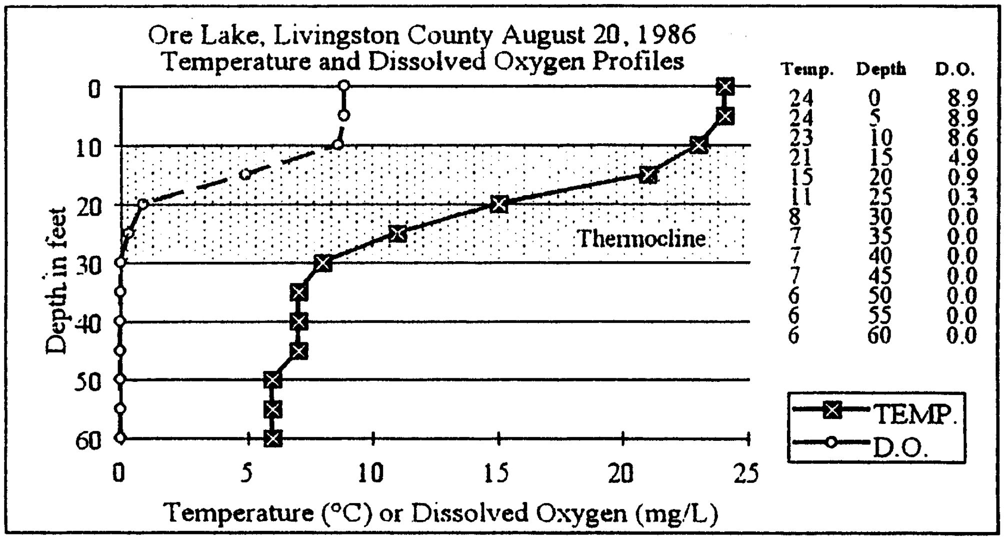


MAY	13	13	10	9	
JUN	8	8	7	6	
JUL	5	4	4	5	5
AUG	6	5	6	6	
SEP	5	5	6		6

DISSOLVED OXYGEN AND TEMPERATURE PROFILES

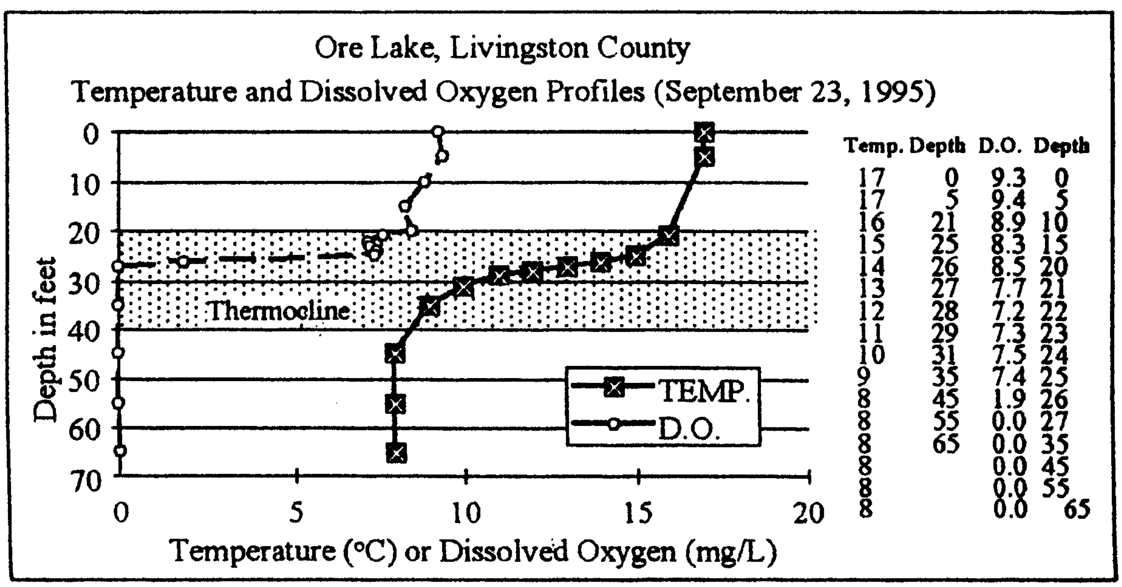
Another method limnologists use to check for changes in the water quality of lakes, is the depth the lake runs out of dissolved oxygen in late summer. (Most Michigan inland lakes run out of dissolved oxygen in late summer somewhere in the thermocline.) Best is no change, or deeper as the years pass. Worse is if the depth the lake runs out of dissolved oxygen gets higher and higher in the water column as years pass. That is what is occurring in Ore Lake.

In late summer (August 20) 1986, Ore Lake ran out of dissolved oxygen at 30 feet. The graph below shows that data.



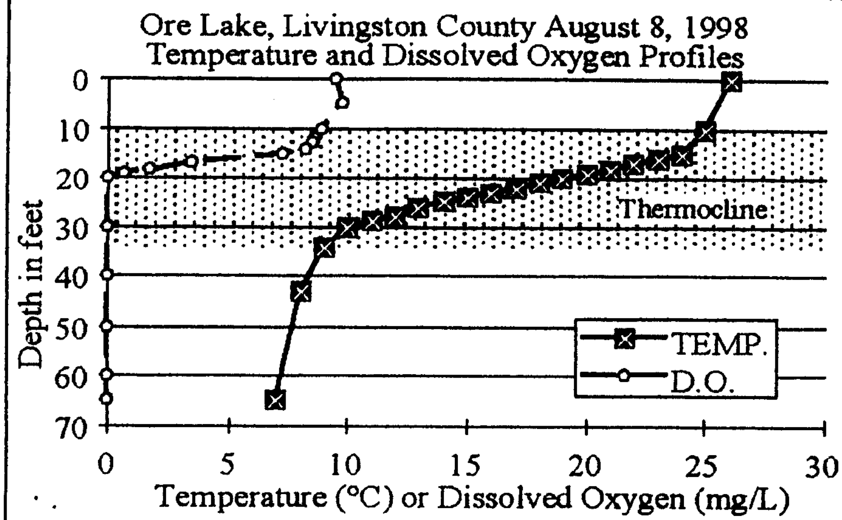
Temp.	Depth	D.O.
24	0	8.9
24	5	8.9
23	10	8.6
21	15	4.9
15	20	0.9
11	25	0.3
8	30	0.0
7	35	0.0
7	40	0.0
7	45	0.0
6	50	0.0
6	55	0.0
6	60	0.0

In late summer (September 23) 1995 Ore Lake ran out of dissolved oxygen at 27 feet. The graph below shows that data.



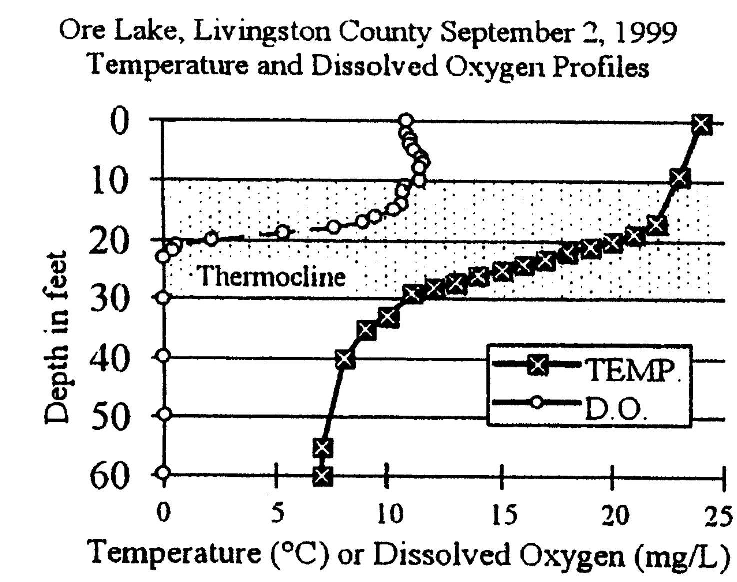
Temp.	Depth	D.O.	Depth
17	0	9.3	0
17	5	9.4	5
16	21	8.9	10
15	25	8.3	15
14	26	8.5	20
13	27	7.7	21
12	28	7.2	22
11	29	7.3	23
10	31	7.5	24
9	35	7.4	25
8	45	1.9	26
8	55	0.0	27
8	65	0.0	35
8		0.0	45
8		0.0	55
8		0.0	65

In late summer (August 8) 1998 Ore Lake ran out of dissolved oxygen at 20 feet. The graph below shows that data.



Temp.	Depth	D.O.	Depth
26	0	9.5	0
25	10	9.8	5
24	15	8.9	10
23	16	8.6	12
22	17	8.5	13
21	18	8.2	14
20	19	7.3	15
19	20	3.5	17
18	21	1.7	18
17	22	0.7	19
16	23	0.0	20
15	24	0.0	30
14	25	0.0	40
13	26	0.0	50
12	28	0.0	60
11	29	0.0	65
10	30		
9	34		
8	43		
7	65		

In late summer (September 2) 1999 Ore Lake ran out of dissolved oxygen at 23 feet. The graph below shows that data. Although deeper than the 1998 dissolved oxygen depletion depth, this is consistent with normal variation in lakes.



Temp.	Depth	D.O.	Depth
24	0	10.9	0
23	9	10.9	2
22	17	11.0	3
21	19	11.0	4
20	20	11.2	5
19	21	11.5	6
18	22	11.6	7
17	23	11.4	8
16	24	11.4	10
15	25	10.8	11
14	26	10.7	12
13	27	10.6	14
12	28	10.3	15
11	29	9.5	16
10	33	8.9	17
9	35	7.6	18
8	40	5.3	19
7	55	2.1	20
7	60	0.6	21
7	80	0.4	22
		0.0	23
		0.0	30
		0.0	40
		0.0	50
		0.0	60

This decrease in dissolved oxygen depletion depth indicates something is removing more and more dissolved oxygen in the lake as time goes by. This material is organic material, and its source is algae growing in the lake which is caused by excessive nutrient concentrations.

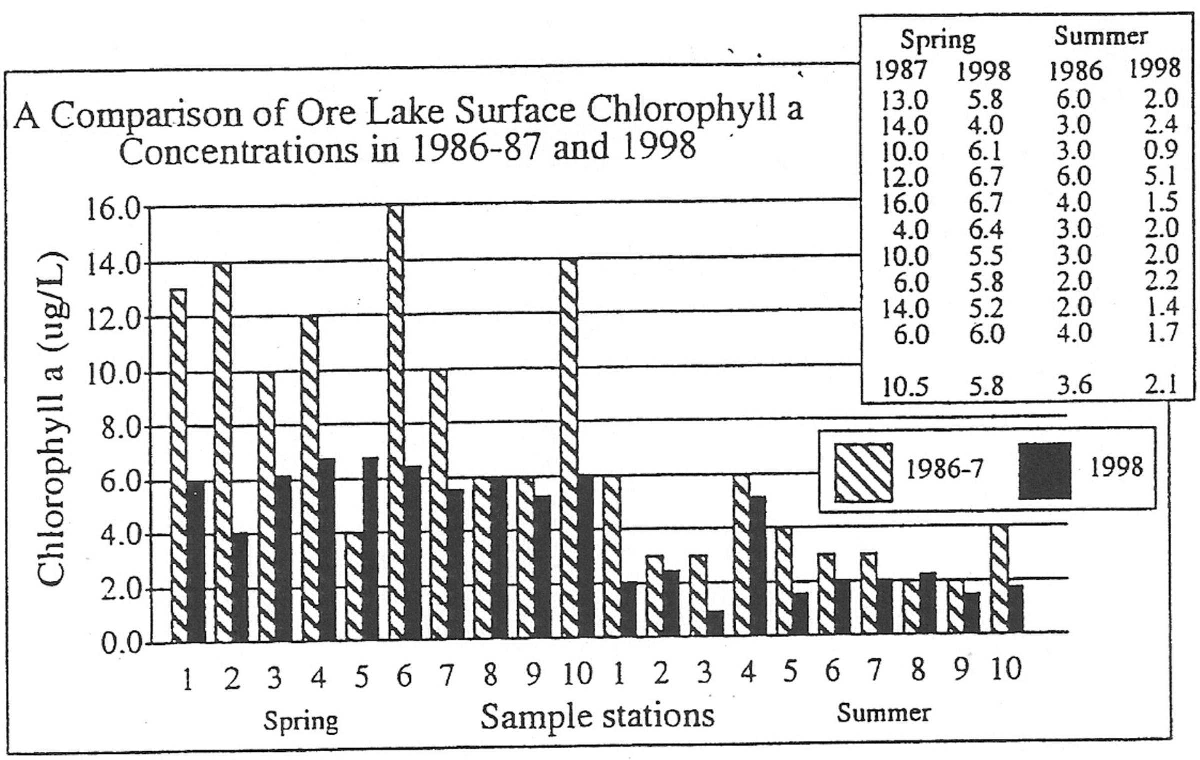
CHLOROPHYLL A

The chlorophyll *a* test is used to estimate algal populations. Generally high chlorophyll *a* concentrations indicate increased amounts of algae in the water. Low concentrations generally indicate fewer algae in the water. In the old days high chlorophyll a concentrations and shallow Secchi disk readings were thought to parallel each other. That was not the case in Ore Lake in 1998 nor was it the ease in more than 40 Michigan Inland lakes and ponds WQI studied in the past few years. The graph below shows the data.

