Remedial Action Plan
for
Deer Lake
Area of Concern

October 27, 1987

Michigan Department of Natural Resources
Surface Water Quality Division
Great Lakes and Environmental Assessment Section
PO Box 30273
Lansing MI 48909-7773

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Prologue-Deer Lake Remedial Action Plan

In 1985, the Water Quality Board (WQB) of the International Joint Commission (IJC) identified 42 Areas of Concern (AOCs) in the Great Lakes Basin for which Remedial Action Plans (RAPs) were to be developed. In their report on Great Lakes Water Quality, the WQB identified specific impaired beneficial water uses and water quality problems in each AOC that the RAPs were to address. The identified problems were suspected of contributing to the degradation of one of the Great Lakes. The intent of each RAP is to outline the course of action that will result in the restoration of designated uses and resolution of water quality problems that impact the Great Lakes. Once it is confirmed that those uses identified in the 1985 WQB report are restored, the AOC should be removed from the AOC list.

In 1986, the Michigan Department of Natural Resources (MDNR) began work on the RAPs for Michigan's fourteen AOCs. During the data collection, fact finding and analysis phases of RAP development, problems other than those reported in the 1985 WQB Report were identified. The additional problems encountered were often of a local nature (i.e. not impacting the Great Lakes), or indicative of a regional problem rather than a problem in one of the Great Lakes caused or contributed to by conditions in the AOC (RAP issues). These issues are included in this RAP regardless of their status as RAP issues, in order to provide a comprehensive list of problems identified in the AOC. Inclusion of all documented problems in the RAP is sound from an ecosystem management perspective. Furthermore, it indicates to the public what the problems are and how they may be addressed.

Although this RAP focuses on the issues identified in the 1985 WQB Report, additional problems are discussed in this document. Inclusion of other issues may be somewhat confusing to the reader, therefore, an attempt was made to clearly identify and distinguish between those water quality problems and impaired uses which are truly RAP issues and those problems that are of local and/or regional (Great Lake wide) concern.

The 1985 WQB report listed the following issues for the Deer Lake AOC: 1) heavy metals, 2) contaminated sediments, 3) fish consumption advisories, 4) impacted biota. These were presumably related to the mercury contamination problem in fish that was the initial reason Deer Lake became an AOC. Although identified as issues in the 1985 WQB Report, an ecosystems analysis of the possible impacts of mercury discharges from Deer Lake via the Carp River indicated that mercury contamination in the Deer Lake AOC is of a local nature. Compared to potential mercury, loadings to Lake Superior from the nearby coal fired generating facilities in Marquette (load), discharges of mercury from the Carp River (load) are insignificant by any measure.

In addition to the mercury problem the highly enriched state of Deer Lake, due to the municipal treatment plant discharges, was discussed in this RAP. Although not a RAP issue, per se, it was a serious problem that deserved attention. A new $20 million wastewater treatment and collection system was constructed to address the enrichment problem in Deer Lake. This facility became operational in 1985.

Remedial actions to address the mercury contamination problem in Deer Lake and the Carp River, which flows 32 km to Lake Superior, began in September 1981 when the problem was discovered. The point source of mercury was discovered and eliminated, and a fish consumption advisory was issued shortly thereafter. Subsequently, this advisory was extended upstream and downstream of Deer Lake to the power station about 1.5 km from Lake Superior which blocks fish passage.

Additional studies evaluated the extent of contamination of sediments and other biota. On the basis of these findings, legal proceedings were taken against industry that discharged mercury bearing wastes to both the Ishpeming wastewater treatment facility and combined stormsewers. A consent decree was issued in 1984 that outlined a ten year program for the recovery and monitoring of Deer Lake and its tributaries. Funds to carry out this program in addition to other activities were allocated. Ongoing monitoring includes an annual assessment of mercury concentration in Deer Lake fish and occasionally other wildlife as the system recovers. In addiiton to the required monitoring, a nutrient budget will also be undertaken to compare with data collected prior to the construction of the new wastewater treatment facility. Water chemistry profiles in the lake will also be completed seasonally. This program is now being carried out by the Michigan Department of Natural Resources and the responsible industry and will be followed as mandated, unless scientific data strongly indicate a need for modification.

1. EXECUTIVE SUMMARY

1.1 DESCRIPTION AND DELINEATION OF MAJOR CONCERNS

1.1.1 Geographic Area

Deer Lake, a 367 hectare (906 acre) impoundment, is located in central Marquette County in Michigan's Upper Peninsula. The lake is connected to Lake Superior by the Carp River. The Deer Lake Area of Concern (AOC) includes Carp Creek, Deer Lake, and the Carp River. The Deer Lake drainage basin is small, covering roughly 93 km^2 (36 mi^2) of primarily forested land. Mining iron ore is the major industry in the area but this occurs outside the drainage basin at this time. The City of Ishpeming, located southeast of the lake is the urban area closest to the lake.

1.1.2 Definition of Existing Problems

As determined by the International Joint Commission (IJC), degradation of fisheries in Deer Lake and its major tributaries is the use impairment of concern in this AOC (GLWQB 1985). Fish in Deer Lake were contaminated with mercury in excess of the U.S. Food and Drug Administration (FDA) action level of 1.0 mg/kg wet weight and the State of Michigan Consumption Advisory level of 0.5 mg/kg. Fish consumption and health advisories were issued for these surface waters in 1981 and 1982 and remain in effect.

In addition to contamination of fish, levels of mercury in Deer Lake sediments are very high (10-15 mg/kg) near the mouth of Carp Creek. Elevated levels of other metals have been observed, but these inorganic compounds have not been implicated in causing use impairments. A comparison of metals content of Deer Lake sediment with that of other lakes in the Upper Peninsula indicated mercury, copper, chromium, and nickel were much higher in Deer Lake sediments than in most other lakes. Lead content of Deer Lake sediment was elevated compared to other lakes, but to a lesser degree than the above mentioned metals. Levels of arsenic and cadmium in Deer Lake sediments fell into the same range observed in the other lakes.

1.1.3 Principal Sources of Pollution

The major sources of pollution contributing to elevated levels of mercury in fish are believed to have been discharges of mercury from the old Ishpeming WWTP and combined storm sewer overflows. Heavy loadings of nitrogen and phosphorus from three primary wastewater treatment plants (WWTP) discharging to Carp Creek in the City of Ishpeming and Ishpeming Township also occurred. Nutrient enrichment of Deer Lake induced development of massive plankton blooms from early summer until ice up.

The major source of mercury to the old Ishpeming WWTP was the Cleveland Cliffs Iron Company (CCI) laboratories. The company maintained two laboratories in the City of Ishpeming which used mercuric chloride in ore assays and research. Spent reagents were poured down drains connected to the sewer system. One laboratory opened in 1929 and the other in 1948, with reagent disposal to the sewer lines occurring throughout most of this period. This disposal was curtailed in 1981 when severe contamination of fish and sediment was discovered. Despite the elimination of this source, the sediments in Deer Lake may be a source of mercury to surface waters and biota for a period of time in the future.

Other minor potential sources of mercury include the following: aerial deposition, leachate from the Ropes' Goldmine tailings, runoff of meltwater from ice and snow above those tailings, and possible input from naturally-occurring geologic formations. Mercury in leachate extractions from tailings sampled by MDNR in 1982, was found to be less than 0.1 ug/l. Mercury concentrations in ice above tailings were quantifiable, however. Sampling of ice and snow was conducted only once by CCI in 1983 and indicated this could be a minor intermittent source of mercury to Deer Lake. Sampling in nearby Teal Lake with many of the same geologic formations revealed no mercury contamination of fish, sediments or water. Mercury in sediments from nearby Goldmine Lake was also at background concentrations.

1.2 REMEDIAL ACTIONS

1.2.1 Nutrient Loading

In 1984, construction began on a new secondary WWTP with nitrogen and phosphorus removal. The new plant replaced the three older primary treatment plants. Construction to separate combined sewers in the City of Ishpeming was also initiated. Total project costs was almost $20 million. In April 1986, the new plant began operating and was in compliance with its permit limitations by July 31, 1986. Separation of stormwater from the sanitary sewer system was also completed.

1.2.2 Mercury Contamination

By October 1981, CCI had terminated mercury discharges to the Isphemine WWTP. In the fall of 1984, Deer Lake was draw down to its lowest level, 413 meters or 1355 feet above sea level, in order to eradicate contaminated fish and further minimize human and wildlife exposure. Fish leaving the impoundment during draw down were killed by a sharp grate placed at the outlet pipe of the Deer Lake dam. Dead fish were not removed from the system. During a fish population survey in late winter of 1985, the Michigan Department of Natural Resources (MDNR) netted and killed an additional 1,500 pounds of fish in the lake that remained in the impoundment. Fish were returned to the lake under the ice. In the fall and winter of 1986-1987, fish remaining in the lake were killed with rotenone. Cleveland Cliffs Iron Company dug a channel to divert the flow of Carp Creek around the lake in order to prevent downstream transport of rotenone. The fish killed with rotenone were left in the lake. MDNR concluded that mercury inputs from this source were insignificant compared to the magnitude of existing contamination. MDNR estimated that approximately 90 percent of the fish in the impoundment were killed.

In the fall of 1984, a Consent Judgement was signed between MDNR and CCI. The Consent Judgement outlined a plan for monitoring and restoration of Deer Lake and held CCI financially responsible. In addition, CCI was to make access available on nearby lakes for use by area residents to compensate for the temporary loss of Deer Lake as a fishing resource. The dam is to be operated in such a fashion that the Deer Lake impoundment is held at its maximum surface elevation of 428.8 meters or 1390 feet above sea level. It was hypothesized that fluctuating water levels in the past increased the availability of sediment bound mercury.

The monitoring program outlined a 10 year environmental sampling regime for fish, sediment, water, and for ice over tailings. The restoration plan calls for the stabilization of Deer Lake water levels near the top of the dam, thus limiting the transformation of sediment bound mercury to methylmercury, the bioaccumulative form. Following water level stabilization, a plan for natural restoration will be undertaken. The sediments will be left in place where they will be largely anoxic and become covered over by clean sediments. It is anticipated that these actions will prevent mercury exchange with the water column and associated aquatic biota.

The key goal of the restoration plan is to create an uncontaminated fishery in the lake and its tributaries. Following the eradication of fish completed in the fall and winter of 1986-1987 and the partial filling of the impoundment, MDNR introduced 15,000 stunted adult yellow perch taken from nearby Silver Lake in May, 1987 followed by about 900,000 to 1,000,000 walleye fry. In July 1987, 19,500 fingerling walleye were also placed in the lake. An initial increase in mercury contamination of these fish is expected but MDNR anticipates that levels will diminish within 5 years.

At this point in time, all planned remedial actions have been completed, or are in the process of implementation. Upgrading of the sewage system was completed with success. The restoration plan is well underway. The lake water level will be stabilized (and will remain so for the next 10 years) and sport fish have been restocked. The primary task remaining is monitoring of the lake and tributaries for the next 10 years, to ensure that restoration is occurring. Monitoring is expected to begin again in October 1987.

Evaluation of the Deer Lake mercury problem in relationship to the Lake Superior ecosystem indicates that there is no significant impact from this contaminant source.

2.0 INTRODUCTION

2.1 AREA OF CONCERN

The Carp Creek, Deer Lake, Carp River System has been designated as an Area of Concern (AOC) by the International Joint Commission (IJC), the Great Lakes National Program Office (GLNPO), and the State of Michigan. Sites are selected as AOCs because use of their water resources was impaired and because impairments may have potentially negative impacts on the Great Lakes ecosystem.

Within the Deer Lake AOC, an impacted area and a pollutant source area have been delineated. The impacted area is that portion of the AOC for which use impairments have been identified. Pollutants causing use impairments in the AOC have been tracked to sources, or source areas.

The use impairment identified in the AOC is degradation of the fish community. Contamination of fish with high levels of mercury in excess of the Michigan Department of Public Health action level of 0.5 mg/kg wet weight resulted in a fish consumption advisory for Carp Creek, Deer Lake, and the Carp River. The impacted area of the AOC includes Carp Creek, Deer Lake, and the Carp River. The pollutant causing the use impairment is mercury.

Sources of mercury in this AOC include both point and nonpoint sources. Point sources included the old Ishpeming sewage treatment plant located on Carp Creek and combined sewer overflows (CSOs) in the City of Ishpeming. The old sewage treatment plants (including two small Ishpeming Township plants) were sources of heavy nitrogen and phosphorus loadings to Deer Lake. The new Ishpeming plant is not a significant source of mercury to Deer Lake since the new plant began operating in the spring 1986.

Sediments throughout Deer Lake are contaminated with mercury (2-16 mg/kg) and will be a potential source of contamination to the biota of Deer Lake for a period of time. Based on available information, the primary future mercury source areas include Deer Lake and that portion of Carp Creek from the site of the old storm sewers in Ishpeming downstream to the Deer Lake Dam. Figure 2-1 and 2-2 illustrate the pollutant source area and impacted area of the AOC.

2.2 BACKGROUND

Deer Lake is situated in the Marquette Iron Region, an area where mining has historically been the dominant industry. Figure 2-3 shows the location of Deer Lake within the Marquette Iron Region and the proximity of the Region to Lake Superior.

The Ropes' Goldmine maintained an operation in the vicinity of Deer Lake from 1882 to 1899. The mine used mercury amalgamation initially to concentrate the gold mined there. Gold mine tailings were deposited along Ropes' Creek, a small tributary to the Carp River. Some tailings from the Ropes' Gold mine exist in a small area along the present