One of the concerns with the Ore Lake data was the chlorophyll *a* data did not parallel the Secchi disk data. These data would indicate algae were not the cause of the shallow Secchi disk readings.

However, more recent data shows it is not unusual for chlorophyll *a* and Secchi disk readings to not follow this pattern (Fusilier, unpublished, 2000.)

In spring 1998, chlorophyll *a* concentrations were relatively high (range 4.0 to 6.7 micrograms per liter, average 5.8 micrograms per liter), but Secchi disk readings were 8 feet. This is certainly better than spring 1987 when chlorophyll *a* concentrations ranged from 4 to 16 micrograms per liter and averaged 10.5 micrograms per liter.



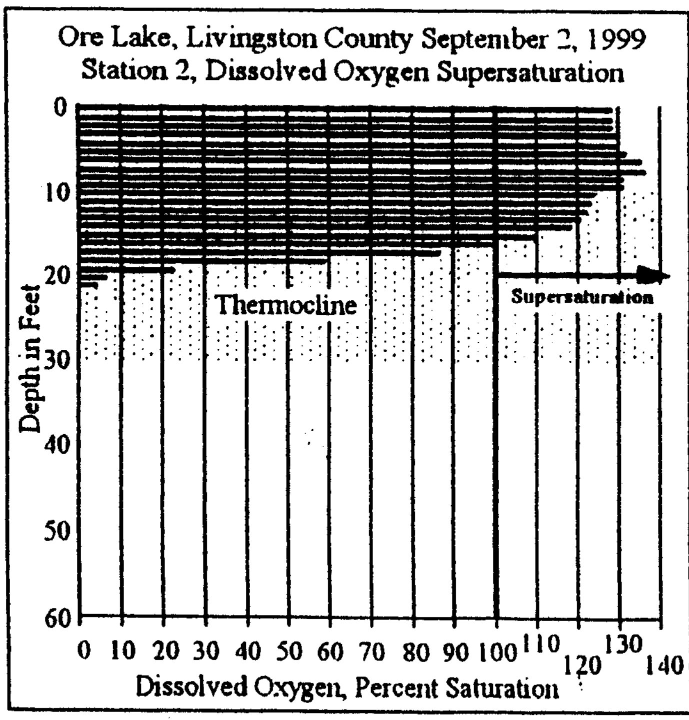
Spring 1987	Spring 1998	Summer 1986	Summer 1998
13.0	5.8	6.0	2.0
14.0	4.0	3.0	2.4
10.0	6.1	3.0	0.9
12.0	6.7	6.0	5.1
16.0	6.7	4.0	1.5
4.0	6.4	3.0	2.0
10.0	5.5	3.0	2.0
6.0	5.8	2.0	2.2
14.0	5.2	2.0	1.4
6.0	6.0	4.0	1.7
10.5	5.8	3.6	2.1

However, in summer, 1998 chlorophyll *a* concentrations were low, ranging from 1.4 to 5.1 micrograms per liter, and averaging 2.1 micrograms per liter. Secchi disk readings were in the 4 to 6 foot range. These chlorophyll *a* data were essentially the same as in 1986 when the chlorophyll *a* concentrations averaged 3.6 micrograms per liter. The graph above shows the 1986-87 and 1998 data.

The data seems to indicate that an algal bloom is not present even though the shallow Secchi disk readings indicate an algal bloom is in the water and algal analysis showed a veritable witches brew of algae present in the lake.

SUPERSATURATED DISSOLVED OXYGEN

In open water when algae photosynthesize, they produce dissolved oxygen, and when the algae are abundant, supersaturated dissolved oxygen conditions can occur. This author is unaware of any source of supersaturated dissolved oxygen conditions in the open water of a lake other than an algal bloom. And the 1999 dissolved oxygen and temperature profiles found supersaturated dissolved oxygen conditions in the top 16 feet of the lake in late summer. The graph below shows the data.



Depth in feet	Temp-erature °C	Dissolved Oxygen mg/L	Dissolved Oxygen Saturation Value	Percent Saturat-ion
1	24	10.9	8.5	128
3	24	10.9	8.5	128
4	24	11.0	8.5	129
5	24	11.0	8.5	129
6	24	11.2	8.5	132
7	24	11.5	8.5	135
8	24	11.6	8.5	136
10	23	11.4	8.7	131
11	23	10.8	8.7	124
12	23	10.7	8.7	123
14	23	10.5	8.7	121
15	23	10.3	8.7	118
16	23	9.5	8.7	109
17	22	8.7	8.8	99
18	22	7.6	8.8	86
19	21	5.3	9.0	59
20	20	2.1	9.2	23
21	19	0.6	9.4	6
22	18	0.4	9.8	4
23	17	0	9.7	0
60	7	0	12.2	0

[sic] dissolved oxygen conditions in the top 16 feet of the lake and the shallow Secchi disk readings.

DISCUSSION

The productivity of Ore Lake is increasing, and the water quality of Ore Lake is getting worse, as measured by a variety of factors.

Average Secchi disk readings are getting shallower as years pass. This when average Secchi disk readings in many Michigan inland lakes are getting deeper. In 1980, DNR data indicate the average Secchi disk reading was 9.0 feet, in 1989-90, it was 8.7 feet, in 1998 it was 7.3 feet, and in 1999 it was 6.3 feet. The decreasing average Secchi disk readings indicate the water quality of the lake is getting poorer.

Dissolved oxygen depletion is occurring higher and higher in the water column as years pass. In 1986, late summer dissolved oxygen depletion occurred at 30 feet, in 1995 it occurred at 27 feet, in 1998 it occurred at 20 feet and in 1999 it occurred at 23 feet. This is an indication that organic material is being produced in the lake faster than the lake can decompose it. The organic material is algal cells.

Bottom sediments are accumulating organic material at a faster than acceptable rate. In the first 7,000 to 10,000 years the average amount of organic material in the bottom sediments reached 10 percent. In the last 12 years the average amount of organic material in the bottom sediments increased another 7 percent, to 17 percent. This increase in organic material in the bottom sediments is caused by excessive production of algae that die and settle to the bottom during anoxic conditions.

Algae biooms are occurring in the lake. The late summer shallow Secchi disk readings and late summer supersaturated dissolved oxygen conditions indicate the presence of a significant algal bloom in Ore Lake.

The nitrate nitrogen concentration increased dramatically between 1986-87 and 1998-99. In spring it about doubled, and in summer it increased more than 15 times.

In 1987 the spring nitrogen to phosphorus ratio averaged 7.9 and in 1986 the summer ratio averaged 2.4, indicating the lake was nitrogen limited, especially in summer. In 1998, the N to P ratio averaged 27.8 in spring and 30.4 in summer. These data indicate the lake is no longer nitrogen limited because nitrogen, the limiting nutrient in earlier years, is being added by the Brighton sewage treatment plant. Because of this productivity of the lake increased until phosphorus became the limiting nutrient. If nitrates continue to be discharged into the creek (and the lake) productivity will continue at its present rate, and water quality will continue to decline. On the other hand, if nitrate nitrogen is limited to less than 200 parts per billion (micrograms per liter), productivity of the lake should return to normal, and the water quality should improve. This conclusion is based on the analysis of water quality data from several hundred Michigan inland lakes by WQI.

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Ore Lake, Livingston County Water Quality Data

Date	Sample Station Number	Temperature °C	Dissolved Oxygen (mg/L)	Dissolved Oxygen Percent Saturation	Chlorophyll a ug/L	Secchi Disk Depth (feet)	Total Nitrate Nitrogen ug/L	Alkalinity mg/L	pH	Conductivity umhos per cm at 25°C	Total Phosphorus ug/L	Lake Water Quality Index	Grade
8/20/86	1	24	8.6	101	6.0	7	29	177	8.7	560	23	81	B
8/20/86	2	24	8.9	107	3.0	7	37	174	8.7	560	14	85	B
8/20/86	2-5	24	8.9	107	---	---	---	---	---	---	---	---	---
8/20/86	2-10	23	8.6	99	---	---	---	---	---	---	---	---	---
8/20/86	2-15	21	4.9	54	---	---	---	---	---	---	---	---	---
8/20/86	2-20	15	0.9	9	---	---	---	---	---	---	---	---	---
8/20/86	2-25	11	0.0	0	---	---	---	---	---	---	---	---	---
8/20/86	2-30	8	0.0	0	---	---	---	---	---	---	---	---	---
8/20/86	2-40	7	0.0	0	---	---	---	---	---	---	---	---	---
8/20/86	2-50	6	0.0	0	---	---	---	---	---	---	---	---	---
8/20/86	2-60	6	0.0	0	---	---	---	---	---	---	---	---	---
8/20/86	3	24	9.0	102	3.0	8	37	171	8.7	570	18	85	B
8/20/86	4	24	9.0	106	6.0	7	34	169	8.7	570	18	80	B
8/20/86	5	24	8.6	101	4.0	8	37	176	8.7	560	16	84	B
8/20/86	6	24	8.6	101	3.0	8	40	170	8.7	560	16	85	B
8/20/86	7	24	8.8	104	3.0	7	37	174	8.7	560	16	84	B
8/20/86	8	24	9.1	107	2.0	7	37	174	8.7	560	15	86	B
8/20/86	9	24	8.6	101	2.0	8	42	175	8.7	560	15	87	B
8/20/86	10	24	8.8	104	4.0	8	37	174	8.7	560	10	85	B
4/8/87	1	6	13.0	104	3.0	7	200	230	8.0	560	32	85	B
4/8/87	1-10	5	12.2	95	---	---	208	235	8.0	560	22	---	---
4/8/87	1-20	5	12.0	94	---	---	204	234	8.0	560	27	---	---
4/8/87	1-30	5	12.0	94	---	---	195	233	8.0	560	29	---	---
4/8/87	1-40	5	12.0	94	---	---	202	234	8.0	560	23	---	---
4/8/87	1-50	5	10.6	83	---	---	200	234	8.0	560	16	---	---
4/8/87	1-60	5	10.5	82	---	---	200	239	8.0	560	14	---	---
4/8/87	1-70	5	10.5	82	---	---	242	236	8.0	560	21	---	---
4/8/87	2	7	12.6	103	14.0	7	203	234	8.0	560	27	78	C
4/8/87	3	7	13.7	112	10.0	7	204	242	8.0	570	23	79	C
4/8/87	4	7	13.5	111	12.0	7	202	238	8.0	570	29	78	C
4/8/87	5	8	13.7	115	16.0	7	213	235	8.0	560	27	77	C
4/8/87	6	8	13.5	113	4.0	7	195	238	8.0	560	32	83	B
4/8/87	7	8	13.8	116	10.0	7	213	238	8.0	560	23	79	C
4/8/87	8	7	13.6	111	6.0	7	200	235	8.0	560	17	83	B
4/8/87	9	7	13.7	112	14.0	7	183	235	8.0	560	32	77	C
4/8/87	10	7	14.4	118	6.0	7	215	235	8.0	560	25	81	B
4/8/87	L Ore	10	12.8	111	6.0	7	192	235	8.0	560	21	---	---
4/8/87	Oulet	10	12.7	110	---	---	203	---	8.0	560	20	---	---
4/15/98	1	12	11.3	105	5.8	8	378	187	8.4	560	14	80	B
4/15/98	2	12	11.3	105	4.0	8	415	186	8.3	560	14	84	B
4/15/98	2-10	12	11.3	105	---	---	425	187	8.3	560	16	---	---
4/15/98	2-20	11	11.4	103	---	---	373	188	8.2	560	12	---	---
4/15/98	2-30	9	10.6	91	---	---	387	189	8.0	560	10	---	---
4/15/98	2-40	7	9.9	81	---	---	401	190	8.0	560	15	---	---
4/15/98	2-50	7	10.0	82	---	---	373	192	7.9	560	12	---	---
4/15/98	2-60	6	10.1	81	---	---	462	191	7.9	570	20	---	---
4/15/98	3	12	11.2	104	6.1	8	439	190	8.3	560	12	82	B
4/15/98	4	12	11.2	104	6.7	8	434	191	8.3	560	16	81	B
4/15/98	5	12	11.3	105	6.7	8	420	188	8.4	560	21	81	B
4/15/98	6	12	11.2	104	6.4	8	415	188	8.3	560	15	82	B
4/15/98	7	12	11.2	104	5.5	8	401	185	8.4	560	15	82	B
4/15/98	8	12	11.3	105	5.8	8	406	187	8.4	560	12	82	B
4/15/98	9	12	11.3	105	5.2	8	406	187	8.4	560	14	82	B
4/15/98	10	12	11.3	105	6.0	8	406	186	8.4	560	20	82	B
4/15/98	Outlet	12	11.3	105	---	8	397	188	8.4	560	18	---	---
4/15/98	Inlet	---	---	---	---	---	816	189	8.3	580	56	---	---
8/8/98	1	26	9.5	116	2.0	4	567	152	8.7	590	20	75	C
8/8/98	2	26	9.5	116	2.4	4	545	150	8.6	585	18	76	C
8/8/98	2-10	25	8.9	106	---	---	665	156	8.6	590	21	---	---
8/8/98	2-20	19	0.0	0	---	---	305	180	7.8	600	16	---	---
8/8/98	2-30	10	0.0	0	---	---	185	170	7.6	600	27	---	---
8/8/98	2-40	9	0.0	0	---	---	48	202	7.5	600	28	---	---
8/8/98	2-50	8	0.0	0	---	---	57	205	7.5	600	54	---	---
8/8/98	2-60	7	0.0	0	---	---	43	207	7.5	600	174	---	---

Ore Lake, Livingston County Water Quality Data

Date	Sample Station Number	Temperature °C	Dissolved Oxygen (mg/L)	Dissolved Oxygen Percent Saturation	Chlorophyll a ug/L	Secchi Disk Depth (feet)	Total Nitrate Nitrogen ug/L	Alkalinity mg/L	pH	Conductivity umhos per cm at 25°C	Total Phosphorus ug/L	Lake Water Quality Index	Grade
8/8/98	3	26	9.8	120	0.9	4	578	150	8.7	600	22	75	C
8/8/98	4	26	9.8	120	5.1	5	575	156	8.7	610	21	73	C
8/8/98	5	26	9.7	118	1.5	5	589	160	8.7	590	23	77	C
8/8/98	6	26	9.7	118	2.0	5	600	154	8.6	585	23	77	C
8/8/98	7	26	9.7	118	2.0	5	611	150	8.6	585	21	77	C
8/8/98	8	26	9.2	112	2.2	6	611	150	8.6	600	16	79	C
8/8/98	9	26	9.2	112	1.4	5	589	150	8.6	600	17	79	C
8/8/98	10	26	9.2	112	1.7	5	605	152	8.6	590	16	80	B
8/8/98	Outlet	26	9.3	113	---	---	584	150	8.6	590	16	---	---
8/8/98	Inlet	---	---	---	---	---	1598	180	8.3	660	16	---	---
8/31/98	Inlet	---	---	---	---	---	2074	186	8.2	740	38	---	---
8/31/98	S. Ore Cr.	---	---	---	---	---	126	157	8.7	570	230	---	---
9/5/98	Brighton L.	---	---	---	---	---	22	90	7.9	460	28	---	---
9/5/98	S. Ore Cr.	---	---	---	---	---	2470	96	7.5	410	100	---	---
9/8/98	Brighton L.	---	---	---	---	---	103	102	7.6	390	51	---	---
9/8/98	S. Ore Cr.	---	---	---	---	---	3013	105	7.6	540	42	---	---
9/14/98	Brighton L.	---	---	---	---	---	21	140	8.5	500	74	---	---
9/14/98	S. Ore Cr.	---	---	---	---	---	3311	140	7.9	820	49	---	---
9/18/98	Brighton L.	---	---	---	---	---	27	105	8.1	490	133	---	---
9/18/98	S. Ore Cr.	---	---	---	---	---	2886	131	7.3	670	42	---	---
9/23/98	Brighton L.	---	---	---	---	---	21	143	8.4	530	72	---	---
9/23/98	S. Ore Cr.	---	---	---	---	---	3203	182	8.0	780	63	---	---
10/13/98	Brighton L.	---	---	---	---	---	16	147	8.9	560	54	---	---
10/13/98	S. Ore Cr.	---	---	---	---	---	1167	176	8.0	630	21	---	---
10/13/98	Above STP	---	---	---	---	---	133	158	8.2	620	39	---	---
10/13/98	Below STP	---	---	---	---	---	9600	224	7.5	1120	14	---	---
5/5/99	Above STP	---	---	---	---	---	11	150	7.8	600	23	---	---
5/5/99	Below STP	---	---	---	---	---	684	145	7.9	600	27	---	---
5/10/99	Above STP	---	---	---	---	---	34	186	8.1	600	27	---	---
5/10/99	Below STP	---	---	---	---	---	4275	189	8.1	650	25	---	---
5/10/99	2-0	17	10.8	111	2.6	14	492	190	8.2	640	50	82	B
5/10/99	2-10	16	10.6	106	---	---	474	190	8.2	640	68	---	---
5/10/99	2-20	12	11.0	102	---	---	456	186	8.2	640	20	---	---
5/10/99	2-30	8	8.0	67	---	---	456	192	7.8	650	18	---	---
5/10/99	2-40	7	6.9	57	---	---	438	195	7.6	660	20	---	---
5/10/99	2-50	7	5.6	46	---	---	420	195	7.6	660	22	---	---
5/10/99	2-60	6	5.0	39	---	---	408	195	7.6	660	20	---	---
6/10/99	Above STP	---	---	---	---	---	34	141	7.6	480	28	---	---
6/10/99	Below STP	---	---	---	---	---	4275	137	7.8	560	32	---	---
9/3/99	Above STP	---	---	---	---	---	50	128	9.1	540	43	---	---
9/3/99	Below STP	---	---	---	---	---	2700	173	8.1	780	35	---	---
9/3/99	2-0	24	10.9	128	3.9	6	1485	140	8.6	650	36	62	D
9/3/99	2-10	23	11.4	131	---	---	1361	141	8.6	610	35	---	---
9/3/99	2-20	20	2.1	23	---	---	1328	152	8.2	590	25	---	---
9/3/99	2-30	11	0	0	---	---	133	200	7.4	660	35	---	---
9/3/99	2-40	8	0	0	---	---	140	200	7.4	660	37	---	---
9/3/99	2-50	7	0	0	---	---	88	208	7.3	690	48	---	---
9/3/99	2-60	7	0	0	---	---	104	208	7.3	690	80	---	---
9/3/99	Outlet	25	10.4	124	13.5	6	468	141	8.5	620	25	73	C
9/22/99	Above STP	---	---	---	---	---	66	101	8.2	500	129	---	---
9/22/99	Below STP	---	---	---	---	---	4180	133	7.2	700	68	---	---
10/15/99	Above STP	---	---	---	---	---	22	88	8.2	530	117	---	---
10/15/99	Below STP	---	---	---	---	---	4565	70	7.7	420	48	---	---

Environmental Problem Solving and the Dangers of Junk Science: The Case of Ore Lake, Michigan

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Part 3: Facts, Theory and Analysis

Evaluation of the scientific claims about Ore Lake

Concerned citizens and elected representatives of Hamburg Township had mobilized an impressive campaign both legally and politically on the presumed strength of their consultant's assurance that "water quality" of Ore Lake had declined from a grade of "B" to a grade of "C". Aligned against the claims of the consultant were several studies by State environmental scientists that detected no problems with the lake. Nonetheless, judging from their letters citizens fervently believed their lake was in trouble. They blamed State officials for siding with the City of Brighton, and for approving what they regarded as further environmental insult and an assault on their property rights and sovereignty.

Amidst the mounting debate, officials from the City of Brighton asked for an independent scientific evaluation of the proposed permit for expansion of their WWTP and the objections filed by the contesting parties, regarding whether or not the proposed permit represented proper lake management strategy. Several features in the analysis produced by Hamburg's consultant raised concerns that the data or interpretations might be flawed, and that they were being used in pursuit of a specific partisan agenda.

Among the initial points of concern even to non-scientists were:

1. **Selective use of data**: The consultant had implicitly rejected large quantities of MDEQ environmental data about Ore Lake by omitting them from consideration in his report, although the MDEQ data were roughly contemporaneous to those produced by the consultant.
2. **Questionable inference**: Although measurement of the algal pigment chlorophyll *a* indicated that the concentrations of algae in Ore Lake had decreased, the consultant concluded that algae must have increased.
3. **Nonscientific premises**: Although the consultant generated a numerical value for "water quality" the term "water quality" has no objective existence as a tangible entity. Hence it is not a valid object of scientific measurement.

The key scientific questions were about nitrogen limitation and what it meant. City officials consequently asked a university professor to evaluate the scientific claims. The realities of processes in nature are rich, complex, and not so easy to capture as a single numerical "index" can suggest. This chapter is about that explanation and evaluation.

Background Information about Ore Lake

Physical Factors
Ore Lake is a multiple basin lake that occupies depressions left in the glacial debris from ice sheets that covered the landscape of Michigan 15,000 years ago. The lake lies along one of the major channels followed by meltwater from the glaciers as they receded north. The Huron River now follows that melt water channel. Ore Lake lies adjacent to the present course of the Huron River, and in fact is in the flood plain of the Huron River (Figure 3.1).

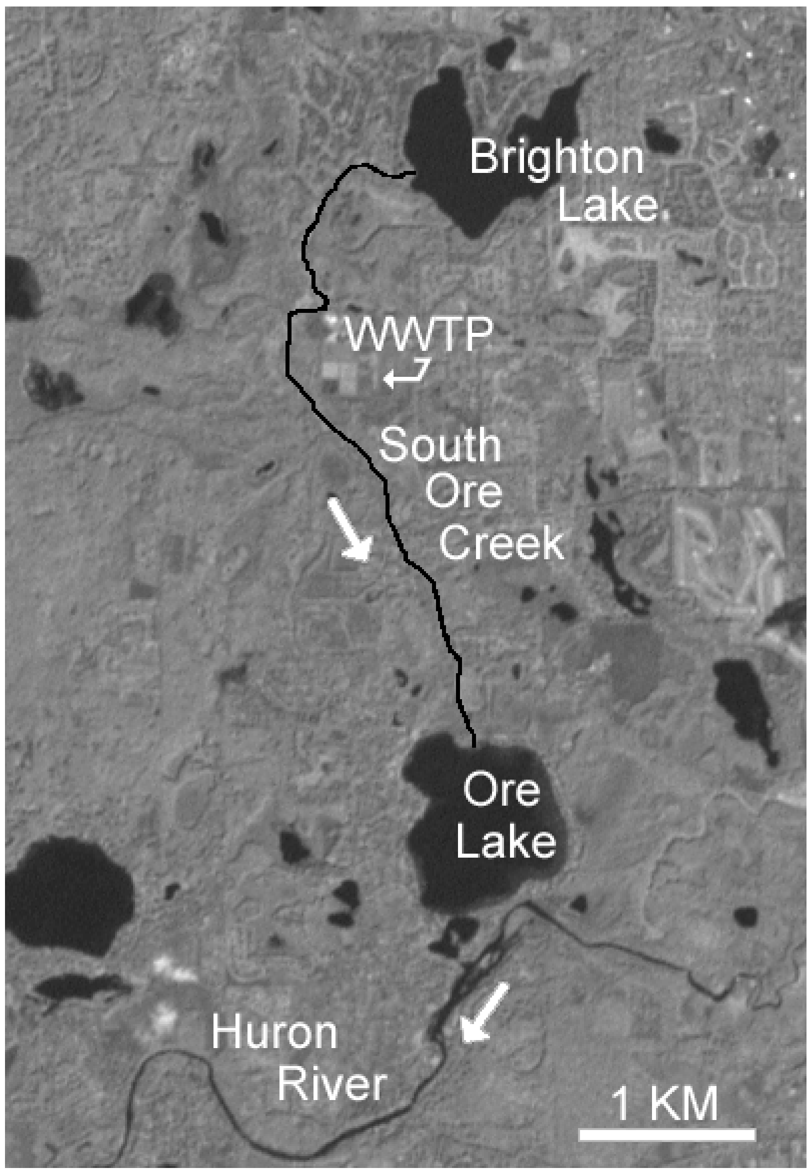

Figure 3.1. Gray-scale image from Landsat 7 satellite on 21 August 2001. The path of South Ore Creek from Brighton Lake to Ore Lake is highlighted in black. Directions of stream flow are indicated.

Ore Lake receives water from a large catchment area, including Brighton Lake and areas upstream of it. Flow of water through the lake is rapid. The U.S. Geological Service maintained a gaging station on South Ore Creek from 1951 to 1968 (station 04171500). Based on the water flow data from that 17-year record, Ore Lake is flushed through on average by 1.5% of its entire volume per day in March and April, but it receives only 0.4% of its volume per day in August and September. Over the course of a year the lake is flushed with about 3 times its own volume. The chemical constituents as well as the algal populations of Ore Lake are perpetually being washed through and out of the lake.