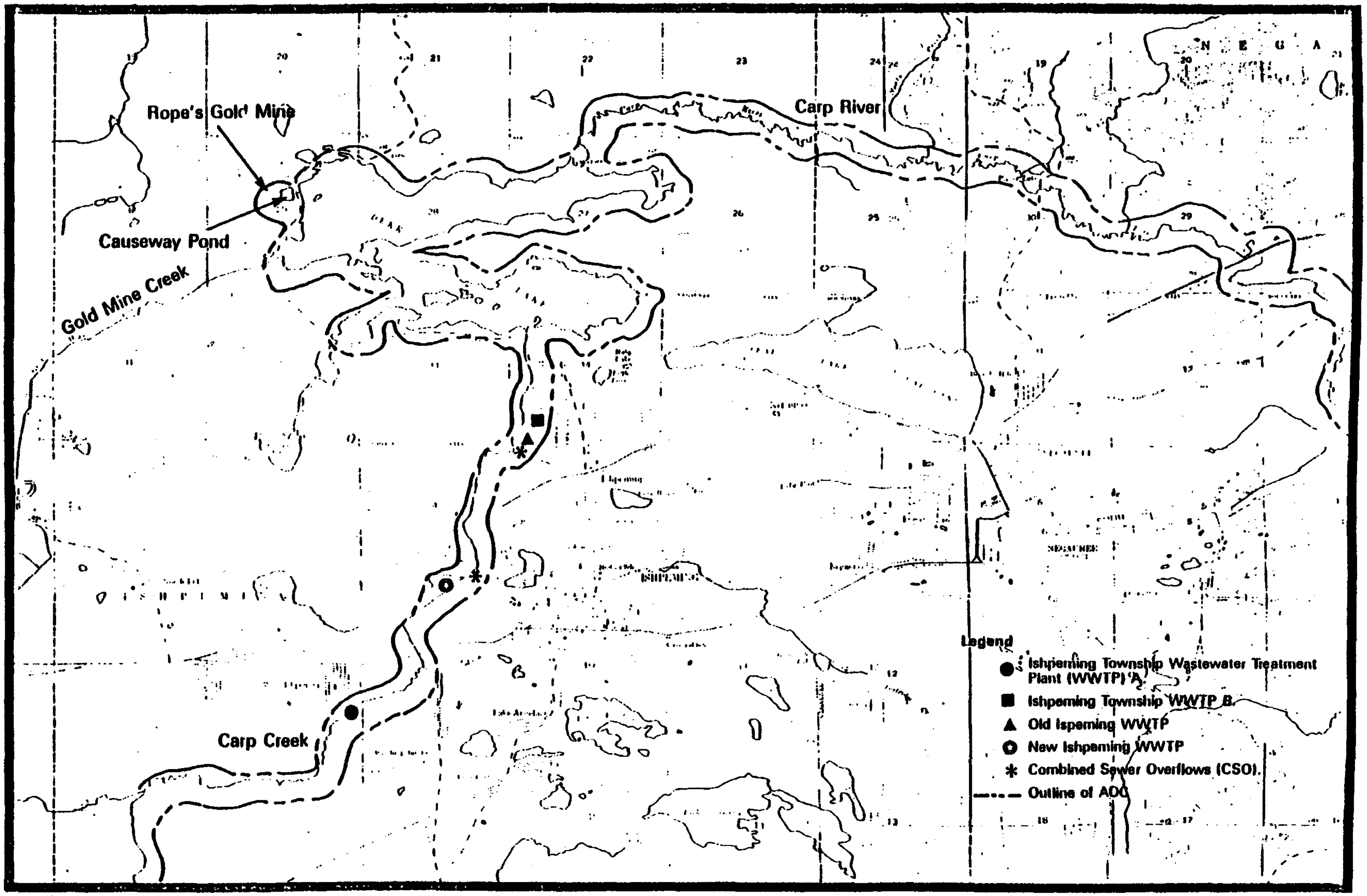


Figure 2-1.
Deer Lake Area of Concern (AOC) — Western Portion

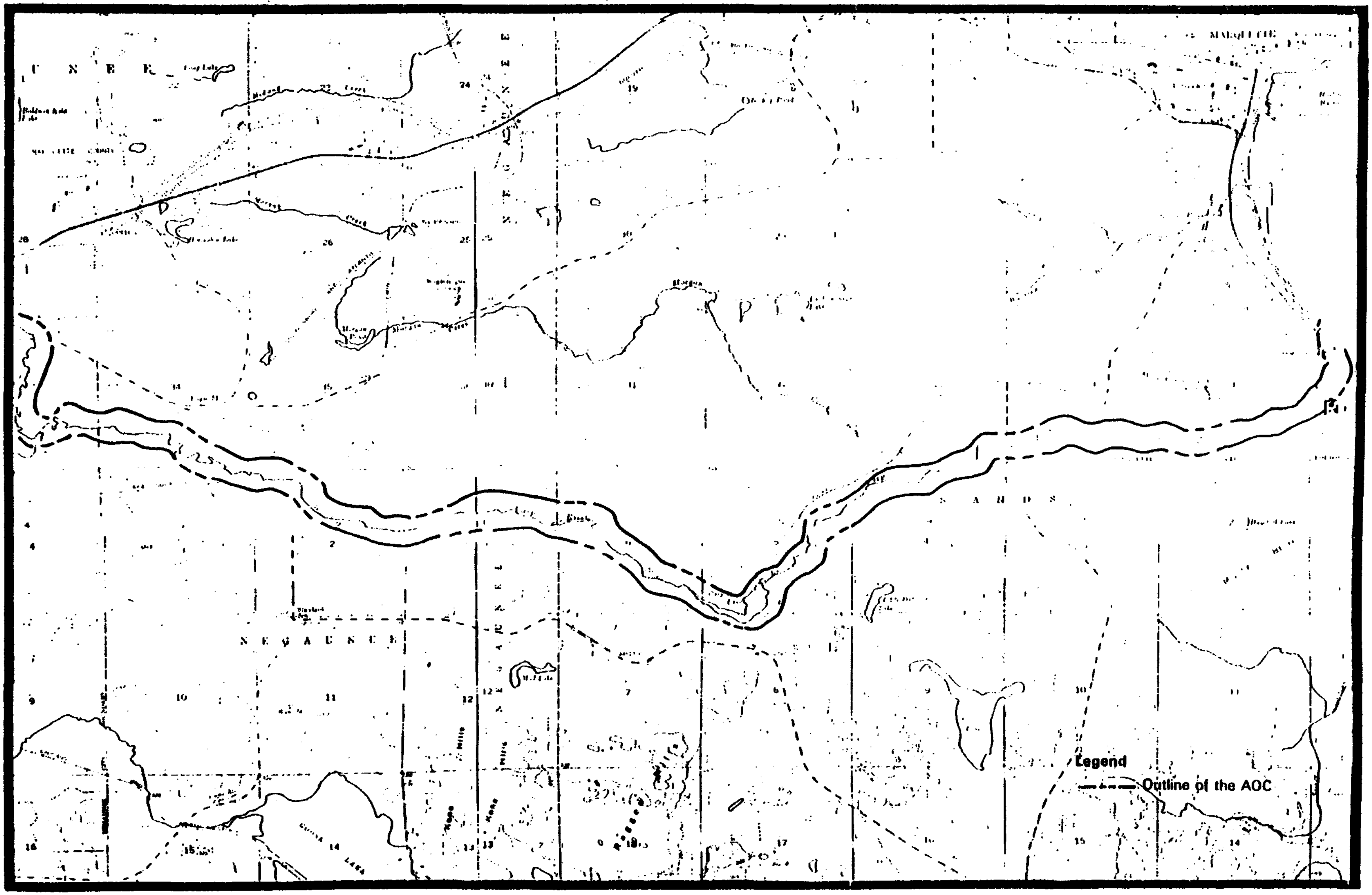


Figure 2-2.
Deer Lake Area of Concern (AOC) — Eastern Portion

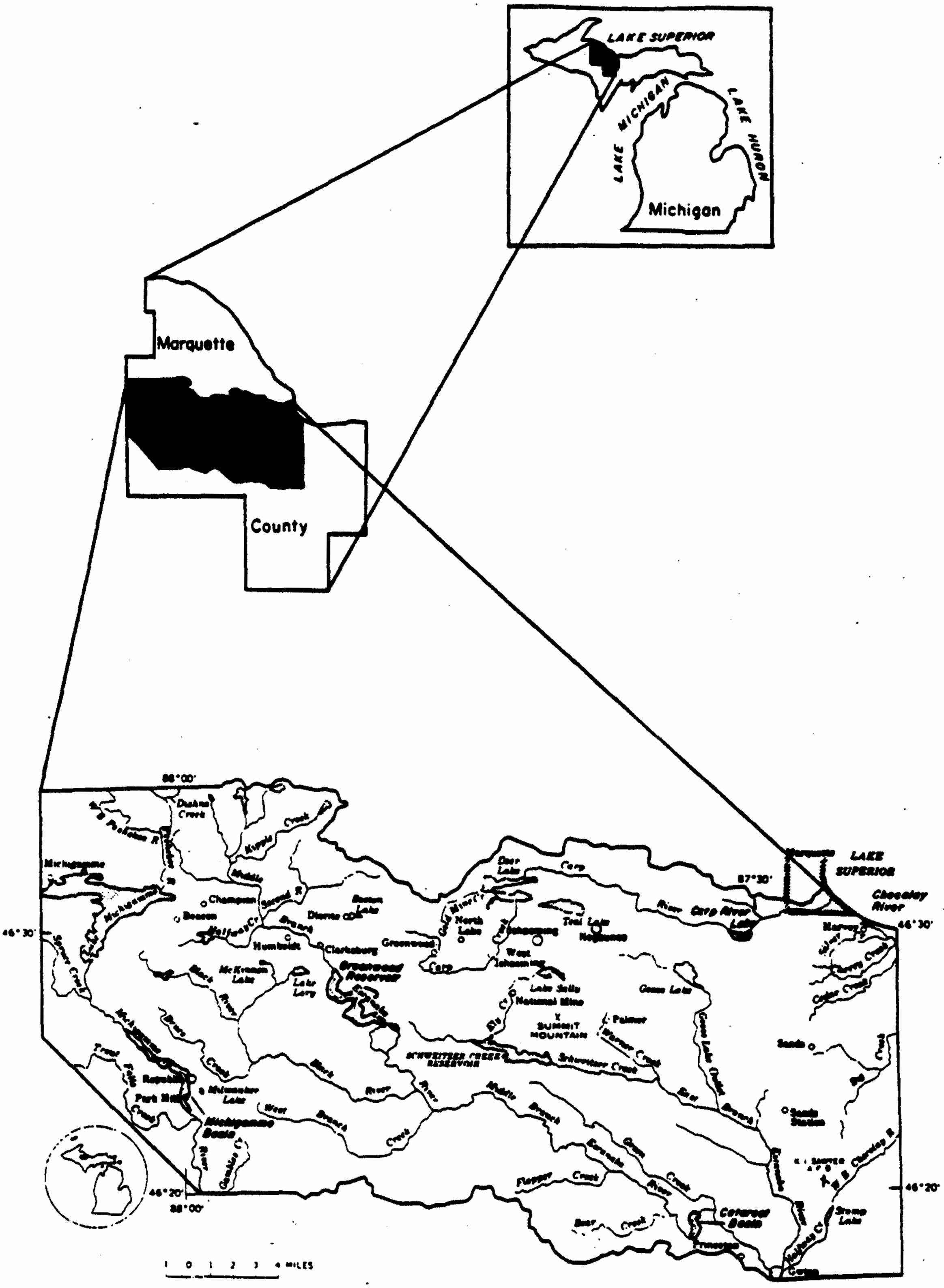


Figure 2-3.--Marquette Iron Range study area.
(Source: USGS 1979)

shoreline of Deer Lake. A road passes over these tailings which are largely buried by sediments that have accumulated since the turn of the century.

The original Deer Lake had a surface area of approximately 36 hectares (90 acres), located in what is now the eastern section of the southern basin of the lake. Initially, a small dam was constructed southeast of the Ropes' Mine on the Carp River to provide a water supply for ore processing. In 1912, a second dam was constructed on the Carp River near the present dam site to form a larger impoundment. In 1942, a third dam was constructed in front of the second dam to increase the size of Deer lake to its present surface area of 367 hectares (906 acres). The present dam is a concrete structure 18 meters or 60 feet in total height with a head of 12 meters or 40 feet.

Outflow of the lake was regulated by the Cliffs Electric Service Company to augment winter flows and power generation near Marquette. Between January and March of each year, until 1978, water from Deer Lake was released for this purpose. The release of water in the past resulted in lake draw-downs that exposed about 52% of the lake sediments (MDNR file).

In 1929, prior to the final impoundment of Deer Lake, Cleveland Cliffs Iron Company opened an assay lab and began using mercuric chloride in their ore assay procedure. At about the same time, the City of Ishpeming became sewered. From 1929 to 1964 all wastewater generated by the City of Ishpeming discharged through combined sewers into Carp Creek. Portions of Ishpeming Township also contributed raw sewage to Carp Creek, but in smaller amounts.

In 1964, three primary sewage treatment plants were constructed to serve the City of Ishpeming (2 MGD), the western portion of Ishpeming Township (0.2 MGD) and the northern portion of Ishpeming Township (0.07 MGD). The operation of these plants was an improvement over previous conditions, but degraded water quality in the system remained (MDNR file). Deer Lake experienced algal blooms in summer and oxygen depletion in winter (MDNR file).

In 1970, the Michigan Water Resources Commission issued Final Orders of Determination to the City and Township to initiate phosphorous removal from wastewater. At about the same time the Michigan Department of Public Health established combined effluent limits for the sewage treatment plants. Following this action, the City and Township, working together, obtained a USEPA/ State of Michigan construction grant for construction of a new sewage treatment plant to service the area covered by the three separate plants (MDNR file).

The construction grant project began in 1984 and resulted in the new Ishpeming WWTP that went online in April 1986. The plant provides secondary treatment and removal of nitrogen and phosphorous. In addition, combined sewers in the City of Ishpeming were separated, eliminating combined sewer overflows to Carp Creek (MDNR file).

In 1979, the Callahan Mining Company proposed to reopen the Ropes' Gold mine. The mining company hired a consultant, Ecological Research

Services, Inc. (ERS), to write an environmental assessment for the reopening. ERS commenced environmental sampling of the Ropes' Goldmine and other areas around Deer Lake in the summer of 1980. The sampling results reported in September 1981 for this project suggested serious mercury contamination of Deer Lake fish, water and sediments. In late September 1981, sludge samples obtained by the MDNR from the Ishpeming WWTP in 1980, were reported to have high levels of mercury. Cleveland Cliffs Iron Company (CCI) was identified as the source of mercury to the WWTP. Mercury reagents from their labs had been poured down sink drains which subsequently discharged into the sewer system. In September 1981, CCI ceased disposing of laboratory reagents in this way. In November 1981, the Michigan Department of Public Health issued a health advisory on fish in Deer Lake on the basis of an October fish survey carried out by the MDNR. Fish consumption advisories were extended to include Carp Creek and the Carp River in 1982 following additional sampling.

In 1982, State Plaintiffs filed a suit against CCI, which resulted in the establishment of a Consent Judgement between the State of Michigan and CCI signed in 1984. After the suit was filed, but before the Consent Judgement was signed, CCI and MDNR jointly began analyzing the extent of mercury contamination in Deer Lake. Cleveland Cliffs Iron Co. hired a consultant, Frank D'Itri, to make recommendations for abatement of mercury contamination. Both parties (CCI and MDNR) felt that the annual fluctuation in water levels of Deer Lake in the past, possibly created conditions promoting the availability of sediment bound mercury to fish and other animals. Therefore, it was deemed desirable to stabilize the water level in Deer Lake (Consent Judgement 1984).

Despite the issuance of the health advisory in 1981, fishing continued in Deer Lake. In order to minimize public and wildlife exposure to mercury contaminated fish, MDNR undertook a fish eradication program. In 1984 the water level in Deer Lake was drawn down to its lowest (410.6 meters or level 1,355 feet above sea level) and a fish grate was installed on the outlet pipe of the dam to kill any fish leaving the impoundment. In the winter of 1985-1986, MDNR netted and killed an additional 1,500 pounds of fish during a survey of the lake that remained in the impoundment. In the fall and winter of 1986-1987, the fish remaining in the original Deer Lake were killed with rotenone. To ensure that no rotenone would be carried downstream, CCI dug a channel to divert the flow of Carp Creek around the lake. It is estimated that 90% of the fish in the impoundment were killed and a complete kill apparently occurred beneath the ice in the lake. Some fish remained in the stream channel, tributaries, and the water ponded near the dam. All fish were left in the system to decompose. The mercury input from these fish was not considered significant compared to other sources and past loadings (Elwin Evans, MDNR, August 19, 1987, personal commun.).

In the spring of 1987, the gates to the Carp River dam were almost closed and the lake partially refilled. Run-off was inadequate to fill the impoundment due to an unusually warm winter with little snowfall. By late August 1987, the impoundment was about three meters from the top of the dam and about 36% full. The lake was restocked with 15,000 adult yellow perch transported from nearby Silver Lake in May and 900,000-1,000,000 walleye fry were added later in the month. In June

1987, 19,500 fingerling walleye were also stocked in the lake. Collections of fish from Deer Lake for mercury contamination monitoring will be completed in October 1987 (Elwin Evans,, MDNR, July 20, 1987, personal commun.).

Both CCI and MDNR anticipate that a minimum of five years will be required to determine if the restoration program outlined in the Consent Judgment will result in fish populations acceptable for consumption. (The monitoring program and Consent Judgement are discussed in greater detail in Chapter 7.) Both parties anticipate that within five to eight years mercury now in Deer Lake sediments will be buried by new, and less contaminated sediments (Consent Judgment 1984).

2.3 GREAT LAKES WATER QUALITY MANAGEMENT

The Great Lakes Water Quality Board (GLWQB) is a technical component of the International Joint Commission (IJC). Among other responsibilities, the IJC monitors progress of the United States and Canada toward achieving the water quality and ecosystem health objectives of the Great Lakes Water Quality Agreements of 1972 and 1978. The Board is responsible for reporting water quality research activities and the environmental quality of the Great Lakes to the IJC. In order to track and measure progress (in terms of environmental health) in the 42 identified Areas of Concern, the GLWQB adopted a ranking system of six categories. These categories represent a logical sequence for problem-solving and resolution; they identify the status of the information base, programs which are underway to fill the information gaps, and the status of remedial efforts. According to the GLWQB, a site can be deleted as an AOC when evidence is represented verifying that the full complement of impaired uses has been restored (WQB 1985). The six categories are:

Category	Explanation
1	Causative factors are unknown but there is no investigative program to identify causes.
2	Causative factors are unknown; however an investigative program is underway to identify causes.
3	Causative factors are known, but a Remedial Action Plan in not developed and remedial measures are not fully implemented.
4	Causative factors are known and a Remedial Action Plan has been developed; however, remedial measures are not fully implemented.
5	Causative factors are known, a Remedial Action Plan has been developed, and all remedial

measures identified in the Plan have been implemented.

6 Confirmation that uses have been restored, and deletion of the site as an Area of Concern.

The GLWQB 1985 report listed Deer Lake as a Category 4 Area of Concern.

2.4 PURPOSE

The purpose of the remedial action planning process is to provide a system-wide approach to environmental management that will ultimately lead to the successful rehabilitation of the entire Great Lakes ecosystem. This approach requires an integration of available data on environmental conditions, socioeconomic influences, and political/institutional frameworks. The purpose of this Remedial Action Plan (RAP) is to focus the RAP development efforts on data gathering and data synthesis, in order to provide a technical basis for development of remedial measures to resolve the immediate problems that impair the AOC's designated uses. Recommendations for restoring the impaired uses (and maintaining other uses) are based on currently available data.

2.5 INTENDED USE

This RAP is intended as a management document, providing a technical basis for targeted future analyses and informed decision making. It is intended to be a detailed review and synthesis of all available data and/or information relevant to the specific problem in the Area of Concern. Every attempt has been made to identify and review the major documents that relate to the use impairments affecting beneficial uses in the Deer Lake AOC. The RAP process is also an opportunity for the public to influence environmental policy and actions.

3.0 ENVIRONMENTAL SETTING

3.1 LOCATION

The Carp Creek - Deer Lake - Carp River system has been identified by the State of Michigan and the International Joint Commission as an Area of Concern. The AOC is in the Upper Peninsula of Michigan. It drains to the south shore of the eastern basin of Lake Superior, near the City of Marquette, in Marquette County, Michigan. Deer Lake is located northwest of the City of Ishpeming in Marquette County approximately 24 km (15 mi) from Lake Superior. This corresponds to approximately 46° 34'N latitude x 87° 40'W longitude.

3.2 NATURAL FEATURES

3.2.1 Drainage Basin Size

The Deer Lake drainage basin, consisting of Carp Creek 62 km^2 (24 mi^2), Gold Mine Creek 12 km^2 (4.9 mi^2), minor tributaries and immediate drainage 15.5 km^2 (6.0 mi^2) is approximately 93 km^2 (36 mi^2). Deer Lake was originally a 36 hectare or 90 acre lake, but has been enlarged about ten times to its current size of 367 hectares or 906 surface acres by the construction of a dam on the Carp River.

The Carp River drainage basin is 191 km^2 (74 mi^2) in area with a water yeild of 1.2 cfs per mi^2 or 0.47 cfs/km^2. The mean annual discharge is estimated as 88.8 cfs.

3.2.2 Topography

The topography of the Deer Lake drainage basin is variable, ranging from a 0-10% slope (flat) in most sections of the Township of Ishpeming to as much as 46% slope (steep) in other areas. Ludwig (1981) characterized the topography as ranging from typically flat plains (associated with areas of glacial outwash) to rocky cliffs and steeply dissected terrain, with many Precambian bedrock outcroppings. An area of wetlands is situated around the western portion of Deer Lake.

3.2.3 Hydrology

Deer Lake, prior to 1912, had a surface area of approximately 36 hectares or 90 acres and apparently was not affected by the low head dam built for water storage for the Ropes' Mine. In 1912, the lake was enlarged by further impoundment of the Carp River. In 1942, a third dam was built with a spillway elevation of 424 meters (1390 ft) above sea level. The third dam created Deer Lake as it is seen today, with a surface area of approximately 367 hectares (906 acres).

A bathymetric survey of the lake conducted in 1974 showed that the north half of the lake and the south half were essentially two distinct basins (Bills 1977). The north basin has a maximum depth of 8 meters and the south basin has a maximum depth of 10.5 meters (Bills 1977). The deepest portion of the south basin is located near an island in part of the original Deer Lake. Figure 3-1 is a hydrographic map of the lake. The total volume of the lake has been estimated at 546 x 10^6 ft^3 or 15.45 x 10^6 m^3.

Prior to 1984, discharges from the dam creating Deer Lake were regulated by the Cliffs Electric Service Company. Until 1979, a hydroelectric generating facility was operated downstream near Marquette. Between 1979 and 1984, winter draw down of the impoundment was continued to provide flood control during spring run off. The normal seasonal operation of the impoundment in the past is shown in Figure 3-2. By June, the impoundment was filled to about 80 percent of its capacity at 423 m or 1387 ft surface elevation and held near this volume until after freeze up in December. Between January and March, flow augmentation of the Carp River normally decreased the surface elevation of the impoundment from about 422 m (1385 ft) above sea level to 420 m (1376 ft), which is 4.3 m or 14 ft below maximum elevation at 424 m (1390 ft). This annual cycle of impoundment fluctuations has complicated past water quality studies, since the lake was filled with relatively clean water each spring and thereafter enriched with nutrients until discharged during the winter.

In the future, the impoundment surface will be maintained at 424 m or 1390 ft above sea level, as ordered by the Circuit Court of Marquette County. This will increase the average impoundment surface elevation by 1.5 m (5 ft), the volume by 34% and surface area by 35 hectares or 86 acres (Table 3.1). When the impoundment becomes both hydrologically and biologically stabilized, an evaluation of lake conditions can be undertaken.

Mean flows for Carp Creek, Gold Mine Creek, and the minor tributaries including immediate drainage to Deer Lake were estimated at 34.6 cfs (MDNR 1987).

USGS maintains a permanent gauging station on the Carp River located approximately 3.2 km or 2.0 miles east of Negaunee with a drainage area of 133 km^2 (51.4 mi^2) (Station Number 04044400). Flows measured at the Negaunee Station for water year 1985 (October 1984 - September 1985) are shown in Table 3-2. The average discharge for the period of record (1961 - 1985) at the gauge is 62.7 cfs. A record high flow of 918 cfs was set on April 20, 1985 even with the dam storing water. The average flow for the year was 75.2 cfs at the gauge.

3.2.4 Precipitation

The National Weather Service (NWS) maintains two weather monitoring stations in Marquette County, located in the cities of Marquette and Champion, just to the west of Ishmpeming.

The Champion station has been operational since 1952. Average annual precipitation is 82.5 cm (33 in) (average annual snowfall is 3.6 m or 139 in). Yearly evaporation is estimated to be 63 cm (25 in), but in the summer months, evaporation exceeds precipitation by about 17% (USGS 1981).