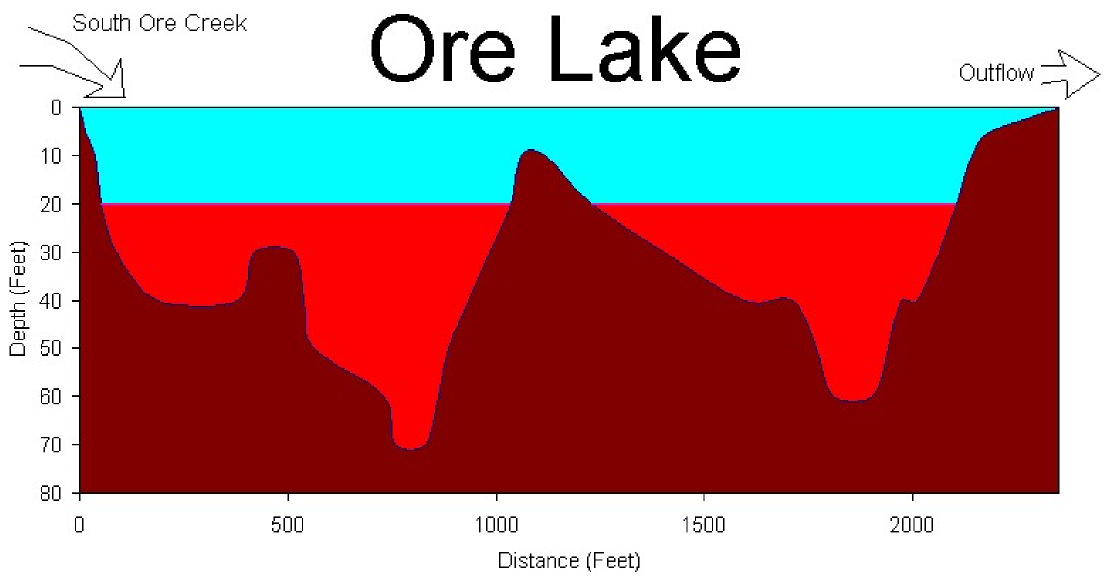

Figure 3.2. Cross-section of Ore Lake from inlet to outlet demonstrating its multi-basin character. Blue represents warm surface water during summer; red represents cold deep water that becomes depleted of dissolved oxygen during summer.

Ore Lake has a surface area of 192 acres, or 777,000 square meters, and a maximum depth of 84 feet, or 25.6 meters, which gives it a relative depth of 2.6%. Relative depth is the percentage ratio of maximum depth to average lake diameter. Small lakes like Ore Lake with relative depths greater than 1% tend to have only a short mixing period in the spring, and in some years they do not mix thoroughly after ice out. These lakes typically develop anoxic conditions (no dissolved oxygen) in their deep water during the summer. Within the anoxic deep-water layer of Ore Lake, bacteria can thrive in the absence of oxygen. The bacteria and associated chemical reactions cause the deep layer to become enriched with phosphate, ammonium, iron, and other mineral nutrients that help plants grow.

Ore Lake is surrounded by permanent residences (Figure 3.3), and the lake is used intensely for recreation during the summer. Historically, the residences were served by septic tanks and drainage fields, but during the 1990s they were connected by sewers to the Brighton WWTP.

Figure 3.3. USGS aerial photograph of Ore Lake on 28 April 1992. Notice the extent of residential development along the shoreline.

Internal Nutrient Sources

Plants and algae cannot grow on the "internal sources" of nutrients that are produced in the anoxic regions of the lake so long as they are confined in deep water where there is no light. But for a short time in the spring, and usually for a longer time in the fall, the lake mixes and the rich nutrients are liberated. Unless the lake is rapidly flushed at these times, significant water blooms of algae may result, and the "internal nutrient loading" becomes a serious obstacle to efforts aimed at reducing nutrients and increasing lake transparency.

Lakes in the Temperate Zone generally mix in the spring and the fall because at those times of year the water temperature is uniform from top to bottom. Temperature changes the density of water. In the summer, the surface water of a lake warms up and it floats on top of colder water underneath. In winter, the ice-cold water also floats on top of slightly warmer water beneath. In both winter and summer, the temperature and density differences between layers inhibit deep mixing. But for short periods in the spring when the lake surface is warming, or in fall when the lake surface is cooling, the top and bottom temperatures become equal and it is easy for the wind to help mix the entire lake. Limnologists call these times *overturn*.

Risk of Nuisance Bluegreen Blooms

Lakes like Ore Lake that develop anoxic conditions run the risk of developing nuisance blooms of bluegreen "algae" during the late summer. Bluegreen algae form blooms that are conspicuous symptoms of poor water quality in lakes. Bluegreen blooms contribute to a wide range of problems including summer fish kills, foul odors, and chemical interactions. Water-soluble nerve toxins and liver toxins are released when bluegreens die or are ingested (Carpenter et al. 1998; Martin and Cooke 1994; Lawton and Codd 1991). The toxins can kill livestock, and may pose serious health hazards to humans. Floating scums produced by bluegreens are an eyesore commonly associated with cultural eutrophication.

Bluegreens are not true algae. They are bacteria with the same chlorophyll as all true algae and higher plants, but they have additional pigments that give them their blue-green color plus they have unique features. For example, they possess vacuoles to float. Under some conditions bluegreens float to the surface and form mats thick enough to support the weight of small pebbles. Mats of living algal debris raft to shore where they decompose and create foul odors and eyesores. Some bluegreens can make their own proteins by using nitrogen gas from the atmosphere instead of using the sources of nitrogen needed by all true algae and higher plants. Many bluegreens are inedible or only poorly edible, so bluegreens rob lake food chains of primary food. Nuisance bluegreens were a feature of Ore Lake in the 1970s.

Figure 3.4. Example of a bluegreen bloom in Ford Lake, Michigan during summer 2001. Photo courtesy of R. Jonna.

Denitrification in Ore Lake

On average, the cellular composition of algal cells is about 7 grams of nitrogen for every gram of phosphorus (or 16 atoms of nitrogen for every atom of phosphorus; phosphorus has greater atomic mass than does nitrogen). From species to species the precise ratio of these elements differs, but the range is not extreme because all cells are made up of the same types of molecules- proteins, fats, sugars, DNA, and so on. All algae get phosphorus by absorbing the mineral form called phosphate, or by using enzymes to extract phosphate from organic molecules. Nitrogen is different. Most true algae and higher plants can fulfill their needs for nitrogen only by consuming it in the forms of ammonium or nitrate. Ammonium is used preferentially. In Ore Lake a lot of nitrate is destroyed in the anoxic deep water.

When Ore Lake mixes in the fall and in early spring, nitrate becomes distributed throughout all depths of the lake. But as soon as the surface waters warm, the deep water becomes isolated from the atmosphere and bacteria rapidly deplete its supply of dissolved oxygen. Then the bacteria in the deep layer turn to destruction of nitrate through processes known collectively as *anaerobic nitrate respiration*. One of these processes, *denitrification*, converts nitrate into nitrogen gas, the same gas that makes up 80% of the atmosphere, and which is a gas that is relatively inert to all higher forms of life.

Denitrification causes a lake to lose its nitrate, and coincidentally it sets the stage for the bluegreens. For when the internal loads of deep-water nutrient are mixed back up into the surface waters, the waters are rich in phosphate and other minerals but their nitrogen content has been reduced. This is the ideal medium for the growth of bluegreens. Bluegreens don't need nitrates; they can make their own nitrogen. Their prowess at fixing nitrogen was first demonstrated on the whole lake scale by the German limnologist W. Einsele in 1937 and 1938 (Edmondson 1991). Einsele fertilized a small lake with nothing but the mineral phosphate. Not only did bluegreens bloom spectacularly, but the nitrogen content of the lake spontaneously increased. The bluegreens literally made their protein nitrogen out of thin air, because they used the dissolved nitrogen gas in lake water that diffuses into it from the earth's atmosphere. Later, C. N. Sawyer at the University of Wisconsin demonstrated that addition of phosphate all by itself made bluegreens grow, and the bluegreens took their nitrogen from the abundant gas of the atmosphere, using nitrogen gas rather than nitrate as their source (Edmondson 1991).

Development of Theory about Bluegreen Nuisance Blooms

During the 1970s a vigorous policy debate raged over whether lake management strategy should emphasize phosphate. Officials from the soap and detergent industry as well as some scientists claimed that carbon or even nitrogen were the nutrients limiting algal growth in many lakes. If they were right, they argued, regulations to control phosphate would be wrong. Canadian scientists repeated Einsele's experiment in lakes within the Experimental Lakes Area east of Kenora in northwest Ontario. A lake was fertilized with carbon and with nitrate (a source of nitrogen), but no phosphate. No algal blooms developed. In another lake, the scientists experimented with fertilizing nitrogen (N) and phosphorus (P) in different ratios. When low ratios of N to P were added to the lake it bloomed with bluegreens. At higher ratios of N to P, the lake formed species that were less obnoxious (Hecky et al. 1994).

From these and later studies an important paradigm for lake management has emerged. In order to protect lakes from nuisance blooms of bluegreens, it is necessary to keep the surface water ratio (grams to grams) of Total N to Total P at about 30:1 or greater. Bluegreens are considered to be competitively favored over other species at lower N:P ratios (Schindler 1977; Smith 1983; Barica 1990). Non-bluegreens typically become growth limited by lack of nitrogen, and nitrogen-fixing bluegreens typically appear when the total amount of nitrate and ammonium nitrogen drops below 50 to 100 milligrams per cubic meter (Horne and Commins 1987). Lake Kinneret, Israel, suddenly became dominated by nuisance bluegreens in 1994, when changes in water use caused the lake to develop low Total Nitrogen to Total Phosphorus ratios. Now bluegreens dominate the lake when the Total Nitrogen to Total Phosphorus ratio falls below 22:1 (Gophen et al. 1998).

Supply of Phosphorus and Nitrogen to Ore Lake from the Brighton WWTP

The new Brighton WWTP exports a mass of Total Phosphorus that is 9 percent of the Total Phosphorus exported from Ore Lake to the Huron River on an annual basis. Most of the phosphorus supplied to Ore Lake at present seems to be in the water flowing downstream from Brighton Lake and upstream tributaries. At most times the phosphorus content of the WWTP discharge is lower than the concentration of Total Phosphorus flowing down South Ore Creek, so that the WWTP discharge has a diluting influence on the phosphorus entering Ore Lake. The nitrate released by the WWTP is an important contribution to the Ore Lake nitrogen budget. In the absence of the nitrate discharge from the Brighton WWTP, Ore Lake would be at risk of forming nuisance water blooms of bluegreen "algae" which create floating scums, odor problems, and in some cases toxicity. Ore Lake was plagued with these nuisance algae in the 1970s when ratios of Total Nitrogen to Total Phosphorus were well below 30:1.

Control of Algal Biomass and Water Transparency in Ore Lake

When data collected by Michigan DEQ scientists and Hamburg's consultant were examined in aggregate, several at first surprising facts came to light. First, the data revealed that noticeably higher concentrations of chlorophyll develop only when Total Phosphorus exceeds 25 mg per cubic meter. There is no clear or consistent relationship (i.e, the two variables are not correlated nor is any nonlinear pattern visible) when TP is less than 25 mg per cubic meter. During the 1970s, the TP levels in the outflow from Ore Lake ranged from 20 to 75 mg per cubic meter (MDEQ 1978) whereas modern TP levels go as low as 10 mg per cubic meter. There is thus no evidence in either MDEQ or WEF data that reductions in TP below 25 mg per cubic meter produce lower concentrations of algae in this lake.

Secchi Disk Transparency in Ore Lake was also not related to chlorophyll concentration (Figure 3.5). If reductions in water clarity are attributed to algae, you would expect to see a relationship whereby algal pigment (a proxy measurement of algal abundance) is elevated when transparency is low, and pigment should be low when transparency is high. The data reveal that both the highest and the lowest water clarity occur at relatively low levels of chlorophyll. Hamburg's consultant argued that these data prove that the algae causing the water clarity problems must have very low levels of chlorophyll. He thereby implicitly rejected the theory that there ought to be a reciprocal relationship between chlorophyll and water clarity, but he retained the theory that there was a reciprocal relationship between algal abundance and water transparency. To do so, he created a new theory by induction: these algae are low in pigment.

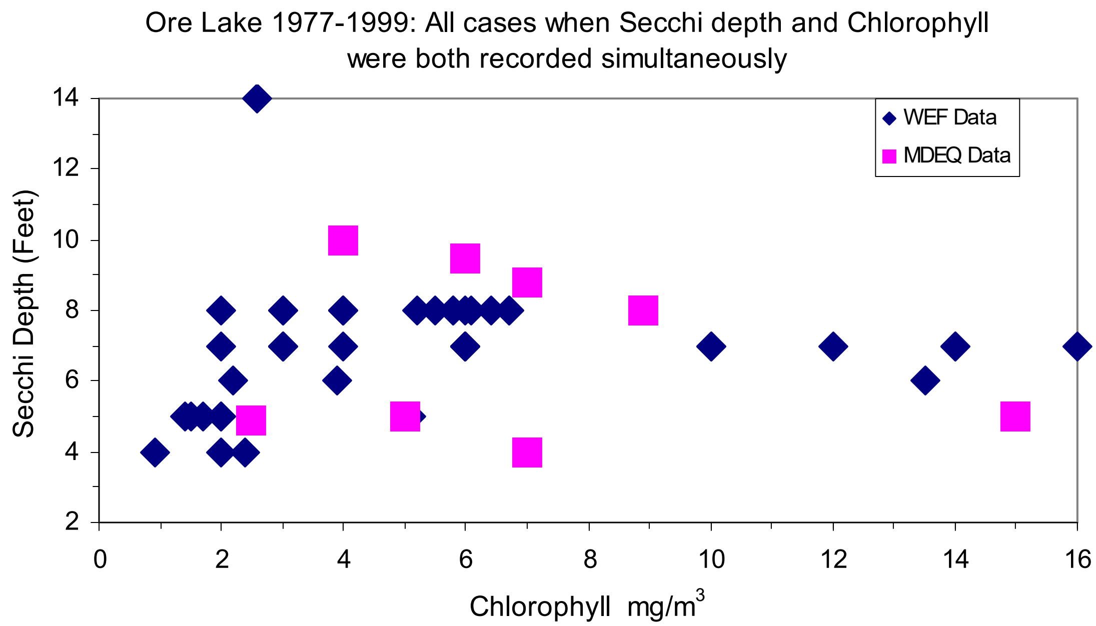

Figure 3.5. Secchi depth plotted against chlorophyll in Ore Lake.

There is, however, no obvious limit on the number of alternative explanations or theories that could be created in reaction to the empirical data displayed in Figure 3.5. Perhaps in Ore Lake it is the case that material other than algae exerts a dominating influence on the transparency. Plausible alternatives based on analogy with other lakes could be colloidal particles resulting from calcium carbonate precipitation or clay particles from stream bank or shoreline erosion. Regardless of the cause, there is no evidence that changes in Total Phosphorus concentrations between 10 and 25 mg per cubic meter imply any changes in water transparency (Figure 3.6).

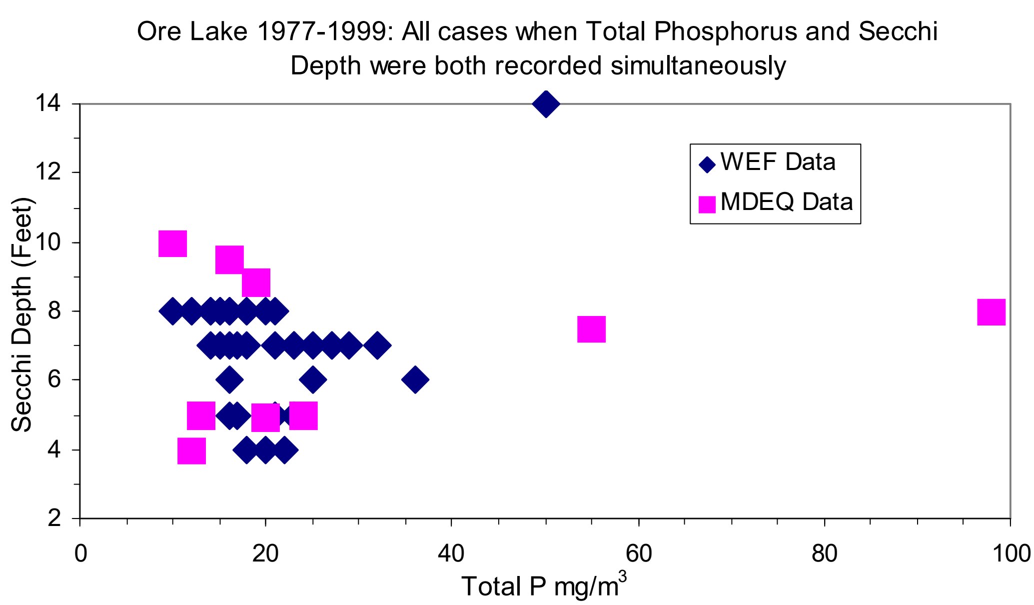

Figure 3.6. Secchi depth plotted against Total Phosphorus in Ore Lake.

Future Total Phosphorus Concentrations and the Projected Condition of Ore Lake

MDEQ collected samples and used them to calculate the amounts of nitrogen and phosphorus flowing into and out of Ore Lake each month from April 1998 to March 1999. These measurements can be used to project hypothetical nutrient budgets into the future under different scenarios. If future conditions were unchanged from the study period, the nutrient budgets would be predicted to be unchanged, as well. It is also possible to examine the potential consequences of future alterations to the nutrient budgets that would result from changes in phosphorus or nitrogen loading. Specifically, it is possible to simulate increased phosphorus discharge from the Brighton WWTP according to the proposed permit. It is also possible to explore the ramifications of nitrate reduction at the Brighton WWTP.

Future conditions were calculated by assuming the maximum loading that the law would allow. The Brighton WWTP presently discharges far less than its allowable Total Phosphorus limit. If that condition of reduced discharge continued into the future, the future concentrations of Total Phosphorus in Ore Lake will be lower than in the specific example presented here. In other words, the projection is a theoretical upper limit of what is expected.

The maximum legal Total Phosphorus discharge from the Brighton WWTP was projected to have only a modest effect on future concentrations of Total Phosphorus in Ore Lake (Figure 3.7). Because of the empirical relationships among TP, chlorophyll, and Secchi depth, there would be expectation of no perceptible increases in Chlorophyll, nor any perceptible decreases in water transparency resulting from these concentrations.

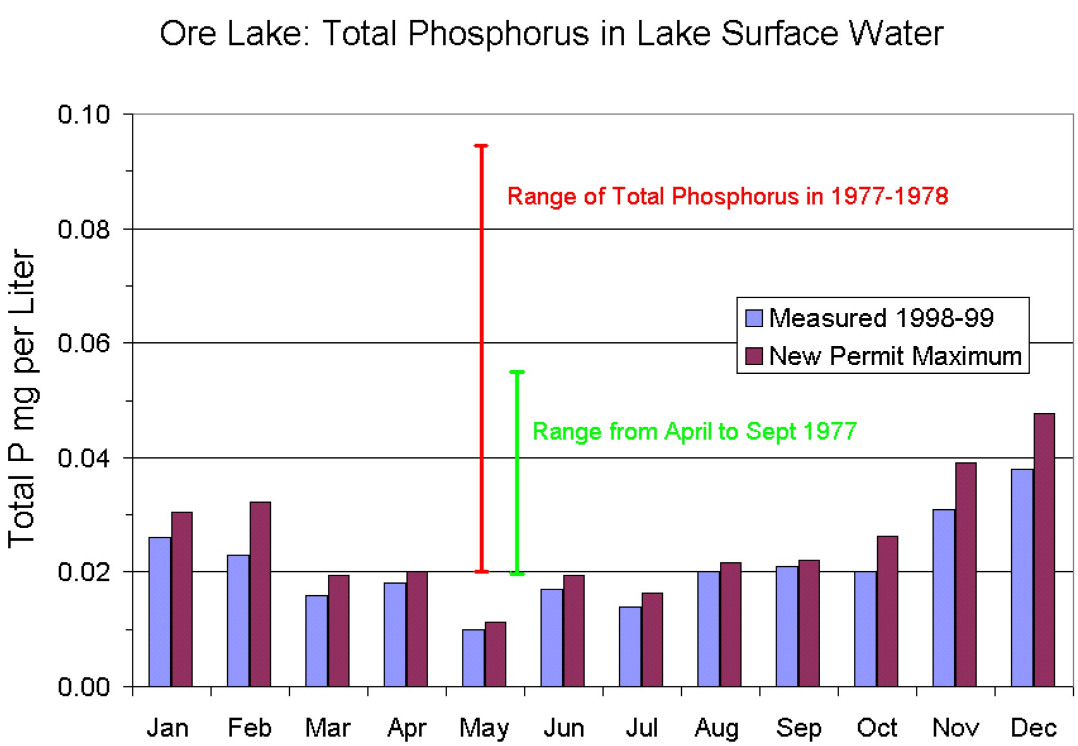

Figure 3.7. Measured Total Phosphorus and projected future Total Phosphorus in Ore Lake, compared with historical levels.

If nitrate were to continue to be discharged from the Brighton WWTP, Total Nitrogen to Total Phosphorus ratios in Ore Lake would help to prevent domination of the lake by nuisance bluegreens during the summer months (Figure 3.8).

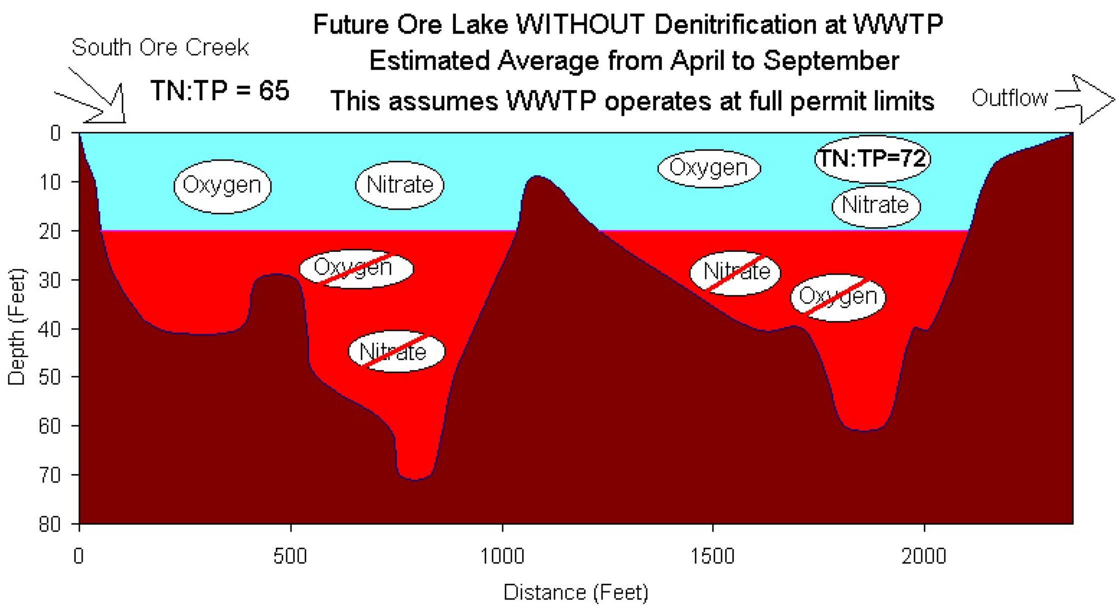

Figure 3.8.

However, if denitrification were conducted on-site at the WWTP facility and no nitrate were discharged to South Ore Creek, Ore Lake would experience nutrient ratios characteristic of perennial nuisance bloom conditions (Figure 3.9).

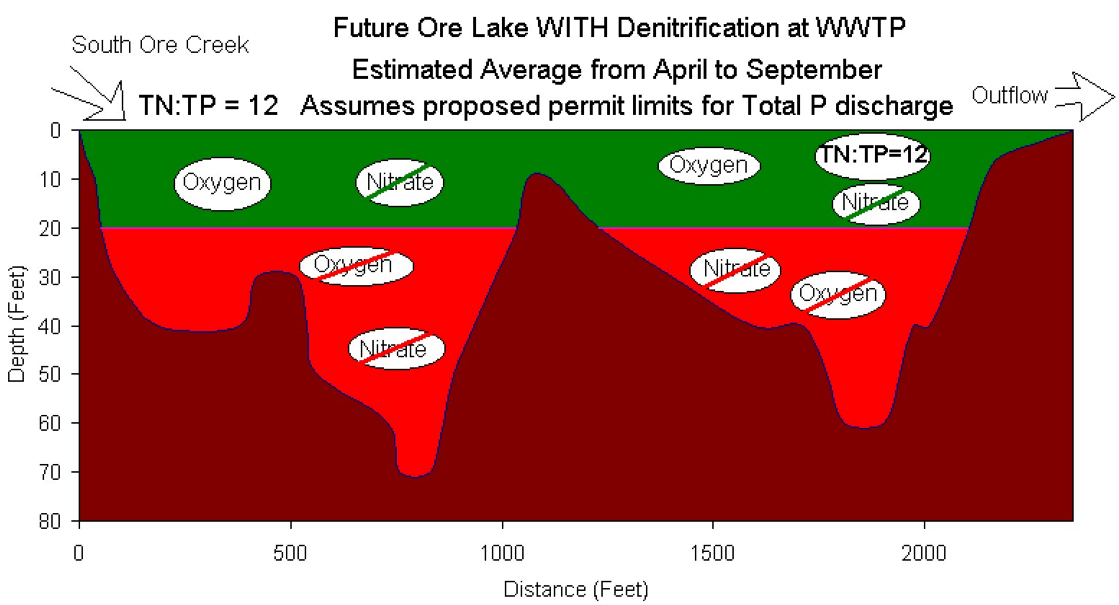

Figure 3.9.