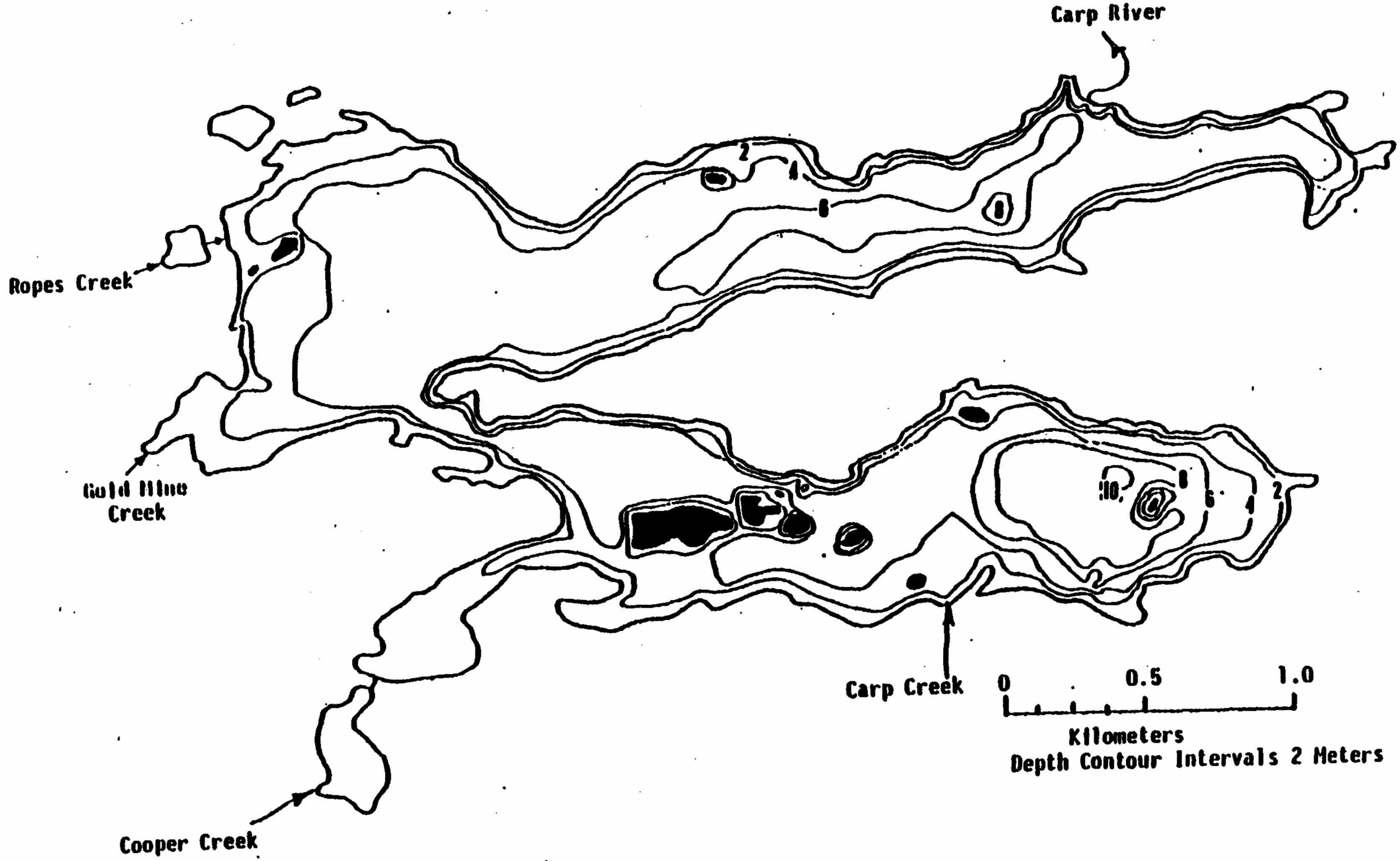


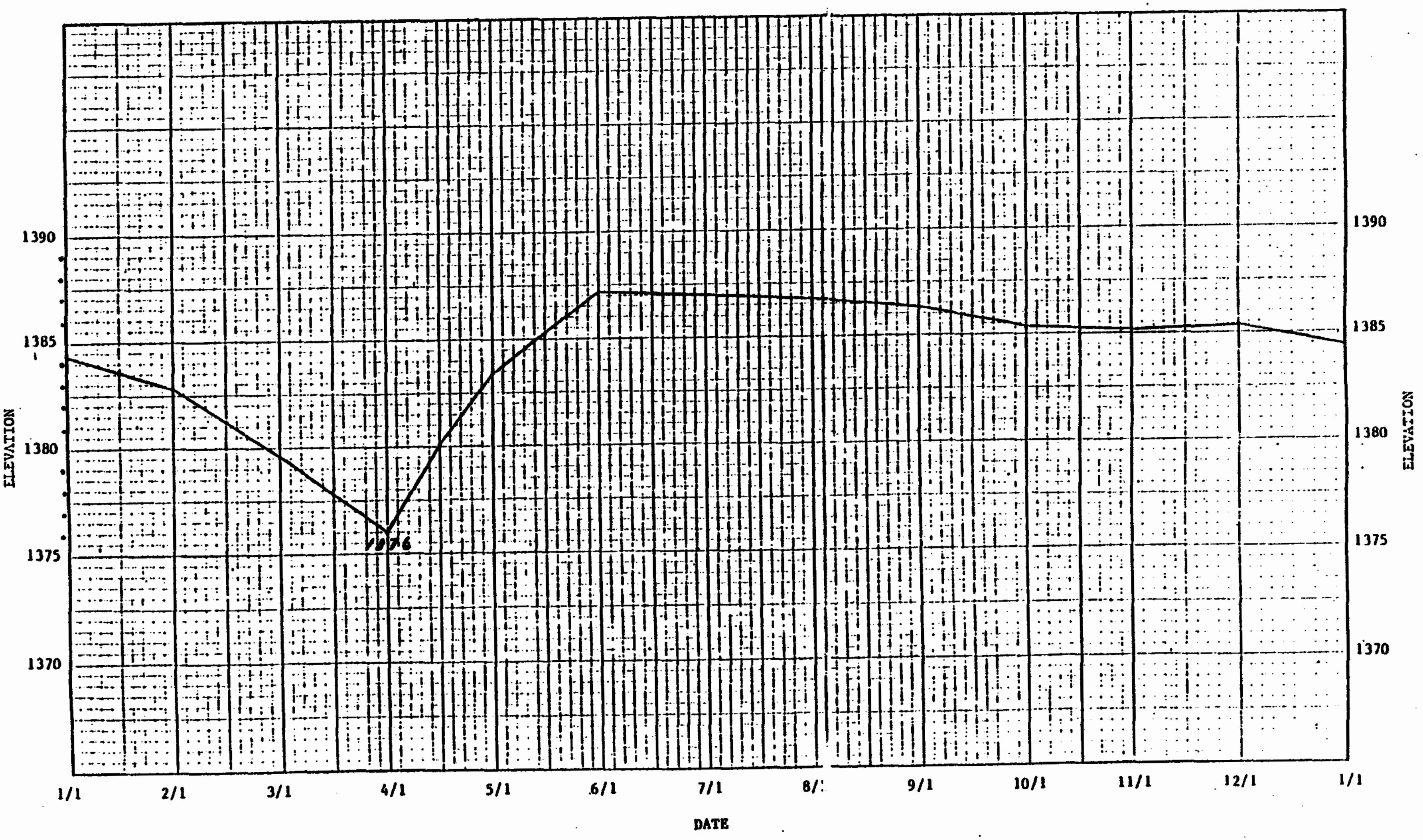
Figure 3-1. Deer Lake Hydrograph

(Source: MDNR Files)

Figure 3-2.

NORMALIZED ANNUAL VARIATION IN
DEER LAKE BASIN SURFACE ELEVATION

(Elevation = Feet Above Sea Level)



Source: Comments on the proposed phosphorus effluent standard for the City of Ishpeming. RE: Ishpeming, Michigan NPDES Permit No. MI 002169. March 6, [illegible]9. MDNR Files

TABLE 3.1 DEER LAKE IMPOUNDMENT NEAR ISHPEMING, MICHIGAN.

Elevation above Sea Level		Surface Area		Volume ($X 10^6$)	
Meters	Feet	Hectares	Acres	Cubic Meter	Cubic Feet
423.8	1390*	366.8	906	15.45	546
422.2	1385**	332.0	820	10.16	359
420.7	1380	277.3	685	5.46	193
419.5	1376***	175.4	433	2.72	96
419.2	1375	147.0	363	2.24	79

*Top of dam spillway; future court ordered maintenance level.
**Average surface elevation, except during winter drawdown.
***Average winter drawdown elevation.

Source: Comments on the proposed phosphorus effluent standard of the City of Ishpeming. RE: Ishpeming, Michigan NPDES Permit No. MI 0002169, March 6, 1979. MDNR Files.

Table 3-2. Discharge Record Carp River October 1984 through September 1985.

STREAMS TRIBUTARY TO LAKE SUPERIOR

04044400 CARP RIVER NEAR NEGAUNEE, MI

LOCATION.--Lat 46°31'29", long 87°34'25", in SE1/4 sec.29, T.48 N., R.26 W., Marquette County, Hydrologic Unit 04020105, on right bank 30 ft downstream from bridge on U.S. Highway 41, and 2.0 mi northeast of Negaunee.

DRAINAGE AREA.--51.4 mi^2.

PERIOD OF RECORD.--July 1961 to current year.

GAGE.--Water-stage recorder. Datum of gage is 1,319.90 ft above National Geodetic Vertical Datum of 1929 (Michigan Department of Highway and Transportation benchmark). Prior to Aug. 24, 1961, nonrecording gage at same site and datum.

REMARKS.--Estimated daily discharges: Nov. 17, 18, Dec. 2-9, 14, 15, Dec. 18 to Mar. 25, July 19-24, Aug. 23-27, and Sept. 18-30. Records good except for periods with ice effect, Dec. 2-9, 14, 15, and Dec. 18 to Mar. 25, which are fair and periods of indefinite stage-discharge relation, Nov. 17, 18, July 19-24, Aug. 23-27, and Sept. 18-30, which are poor. Flow regulated by Deer Lake storage reservoir (capacity, 22,500 acre-ft) 5 mi upstream. The reservoir was drained during October, November, and December; natural streamflow remainder of water year, except for some regulation during parts of April and May. The city of Ishpeming diverted an average of 2.2 ft^3/s into basin as waste effluent (station 04058200). Several measurements of water temperature were made during the year.

AVERAGE DISCHARGE.--24 years, 62.7 ft^3/s.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 918 ft^3/s, Apr. 20, 1985, gage height, 6.83 ft; minimum, 3.7 ft^3/s, July 29, 1965; minimum gage height, 1.94 ft, Aug. 1, 1962; minimum daily discharge, 3.9 ft^3/s, July 29, 30, 1965.

EXTREMES FOR CURRENT YEAR.--Maximum discharge, 918 ft^3/s, Apr. 20, gage height, 6.83 ft; minimum, 17 ft^3/s, Aug. 20, 21, gage height, 2.36 ft.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1984 TO SEPTEMBER 1985
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	91	120	153	36	27	30	79	205	136	31	34	43
2	98	119	120	35	26	29	62	201	126	32	30	41
3	102	111	100	34	25	29	67	211	113	32	30	62
4	120	110	90	34	25	29	100	211	94	40	30	93
5	108	109	86	34	24	30	107	209	72	119	32	82
6	100	108	82	33	23	31	90	200	60	137	47	76
7	107	127	80	33	23	31	79	223	58	125	60	70
8	111	154	78	33	23	32	77	230	60	114	58	96
9	114	143	76	33	23	32	73	224	67	101	58	85
10	120	155	73	33	23	33	68	223	60	85	61	73
11	120	155	112	33	23	33	86	219	54	66	58	64
12	119	152	141	33	24	32	107	214	50	54	55	58
13	118	152	157	33	24	32	129	207	47	46	71	53
14	118	155	160	33	25	31	178	197	45	42	67	48
15	117	160	145	33	26	31	243	197	44	40	65	45
16	117	162	123	33	28	30	275	206	43	37	64	42
17	121	160	130	33	28	30	263	245	44	36	71	39
18	121	160	120	33	28	30	265	208	54	37	59	37
19	123	164	100	33	28	30	594	192	63	38	55	36
20	121	154	80	33	28	31	853	184	58	35	19	34
21	118	169	70	32	29	31	582	176	52	33	26	34
22	114	167	60	31	30	32	420	205	50	31	42	37
23	112	136	50	30	30	33	341	206	48	29	35	47
24	112	136	40	30	30	36	273	190	43	28	37	57
25	112	134	36	29	30	45	244	169	40	36	46	53
26	115	133	35	29	30	71	209	156	37	37	49	55
27	116	154	35	29	30	102	222	140	35	36	40	57
28	127	174	35	29	30	130	220	117	34	35	36	54
29	122	165	36	28	—	143	215	83	33	33	44	62
30	116	156	42	28	—	160	210	119	33	36	52	127
31	113	—	38	27	—	120	—	144	—	37	47	—
TOTAL	3543	4354	2683	990	743	1519	6731	5911	1753	1618	1498	1760
MEAN	114	145	86.5	31.9	26.5	49.0	225	191	58.4	52.2	48.3	58.7
MAX	127	174	160	36	30	160	853	245	136	137	71	127
MIN	91	108	35	27	23	29	62	83	33	28	19	34

CAL YR 1984 TOTAL 27523 MEAN 75.2 MAX 174 MIN 35
WTR YR 1985 TOTAL 33123 MEAN 90.7 MAX 853 MIN 19

(Source: USGS 1985)

The Marquette weather station has been operating since 1880. Average annual precipitation is 80 cm (32 in), slightly lower than at Champion. Of the 80 cm of annual rainfall, evapotranspiration returns 45-60% to the atmosphere. Approximately 18 cm (7 in) of precipitation goes to groundwater reservoirs and the remainder becomes runoff (USGS 1981).

3.2.5 Soil Types

Soils in the Deer Lake watershed are composed of thin glacial deposits of the Iron River - Michigamme - Rockland Association. Land immediately around the lake is steeply dissected with coarse sandy areas near the shoreline.

Deer Lake is located in an area with an infiltration rate considered to be moderate to very slow. The rate is slow due to the presence of shallow bedrock.

3.2.6 Limnology

Deer Lake is a hypereutrophic, dimictic reservoir that experienced supersaturation of dissolved oxygen in the epilimnion and hypolimnetic anoxia during periods of thermal stratification. Anoxic conditions developed primarily because of excessive nutrient loadings (D'Itri 1983). Bills (1977) reported total phosphorous concentrations ranging from 0.18 to 1.66 mg/l and nitrate concentrations ranging from 0.4 to 15 mg/l. Carp Creek is the primary source of nutrients to the lake.

Nutrient enrichment caused massive algae and zooplankton blooms in Deer Lake (MDNR file). Blooms develop by mid-June and persisted throughout the summer. As these organisms died, large amounts of organic matter sank to the hypolimnion. Bacterial decomposition of this organic matter severely reduced dissolved oxygen in the hypolimnion and the sediments. Anoxic conditions facilitate the mobilization of nutrients from the sediments to the surface waters, thereby exacerbating nuisance plant conditions. This condition persisted until fall overturn, when the water column was reoxygenated. After fall overturn, quantities of organic matter remained high enough to cause oxygen depletion shortly after the lake froze. Oxygen in most of the lake was depleted by spring except under the ice near Carp and Gold Mine Creeks.

During drawdown of the lake from January to March, the weight and movement of ice compressed the sediments as it collapsed. As the lake refilled, waves could stir the sediments for a short time but these sediments would be less erodable than uncompacted sediments. The combination of excess nutrients, alternating oxic/anoxic conditions, and agitation of sediments during drawdown and refilling could possibly provide environmental conditions which would promote the transformation of sediment bound mercury into methylmercury. Whether or not mercury contamination of the biota will be reduced by the stabilization of the lake level is hypothetical.

More detailed information on the limnology of Deer Lake can be found in Chapter 4.

3.2.7 Air Quality

Ishpeming is designated a Class II PSD (Prevention of Significant Deterioration) region. The National Ambient Air Quality Standards (NAAQS) and PSD regulations for Ishpeming are:

Sulfur Dioxide:

Annual - 20 micrograms/m^3
24 hour - 91 micrograms/m^3
3 hour - 512 micrograms/m^3

Suspended Particulate Matter:

Annual - 19 micrograms/m^3
24 hour - 37 micrograms/m^3

Most areas of the Upper Peninsula are designated as NAAQS attainment areas, that is, areas in consistent compliance with standards set for six pollutants: particulates, sulfur dioxide, carbon monoxide, ozone, NO_2 and lead (Ludwig 1981). In 1986, approximately 1,328,000 metric tons of coal were burned by power plants in the vicinity of Marquette.

3.2.8 Geology

The Deer Lake watershed is situated in an area of Precambrian age bedrock. The bedrock is composed of igneous and metamorphic type rocks. The igneous and metamorphic rocks consist of quartzite, schist, gneiss, metamorphosed volcanic and sedimentary rocks, iron bearing rocks, granite, diorite, and basic igneous rocks. This complex of rocks has been folded and deformed. A large structural feature of this formation is the Marquette Synclorium, which extends from the City of Marquette westward to Baraga County. The synclorium contains the majority of iron-bearing rocks mined in the county and Deer Lake is located within the synchlorium.

Table 3-3 shows mercury analysis of ice and snow samples from rock outcrops in the Deer Lake watershed. The ice cover, which is in direct contact with rocks generally has a higher mercury content than the snow. The table shows that ice above the Kitchi schist rock type has the highest mercury content. Rock was not analyzed and the source of mercury in ice and snow is still questionable and may in large part be from aerial transport and deposition.

3.3 LAND USES

Land use within Marquette County is primarily open forested lands as shown in Table 3-4. Over 96% of the area is in forested lands and less than two percent of the county is developed for residential/ industrial purposes.

Large corporate holdings exist in Marquette County, including lands owned by Cleveland Cliffs, Inc.; Gannon Lumber Company; North Woods Products, Inc.; Mead Paper Company; and the Nekossa-Edwards Paper Company. Most of the corporate holdings are held for their timber and mineral values.

TABLE 3-3. TOTAL MERCURY ANALYSIS OF ICE AND SNOW SAMPLES FROM ROCK OUTCROPS IN THE DEER LAKE WATERSHED.

Sample Number	Date Collected	Sample Location Map No.	Rock Type Abbreviation	Rock Type	Ice Layer (ug/l)	Snow Cover (ug/l)
1	Mar. 29	1	Wkf	Kitchi schist (dacitic tufts)	0.05	0.20
2	Mar. 29	1	Wkf	Kitchi schist (dacitic tufts)	2.95	0.41
3	Apr. 15	1	Wka	Kitchi schist (agglomerate)	1.53	0.01
4	Apr. 15	1	Xa	Ajibik quartzite	0.01	0.01
5	Mar. 29	1	Ws	Serpentinized peridotite	0.05	0.01
6	Apr. 15	2	Xmd	Metadiabase	0.10	0.01
7	Mar. 29	1	Xa	Ajibik quartzite	0.05	0.05
8	Mar. 29	3	Wmg	Metagabbro	0.05	0.10
9	Apr. 15	3	Wg	Granite	0.05	0.01
10	Apr. 15	2	Xmc	Clarksburg volcanics	0.01	0.01
11	Mar. 29	1		Ropes tailings	0.31	0.05
12	Mar. 29	1		Ropes tailings	0.00	0.01
13	Mar. 29	1		Ropes tailings	0.05	0.05
14	Apr. 18	2	Xg	Goodrich quartzite	0.01	0.05

(Source: D'Itri)

3.3.1 Urban/Suburban/Residential Land Use

Deer Lake is in a rural and largely undeveloped watershed. The Township of Ispheming lies to the east of the lake.

3.3.2 Sewer Service Areas

The City and Township of Ishpeming are completely sewered. All CSOs have been dismantled. Prior to April 1986, sanitary and combined sewers from the two areas fed into primary treatment plants or discharged directly during high flows into Carp Creek. Since April 1986, a new tertiary treatment plant has been in operation, replacing the three older systems. The new WWTP includes advanced waste water treatment with nitrogen and phosphorus removal. More detailed information on sewage service is contained in Chapter 5.

3.3.3 Unsewered Areas

Population centers in the AOC are sewered. Due to shallow bedrock the area is not well suited to septic disposal systems.

3.3.4 Industrial Land Use

Deer Lake is situated in the Marquette Iron Range. The chief industry in the area is the mining of iron ore. Approximately 500 million tons of ore have been mined since iron was discovered there in 1844 (USGS 1981). The mining corridor generally corresponds to the location of the Marquette Synclorium.

In the recent past the majority of production has been from three mines: Empire, Republic, and Tilden. The Empire and Tilden are the only active mines in the Marquette Iron Range and are not in the Carp River drainage basin. Reserves of ore are considerable, however, and mining is expected to continue (USGS 1981).