Conclusions from this Analysis

1. The discharge limits present in Permit No. M10020877 issued 3 August 1999 to the City of Brighton represented lake management strategy consistent with publicly-defined uses of the lake.
2. Denitrification should not be performed on the WWTP effluent. Doing so would create conditions that are not consistent with publicly-defined uses of the lake.
3. Even if the Brighton WWTP discharges its full legal amount of Total Phosphorus under the Permit, the resulting Total Phosphorus concentrations will not cause perceptible negative changes in Ore Lake Chlorophyll levels, nor any perceptible negative changes in Ore Lake water transparency.

The Appendix attached to this section summarizes the key findings and explains further some of the technical limitations of the analysis offered by Hamburg's consultant.

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Appendix to Part 3
Fact-Finding Report and Analysis: Ore Lake, Michigan

SCOPE OF THE STUDY

The scope of this study included review of existing documents, site visits, direct measurements, and computer-assisted calculations. Elements included:

1. NPDES Permit No. M10020877 issued 3 August 1999 to the City of Brighton
2. Supporting documents for the Permit application
3. Summaries, transcripts, communications and supporting documents from public meetings about the proposed Permit.
4. The complete file of the Michigan Department of Environmental Quality about Ore Lake and the Permit application- about 1800 pages.
5. Letters and documents from the contesting parties.
6. MDEQ reports and data tabulations, including
    a. Water Quality and Phosphorus Loading Analysis of Brighton, Kent, and Ore Lakes, Livingston and Oakland Counties April 1998 – April 1999. October 1999: MI/DEQ/SWQ-99/107.
    b. A Nutrient Chemistry Survey of Brighton, Kent, Ore, Portage, Sandy Bottom, and Strawberry Lakes, Livingston, Oakland, and Washtenaw Counties April, June, & August 1997. February 1998: MI/DEQ/SWQ-98/010.
    c. A Nutrient Chemistry Study of Kent, Brighton, Ore, Limekiln, and Sandy Bottom Lakes, Livingston and Oakland Counties, April 13, 1994 and April 24, 1996. April 1996: MI/DEQ/SWQ-96/044
    d. Water Quality and Phosphorus Loading Analysis of Brighton and Ore Lakes, 1977-1978. Michigan Department of Natural Resources Water Quality Division, November 16, 1978. Publication No. 4833-9790.
7. Reports and data tabulations produced by the Ore Lake Preservation Association and the Township of Hamburg, including
    a. Lake degradation of Ore Lake, Livingston County Michigan between 1986-7 and 1998-9, dated March 2000.
    b. Ore Lake Hamburg & Green Oak Townships Livingston County A water quality re-study of the lake and its tributaries, dated 1998-99.
8. Brighton Environmental Control Facility Monthly reports of Waste Water Treatment Plant chemical analyses, January 1997 to January 2000.
9. Brighton Environmental Control Facility Algae Study, dated December 1998
10. *The Water Newsletter*, February 1994 to January 2000.
11. Site visit to the Brighton Waste Water Treatment Facility and grounds.
12. Site visits to Ore Lake
13. Published scientific literature

A. SUMMARY CONCLUSIONS OF THE SCIENTIFIC REVIEW

A.1. IS PERMIT NO. M10020877 CONSISTENT WITH PROPER LAKE MANAGEMENT STRATEGY?

Yes. The remainder of this report explains this judgment.

A.2. SHOULD BRIGHTON WASTE WATER TREATMENT FACILITY REMOVE NITRATE FROM ITS EFFLUENT?
No. Nitrate from the WWTP replaces nitrate that is destroyed in Ore Lake by natural processes. Nitrate from the Brighton WWTP helps protect Ore Lake from nuisance blooms of bluegreen algae. Algae in Ore Lake are limited by phosphorus, not by nitrogen.

A.3. WHAT ARE THE NUISANCE IMPLICATIONS OF BLUEGREENS?
Bluegreen algae form blooms that are conspicuous symptoms of poor water quality in lakes. Bluegreen blooms contribute to a wide range of problems including summer fish kills, foul odors, and chemical interactions. Water soluble nerve toxins and liver toxins are released when bluegreens die or are ingested. The toxins can kill livestock, and may pose serious health hazards to humans.

A.4. DISTINCTIONS BETWEEN BLUEGREEN ALGAE AND TRUE ALGAE
Bluegreens are not true algae. They are bacteria with the same chlorophyll as all true algae and higher plants, but they have additional pigments that give them their blue-green color plus they have unique features found only in bacteria. For example, they float by use of gas vacuoles. Under some conditions bluegreens float to the surface where they form mats so thick that they can support the weight of small pebbles. Mats of living algal debris raft to shore where they decompose and create foul odors and eyesores. Bluegreens can make their own proteins by using nitrogen gas from the atmosphere instead of using the sources of nitrogen needed by all true algae and higher plants. Many bluegreens are inedible or only poorly edible, so Bluegreens rob lake food chains of primary food. Nuisance bluegreens were a feature of Ore Lake in the 1970s.

A.5. WITHHOLDING NITRATE MAKES NUISANCE BLUEGREENS GROW
A simple analogy explains this point. To grow a healthy lawn of green grass, you water your lawn regularly. Watering less during summer encourages growth of weeds. Weed species need less water than grass does in order to grow in hot weather. The same principle applies to nuisance bluegreen algae. They need little or no nitrate to grow. If desirable species of algae are prevented from growing by withholding nitrate from them, the bluegreen “weeds” take over the lake. If desirable algae get enough nitrate, on the other hand, they outcompete the bluegreens.

A.6. ORE LAKE NATURALLY DESTROYS NITRATE
Ore Lake develops anoxic (no oxygen) conditions near its bottom every summer. Bacteria in this deep anoxic water destroy nitrate. They are called denitrifying bacteria. They convert nitrate into nitrogen gas which is unavailable to everything but bluegreens. During the summer Ore Lake by nature tends to develop lower and lower ratios of Total Nitrogen to Total Phosphorus and becomes a bluegreen nuisance factory. The nitrate supplied by the Brighton WWTP replaces the lost nitrate and works against the nuisance menace. If the nitrate supplied by the WWTP were eliminated, Ore Lake would become susceptible to nuisance bluegreen blooms from April to September.

A.7. TOTAL NITROGEN VERSUS NITRATE NITROGEN

Nitrogen is a basic element in living organisms. It is part of proteins and other vital molecules of life. Nitrate is only one of several forms of nitrogen. In Ore Lake, nitrate makes up on average no more than one-third of Total Nitrogen. All organisms need nitrogen in order to grow, but all organisms do not need nitrate. Bluegreens that cause nuisance blooms in lakes do not need nitrate. They can use nitrogen gas from the atmosphere. Nitrogen to phosphorus ratios can be used to tell if a lake is in danger of forming nuisance bluegreen blooms. These ratios must be based on Total Nitrogen, not on Nitrate Nitrogen, or else the ratios are invalid for drawing conclusions.

A.8. EXPLAIN "PHOSPHORUS LIMITATION" AND "NITROGEN LIMITATION"

Phosphorus limitation is accepted as the standard for lake management because all lake algae need phosphorus, and they need to get their phosphorus from the water. The term "nitrogen limitation" is misleading. Lakes are not limited by nitrogen. True algae cannot grow without added nitrogen, but undesirable and obnoxious "bluegreen algae" are not stopped from growing by lack of nitrogen. Bluegreens create their own nitrogen supply from nitrogen gas in the air. Proper lake management calls for keeping the Total Nitrogen to Total Phosphorus ratio high, generally greater than 29:1 on a gram to gram (or pound to pound) basis, to prevent nuisance conditions from developing.

A.9. WILL WATER TRANSPARENCY IN ORE LAKE BE REDUCED IF THE BRIGHTON WWTP DISCHARGES PHOSPHORUS AT THE FULL MAXIMUM LIMIT OF ITS PROPOSED PERMIT?

No. Even if the Brighton WWTP were to discharge at the full 50 pounds of phosphorus per month specified in the proposed Permit, resulting Total Phosphorus concentrations in Ore Lake would remain less than 25 milligrams per cubic meter (0.025 milligrams per liter) from March to September. The scientific evidence produced by both the Michigan DEQ and the contesting parties demonstrate that there is no detectable difference in transparency measured by Secchi disk between the current Total Phosphorus concentrations and the projected future ones.

A.10. IS ORE LAKE FLOODING CAUSED BY THE WWTP?

Flooding is not caused by the WWTP. Ore Lake and much of its surrounding lake shore lies within the flood plain of the Huron River. Whenever the Huron River reaches extreme flood stage, it reverses the flow in the culvert separating the River from Ore Lake and inundates the low lying properties, regardless of the WWTP discharge. Risk of flooding to Ore Lake residents is dominated by the hydrology of the Huron River and by the management of its impoundments. Flood times coincidentally are the times when the WWTP discharge to South Ore Creek is at the absolute minimum relative contribution to its flow.

B. ASSESSMENT OF SCIENTIFIC CLAIMS BY THE CONTESTING PARTIES

Parties who contest the permit application by Brighton produced "A Report on the Causes of Lake Degradation in Ore Lake, Livingston County, Michigan" by W. E. Fusilier (WEF), dated March 2000. The report alleges that water quality in Ore Lake has declined from the 1980s to 1990s based on measurements of: (1) water temperature, (2) dissolved oxygen, (3) Secchi disk transparency depth, (4) pH, (5) titration alkalinity, (6) Total Phosphorus concentration, (7) nitrate concentration, (8) specific conductance referenced to 25° C (K_{25}), and (9) chlorophyll concentration. The report alleges that water quality of Ore Lake is being degraded by addition of nitrate from the Brighton WWTP.

Data produced by the contesting parties (WEF) plus additional data produced by the Michigan Department of Environmental Quality (MDEQ) were studied in order to assess the merits of the claims by the contesting parties.

B.1. IS ORE LAKE DEGRADED BY DISCHARGE OF THE BRIGHTON WWTP?

There is no credible scientific evidence that Ore Lake is in a state of degradation caused by discharge of the Brighton Waste Water Treatment Facility. On the contrary, the WWTP discharges water that is on average lower in Total Phosphorus concentration than South Ore Creek itself. Existing data do not substantiate a claim of degradation, nor is the proffered explanation for alleged degradation consistent with modern theory about lake functioning.

B.2. COMPARISON OF DATA BETWEEN WEF AND MDEQ

Data by WEF and MDEQ do not differ seriously for temperature, dissolved oxygen, Secchi depth, specific conductance, Total Phosphorus and chlorophyll concentration. Measurements of pH differ seriously, with WEF values being at times more than one full unit higher than those measured by MDEQ. This difference is far greater than acceptable measurement error. Nitrate nitrogen reported by WEF is also higher than MDEQ measurements. Relative magnitudes of discrepancy are greatest for anoxic water. The pattern of discrepancy suggests that ammonium in the anoxic water oxidized to nitrate (nitrification) in the WEF samples thereby causing overestimation of the nitrate concentration by WEF. Data for pH and Nitrate-N show evidence of measurement bias (systematic error).

B.3. WATER TRANSPARENCY AND CHLOROPHYLL

There is no credible scientific basis to claim that the water transparency of Ore Lake has declined from the late 1980s to the late 1990s. Water transparency of Ore Lake is not affected by the amount of chlorophyll measured in the lake. Secchi disk transparency depth has not declined in Ore Lake (Exhibit 1), and, contrary to the heart of arguments by the contesting parties, water transparency in the lake is not controlled by the abundance of algae in the lake (Exhibit 2). Seasonal variations in water transparency are probably caused by clays and colloidal soil particles entering the lake.

Chlorophyll *a* is found in all algae, as well as bluegreens, and so it is measured by lake scientists as a proxy for algal biomass. Chlorophyll concentrations measured for Ore Lake in 1998 to 1999 include lower values than were ever recorded in 1977 and 1986-87. The amount of chlorophyll in Ore Lake is about 35% lower than would be expected on average for other lakes with the same levels of Total Phosphorus and Total Nitrogen. This may be the result of limited water transparency caused by stream and lake shore erosion, or by dissolved organic matter which colors the lake water. Algal biomass in Ore Lake has been controlled historically by phosphorus, not by nitrogen.

B.4. DISSOLVED OXYGEN AND DENITRIFICATION OF NITRATE

The vertical distribution of dissolved oxygen in summer is set by the surface mixed layer thickness of Ore Lake. Lakes of this type usually develop deep water anoxia during the spring.

Thereafter, the vertical range of oxygen is set by weather which varies from year to year. When the lake surface begins to cool in September and mixing depths increase, the vertical penetration of oxygen is increased. As soon as anoxic (no oxygen) conditions develop in the deep water during summer, the nitrate concentrations drop to zero as the result of natural denitrification within the lake (Exhibit 3 and Exhibit 4). Most of the denitrification in Ore Lake occurs from April to September.

B.5. SPECIFIC CONDUCTANCE AS A TRACER OF LAKE CHANGES
Specific Conductance is a measure of how well water conducts electricity. Conductance of pure water is low but increases when substances dissolve in the water. Specific conductance in the surface 10 feet of Ore Lake increased right after 1997 (Exhibit 5). The 1998 to 1999 data show that increases were recorded by both WEF and MDEQ (Exhibit 6). Ore Lake may still be receiving sources of dissolved matter. A potent clue to the source is found in communications posted on the World Wide Web, in a newsletter produced for Lake Association members by W. E. Fusilier. The August 1997 version of the newsletter contains the following exchange (Exhibit 7A). Corroborating evidence for the resulting algal bloom is found in additional letters from citizens as represented in the files of the MDEQ (Exhibits 7B, 7C, and 7D).

> *Q. A big garbage truck drove over a sewer line and broke it. Now sewage is ponding in a wetland area above the lake, and I'm afraid the sewage might be reaching the lake. What should we do?*
>
> *Mary Florida, Ore Lake, Livingston County*
>
> *A. As I suggested in last month's newsletter, get a conductivity meter. Conductivity meters detect and measure salts in water. And since sewage should have a much higher salt content than lake water, use the meter to determine this. If the conductivity of the lake water is the same as the water flowing into the lake from the wetland, there is a pretty good chance that sewage is not reaching the lake. However, if the conductivity of the water flowing into the lake from the wetland area is a lot higher than the lake, sewage might be reaching the lake. We can either run some nutrient tests, or fecal coliform tests if the conductivity data indicates this is needed.*

Recent increases in conductance of Ore Lake water suggest that the sewer lines maintained by Hamburg Township should be inspected and repaired if necessary.

B.6. TOTAL PHOSPHORUS
Total Phosphorus is the dissolved and particle phosphorus in mineral plus organic form. Total Phosphorus in the top 10 feet of Ore Lake is low and acceptable, except for some measurements by WEF in 1999 (Exhibit 8). The changes recorded by WEF are not paralleled by MDEQ data. Values of Total Phosphorus recorded by WEF in 1999 doubled to tripled from previous values. They correspond with the high values of Total Phosphorus measured in Ore Lake during the 1970s, before modern WWTP technology was installed (see Exhibit 9). If these increases in Total Phosphorus can be accepted at face value, they indicate severe increases in

phosphorus loading to Ore Lake during 1999. If real, these remarkable increases in Total Phosphorus within Ore Lake cannot have originated from the Brighton WWTP.

WEF produced in his March 2000 report a series of measurements of South Ore Creek both above and below the discharge site of the Brighton WWTP in 1998 and 1999. Of 8 pairs of measurements, the concentration of Total Phosphorus in Ore Creek downstream of the WWTP was **lower** than Total Phosphorus upstream of the discharge in 6 cases (75%). MDEQ data from 1998 and 1999 show that the Total Phosphorus concentration of South Ore Creek **decreases** from upstream to downstream of the Brighton WWTP 83% of the time (10 months out of 12). These findings show that effluent from the Brighton WWTP currently has a diluting influence on the Total Phosphorus flowing into Ore Lake.

It is possible to project future concentrations of Total Phosphorus in Ore Lake that would result if the Brighton WWTP discharged at the full maximum levels permissible under the proposed Permit. The proposed limit is 600 pounds per year, or 50 pounds per month on average. The projected lake concentrations that would result from this hypothetical maximum discharge is illustrated in Exhibit 9.

B.7. CHEMICAL FORMS OF NITROGEN IN ORE LAKE

Most of the nitrogen in lake water exists as dissolved gas from the atmosphere. In this form it is available for use only by bluegreens. The most biologically active forms of nitrogen in water available to true algae are ammonium, nitrate, and organic nitrogen. Scientific studies of Total Nitrogen calculate Total Nitrogen as the sum of ammonium + nitrate + organic nitrogen. In the surface water of Ore Lake, the most common form of Total Nitrogen most of the time is organic nitrogen (Exhibit 10). Only in March 1977 did nitrate account for more than one-third of Total Nitrogen. The contesting parties cite only nitrate-nitrogen, and ignore the bulk of the element present in the lake. This approach by the contesting parties is inconsistent with objective scientific analysis of the facts.

Calculation of Total Nitrogen in Ore Lake must **not** be based on nitrate measurements alone. Use of nitrate nitrogen to predict nitrogen to phosphorus ratios is incorrect and underestimates Total Nitrogen to Total Phosphorus by at least a factor of 3.

B.8. TOTAL NITROGEN TO TOTAL PHOSPHORUS RATIOS IN ORE LAKE

Ratios of Total Nitrogen to Total Phosphorus by weight (grams to grams) in the surface water of Ore Lake were 3.5 in March 1977 and 14.5 in August 1977. From April 1998 to April 1999, Total Nitrogen to Total Phosphorus ranged from 64 to 101 (grams to grams). The ratios observed in 1977 placed the lake at risk of nuisance blooms of bluegreens. The ratios observed in the 1990s should protect the lake from such blooms if the sanitary sewage system functions correctly.

It is possible to project future Total Nitrogen to Total Phosphorus ratios in Ore Lake under different scenarios. If the Brighton WWTP were to operate at its discharge limits, but **does not** eliminate nitrate by denitrification, nitrogen to phosphorus ratios in Ore Lake will remain high enough to keep it out of danger of nuisance bluegreen blooms (Exhibit 11). If the WWTP **does**

denitrify its effluent, however, Ore Lake will be at **serious risk** of developing nuisance or toxic blooms of bluegreens during the months of April to September (Exhibit 12).

C. ANALYSIS AND RECOMMENDATIONS

C.1. WHAT TRIGGERED CONCERN IN 1997 THAT THE BRIGHTON WWTP MIGHT BE HARMING ORE LAKE WITH NITRATES?

During summer 1997, a sewer line rupture was reported near the shore of Ore Lake. Subsequently, in late August 1997, a nuisance algal bloom developed in Ore Lake. Lakeshore residents enlisted the services of a consultant who advised them that nitrates from the WWTP were at fault. In fact, there is no credible scientific evidence to support that claim. Instead, there are continuing signals in the recent water chemistry of Ore Lake that suggest that the local sewer system at the lake should receive inspection and that it may still need repair.

C.2. WHY LOCAL SEWER LINE FAILURE IS PROBABLY AT THE ROOT OF CONCERN EXPRESSED BY HAMBURG CITIZENS

There is eyewitness evidence that a nuisance algal bloom did occur in Ore Lake during summer 1997. There is credible scientific evidence that the specific conductance of the lake water increased in 1998 and 1999. There is some evidence indicating that the Total Phosphorus content of the lake increased abruptly. There is also an eyewitness report of a sewer line rupture and spill in the immediate vicinity of the Ore Lake shore. Sewage spills can certainly cause algal blooms. The ratio of Total Nitrogen to Total Phosphorus in untreated sewage is typically less than 10 by weight (gram to gram or pound to pound). These low nitrogen to phosphorus ratios are emblematic of nuisance bloom conditions. All of these lines of evidence are consistent with structural failures in the local sewer lines serving the community around Ore Lake. This idea is reinforced by reports that the influent volume per capita of raw sewage received from the Ore Lake or Hamburg Township region is lower than the regional average.

C.3. RECOMMENDATIONS

The Township of Hamburg should inspect its local sewer line system around Ore Lake and repair it if necessary. Denitrification should not be implemented at the Brighton WWTP. Non-point sources of Total Phosphorus that are entering Ore Lake should be identified and eliminated.

In order to protect lakes from nuisance blooms of Bluegreens, it is necessary to keep the surface water ratio of Total Nitrogen to Total Phosphorus at about 30:1 or greater. Professor Val Smith, a scientific leader in development of the strategy, has urged that high TN:TP ratios should be targets of water quality management. In his 1983 article in the journal *Science*, Professor Smith pointed out:

> *Nitrogen removal is often practiced by advanced waste water treatment plants, and in some cases this may be counterproductive if it results in low N:P ratios in downstream lakes. Leonardson and Ripl suggested that waste water treatment can be optimized to maintain proper water quality in lakes receiving such effluent. Alternatively, in other lakes,* ***nitrogen fertilization may be of practical value****.* [emphasis added]

At most times the phosphorus content of the Brighton WWTP discharge is lower than the concentration of Total Phosphorus flowing down South Ore Creek, so that the WWTP discharge acts as a diluting influence on the phosphorus entering Ore Lake. The nitrate released by the WWTP contributes to the Ore Lake nitrogen budget. In the absence of the nitrate discharge from the Brighton WWTP, Ore Lake would be at risk of forming nuisance water blooms of bluegreens. Ore Lake was plagued with these nuisance algae in the 1970s and blooms may have reappeared episodically in 1997 in response to a local sewage spill. Fortunately, the nitrate supplied from the WWTP generally prevents the nuisance bluegreens from achieving dominance as long as the sewer system functions properly.

At the present time, Ore Lake is protected from nuisance summer blooms of bluegreens by the Total Nitrogen to Total Phosphorus ratio present in South Ore Creek. Exhibit 13 depicts a cross section of Ore Lake from South Ore Creek inlet to the lake outlet. Actual measurement by MDEQ are used to calculate the average nitrogen to phosphorus ratios in the Creek and the lake outflow. If the nitrate discharge from the Brighton WWTP were eliminated, Total Nitrogen to Total Phosphorus ratios from April to September would fall, and the lake would almost certainly develop nuisance bluegreen blooms (Exhibit 14).

It is possible to project the future condition of Ore Lake under different scenarios. If the Brighton WWTP expands its facilities in accord with its proposed Permit, and even if it discharges phosphorus to the maximum that the law allows, Ore Lake should not produce nuisance blooms. The average Total Nitrogen to Total Phosphorus ratio from April to September would be high enough to keep the lake out of danger (Exhibit 15). However, if the Brighton WWTP removes the nitrate from its discharge by a process of on-site denitrification, the nitrogen to phosphorus ratio of Ore Lake will drop during April to September, and the lake will develop nuisance conditions (Exhibit 16).

Exhibits for this Report

1. Secchi Disk Transparency Depth versus time in Ore Lake
2. Secchi Disk Transparency versus Chlorophyll concentration
3. Dissolved oxygen vertical profiles, August 1998
4. Nitrate Nitrogen vertical profiles, August 1998
5. Specific Conductance, 1986 to 1999: time plot
6. Specific Conductance, 1998 to 1999: time plot
7. *The Water Newsletter*, August 1998, pages 1-2, plus corroborating documentation about an algal bloom
8. Total Phosphorus, 1998 to 1999: time plot
9. Current Total Phosphorus and projected future Total Phosphorus in Ore Lake, compared with historical levels
10. Total Nitrogen in Ore Lake: pie charts
11. Current and projected future TN:TP in Ore Lake without denitrification
12. Projected future TN:TP in Ore Lake with denitrification
13. Diagram of Ore Lake: Current, without denitrification at WWTP
14. Diagram of Ore Lake: Current, with denitrification at WWTP
15. Diagram of Ore Lake: Future, without denitrification at WWTP
16. Diagram of Ore Lake: Future, with denitrification at WWTP
17. Published graph by V. H. Smith 1983
18. Chlorophyll versus Total Phosphorus in Ore Lake
19. Secchi Depth versus Total Phosphorus in Ore Lake

Environmental Problem Solving and the Dangers of Junk Science: The Case of Ore Lake, Michigan

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Part 4: Contested Hearing, Legal Findings and Aftermath

Representation of Science in the Public Policy Arena

The administrative rules under which Brighton's NPDES permit were enacted gave considerable weight to scientific reasoning, but not to the exclusion of other factors such as economic growth and development. By April 2000 it was clear to all parties that the issues of nitrogen limitation, denitrification, algal species composition, and lake sediment chemistry would be placed before an administrative judge (AJ). The duty of the AJ was to make a recommendation to the Director of the MDEQ about whether the City of Brighton was entitled to the permit it had been issued in August 1999.

The Contested Case Hearings of SWQD operate under the adversarial model of the U.S. legal system. Two partisan camps engage in a formalized struggle over issues of fact and law. Under the rules governing the administrative hearing, the AJ is the finder of both fact and law based on his perceptions gained from testimony and evidence. In this case, one side of the argument would be presented by an Assistant Attorney General of Michigan, representing MDEQ's Surface Water Quality Division (SWQD), and by the City Attorney for Brighton. The other side would be represented by an attorney for the Township of Hamburg retained for the purpose because of his training in environmental law. Both sides would offer documents and testimony from witnesses.