The only industry identified within the AOC is the Cleveland Cliffs Iron Company which discharges to the Ishpeming WWTP. No other major industries currently exist in the region.

Prior to the turn of the century the Ropes' Goldmine operated along Ropes' Creek. From 1882 to 1899, Ropes' used mercury amalgamation to concentrate the gold in mine tailings. Any leachate or discharge would have flowed to the Carp River. Gold mine tailings still exist on the southwestern edge in a small area of the lake, but are largely buried beneath accumulated sediments.

Callahan Mining Company (CMC) purchased the Ropes' Goldmine in 1975 and has reopened the mine. Ore is removed from the ground and trucked to a different location outside the basin for processing (pers. comm., Elwin Evans, MDNR, August 19, 1987). An environmental assessment performed for CMC by Ecological Research Services, Inc. in 1981, first identified the problem of mercury in Deer Lake.

TABLE 3-4. MARQUETTE COUNTY LAND, AS USE % OF TOTAL

Residential, Commercial & Institutional	1.1
Industrial	0.1
Extractive	0.7
Other Urban	0.4
Agricultural	1.3
Open Lands - Forests	96.4
TOTAL:	100.0

SOURCE: CUPPAD 1981 Executive Summary Characteristics (From Ludwig 1981)

3.3.5 Recreational Land Use

There are no city or county parks or beaches on Deer Lake. Nearby Teal Lake is used for recreation by residents as well as a water supply for the City of Negaunee.

3.3.6 Agricultural Land Use

The combination of extensive forests, rugged topography and cold weather preclude any large scale agriculture within the AOC.

3.3.7 Wildlife Habitat

The forests and wetlands surrounding Deer Lake support an abundance of birds and mammals. Ludwig (1981) found that a total of 103 bird species used the area. Of those, the osprey and bald eagle were the only species listed by the DNR as endangered or threatened. Fourteen species of small mammals and a variety of large mammals were also found. All of the species of mammals that Ludwig encountered are common in the Upper Peninsula (see also Section 4.1.6, Biota Impairments). A more detailed faunal inventory can be found in Ludwig (1981).

3.4 WATER USES IN DEER LAKE

3.4.1 Fish and Wildlife Habitat

MDNR has not managed Deer Lake since public ownership does not exist on the lake. Intensive fishing for yellow perch and northern pike has occurred over the years. Bullheads, white suckers, golden shiners, fat head minnows, and sunfish are also found in the lake. Carp Creek and the Carp River are protected for cold water fishing and are designated trout streams.

Deer Lake wetlands are important in sustaining a wide variety of terrestrial animal life and waterfowl. Many of the 103 species found were noted to be transients, passing through the area during spring migration (Ludwig, 1981).

3.4.2 Water Supply

Deer Lake is not a source of municipal drinking water, however it was used to augment the flow in Carp River. Cleveland Cliffs Iron Company owns and regulates the dam. They have an agreement with the City of Negaunee to release enough water to maintain a minimum flow of 6 cfs during the months from June - October and a minimum of 12 cfs at other times of the year (D'Itri 1983). The impoundment is no longer used for water storage for hydroelectric power generation, although some flood control benefits may be available in the future.

3.4.3 Commercial Fishing

No commercial fishery exists in Deer Lake.

3.4.4 Sport Fishing

Deer Lake was well known among Michigan and Wisconsin fishermen for its perch/pike fisheries but the MDNR has only recently become involved in managing the fishery. Fishing was largely eliminated by the drawdown of the impoundment in the fall of 1984.

3.4.5 Contact Recreation

Contact recreation, such as swimming or water skiing, is not a primary use of Deer Lake. Swimming is not prohibited, however, no swimming areas or beaches exist.

3.4.6 Navigation

The Deer Lake impoundment has no appreciable navigational uses except for small fishing boats.

3.4.7 Noncontact Recreation

Pleasure boating, fishing, hunting and hiking are some of the noncontact recreational activities. Since its drawdown, Deer Lake has had little recreational activity.

3.4.8 Drainage/Flood Control

No flood control purposes have been designated for Deer Lake. However, the water level may be regulated for management purposes such as flow augmentation, flood control, and fisheries management in the future.

3.4.9 Waste Disposal

Carp Creek is the receiving stream for the discharges from the new WWTP that services the City of Ishpeming and portions of Ishpeming Township. Carp Creek discharges to Deer Lake. Cleveland Cliffs, the only industry in the watershed, discharges to the Ishpeming WWTP. Uncontrolled waste discharges have not been identified at this time.

3.5 WATER QUALITY STANDARDS, GUIDELINES, OBJECTIVES, AND APPLICABLE BENEFICIAL USES

The Michigan Department of Natural Resources and its Water Resources Commission have recently completed a review and update of water quality criteria for the state.

The State of Michigan established seven designated uses for which all surface waters are protected as a minimum. These uses are:

- Industrial water supply, agriculture, and public water supply at the point of intake
- Partial body contact recreation
- Waterwater fish, indigenous, other aquatic life and wildlife
- Navigation.

Furthermore, all waters of the state are designated for total body contact recreation from May 1 to October 31; and certain waters of the State are protected for coldwater fish. In cases where the same body of water has more than one use, the more stringent water quality standards apply. Deer Lake is protected as a warmwater fishery. Carp Creek and Carp River are designated trout streams.

Table 3-5 summarizes the State standards. Deer Lake, as an inland lake and warmwater fishery, must maintain a minimum of 5 mg/l dissolved oxygen throughout the epilimnion during periods of stratification. At all other times, dissolved oxygen concentration should be greater than 5 mg/l.

The Carp River and Carp Creek are designated as trout streams and must maintain a minimum dissolved oxygen concentration of 6 mg/l at its design flow during warm weather. The design flow is defined in the Michigan Water Quality Standards as the flow equal to the most restrictive of the 12 monthly 95 percent exceedance flows. At design flow during other seasons, a minimum dissolved oxygen concentration of 7 mg/l shall be maintained.

Rule 323.1057 of the Water Quality Standards limits toxic substances within and at the edge of the mixing zone. Mercury is limited on the basis of human health concerns and should not exceed 6×10^{-4} ug/l in Carp Creek as a monthly average.

State-of-the-art analytical techniques are not sufficiently sensitive to detect this chemical at this level in the effluent. The discharge of this chemical at a level which is or may become injurious to the designated uses of the waters of the state or constitutes a threat to the public health or welfare is prohibited. In addition to this prohibition, the discharge of this chemical at detectable levels is a specific violation of the permit. The reported detection level for the method specified shall not exceed 0.5 ug/l unless a higher level is appropriate because of sample matrix interference. A report containing a plan and schedule to minimize the discharge of this chemical should be submitted by the permitted following issuance of the permit. Such a plan was part of the consent judgment and has been implemented.

The IJC water quality objective is 0.2 ug/l in a filtered sample.

TABLE 3-5. SUMMARY OF MICHIGAN WATER QUALITY STANDARDS; PARAMETERS (SUBSTANCE OR CHARACTERISTIC) AND ESTABLISHED LIMIT OR RANGE.

Parameter	Limit
Dissolved Solids (TDS)	500 mg/l monthly average; 750 mg/l maximum at any one time.
Chlorides	50 mg/l average monthly for Great Lakes and connecting waters at point of intake; 125 mg/l monthly average for all other state waters.
Hydrogen ion concentration (pH)	6.5-9.0 in all waters of the state; artifically induced variation shall not exceed 0.5 units of pH.
Phosphorus (P)	1.0 mg/l monthly average for point source discharges.
Fecal coliforms	200 organisms per 100 ml for total body contact recreation; 1,000 organisms per 100 ml for all other waters.
Dissolved oxygen (DO)	Great Lakes and connecting waters and inland streams: ° Minimum of 7 mg/l shall be maintained at all times in Great Lakes and connecting waterways. ° Minimum of 5 mg/l shall be maintained in inland streams. Inland lakes: ° Stratified coldwater lakes: - If D.O. 7mg/l in upper half of hypolimnion then a minimum of 7 mg/l shall be maintained throughout the epilimnion and upper 1/3 of the thermocline during stratification. - If D.O. 7 mg/l throughout the hypolimnion then a minimum of 7 mg/l shall be maintained throughout the lake.

TABLE 3-5 CONTINUED

Parameter	Limit
DO	° Unstratified coldwater lakes: a minimum of 7 mg/l shall be maintained throughout the lake. All other inland lakes: - During stratification a minimum of 5 mg/l shall be maintained throughout the epilimnion. - At all other times concentrations greater than 5 mg/l shall be maintained.
Toxic Substances	Toxic substances shall not be present in the waters of the state at levels which are or may become injurious to the public health, safety, or welfare; plant and animal life; or the designated uses of those waters. Allowable levels of toxic substances shall be determined by the commission using appropriate scientific data. Allowable levels of toxic substances in the surface water after a discharge is mixed with the receiving stream volume specified in R 323.1082 shall be determined by applying an adequate margin of safety to the maximum acceptable toxicant concentration (MATC), level at which adverse affects are not observable in exposed test organisms (NOAEL), or other appropriate effect end points, based on knowledge of the behavior of the toxic substances, characteristics of the receiving water, and the organisms to be protected.

4.0 PROBLEM DEFINITION

4.1 IMPAIRED USES AND USE ATTAINABILITY

The only impaired designated use identified in the Deer Lake AOC is a degraded fishery. A fish consumption advisory is in effect for all species in Carp Creek, Deer Lake, and Carp River due to elevated levels of mercury detected in fish. Fishing will continue to be an impaired use until fish are no longer have mercury at levels that exceed the MDPH Standard. Once tissue concentrations of mercury fall below the Michigan MPDH action level of 0.5 mg/kg wet weight, the advisory will be rescinded.

4.1.1 Eutrophication/Impacts on Biota

Carp River, just below the dam on Deer Lake, also showed signs of eutrophication. Growths of aquatic vascular plants were heavy, and invertebrates were low in diversity and dominated by pollution-tolerant species (Ludwig 1981).

4.1.2 Commercial Fishery

No commercial fishery exists on the Carp Creek/Deer Lake/Carp River system. However, MDNR has estimated the number of angler days of sport fishing lost as a result of mercury contamination in Deer Lake. Using the Michigan Fisheries Division's value for each angler day of inland warmwater fishing, the Deer Lake fishery, during the 1980-81 period, was worth approximately $56,050 annually (MDNR Interoffice Memorandum, April 19, 1984).

4.1.3 Fish Community

The fish community in Deer Lake is dominated by yellow perch, bullheads, white suckers and northern pike. Minnows, sunfish and occasionally brook trout are caught. Carp Creek, upstream of Deer Lake, has a good population of brook trout with white suckers and minnows. Downstream of Deer Lake in the Carp River, brook trout populations are restricted to river reaches around of coldwater inputs during the summer. Northern pike and other warmwater species from Deer Lake, also exist in the river in its slower reaches. The fish community in the last kilometer (0.1 mi) downstream of the power station, seasonally, contains runs of anadromous salmonids. The power station blocks further upstream movement of fish.

Mercury in Carp Creek and Deer Lake have not impaired the fish community directly. Discharges to the creek from the WWTPs increased fish production by nutrient enrichment where other effects of their waste loadings (low D.O., chlorine toxicity) were not a problem. In Deer Lake, fish populations have been largely restricted to those fish species that can tolerate low dissolved oxygen (less than or equal to 2 mg/l) conditions (northern pike, yellow perch, bullheads and white suckers). These conditions were created by excessive phytoplankton production and loadings of readily degradable organic substances from the WWTPs.

Drawdown of the impoundment during past operations further restricted fish populations.

Fish kills of varying size have been observed with regularity in the past following ice out in the spring. Past fish kills did not apparently degrade the sport fishery because fish productivity in this lake rapidly replaced the losses.

4.1.4 Fish Consumption Advisories

In the summer of 1981, fish samples were collected from Deer Lake by Ecological Research Services of Iron River, Michigan, for the Callahan Mining Company. Mercury levels of 1.29 mg/kg (wet weight basis) were found in 10 yellow perch and 1.8 mg/kg in five northern pike. The MDNR was notified of these results and began its own investigation in October 1981. They reported an average mercury concentration in 40 fish (yellow perch, northern pike, black bullheads, and white suckers) of 1.38 mg/kg (MDNR Interoffice Memorandum, October 1981). Of the fish analyzed, 59 percent equalled or exceeded the U.S. Food and Drug Administration action level of 1.0 mg/kg.

In response to data on mercury contamination in Deer Lake fish, the Michigan Department of Public Health (MDPH) issued a fish consumption advisory in November 1981. The advisory in the Michigan Fishing Guide is depicted in Figure 4-1.

4.1.5 Beach Closings

No beaches exist on Deer Lake.

4.1.6 Aesthetic Impacts

Large algal blooms during late summer months prior to improved waste treatment caused malodorous and unsightly conditions.

4.1.7 Biota Impairments

Mercury contamination in the Carp River basin has apparently affected reproduction of bald eagles in the area. A pair of bald eagles have nested near the lake since 1964 without reproductive success (MDNR, 1985). Other contaminants, such as chlorinated hydrocarbon (DDT, PCB, etc.), can also cause reproductive failure in eagles but these substances occur in only trace amounts in the Deer Lake-Carp River system fish (MDNR 1981, Appendix A).

Eutrophication was very evident in Deer Lake and was characterized as eutrophic in a 1972 survey (USEPA 1975) and hypereutrophic in a 1974-1975 study (Bills 1977). The lake experienced algal blooms, hypolimnetic oxygen depletion in summer and winter, and had a fish population characteristic of nutrient-rich, oxygen-depleted lakes. Zooplankton in 1981 was dominated by species common in hypereutrophic lakes (Ludwig 1981). Because of lake drawdown and the new WWTP, future lake conditions will be improved once conditions stabilize.

Figure 4-1. Fish Consumption Advisory

DNR

MICHIGAN FISHING GUIDE 1987

Rules Apply April 1, 1987 Through March 31, 1988

YES M!CH!GAN

A celebration of what was and will be.

PUBLIC HEALTH ADVISORY

You should be aware that some fish from some locations contain one or more chemical contaminants at levels of public health concern. Mercury, PCB, PBB, DDT, Dieldrin, Chlordane, Toxaphene and Dioxin are among the list of such contaminants. It should not be assumed that fish from waters which are not listed below are contaminant-free. Many lakes and streams have not yet been tested. Even in the locations listed, not all of the fish species in the waterway have been tested in some cases.

As an eating precaution, it is advised that fish be skinned, trimmed, and filleted to remove fatty portions and cooked by baking, barbecuing or broiling on a rack to reduce the level of contaminants.

Based on available monitoring data, the following additional precautions are advised:

1. DO NOT EAT ANY FISH caught from: Deer Lake, Carp River and Carp Creek (Marquette County); Pine River (downstream from St. Louis, Gratiot and Midland Counties); South Branch Shiawassee River (M-59 to Byron Rd.)
2. DO NOT EAT LISTED SPECIES caught from: Lake Michigan* (Applies to Michigan, Indiana, Illinois, and Wisconsin waters): brown trout over 23", lake trout over 23", chinook salmon over 32", carp, and catfish; Green Bay (Wisconsin waters south of Marinette/Menominee): rainbow trout over 22", chinook salmon over 25", brown trout over 12", brook trout over 15", splake over 16", northern pike over 28", walleye over 20", white suckers, white bass, and carp; Lake Superior (Applies to Michigan, Minnesota and Wisconsin Waters): lake trout over 30"; Lake Erie (Applies to Michigan, Ohio, and Pennsylvania waters): carp and catfish; Lake St. Clair (Applies to Michigan and Ontario waters): largemouth bass over 14", muskie and sturgeon; St. Clair River (Applies to Michigan and Ontario waters): gizzard shad over 10"; Saginaw River and Saginaw Bay: carp and catfish; Rouge River (Wayne County): carp; Detroit River: carp; Kalamazoo River (downstream from city of Battle Creek to Morrow Pond Dam, Kalamazoo County): carp; Kalamazoo River (downstream from Morrow Pond Dam to Lake Michigan) and Portage Creek (downstream from Monarch Millpond Dam): carp, suckers, catfish, and largemouth bass; Torch Lake (Houghton County): walleye and sauger; Langford Lake (Gogebic County): walleye over 23"; Shiawassee River (Byron Road to Owosso): carp; Cass River (downstream from Bridgeport): catfish; Tittabawassee River (downstream from Midland): carp and catfish; Lake Macatawa (Ottawa County): carp; Hersey River (downstream from Reed City): bullheads and brown trout; St. Joseph River (downstream from Berrien Springs Dam): carp; Manistique River (downstream from M-94/Old US-2): carp; River Raisin (downstream from Winchester Bridge, Monroe): carp.
3. RESTRICT CONSUMPTION. Michigan recommends no more than one meal per week of the following fish: Lake Michigan* (Applies to Michigan, Indiana, Illinois and Wisconsin waters): lake trout 20-23", coho salmon over 26", chinook salmon 21-32", and brown trout up to 23"; Green Bay (Wisconsin waters south of Marinette/Menominee): splake up to 16"; Lake Superior: lake trout up to 30"; Lake Huron*: rainbow trout, lake trout and brown trout; Lake St. Clair (Applies to Michigan and Ontario waters): walleye over 18", white bass over 14", smallmouth bass over 14"; yellow perch over 12", carp over 22", rockbass over 8", black crappie over 10", largemouth bass 12-14", bluegill and pumpkinseed over 8", freshwater drum over 12", carpsucker over 18", brown bullhead over 10", catfish over 22", and northern pike; Saginaw Bay*: rainbow trout, lake trout, and brown trout; Kalamazoo River (downstream from Morrow Pond Dam to Lake Michigan) and Portage Creek (downstream from Monarch Millpond Dam): all species except those listed in category 2 above for these same waters; Chicagon Lake (Iron County): walleye over 18"; Lake Michigamme, Michigamme Reservoir, Peavy Pond, Paint River Pond, and the Michigamme River system to its junction with the Menominee River: rock bass over 9", northern pike, walleye, smallmouth bass and muskie; Langford Lake (Gogebic County): walleye 15-23", northern pike over 22"; Duck Lake (Gogebic County): walleye over 16"; Caribou Lake (Chippewa County): walleye over 18" and rock bass over 10"; Cass River (downstream from Bridgeport): carp; Grand River (Clinton County): carp; White Lake (Muskegon County): carp;

*Advisory also applies to listed species migrating into streams tributary to these waters.

NOTE: NURSING MOTHERS, PREGNANT WOMEN, WOMEN WHO ANTICIPATE BEARING CHILDREN, FEMALE CHILDREN OF ANY AGE, AND MALE CHILDREN AGE 15 OR UNDER SHOULD NOT EAT THE FISH LISTED IN ANY OF THE CATEGORIES LISTED ABOVE.

For further information, call the Center for Environmental Health Sciences at 1-800-648-6942.

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4.1.8 Risks to Human Health

Of all forms of mercury, the alkyl mercury compounds present the most serious risks to human health. Microbial transformations of inorganic mercury result in the formation of mono- and dimethyl mercury. These transformations can occur in sewers, WWTPs, sediments, water and within animals digestive systems. These compounds (the methyl form in particular) have been found to rapidly accumulate in tissues. The dimethyl form is very volatile and is readily released to the atmosphere as a gas. Elemental mercury is also volatile.

A number of surveys have been conducted on levels of mercury in fish of the United States. The results of these surveys indicate an average concentration of 200 nanograms (0.200 mg/kg or ppm) in fish muscle (USEPA 1980). Average levels of mercury in fish at Deer Lake in 1981 were 1.38 mg/kg (1.38 ppm) wet weight (MDNR file).

The primary concern associated with consumption of contaminated fish from Deer Lake by humans is the risk of chronic toxicity (i.e., the effects of long-term, low-level exposure). Central nervous system dysfunction is the primary health effect associated with chronic exposure to alkyl mercury compounds. The group at highest risk would be pregnant women consuming contaminated fish flesh on a regular basis. The manifestations of mercury toxicity include mental disturbance; ataxia; impairment of gait, speech, and mastication; increased tendon reflex; and involuntary movement (Casarett and Doull 1975). Chronic exposure has also been found to cause renal toxicity and (in experimental situations) chromosome breakage and mutation.

No studies have been conducted characterizing/quantifying exposure of humans to contaminated fish from Deer Lake. Recognizing the potential risks to human health, the MDPH issued a fishing advisory.

4.2 MAJOR POLLUTANTS OF CONCERN

4.2.1 Water Quality Contamination

4.2.1.1 Nutrients and General Water Quality Parameters

Data from four studies provide information on water quality in Deer Lake and its major tributaries. The earliest study was conducted by the U.S. Environmental Protection Agency (EPA) in 1972, and contains nutrient data from major tributaries to Deer Lake and Deer Lake. The 1972 sampling of Deer Lake was conducted once in the fall and once in early summer. Tributaries, including Carp Creek and Goldmine Creek, were sampled approximately once a month. In 1974-1975, Bills sampled water quality parameters and nutrients in Deer Lake. This study presents the most comprehensive picture of Deer Lake water quality. Sampling was conducted regularly for one year. Ecological Research Services, Inc. sampled Deer Lake and the Ropes' Goldmine area in the summer of 1981. In 1985 MDNR sampled water quality on Carp Creek, Goldmine Creek, and the Carp River periodically throughout the year. Deer Lake was not sampled during the 1985 MDNR survey since the impoundment was drawn down.

Physical and Chemical Water Quality Characteristics

Physical and chemical water quality sampling of Deer Lake will be discussed in order to characterize lake processes which are relevant to the use impairment. This section is not intended to present a comprehensive synthesis of all such data collected from Deer Lake. Only the parameters that reflect the impairment or most directly influence processes relevant to the impairment or remedial actions will be discussed.

Temperature

Seasonal changes in temperature are important in the regulation of physiochemical cycling and consequently of lake metabolism and productivity (Bills 1977). Lake productivity influences the rate at which mercury is transformed to methylmercury or bound in lake sediments. The most complete survey of the Deer Lake thermal regime was conducted by Bills (1977).

Temperature was measured at 1.0 meter depth intervals from surface to near bottom periodically from July 1974 to June 1975. Temperature profiles obtained for the south basin of Deer Lake are shown in Figure 4-2. The profiles reflect various stages of stratification and resultant circulation patterns from July 1974 through May 1975. In July 1974, the south basin was stratified into an epilimnion (0-5 meters), metalimnion (5-9 meters), and a hypolimnion (9-10.5 meters). Profiles from September and October 1974 indicate that circulation was typical of a holomictic lake in autumn. The lake became covered with ice in December and the profile from February 1975 reflects conditions during draw down. The profile for May 1975 indicated that the lake was beginning to stratify once again following spring storage of runoff (Bills 1977).

Dissolved Oxygen

Thermal stratification influences the vertical dissolved oxygen (D.O.) gradient. Availability of D.O. influences mercury transformations directly and indirectly by regulating bacterial activity.

Figure 4-3 shows dissolved oxygen profiles from the south basin of Deer Lake taken on the same days as the temperature profiles of Figure 4-2. During July 1974, the metalimnion and hypolimnion of the south basin were anoxic. This was attributed to stagnation followed by utilization of dissolved oxygen by microbial metabolic processes. The lake was isothermal and well mixed with adequate oxygen throughout the fall. Ice cover was established by December and stopped the effects of wind, leading to winter stagnation and reduction in solar radiation to the water. The combination of reduced biological oxygen production relative to oxygen-consumptive metabolic processes, led to anoxia below 5 meters by February 1975. Following ice melt had run-off in the spring, mixing by wind led to reoxygenation of the water column (Bills 1977). The lake continued to experience hypolimnetic oxygen depletion throughout most of the summer and winter even in the lake that remained after drawn down (pers. comm. Elwin Evans, Jerry Peterson, MDNR, 1987).

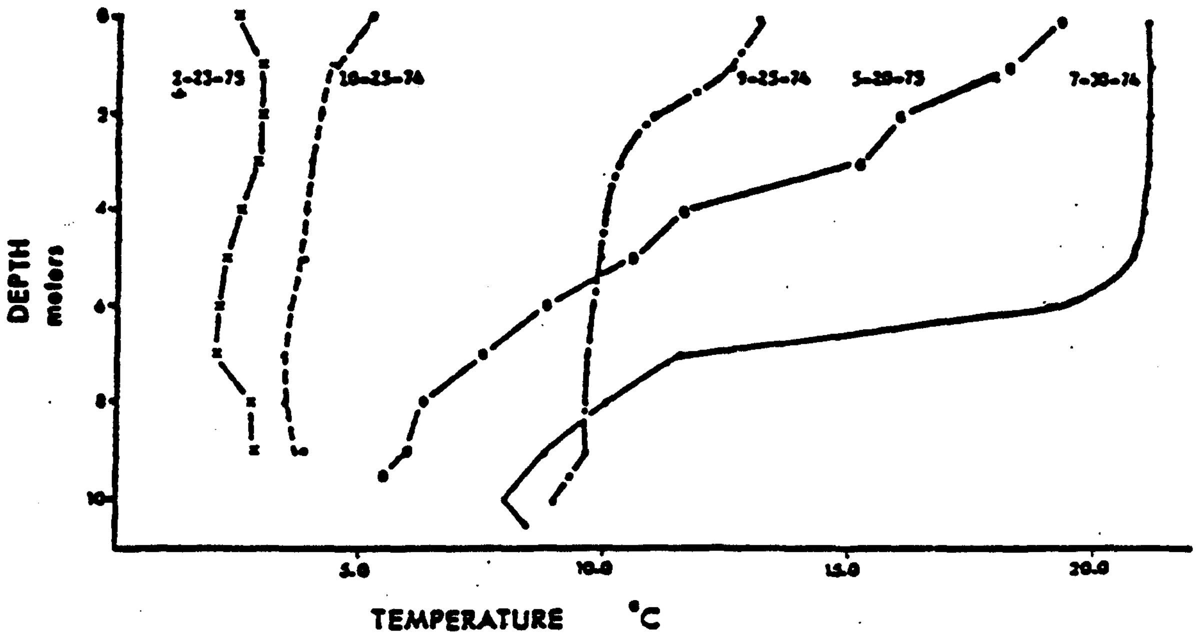

FIGURE 4-2. Thermal profiles of South Basin of Deer Lake on on selected dates.
(Source: Bills 1977)

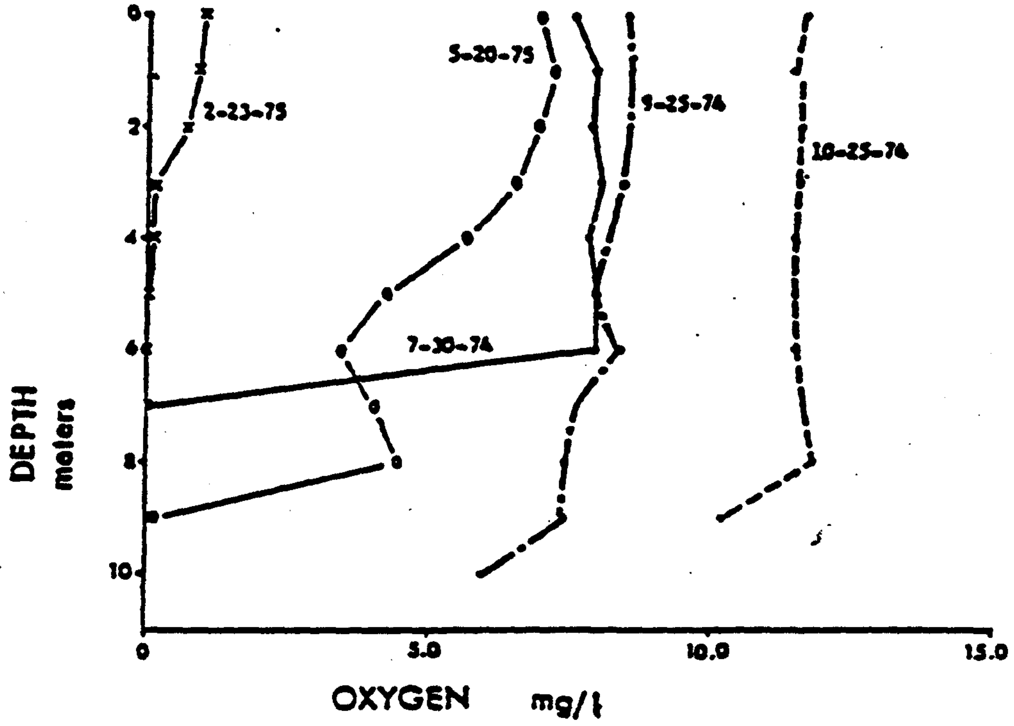

FIGURE 4-3. Dissolved oxygen profiles of South Basin of Deer Lake on selected dates

(Source: Bills 1977)

Ludwig (1981) noted the occurrence of hypolimnetic oxygen depletion while sampling Deer Lake in the summer of 1981. Table 4-1 summarizes physical and chemical data collected from tributaries and Deer Lake during this survey. Ropes' Creek experienced the lowest D.O. levels, particularly in the vicinity of the wetland (average concentration at this station was 6.1 mg/l or ppm). Gold Mine Creek had the highest mean D.O. concentration of all tributaries (9.6 mg/l or ppm). Average D.O. in Carp Creek near the mouth was 7.5 mg/l or ppm.

pH

The levels of pH in Deer Lake are typical of bicarbonate type waters (Bills 1977). In the southern basin of Deer Lake, Bills (1977) reported values in the epilimnion ranging from 6.5 to 9.2 and in the hypolimnion ranging from 6.4 to 8.4. Ludwig (1981) reported a range of 7.99 to 9.34 in surface waters of Deer Lake. High pH was measured in conjunction with algal blooms and supersaturated levels of dissolved oxygen. Rapid photosynthesis results in liberation of hydroxyl ions and oxygen in bicarbonate-carbonate systems (Ludwig 1981).

The pH reported for Ropes' Creek (Table 4-1) was the lowest of all tributaries sampled in 1981 (6.27-7.46). The pH range in Carp Creek near the mouth, was 7.08-8.14 and in Gold Mine Creek it was 7.67-8.44.

In the 1985 MDNR survey of Deer Lake tributaries, pH showed little variation from one sampling site to the next. Sampling sites are shown in Figure 4-4. The two furthest upstream stations on Carp Creek had a pH range of 7.6-8.1. The third station at the mouth of Carp Creek, had a pH range of 7.5-8.0. The pH range at the Gold Mine Creek station was 7.5-8.3 and at the Carp River station it was 7.4 to 8.2. These ranges are comparable to those reported in Ludwig (1981).

Conductivity

Generally lakes and streams on Precambrian rocks in the Lake Superior watershed have low conductivities ranging from 35 to 140 umhos/cm (Ludwig 1981). Studies of Deer Lake and its tributaries show conductivities which are considerably higher. Bills (1977) reported conductivity in Deer Lake ranging from 280-460 umhos/cm. Ludwig (1981) noted that conductivities in tributaries to Deer Lake were apparently high. Average conductivity in Gold Mine Creek was 290 umhos/cm and in the headwaters of Carp Creek it was 255 umhos/cm. Additional data on conductivities in tributaries from Ludwig (1981) as shown in Table 4-1. Reasons for the high conductivities could be significant input of groundwater through glacial sediments, cultural alterations or inputs of water having had lengthy contact with reactive bedrock (Ludwig 1981).

Average conductivity in Carp Creek in 1985 (from the MDNR survey) increased from 163 umhos/cm at the headwaters to 241 umhos/cm at the mouth. The increase with distance downstream would more likely be due to cultural factors rather than groundwater inputs, which are usually greatest in the headwaters. Average conductivity at the Gold Mine Creek station was 216 umhos/cm and it was 221 umhos/cm at the Carp River Station.

Table 4-1

SUMMARY OF GENERIC WATER QUALITY STUDY

Station	# Observations	Temp. °C. (Range)	Conductivity µohms/cm (Range)	pHs.u. (Range)	Dissolved Oxygen ppm/% Saturation (Range)	Total Soluble Iron/mg/l (Range)
		Mean Values ±S.D. and Range of Values for Parameters:				
Headwaters of Carp Creek	14	17.7±2.5 (14-24)	290±21 (250-325)	7.74±0.21 (7.15-8.01)	8.5±0.66 (6.6-9.3) 89±7 % (70-96 %)	0.17±0.10 (<0.1-0.3)
Carp Creek at M28-41 Crossing in Ishpeming	15	14.6±3.0 (9-19)	225±32 (170-300)	7.59±0.33 (7.07-8.14)	8.8±11 (6.2-10.1) 87±11 % (67-103 %)	0.18±0.15 (<0.1-0.6)
Carp Creek at Discharge to Deer Lake	15	14.6±2.9 (10-20)	262±26 (205-300)	7.34±0.28 (7.08-8.14)	7.5±0.9 (5.6-8.5) 74±9 % (60-83 %)	0.19±0.15 (<0.1-0.6)
Cold Mine Creek	15	13.9±2.9 (9-18)	255±48 (196-310)	7.86±0.18 (7.67-8.44)	9.6±0.6 (8.7-10.8) 94±6 % (81-99 %)	0.08±0.07 (<0.10-0.30)
Ropes Wetland	15	19.1±4 (13-28)	145±35 (95-210)	6.91±0.34 (6.27-7.46)	6.1±1.6 (3.8-8.5) 66±17 % (41-90 %)	0.69±0.87 (<0.1-3.0)
Seep from Western Tailings Pile	13	18.2±3.4 (14-27)	479±190 (190-800)	7.3±0.3 (6.82-7.77)	6.2±2.6 (1.5-8.6) 66±28 % (16-90 %)	2.05±3.58 (0.1->10.0)
Ropes Creek just Above the Causeway Pond	15	16.7±2.5 (12-22)	241±55 (180-365)	7.43±0.28 (6.96-8.22)	7.4±0.9 (5.5-8.6) 76±10 % (63-84 %)	0.13±0.09 (0-0.3)

(Source: Ludwig 1981)

TABLE 4-1 (Continued):

Station	# Observations	Mean Values ±S.D. and Range of Values for Parameters: Temp. °C. (Range)	Conductivity µohms/cm (Range)	pH s.u. (Range)	Dissolved Oxygen ppm/% Saturation (Range)	Total Soluble Iron/mg/l (Range)
Deer Lake East of Causeway Pond	15	19.3±3.3 (12-23)	207±5 (200-215)	8.69±0.43 (7.99-9.34)	9.8±1.3 (8.3-13.0) 107±14 % (87-149 %)	0.05±0.04 (0-0.1)

(Source: Ludwig 1981)

Nutrients

Nutrient surveys of Deer Lake noted that the lake trophic condition was due to high nutrient loadings via Carp Creek. These excess nutrients elevated primary productivity, causing super saturation of oxygen in the upper waters during the day in summer. Inputs of BOD and in-lake organic matter, which are eventually deposited to the sediments, caused rapid depletion of hypolimnetic oxygen. The major pollutants degrading water quality are phosphorus, nitrogen, and organic matter.

Information from four lake surveys are discussed below. The earliest survey was conducted by USEPA (1975) in 1972, as part of the National Eutrophication Survey. The second survey, and the most comprehensive, was conducted by Gerald Bills in 1974-1975 as part of a graduate research program. The third survey was conducted by Ecological Research Services, Inc. (ERS) in the summer of 1981 for an environmental assessment for the proposed reopening of Ropes' Goldmine. This survey focused on the area of the watershed where the old mine was located. The fourth survey was conducted by MDNR to develop a phosphorus budget for Deer Lake prior to the upgrading of the Ishpeming WWTP. For this survey, only the major tributaries were sampled since the lake was drawn down (Figure 4-4).

National Eutrophication Survey - 1972

In 1972, Deer Lake and its major tributaries were sampled as part of the National Eutrophication Survey conducted by the USEPA. Nutrients sampled were total phosphorus (P), dissolved P, nitrate + nitrite, and ammonia. Sample locations are illustrated in Figure 4-5. Samples were collected from the surface and near the bottom of Deer Lake once in June and once in September 1972. In addition to chemical parameters, analyses of phytoplankton and chlorophyll-a were also conducted. For each of these parameters, a single depth-integrated sample was used for analysis.

Table 4-2 presents summary statistics of selected material concentrations in Deer Lake. In the fall the lake was well mixed, but in summer stratification was evident. Differences between surface and bottom concentrations were most pronounced for temperature, dissolved oxygen and forms of phosphorous and ammonia. The conclusion of the study was that Deer Lake was eutrophic.

Bills' Survey - 1974 to 1975

Nutrients sampled by Bills (1977) were total P, total orthophosphate, total acid-hydrolyzable phosphate, total organic phosphate, and total nitrate-nitrogen. Phytoplankton and zooplankton densities were also determined for the lake. Sampling focused on the south basin which received the waste loads from Carp Creek and would not characterize the discharge from the impoundment.

The results of this survey indicate that Deer Lake was hypereutrophic, with total phosphorus concentrations ranging from 0.18 - 1.66 mg P/l. The range of total phosphorus reported in the USEPA 1972 survey was lower (0.067-0.359 mg P/l). Oxygen depletion occurred in bottom waters during

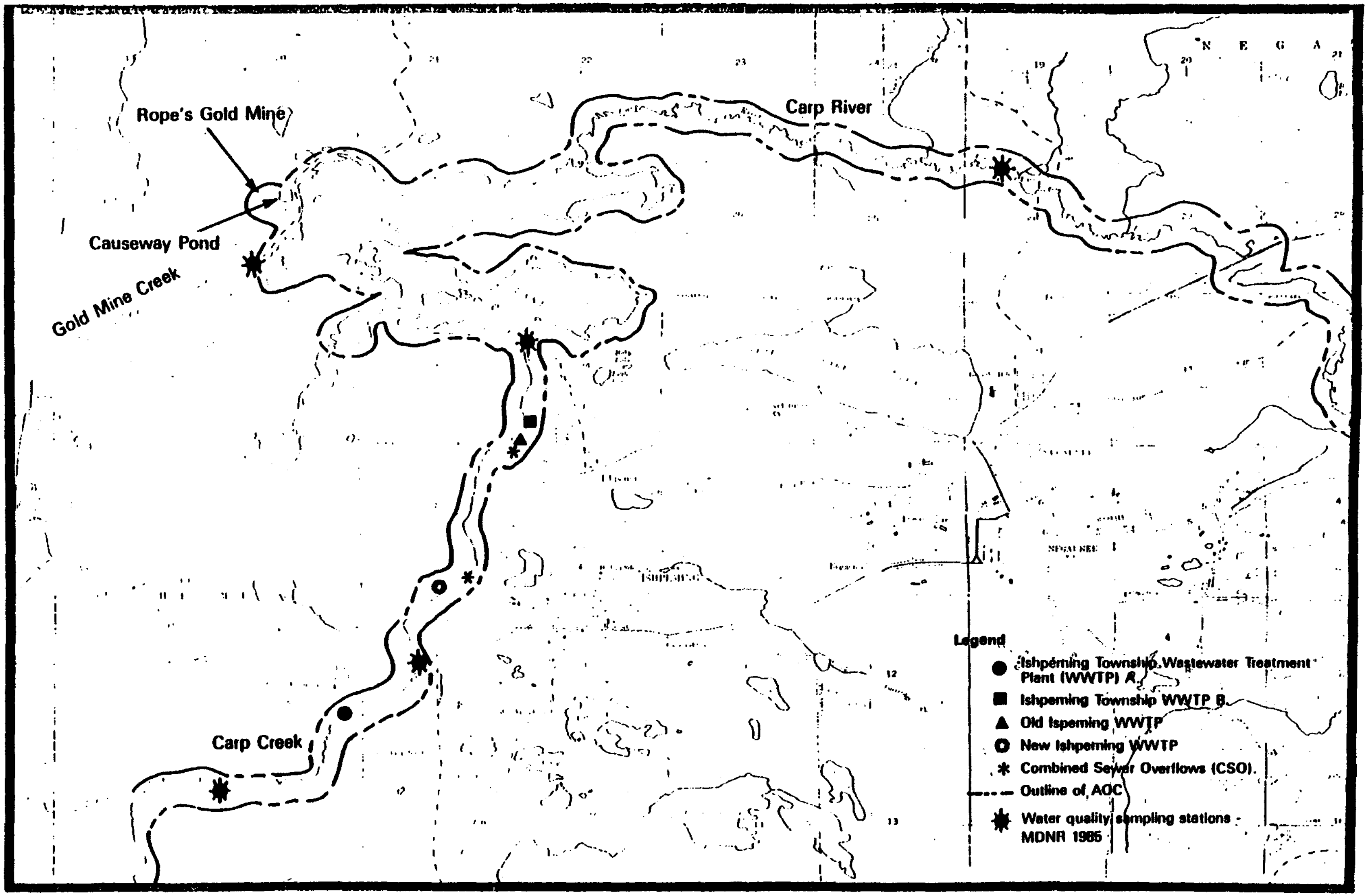

Figure 4-4.