Witnesses are assigned to either of two categories. Ordinary witnesses can testify only to matters of fact, such as eyewitness events. Expert witnesses, on the other hand, are permitted to offer their "opinions" as well. Scientific theory, facts, knowledge, interpretation, and analysis, therefore, fall into the legal category of expert "opinion." These formalized "opinions" are circumscribed by topics or fields, and the judge must accept witnesses as "expert" on a subject before their "opinion" is given any weight. The formalized legal procedures enable the "opinions" of any expert to be directly examined by one side and then to be cross-examined by the opposing side.

As a practical matter of fact, most attorneys are not technical experts in subjects outside of the law. Although they may develop impressive knowledge on diverse topics during their practice, most would not feel justified challenging the technical interpretations of an expert without some coaching. Thus when one side declares that its case will rely mainly on the testimony of an expert witness, the other side seeks expert advice in reaction.

In this case, Hamburg announced its intention to feature their consultant as an expert witness and to have him offer his opinions about Ore Lake. The State selected two environmental scientists from the SWQD to explain the scientific reasoning for issuing the NPDES permit. Brighton enlisted two civil engineers to discuss hydrology and wastewater treatment plants, and two professors to discuss lake processes. Based on credentials offered to the court, the AJ accepted Hamburg's witness as an expert in limnology. He accepted one SWQD scientist as expert in limnology and the other as expert in hydrology and hydraulics. The civil engineers were accepted as experts in their licensed profession, with further specialties in design of wastewater treatment plants and site planning, hydrology, and hydraulics. One professor (J.T. Lehman) was accepted as expert in biology, limnology, chemistry, algal ecology, the effect of the nitrogen and phosphorus ratios in surface water on algal growth; the other (V.H. Smith) was accepted as expert in limnology, ecology, lake water quality, biology, algology, and zoology.

Characterization of science within legal arenas as "expert opinion" bears only distant relationship to its characterization in scientific circles as "the creation and testing of theory". There are no provisions within the law to ensure that statements asserted to be scientific are in fact founded on measurements that can be reproduced or tested. Whereas it is argued that the ultimate arbiter of science is the testimony of observation rather than the fervor of belief, the courtroom arbiters of fact and law rely on testimony of observation and opinion.

The adversarial model of U.S. legal proceedings obviously has immense value in the defense of civil liberty and constitutional rights. Nonetheless, when partisan sides invoke science in their struggles to win the court's favorable judgment, there is great danger that the arguments may lapse into junk science. Junk science is defined as faulty data or analysis used to further a special agenda. Given that an agenda (i.e., winning the case) is always present in these partisan disputes, the specter of junk science is always looming.

Motivations for Environmental Activism

The sincere concerns of citizens around Ore Lake became evident from the non-expert testimony offered by two residents. One declared that she had discovered a foul smelling pea soup-like slime with a texture similar to paint along the west shore of Ore Lake in August 1997. She could only guess that it was some kind of algae. She explained that the slime did not cover the lake as in the 1960s and 1970s, but rather hugged the shore. She produced photographs that documented the presence of the substance, but none of the experts could make a reliable guess at its identity from low magnification and low resolution photographs. There was no trace of the substance in the lake during 2000, so there was no opportunity to inspect it microscopically and to identify it. The second resident testified that their concerns over water quality and specifically their concern that the Brighton WWTP might be the cause of the slime caused them to retain a consultant to study the lake.

Telltale Signs of Faulty Science

Both experience and instinct made citizens of Hamburg suspicious of the environmental conscience of their neighbors in Brighton. They seemed predisposed to an argument that invoked science to point guilt at those neighbors. It is hard to say whether the consultant report of September 1998 was the chicken or the egg in the resulting legal and political struggle that ensued. However, in the thick of a developing crusade, the pronouncements and interpretations of the consultant were not independently reviewed until partisan lines were already drawn.

MDEQ environmental scientists had received earlier versions of the consultant's report about Ore Lake, and they had dismissed its interpretations as faulty. That perceived rebuke unleashed a storm of recrimination in the letters from grassroots activists to State officials in summer 1999 (see Appendix to Part 1). The consultant himself labeled the State's experts as "bureaucrats" rather than scientists (see Part 2).

But how are most non-scientists able to judge for themselves the merit of purported scientific claims? The word "science" traces to the Latin root verb *scio*, to know. Hence, a scientist is one who knows. What does it mean to possess scientific knowledge? If scientific knowledge can be conferred by diploma or certificate, the bearers of advanced degrees could be automatically regarded as experts, and their pronouncements might carry the weight of authority whether they seem to make sense or not. Ordinary citizens who lack specific technical knowledge on the many complex workings of the natural world are called upon regularly to make judgments about science with their votes, their taxes, their wallets, or their health. If they choose to place their faith in the opinions of scientists, how can they distinguish real science from "junk science"?

In the adversarial system of legal procedure, scientific expertise is indeed a credentialing process, and expert opinion is tested in partisan examination in front of a third party. That doesn't seem like a very practical model for concerned citizens to adopt before they launch an activist campaign. And yet some type of quality control on the scientific merit of a cause seems prudent if science is invoked in the campaign.

What, then, are the warning signs of faulty science that may come to plague a well-intentioned program of environmental concern? Without delving too deeply into specialized areas of knowledge, let's examine some of the telltale signs that should raise warning flags to any reasonable person acquainted with the practice of science.

1. Scientists should be well acquainted with the current literature and recent developments in their declared field of knowledge. Their professional world is one in which theories are created, tested, discarded, and revised all the time, so failure to stay current risks becoming obsolete.

2. Beware of any scientist who avers the role of theory in science. They may not even understand how their own instruments permit them to make measurements, because even the seemingly straightforward measurement of oxygen with a meter involves considerable foundation in theory.

3. Understand that science applies only to properties that have an objective existence as entities that can be weighed, measured, counted, or observed. Creations of the human mind or conceptual abstractions, such as "health" or "well-being" or "value" are not open to direct scientific inquiry. That does not mean they are poor objects for human contemplation, but invoking science in their pursuit is nonsense.

4. Scientists whose written findings and analysis have not withstood critical examination from peer experts have failed the crucial test of quality control. Journalists and authors are known to say that everyone likes to be read but no one likes to be read too closely. Scientific writing is meant to withstand the most critical of close examination, and independent testing as well.

Contested Case Hearing in the Brighton Case

Evidence and testimony was presented to the Administrative Judge over 6 days in May 2000. The arguments were essentially those contained in Parts 2 and 3 of this case study.

Findings of Fact, and Proposed Decision

After some months of deliberation, the Chief Administrative Judge issued a 22-page opinion on 30 October 2000. His summary pronouncement was "Based on the Findings of Fact and Conclusions of Law contained herein, it is proposed that the City of Brighton is entitled to the permit it was issued on August 3, 1999, under NPDES Permit No. MI 0020877." The Director of MDEQ subsequently accepted his proposal.

It is instructive to inspect the various "Matters of Fact" pertaining to environmental issues that are declared within the opinion in light of conventional scientific definitions of "fact", "theory" or "prediction". The written opinion contains many of these legal Findings of Fact. After each Finding of Fact, italicized in the list below, comments are added from a scientific perspective.

- *The current discharge of phosphorus from the facility is diluting background phosphorus concentrations in South Ore Creek and Ore Lake.* This is a generalization based on a series of observations that can be reproduced and tested. It could be called a scientific theory.

- *Increasing the discharge volume to 3 million gallons per day, with the phosphorus permit limit at 50 pounds a month, would not cause an increase in nuisance aquatic plant growth.* This is a prediction based on explanatory scientific theory, and it can be falsified if it is untrue.

- *The phosphorus limit contained in the permit at issue is protective of the uses of the waters of South Ore Creek and Ore Lake.* This is a prediction based on explanatory scientific theory in combination with definitions of the various uses. It is not easy to design an objective test, however, and so it is not a meaningful scientific statement.

- *The permit limit for an increased discharge of 1.5 million gallons per day would not aggravate flood conditions around Ore Lake.* This is a prediction based on explanatory scientific theory, and it is subject to test.

- *The contested discharge volume of 3.0 million gallons per day is protective of the uses of the waters of South Ore Creek and Ore Lake and would not cause injury to the value or utility of riparian property.* This is a prediction not subject to proper scientific test or theory.

- *The proposed increase in treatment capacity to 3.0 million gallons per day is necessary in light of the present and future residential, commercial and industrial development in this area.* This is a prediction not subject to scientific test or theory.

- [Hamburg's consultant's] *opinion that the WWTP's discharge of nitrate nitrogen is causing the localized bluegreen algae blooms is inconsistent with the scientific principle that these bacteria do not require nitrate nitrogen to grow in nuisance proportions.* This is an observation that can be tested only against an existing written record. It expresses implicit acceptance of a scientifically unverified claim that bluegreen blooms did occur in Ore Lake. It seems to adopt specific theory about chemistry and physiology.

- *The algae that indicate good water quality, true algae, require an adequate supply of nitrate nitrogen to survive.* This is a statement of theory about physiology that can be tested, but it also adopts another theory about indicator species. The term "good water quality" is however, scientifically vague.

- [Hamburg's consultant's] *opinion that discharging nitrate nitrogen to the water is the cause of a water quality problem is not consistent with the scientific principles of nutrient limitation in lakes.* This is an observation that can be tested only against an existing written record. It seems to adopt specific theory about lake processes. It is not clear what "water quality problem" is at issue.

- *Because these water bodies are phosphorus limited, the nitrate nitrogen in the Brighton WWTP discharge is essentially benign as to the propagation of aquatic plants and bluegreen algae.* This is a statement of theory predicated on a testable observation.

- *The discharge of nitrate nitrogen from the Brighton WWTP is not the cause of the bluegreen algae problems testified to by* [residents]. This is a statement of theory, but it is predicated on irreproducible observations. Thus it is not a subject for science.

- *The addition of nitrate nitrogen to the surface water is a good lake management practice because it reduces the probability of nuisance bluegreen algae blooms.* This is a statement of theory. It is testable and it is capable of being proven wrong if it is wrong.

- *There is no basis in law or fact to either monitor the discharge for nitrate nitrogen or to denitrify the effluent.* This statement is outside of science.

- *Denitrifying the effluent from the plant would in all probability increase the potential for nuisance bluegreen algae blooms and would be a poor lake management practice.* This is a statement of theory, and it is testable.

- [Hamburg's consultant's] *water quality index and the testimony of* [residents] *is the only evidence offered by the Petitioners that the discharge of nitrate nitrogen from the Brighton WWTP is responsible for the localized occurrence of bluegreen algae. For the reason discussed, this evidence fails to support the proposition that the problem is the result of discharges from the Brighton WWTP.* This is irreproducible observation outside the province of science.

- *The scientific principles and findings indicate the decrease in the water quality of Ore Lake is not the result of the Brighton WWTP's discharge of nitrate nitrogen.* This statement is outside of science because there is no objective measurement of "the decrease in the water quality".

- *There is likely a source of phosphorus entering Ore Lake and causing the localized water quality problems it is experiencing.* There are two statements here. The first is testable theory. The second statement is outside of science because there is no objective reproducible measurement of "the localized water quality problems."

Aftermath

Brighton and the SWQD received a complete and unqualified positive decision from the Administrative Judge. After the Hearing, the president of the Ore Lake Association announced their decision to withdraw from the legal fracas but to continue monitoring the lake. What he said they most wanted was for the MDEQ to commit resources to a long-term study of Ore Lake. Ironically, MDEQ officials had offered to conduct the requested study in lieu of a legal battle, citing lack of sufficient finances to do both. But MDEQ had insisted on awarding Brighton its permit, and the Ore Lake residents were bound to resist that action.

The Hamburg Board of Trustees, on the other hand, vowed to continue its fight. Its focus shifted to the State Circuit Court, where its claim of primacy over Brighton's WWTP was being contested by Brighton, and where the State Attorney General had intervened on Brighton's side. Political forces, opportunities, and constituency groups created by the initial scientific issues took on a life of their own, far outside of the scientific arena.

Hamburg's political leaders continued to insist that denitrification be installed at the WWTP, and they insisted on discharge limits for nitrate that were beyond existing technology. Hamburg dismissed its original attorney, who lost the administrative hearing, and engaged a different law firm to plead its case in the State Circuit Court. In 2002, however, Hamburg finally abandoned its legal fight. Brighton proceeded with construction activities to expand its WWTP. The struggle offers an interesting model for study of civics and political process. As we have seen from the commentary above, there would have been opportunities to test scientific theory in this case whether or not Hamburg succeeded in making Brighton build a denitrification facility.

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