Stations sampled for water quality by MDNR in 1985.

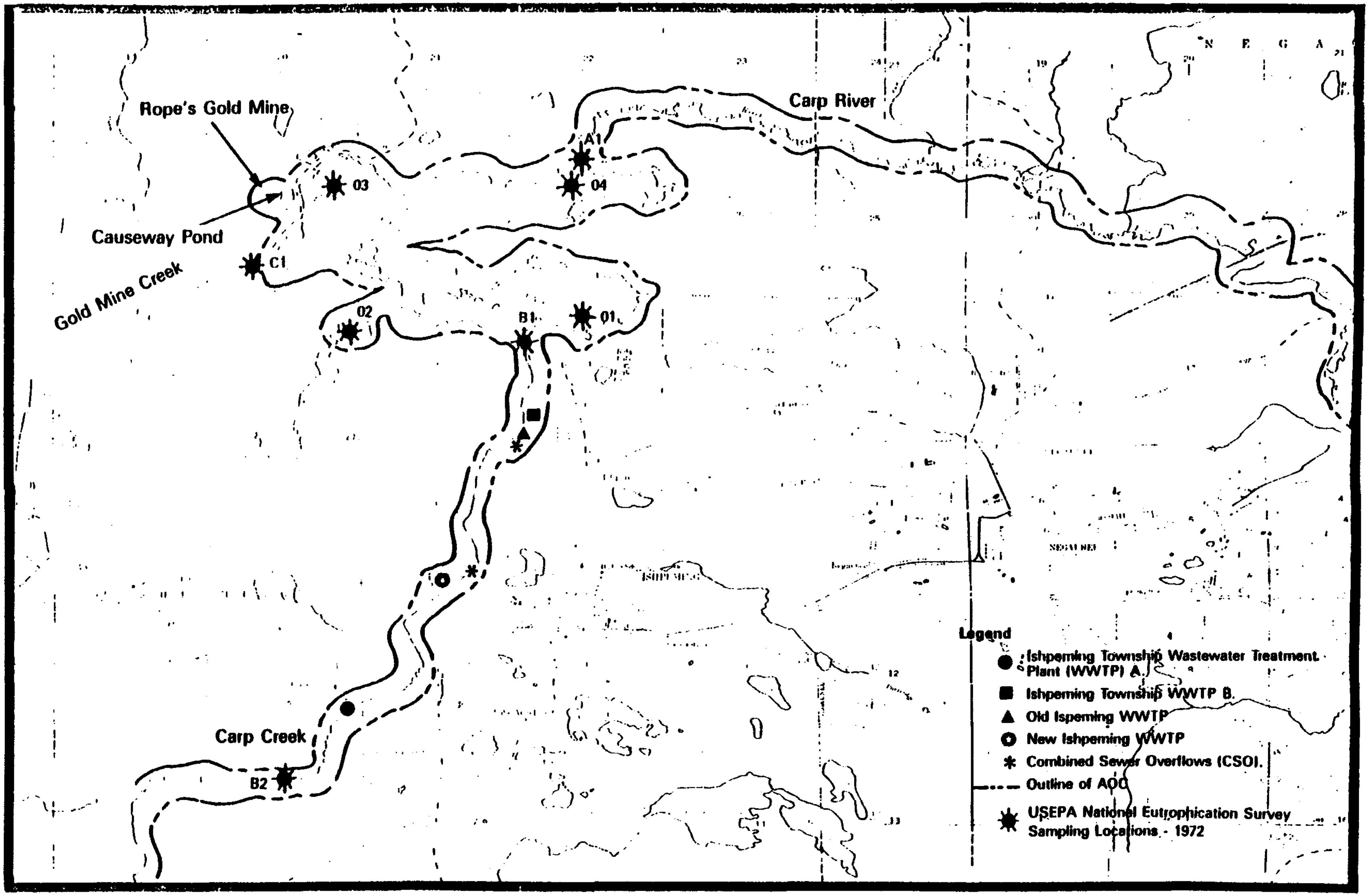

Figure 4-5.

Stations sampled for water quality by USEPA for the National Eutrophication Survey in 1972.

TABLE 4-2. RESULTS OF DEER LAKE WATER CHEMISTRY ANALYSES CONDUCTED AS PART OF THE NATIONAL EUTROPHICATION SURVEY - 1972

Parameter	June Values: Surface Range	June Values: Bottom Range	June Values: Mean
Temperature (°C)	16.0-16.2	12.0-15.8	15.27
Dissolved oxygen (mg/l)	11.6-12.0	5.4-10.9	10.19
Total phosphorus (mg/l)[1]	.067-.099	.099-.359	.139
Dissolved phosphorus (mg/l)[1]	.054-.076	.076-.288	.103
Nitrite + nitrate (mg/l)[2]	.04- .08	.04- .08	.056
Ammonia (mg/l)[2]	.06- .110	.090-.680	.196

Parameter	Fall Values: Range	Fall Values: Mean
Temperature (°C)	16.9-17.6	17.3
Dissolved oxygen (mg/l)	6.4- 9.4	8.0
Total phosphorus (mg/l)[1]	.231-.249	.255
Dissolved phosphorus (mg/l)[1]	.203-.243	.219
Nitrite + nitrate (mg/l)[2]	.03- .05	.038
Ammonia (mg/l)[2]	.06- .170	.082

[1] Measured as P

[2] Measured as N, fraction is total

periods of stagnation in summer and winter. Sources of nutrients to the lake identified in the study include effluent from wastewater treatment plants on Carp Creek and bottom sediments during periods of anxoia. Algae populations in summer were high, reflecting nutrient loadings (Bills 1977).

Figure 4-6 shows seasonal variations of the various forms of phosphorus sampled. Total phosphorus in the bottom waters ranged from 0.365 to 1.660 mg P/l, while the range in surface waters was 0.108 to 0.406 mg P/l. Bottom concentrations always exceeded surface concentrations. Bottom waters showed a phosphorus increase late in the stagnation periods. The increase in phosphorus during stagnation may be due to high biological production in the lake combined with organic pollution which contributes to anoxic conditions at the sediment surface. Anoxia reduces redox potential in the upper layer of sediment, which may result in a release of substantial quantities of phosphorus. Orthophosphate was the principal form found in the lake throughout the year, constituting from 46 to 82 percent of the total phosphorus. In most natural waters, orthophosphate constitutes about 10 percent of the total phosphorus. This indicates that phosphorus probably does not limit biotic production in the lake. This is in accordance with the USEPA (1975) evaluation that nitrogen was the limiting nutrient. Bills (1977) suggests that the major source of high phosphorus concentrations was effluent from sewage treatment plants on Carp Creek.

Seasonal nitrate levels are shown in Figure 4-7. Nitrate levels were lowest during late summer stagnation in 1974, when the concentration was about 0.5 mg NO_3-N/l through the water column. During autumnal circulation, nitrate in the hypolimnion rose to about 15 mg NO_3-N/l and to about 2 mg NO_3-N/l in the epilimnion. The concentration in the hypolimnion dropped in winter to about 2 mg $NO-_3$-N/l. Throughout winter, concentrations in the epilimnion and hypolimnion were close, and both increased from November to February. Concentrations peaked early in summer, before summer stagnation. Concentrations were lowest during summer stagnation due to denitrification and biotic uptake. With the onset of autumnal circulation, water in the hypolimnion became oxygenated allowing nitrification to occur. This, combined with mixing, increased nitrate levels in the epilimnion as well. Higher concentraitons of nitrate found in the lake during winter stagnation may be due to sewage treatment plant inputs and reduced biotic assimilation. Further increases in nitrate during vernal circulation may be attributed to nitrification of reduced nitrogenous compounds that accumulated during winter stagnation (Bills 1977).

A comparison of average total epilimnetic phosphorus and nitrate in Deer Lake with Vollenweider's classification of lake trophic levels (1968) is provided in Table 4-3. Based on this scale, Deer Lake may be classified as hypereutrophic (Bills 1977).

<u>Ecological Research Services, Inc. - Summer 1981</u>

In 1981, Ecological Research Services, Inc., conducted an environmental assessment of Ropes' Goldmine in which various forms of nitrogen and phosphorous were sampled.

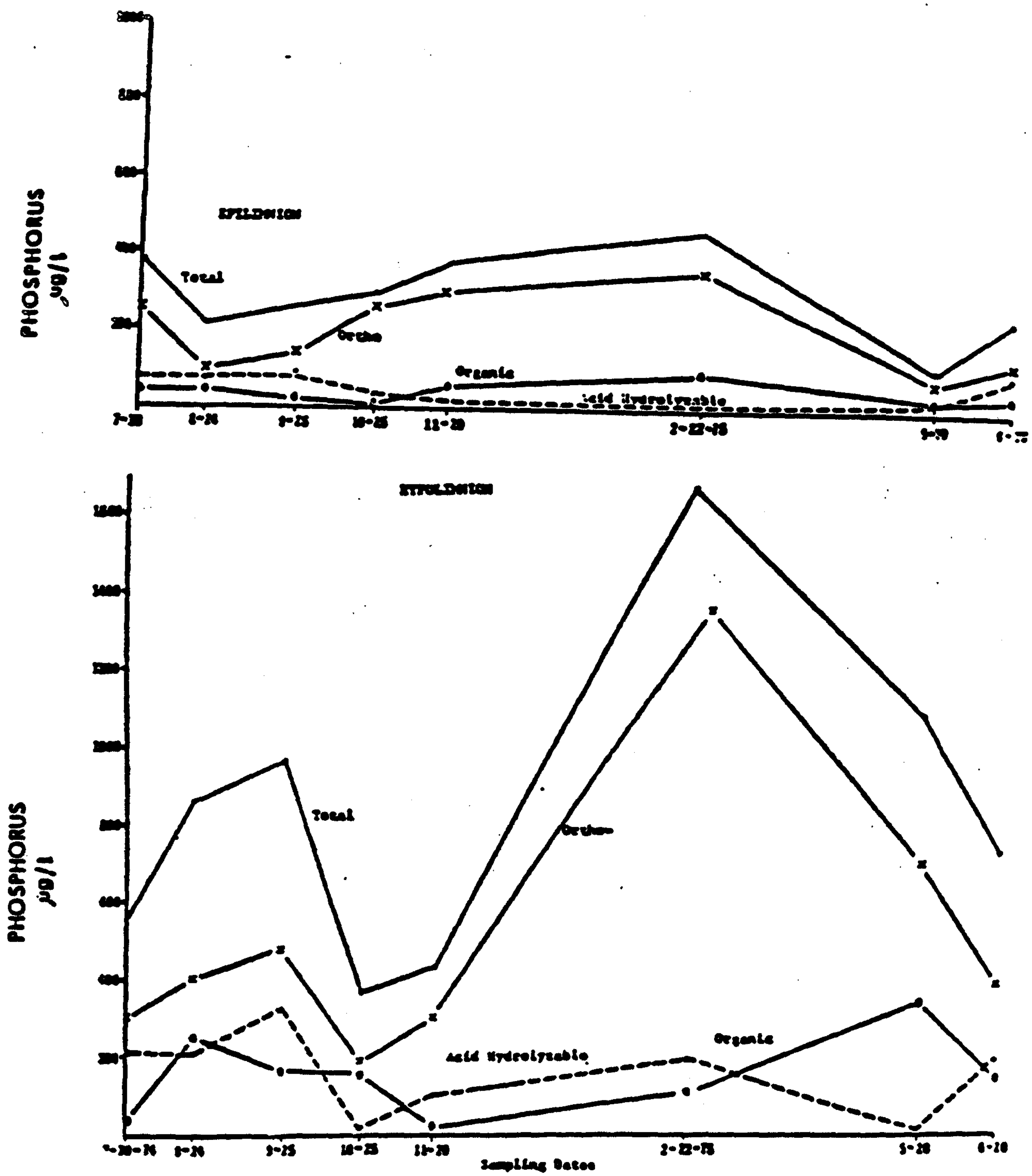

FIGURE 4-6. Forms of phosphorus in Deer Lake

(Source: Bills 1977)

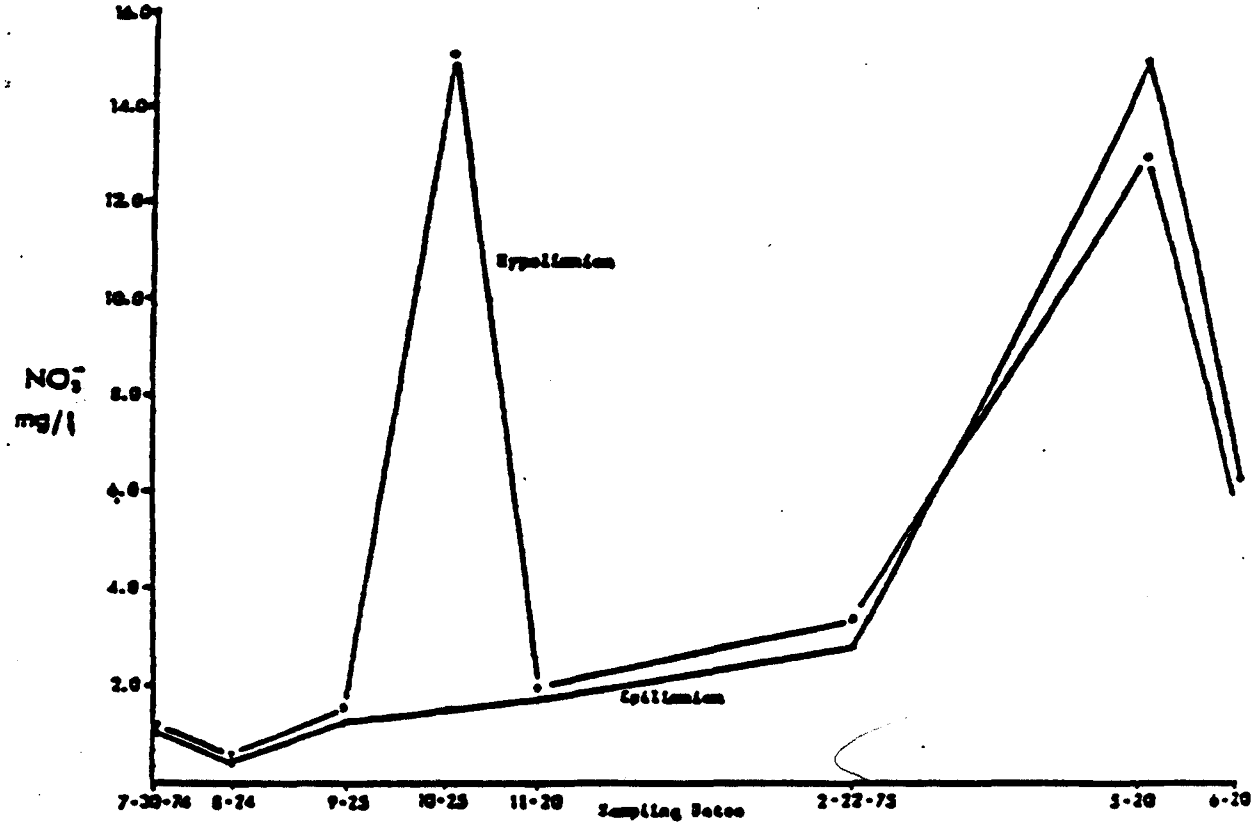

FIGURE 4-7. Nitrate-Nitrogen concentrations in Deer Lake (Source: Bills 1977)

Tables 4-4 and 4-5 show results of sampling for nitrogen and phosphorus in Deer Lake tributaries and Deer Lake, respectively. Concentrations of all forms of phosphorus and nitrogen were highest in Carp Creek just above Deer Lake. Carp Creek was the major source of nutrients to the lake.

In Deer Lake, concentrations of TKN, ammonia, and organic nitrogen were clearly highest in the Causeway (Ropes') Pond which is largely unaffected by the WWTP discharges. Nitrate and ammonia were below detection limits for most of the other sampling locations. This may be a result of biotic uptake. There is some evidence of ammonia generation from bottom sediments in the south basin. Both organic nitrogen and total phosphorus were usually higher in concentration in the bottom layers of Deer Lake than the surface layers. This may be due to sinking organic matter (plant detritus, algal cells) from the surface. Concentrations of total phosphorus may also be augmented by releases of inorganic forms from the sediments.

MDNR - 1985

In 1985, Michigan DNR sampled total phosphorus as well as 11 other parameters, 12 times at Goldmine Creek, Carp Creek, and the Carp River. Sampling stations are shown in Figure 4-4. The results indicated that concentrations of phosphorus in Carp Creek sharply increase near Deer Lake. Concentrations in the Carp River below Deer Lake were lower than those in Carp Creek just above Deer Lake, even though the lake was drawn down. Concentrations in Gold Mine Creek were comparable to those in Carp Creek upstream of the WWTPs.

Comparison of Nutrients in Tributaries - 1972 and 1985

Mean total phosphorus concentrations and their associated ranges from the 1985 study are compared with those from the 1972 study in Table 4-6. Concentrations showed little change between 1972 and 1985 in Goldmine Creek and the most upstream Carp Creek station. This indicates that little change has occurred in the drainage basins and that nonpoint source contributions have remained constant. Concentrations dropped considerably between 1972 and 1985 in the downstream Carp Creek stations and the Carp River stations.

Summary of Nutrient Data

All surveys indicate Carp Creek was the major source of nutrients to Deer Lake, although loadings of total phosphorus from the creek were much lower in 1985 than in 1972. It is difficult to determine if phosphorus levels in Deer Lake have decreased accordingly. Concentrations of total phosphorus were approximately equal in 1972 (USEPA 1975) and 1981 (Ludwig 1981), but only summertime concentrations could be compared. In the summer of 1974 Bills (1977) reported two total phosphorus concentrations of about 200 ug/l (July 1974) and 400 ug/l (August 1974) in the surface of the south basin. The values are 2 to 4 times higher than those reported by USEPA (67 - 99 ug/l) or Ludwig (86 ug/l). Because of limited sampling, trends cannot be established. The situation is similar for summer concentrations of nitrate in Deer Lake. Bills (1977) reported 1

TABLE 4-3. CLASSIFICATION OF DEER LAKE TROPHY ACCORDING TO AVERAGE EPILLMNETIC NUTRIENT CONCENTRATION

General Level of Lake Productivity	Total Phosphorus ug/l	Total Inorganic N mg/l
TROPHY CLASSIFICATION (Vollenweider, 1968)		
Ultra-oligotrophic	less than 5	less than 0.2
Oligo-mesotrophic	5 to 10	0.2 to 0.4
Meso-eutrophic	10 to 30	0.3 to 0.65
Eutrophic	30 to 100	0.5 to 1.5
Hypereutrophic	greater than 100	greater than 1.5
DEER LAKE (Bills, 1977)		
Average	278	2.6

TABLE 4-4 WATER QUALITY PARAMETER ANALYSIS OF TRIBUTARY WATERS TO DEER LAKE OF ROPES CREEK, GOLD MINE CREEK AND CARP RIVER.

Sampling Site	Date	Alkalinity (as $CaCo_3$) pH8.3	Alkalinity (as $CaCo_3$) pH4.5	Hardness (as $CaCo_3$)	TKN	NO_3-N	NO_3	NH_3	Org-N	Total Phosphorus
		Parameter (ppm)								
Wetlands, above beaver Dam	6/16/81	N/A	55	54	0.25	0.10	0.44	LMD	0.85	0.053
	7/22/81	19	90	91	1.2	LMD	LMD	LMD	1.2	0.053
Ropes Creek, below upper culvert	7/22/81	N/A	151	154	LMD	0.10	0.44	LMD	LMD	0.028
Ropes Creek, just above Deer Lake	6/16/81	N/A	79	80	0.60	LMD	LMD	LMD	0.60	LMD
	7/22/81	N/A	151	152	0.77	LMD	LMD	LMD	0.77	LMD
Ropes "Trickle"	7/22/81	N/A	201	169	0.85	0.11	0.50	LMD	0.85	0.045
Gold Mine Creek, just above Deer Lake	6/16/81	N/A	70	76	2.14	LMD	LMD	1.2	0.94	0.036
	7/22/81	N/A	178	172	0.43	0.47	2.1	LMD	0.43	LMD
Carp River, at entrance to Deer Lake	6/16/81	N/A	78	84	6.1	0.62	2.76	LMD	6.1	0.220
	7/22/81	N/A	134	133	1.7	0.18	0.79	LMD	1.7	0.337
Carp River, below U.S. 41 Bridge	6/16/81	N/A	66	76	0.94	LMD	LMD	LMD	0.94	0.136
	7/22/81	N/A	122	129	0.94	0.26	1.17	LMD	0.94	LMD
Carp River, 100m below Deer Lake	7/16/81	N/A	92	96	0.68	LMD	LMD	LMD	0.68	0.295

N/A=Not applicable; LMD=Less than minimum detectable.

(Source: Ludwig 1981)

TABLE 4-5 WATER QUALITY PARAMETERS ANALYSIS OF DEER LAKE.

Sampling Site	Date	Alkalinity (as $CaCO_3$)		pH s.u.	Hardness (as $CaCO_3$)	TKN	NO_3-N	NH_3	Org-N	Total Phosphorus
		pH8.3	pH4.5							
South Basin, Surface	7/16/81	6.4	111	9.10	95	1.1	LMD	LMD	1.1	0.086
South Basin, Bottom	7/16/81	N/A	102	7.20	102	2.05	LMD	1.2	0.85	0.545
Deer Lake, opp. Causeway Pond, Surface	6/16/81	N/A	79	7.60	86	0.68	0.226	LMD	0.68	0.045
	7/16/81	N/A	90	9.20	95	1.4	LMD	LMD	1.4	0.070
Deer Lake, opp. Causeway Pond, 4m deep	7/16/81	N/A	92	7.90	95	0.85	0.1	LMD	0.85	0.095
Causeway Pond, Surface	6/16/81	N/A	87	7.60	92	8.5	0.122	4.5	4.1	0.053
	7/16/81	19.0	90	9.65	91	11.7	LMD	2.7	9.0	0.036
North Basin, Surface	6/16/81	N/A	84	7.95	91	0.77	LMD	LMD	0.77	0.045
	7/16/81	10.0	88	9.20	93	1.3	LMD	LMD	1.3	0.082
North Basin, Bottom	6/16/81	N/A	91	7.30	95	0.43	LMD	LMD	0.43	0.103
	7/16/81	N/A	101	7.10	97	1.7	LMD	LMD	0.7	0.303

N/A-Not applicable; LMD-Less than minimum detectable.

(Source: Ludwig 1981)

TABLE 4-6. MEAN CONCENTRATIONS OF TOTAL PHOSPHORUS (MG/L) IN DEER LAKE TRIBUTARIES, 1972 VERSUS 1985

	1972 X-1 (range) n=12	1985 X-1 (range) n=12
Goldmine Creek	X- = 0.013 (0.006-0.025)	X- = 0.013 (0.005-0.027)
Carp Creek upstream	X- = 0.014 (0.006-0.020)	X- = 0.015 (0.008-0.041)
Carp Creek just above Deer Lake	X- = 0.329 (0.020-0.720)	X- = 0.215 (0.117-0.364)
Carp River	X- = 0.203 (0.050-0.430)	X- = 0.126 (0.062-0.240)

X- = statistical mean value

mg/l in July and 0.5 mg/l in August of nitrate-nitrogen in surface waters of the south basin. USEPA (1975) reported a range of 0.04 to 0.08 mg/l nitrate-nitrogen in surface waters throughout the lake in June. Ludwig (1981) reported values below the detection limit in summer 1981 in the south basin.

4.2.1.2 Heavy Metals

Data presented here on heavy metals in the Carp Creek-Deer Lake-Carp River system were obtained from the following sources: Ecological Research Services, Inc., conducted in 1981 (Ludwig 1981) and Cleveland Cliffs Iron Company conducted in 1983 (CCI 1983). The information is reviewed below in chronological order. In addition to discussing mercury, information on other metals will be reviewed. To date, use impairments have not been identified for other metals, but available data indicates elevated concentrations in water and sediments.

In 1981, Ecological Research Services, Inc. conducted an environmental assessment of the old Ropes' Goldmine due to interest in reopening the mine. Data in the report focuses on the Ropes' Creek area but contains data from other tributaries to Deer Lake and Deer Lake itself.

ERS Survey - Deer Lake Tributaries

The results of analyses for heavy metals in Ropes' Creek, Goldmine Creek, Carp Creek, and Carp River are shown in Table 4-7. Mercury was at or below the level of detection (5 ug/l or ppb before July 16, ug/l or 0.5 ppb after July 16) at all sites except the Ropes' wetland and the mouth of Carp Creek. Mercury in the wetland was below detection limits on two of three sampling dates, but on the remaining date the concentration was 1.6 ug/l or ppb. In Carp Creek, downstream of the WWTP's, concentrations were 10 ug/l in June, 16 ug/l in July, and 12 ug/l in August. At the Carp Creek station located near the U.S. 41 Bridge upstream of the WWTP's, all samples were below the detection limits. This indicated that a source of mercury existed on Carp Creek between the two stations.

The quantified samples collected at the mouth of Carp Creek contained concentrations of mercury that exceeded current Federal water quality criteria for protection of aquatic life (both acute 2.4 ug/l and chronic (0.012 ug/l). The quantified sample collected from the Ropes' wetlands exceeded the Federal water quality criteria for chronic exposure of aquatic organisms, but was lower than that for acute exposure. The detection limits for mercury were higher than acute and chronic aquatic criteria for samples collected before July 16 (detection limit of 5 ug/l). The detection limit for mercury after July 16 (0.5 ug/l) exceeded the guideline for acute exposure of aquatic organisms.

Concentrations of all metals except nickel, were generally higher in the Ropes' Goldmine area and mouth of Carp Creek than at any of the other stations (upstream Carp Creek, Carp River and Gold Mine Creek). However, suspended solids were not measured nor were samples filtered, therefore, metals concentrations as measured (except mercury) may be of little ecological significance. This is probably most important for samples in the Ropes' Goldmine area where small streams exist and sampling can disturb sediments.

TABLE 4-7. RESULTS OF HEAVY METAL ANALYSES ON WATERS OF TRIBUTARY SOURCES TO DEER LAKE INCLUDING ROPES CREEK, GOLD MINE CREEK, AND CARP RIVER.

Sampling Site	Date	Element as ppb or µg/l Hg	Pb	Cu	Ni	Zn	Cr	Cd
Wetlands above beaver dam	6/16/81	<5.0	1	6.0	17	22.0	0.17	0.4
	7/22/81	1.6	7	7.0	29	4.0	<1.0	0.5
	8/18/81	<0.5	15	23.0	32	12.0	1.0	1.3
Ropes Creek below upper culvert	7/22/81	<0.5	13	9.0	95	4.2	<1.0	0.2
Ropes Creek just above Causeway Pond	6/16/81	<5.0	2	2.7	35	18.0	0.47	0
	7/22/81	<0.5	13	3.0	91	7.8	<1.0	0.3
	8/18/81	<0.5	12	1.0	80	9.4	0.56	0.6
Ropes South Stream	7/22/81	<0.5		2.0	64	29.0	4.0	0.8
	8/18/81	<0.5	0.83	5.5	60	22.0	2.9	0.9
Gold Mine Creek just above Deer Lake	6/16/81	<5.0	1.0	3.9	25	14.0	0.69	0
	7/22/81	<0.5	3.3	8.0	150	5.0	<1.0	0.4
	8/18/81	<0.5	2.1	0.67	110	7.5		1.1
Carp River at entrance to Deer Lake	6/16/81	<10.0	3.0	5.7	44	19.0	0.57	0.2
	7/22/81	16.0	15.0	20.0	110	27.0	1.3	0.4
	8/18/81	12.0	1.1	20.0	120	22.0	1.3	1.1
Carp River below U.S.41 Bridge	6/16/81	<5.0	1.0	4.0	28	13.0	1.3	0.9
	7/22/81	<0.5	5.9	10.0	100	14.0	<1.0	0.8
	8/18/81	<0.5	0.63	5.9	110	9.4	0.7	0.2
Carp River, 100 meters below Deer Lake	7/16/81	<5.0	<5.0	8.6	17	15.0	2.2	0.6
Mean ±S.D. of all Deer Lake tributary stations Sample size=19	June-Aug. 1981	2.6 ± 4.3	5.5 ± 5.5	7.7 ± 6.5	69 ± 41	14.4 ± 7.6	1.1 ± 1.0	0.71 ± 0.67
Mean levels ±S.D. found in 16 streams on the N. Lake Superior shoreline (Wagner et al., 1972) Sample size=196	1971-72	n.d.	1.4 ± 0.5	1.8 ± 0.7	3.5 ± 0.7	3.4 ± 1.1	n.d.	0.23 ± 0.08

*Values reported as less than the limit of detection were assumed to be ½ the value of the limit of detection to be able to average and compare values.

(Source: Ludwig 1981)

ERS Survey - Deer Lake

Results of metals analyses for Deer Lake are shown in Table 4-8. Concentrations tended to be higher in the tributaries than in the lake. Similarly concentrations in surface waters of the Causeway Ropes' Pond were generally higher than those in the lake. Highway runoff as well as tailings and runoff from the Ropes' mine area influence water chemistry in this stagnant pond. Concentrations throughout the lake itself were highly variable.

Mercury concentrations were below detection limits (5 ppb through July 16, 1981, 0.5 ppb thereafter) for most samples.

CCI Survey - 1983

In 1983, Cleveland Cliffs Iron Company (CCI) conducted sampling of mercury in tributaries to Deer Lake (Figure 4-8). The data are shown in Table 4-9. Of 17 water samples analyzed, only 4 contained quantifiable concentrations of mercury. Those samples were collected from Carp Creek, near the U.S. 41 Bridge (0.24 ug/l or ppb), Deer Lake just inside the dam outfall (0.20 ug/l or ppb), Carp River just before Pickett Lake (0.16 ug/l or ppb), and Ropes' Goldmine discharge (0.13 ug/l or ppb). The sample collected downstream on Carp Creek, 50 feet from the entrance to Deer Lake, had an unquantifiable concentration of mercury (less than 0.10 ug/l). In contrast, the survey conducted in 1981 (Ludwig 1981) found higher concentrations in Carp Creek just above Deer Lake (16.0 and 12.0 ug/l) than at a similar upstream station near the U.S. 41 Bridge. The quantified concentrations of mercury from 1983 were much lower than those from 1981.

Summary of Metals in Water

Data on heavy metals in surface waters of the Deer Lake watershed are sparse. Of the surveys discussed above, the sampling conducted by ERS in the summer of 1981 provided the most comprehensive view. However, it should be noted that circumstances have changed in the Deer Lake system since that survey, most notably lake drawdown and stabilization (1985-1986), improved wastewater treatment, and discontinuance of mercury discharges through the sewer system by CCI (1981). These data no longer present an accurate picture of heavy metals concentrations in Deer Lake. Quantified mercury concentrations in Deer Lake tributaries exceeded Federal Water Quality Criteria for protection of aquatic organisms (chronic exposure) in 1981 and 1983. The majority of samples had unquantifiable concentrations of mercury. Two samples, both collected at the mouth of Carp Creek by ERS in 1981, exceeded Federal criteria for freshwater aquatic organisms for acute exposure. Quantified concentrations were higher in 1981 than in 1983. Data was insufficient to compare other metals with Federal criteria.

Of the areas sampled, Carp Creek appeared to be the major source of most metals to Deer Lake. Potential sources of mercury, lead, copper, and zinc may exist on Carp Creek. Flows in Ropes' Creek, however, are very low and discharges to a pond which is largely isolated from Deer Lake by a road (pers. comm., Elwin Evans, MDNR, August 1987). Actual loadings of metals from Ropes' Creek to the lake are insignificant. Except for mercury, other heavy metals were not at concentrations of concern.

TABLE 4-8 RESULTS OF HEAVY METAL ANALYSIS OF DEER LAKE WATERS.

Sampling Site	Date	Hg	Pb	Element (ppb) Cu	Ni	Zn	Cr	Cd
South Basin, Surface	7/16/81	<5.0	<5.0	13	22	12	0.61	0.64
South Basin, Bottom	7/16/81		<5.0	0.43	19	6.8	0.78	0.16
Opposite Cause-way Surface	6/16/81	<5.0	2.0	2.4	33	13.0	0.70	0.09
	7/16/81		<5.0	2.9	9.6	2.5	0.78	0.58
Causeway Pond, Surface	6/16/81	<5.0	1.0	1.2	35	13.0	0.90	0.06
	7/22/81	<0.5	2.0	20.0	31	18.0	<1.0	0.2
	8/18/81	<0.5		4.4	42	11.0	1.0	0.84
North Basin, Surface	6/16/81	<10.0	1.0	2.7	37	14.0	1.1	0.0
	7/16/81		<5.0	10.0	22	16.0	2.2	0.35
North Basin, Bottom	6/16/81	<5.0	4.0	2.4	42	27.0	0.99	0.5
	7/16/81		<5.0	2.9	16	6.2	0.61	20.0

(Source: Ludwig 1981)

Figure 4-8. Cleveland Cliff's Mercury Sampling Locations in the Vicinity of Deer Lake, Marquette County, Michigan 1982.

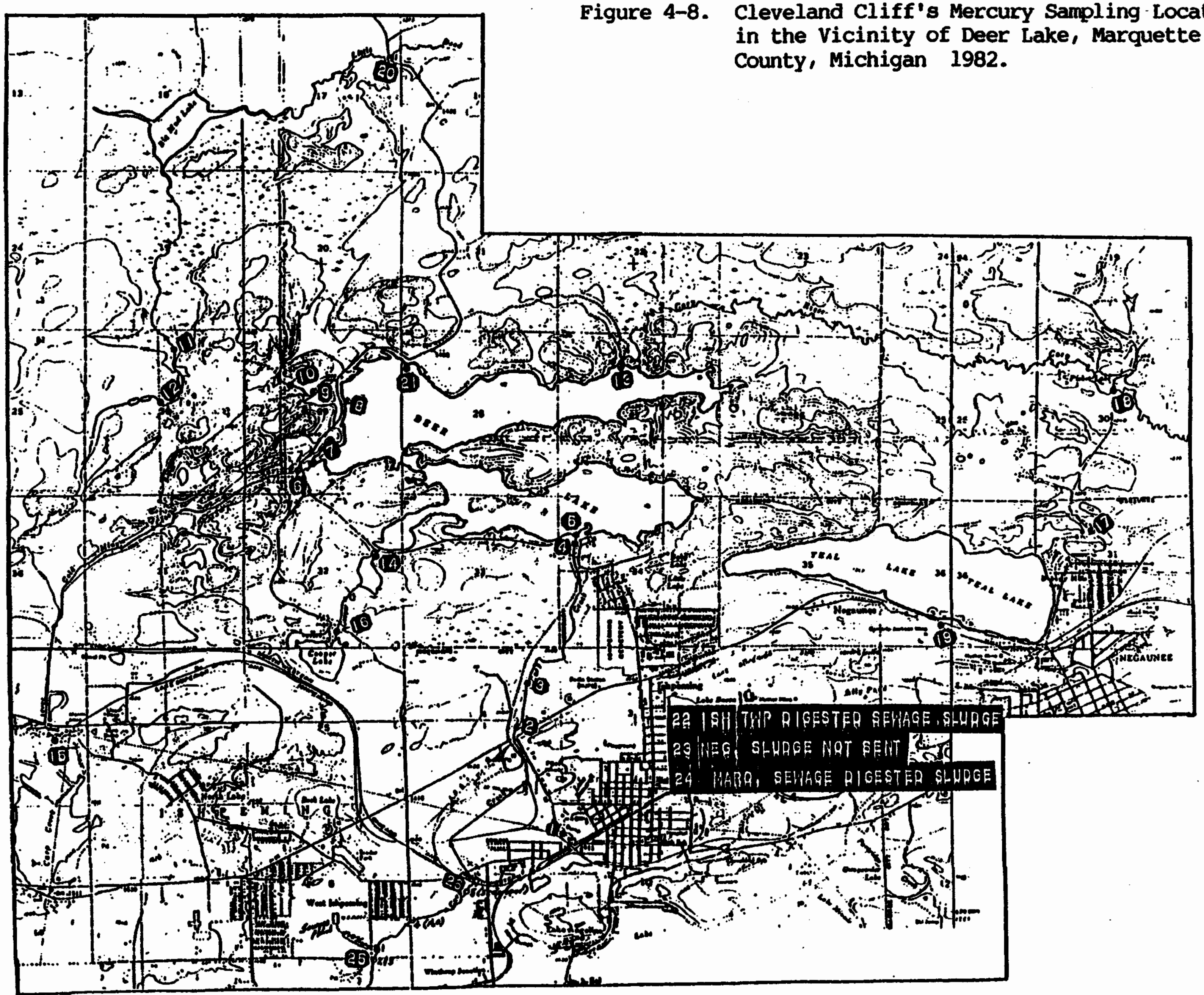

Table 4-9. Cleveland Cliff's Mercury Data for Sediments, Soils, Water and Sludge in the Vicinity of Deer Lake, Marquette County, Michigan 1982.

SAMPLE NO.		CCI WATER ppb	MTU WATER ppb	BONDAR-CLEGG, INC. SEDIMENT ppb +10M	BONDAR-CLEGG, INC. SEDIMENT ppb -10+65	BONDAR-CLEGG, INC. SEDIMENT ppb -65M	BONDAR-CLEGG ppb
1	Carp creek near Cliffs Shaft on Euclid Street	0	—	190	460	875	
2	Carp creek at U.S. 41 from Euclid St.-North side about 100'	0	0.24	1155	320	965	
3	Carp creek at U.S. 41 from Euclid St.-North side about 1000'	0	<0.10	635	2260	930	
4	Carp creek at Deer Lake - about 50' in from mouth	0	<0.10	810	2315	3385	
5	Carp creek at Deer Lake mouth	0	<0.10	185	635	1225	
6	Gold Mine creek North of Ishpeming-West side near culvert	0	<0.10	115	25	20	
7	Gold Mine creek North of Ishpeming-East side near mouth to Deer Lake	0	—	25	20	20	
8	Deer Lake at edge of causeway rock	0	<0.10	<5	30	20	
9	Ropes Gold Mine discharge	0	0.13	3870	3160	1500	
10	Ropes drain-off above No. 9 sample dump area	0	<0.10	45	385	705	
11	Headwaters of south inlet to Big Mud Lake	0	<0.10	25	25	5	
12	Bjork-Lundin outlet	0	<0.10	<5	15	10	
13	Deer Lake outfall at Carp River dam (taken inside dam)	0	0.20	5	55	20	
14	Cooper Lake outlet ahead of Deer Lake	0	—	<5	<5	15	
15	Gold Mine creek discharge channel above North Lake location	0	—	<5	<5	20	
16	Cooper Lake outlet at Cooper Lake road	0	—	20	<5	<5	
17	Teal Lake outlet north of Negaunee	0	—	—	115	585	
18	Carp river north of Negaunee just before Pickett Lake	0	0.16	—	—	—	
19	Slough on south side of U.S.41 opposite Teal Lake near Mather "B"	0	<0.10	<5	<5	<5	
20	Little Dead river before north camp road (Big Mud Lake outlet)	0	—	40	70	40	
21	Deer Lake boat launching site	0	<0.10	5	<5	<5	
22	Ishpeming Twp. digested sewage sludge	—	—	2055	2435	3695	
23	Negaunee city digested sewage sludge	—	<0.10	-	-	3480	
24	Marquette city digested sewage sludge	0	<0.10	3610	3265	945	
25	Carp creek sediment above township sewage effluent (Ish.)	—	<0.10	5	5	20	
26	Carp creek sediment below township sewage effluent (Ish.)	—	—	<5	5	5	
27	Deer Lake #1 - DNR sample of top core - ROPES TAILINGS						2250
28	Deer Lake #1 - DNR sample of bottom core - " "						3300
29	Deer Lake #2 - DNR sample of core - " "						1400
30	Deer Lake #3 - DNR sample of core - " "						2675
31	Ropes Gold Mine Tailings Dump - DNR sample of core - Sample #4						1650
32	Ropes Gold Mine Tailings Dump - DNR sample of core - Sample #5						2050
33	Gold Mine Lake - DNR sediment sample						355
34	Teal Lake East End - DNR sediment sample						110
35	Teal Lake West End - DNR sediment sample						155

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(Source: D'Itri 1983)

Almost all the data presented above on heavy metals in water are not relevant to problems in this ecosystem.

4.2.2 Sediment Contamination

Information on mercury contamination of Deer Lake sediments was collected between 1981 and 1986. Table 4-10 lists and describes the specific sources of data available for this report.

Surficial Sediment Samples

Ecological Resources Inc. Survey - Summer 1981

Table 4-11 presents the results of sediment analyses for heavy metals conducted by Ecological Research Services, Inc. (Ludwig 1981). Sampling was conducted in the vicinity of the Ropes' Goldmine and in Deer Lake. Mercury concentrations ranged from 4.5 to 10.0 mg/kg dry weight. The highest concentration occurred in the south basin of Deer Lake near Carp Creek inlet; the lowest concentration occurred in an area near the Causeway Pond. The lead and copper values from Deer Lake are reportedly twice as high as levels of these metals in sediments from Big Bay, Marquette, and Presque Isle Harbors. Zinc levels in Deer Lake are 10 times as high as those in Big Bay and Presque Isle Harbors, and mercury levels from Deer Lake are 5 times as high as those in coastal water bodies. Cadmium levels are lower than those from the bay and harbor (Ludwig 1981).

Heavy metals concentrations in water (Table 4-8) collected by ERS indicated that potential sources of mercury, lead, copper, and zinc might have existed on Carp Creek. The sediment sample collected from the south basin show that mercury, lead, and zinc are present in concentrations greater than at any other sampling station. Chromium and cadmium in sediment were also highest at the south basin station.

MDNR Survey - October 1981

Table 4-12 gives the heavy metal concentrations in surficial sediments in the Deer Lake AOC collected by MDNR in 1981 and 1982. Locations of the sampling stations in Carp Creek, Deer Lake and upper Carp River are shown in Figures 4-9 and 4-10.

Mercury concentrations in Deer Lake ranged from 0.4 to 12.0 mg/kg dry weight, and were highest at the station closest to the Carp Creek inlet. Levels decreased from that point west to station 7, located near Goldmine Creek. Station 7 had the lowest concentration of mercury. Concentrations in the south basin of the lake were higher than those in the north basin. At Station 10 nearest the dam, sediment mercury was 3.6 mg/kg.

Mercury concentrations in Carp Creek sediment upstream of the Ishpeming WWTP measured 1.0 and 7.8 mg/kg dry weight at stations 1 and 2, respectively, as shown in Table 4-13. Both stations were located downstream of CSOs (pers. comm., Elwin Evans, MDNR, July 1987). Since separation of the sewer system was complete in spring 1986, these CSOs convey only storm water runoff.

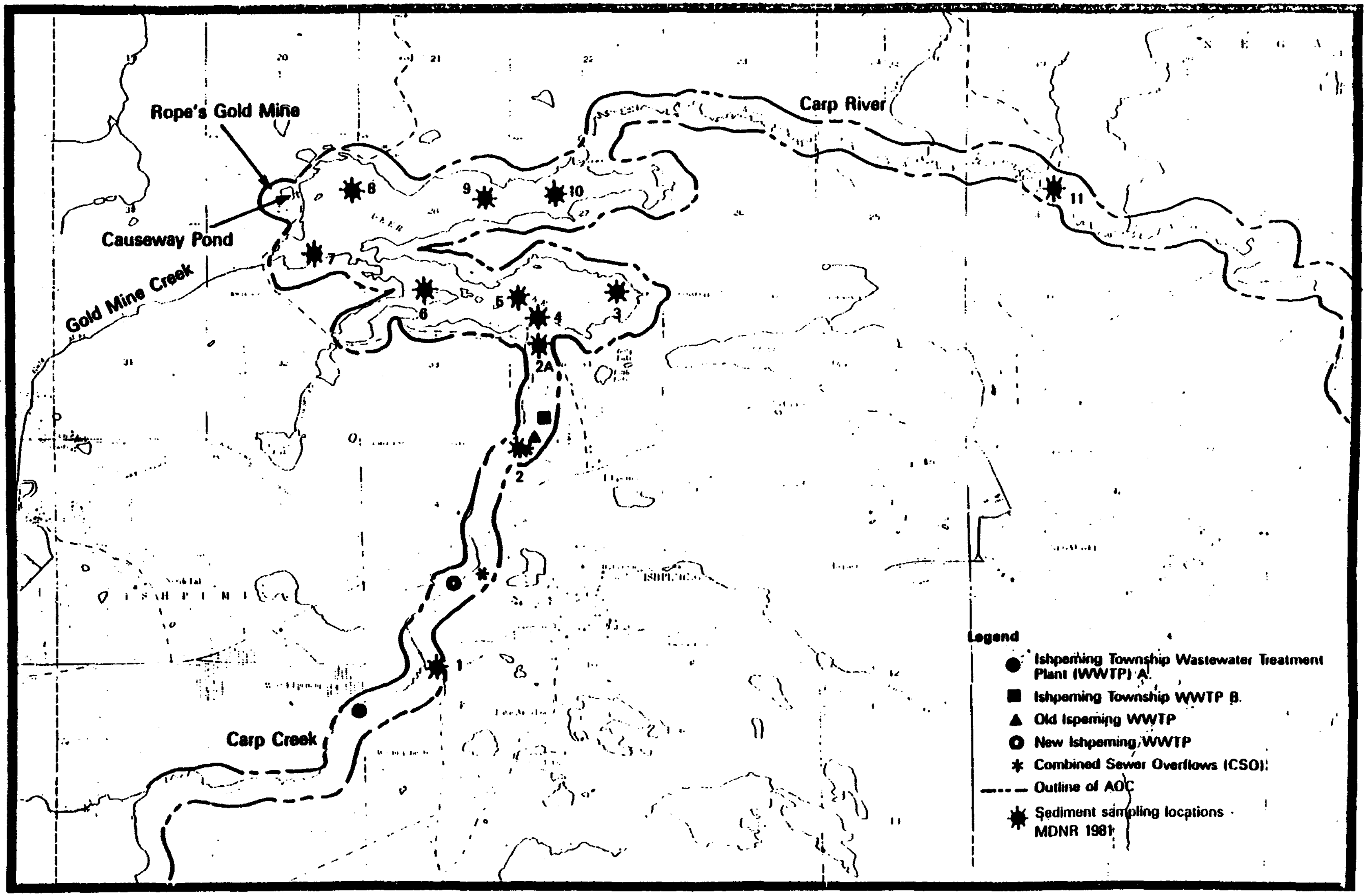


Figure 4-9.

Locations of MDNR sediment sampling stations in Carp Creek and Deer Lake

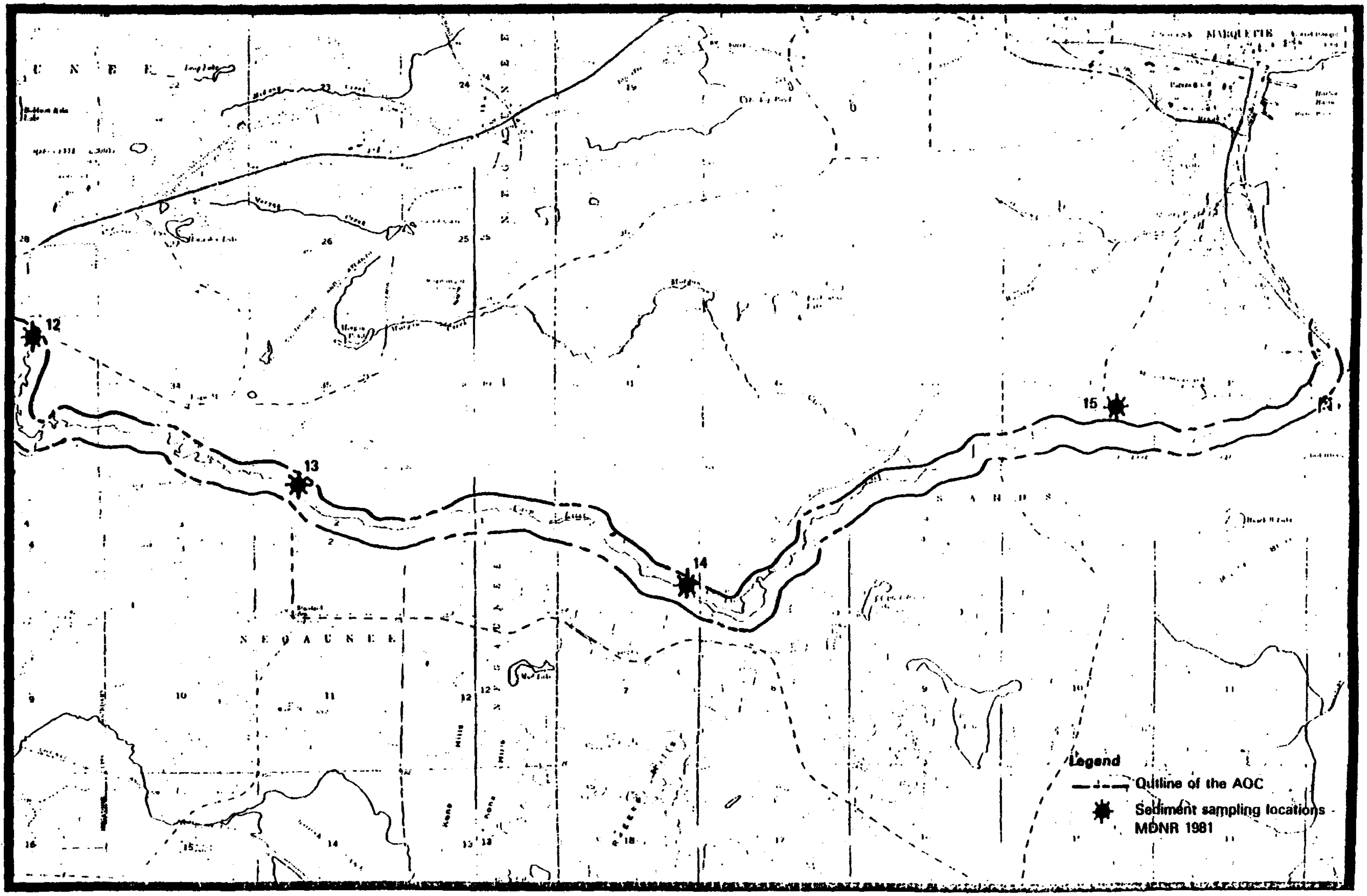


Figure 4-10.

Locations of MDNR sediment sampling stations in Lower Carp River and Deer Lake

Table 4-10. SOURCES OF DATA FOR SEDIMENT CONTAMINATION IN DEER LAKE

ORGANIZATION	DATES OF SAMPLING	DESCRIPTION
Ecological Research Services, Inc.	Summer 1981	Analysis of sediments in Deer Lake and tailings near Ropes' Creek and Causeway Pond for mercury and other heavy metals.
MDNR	October 1981	Surficial sediments throughout Deer Lake and in Carp Creek and the Carp River were sampled for mercury and other heavy metals.
MDNR	March 1982 and October 1982	Core samples of Deer Lake sediments were analyzed for mercury and other heavy metals. Samples were taken near Carp Creek inlet and in the deep basin of the southeastern portion of the lake.
MDNR	March 1982	Sampled mercury in sediments and leachate from tailings in Causeway Pond and adjacent portion of Deer Lake. The west end of Goldmine Lake and the west and east ends of Teal Lake also were sampled.
CCI	1983	Surficial sediments sampled for mercury only. Some core samples may have been taken. March 1983 - Ropes' Tailings sampled for mercury. March 1983 - Ice and snow over tailings sampled for mercury.
MDNR	1985	Surficial sediments of Deer Lake during draw down were sampled for mercury.
MDNR	1986	Surficial sediments of Deer Lake during drawn down were resampled for mercury. A core was taken from Deer Lake near Carp Creek inlet. A core was taken from an upland site north of Deer Lake and analyzed for mercury.

TABLE 4-11. ANALYSIS OF SEDIMENTS FOR METALS

Sample Site/Data	Analysis by Element mg/kg dry weight							
	Hg	Pb	Cu	Ni	Zn	Cr	Cd	% H_2O
Beaver Dam 6/16/81	4.5	20	14	53	118	11	0.42	38.3
South Basin, Deer Lake 6/16/81	10.0	45	36	31	245	34	1.1	95.1
North Basin, Deer Lake 6/16/81	4.6	29	45	50	150	26	0.38	90.8
Causeway, Deer Lake 6/16/81	5.5	35	45	70	200	28	0.63	35.5
Deer Lake, by Road 6/16/81	7.4	40	46	58	260	24	1.0	94.0

(Source: Ludwig, 1981)

TABLE 4-12. HEAVY METALS IN SURFICIAL SEDIMENTS FROM THE CARP RIVER AND DEER LAKE, MARQUETTE COUNTY, MICHIGAN, 1981 AND 1982.

Station	Total Solids (%)	Cd	Cr	Cu	Ni	Pb	Zn	Fe	Mn	As	Hg
1	31	2	25	20	12	6	89	32,000	2,200	30	1
2	41	2	56	120	26	140	260	45,000	1,200	13	7.8
2A	40	2	20	25	12	35	60	--	--	--	2.4
3	20	2	90	170	24	150	34	46,000	1,100	19	4.1
4	37	2	57	210	23	160	320	35,000	390	9	9.1
	6	2	76	180	22	150	350	70,000	730	16	12
5	30	2	80	180	26	170	400	66,000	1,100	11	7.8
6	21	2	60	140	28	120	320	46,000	420	16	5.1
7	20	2	22	46	29	34	75	23,000	700	5	0.4
8	22	2	56	90	56	76	220	30,000	500	10	2.2
	8	2	62	110	55	81	240	40,000	460	14	7.6
9	8	2	53	85	47	67	170	39,000	450	15	5.0
10	8	2	49	72	45	56	170	31,000	490	12	3.6
11	21	2	27	20	11	11	66	33,000	3,200	18	1.0
12	33	2	24	19	10	10	51	28,000	1,600	9	0.2
13	20	2	33	25	12	10	91	43,000	3,700	16	0.7
14	51	2	10	10	10	10	17	11,000	390	5	0.2
15	48	2	18	12	8	8	35	11,000	340	3	0.5
Lake Superior depositional zone surifical sediments[1]		0.8	124	49	72	26	63			1.3	0.053

[1]Guidelines and Register for Evaluation of Great Lakes Dredging Projects, 1982. International Joint Commission. 365 p.

(Source: MDNR File, 1986)

Mercury concentrations in sediments from Carp River downstream of Deer Lake ranged from 0.2 to 1.0 mg/kg dry weight (stations 11 through 15, Table 4-12). The highest concentration occurred at the location closest to Deer Lake (Station 11). The remaining stations all had concentrations below 1.0 mg/kg dry weight.

The data in Table 4-12 indicate that for most metals, average concentrations in Deer Lake sediments exceeded average concentrations in Carp Creek sediments, and that average concentrations in Carp River sediments were generally the lowest of the three segments of the Deer Lake system.

Cleveland Cliffs Iron Co. Survey - 1983

In 1983, CCI sampled and analyzed sediments in the Deer Lake area for mercury content. These data are shown in Table 4-9 (Section 4.2.1.2).

MDNR Survey - 1985

Michigan DNR sampled surface exposed sediments in Deer Lake in the summer of 1985 when the lake was drawn down and tested them for mercury content. Table 4-13 shows the concentrations and Figure 4-11 shows the sampling locations. For locations with two sample numbers, on Figure 4-11, the top number represents a surface sample and the bottom number represents a subsurface sample. Surface concentrations ranged from 0.01 to 10.99 mg/kg dry weight. The highest concentrations were found in the vicinity of Carp Creek Inlet again.

MDNR Survey - 1986

Samples collected along sandy shores of the lake tended to have lower concentrations of mercury (less than or equal to 1 mg/kg) than those from depositional areas.

In 1986, MDNR again resampled Deer Lake sediments for mercury to determine if mercury concentrations had decreased due to volatilization, as previous anaerobic sediments became oxidized. Results are shown in Table 4-14; sampling stations are illustrated in Figure 4-12. The surface samples were collected from sediments exposed to air for an additional 16 months as the lake had remained drawn down at the time of sampling. Station DL-7 was a sand subsurface sample taken from the area below station DL-6, a sand surface sample (personal communication Elwin Evans, MDNR, July 30, 1987). Stations DL-4 and DL-5 are upland stations where soil was collected from the upper four inches and from 12 to 16 inches below the surface, respectively.

The sample collected at Station DL-3, near Carp Creek Inlet, had the highest concentration (15.8 mg/kg dry weight) of all samples collected from 1981 to 1986. The upland surface and subsurface samples both had very low mercury concentrations (0.2 mg/kg dry weight) as did the lake basin samples with sandy substrates (0.6 and 0.01 mg/kg dry weight).

Comparison of Sediment Surveys - 1981-1986

Figure 4-13 through 4-15 show mercury concentrations in Carp Creek, Deer Lake, and Carp River, respectively, for all surface sediment samples

TABLE 4-13. ANALYSIS OF MERCURY IN SEDIMENTS - MDNR 1985 SURVEY

Number	Hg Wet Wt. (ug/gm)	Percent Solids	Hg Dry Wt. (ug/gm)
DR-1	0.46	27.54	1.67
DR-2	0.17	84.75	0.20
DR-3	0.54	26.53	2.04
DR-4	0.41	30.42	1.35
DR-5	0.37	30.61	1.21
DR-6	1.13	44.01	2.57
DR-7	0.01	89.81	0.01
DR-8	0.03	43.25	0.07
DR-9	0.23	29.41	0.78
DR-10	0.01	34.31	0.03
DR-11	0.25	44.81	0.56
DR-12	1.76	74.19	2.37
DR-13	1.99	31.40	6.34
DR-14	1.28	65.38	1.96
DR-15	0.01	22.39	0.05
DR-16	0.63	22.86	2.76
DR-17	1.24	35.18	3.53
DR-18	1.20	36.85	3.26
DR-19	0.74	88.80	0.83
DR-20	4.02	36.58	10.99
DR-21	3.68	39.69	9.27
DR-22	3.37	92.94	3.63

(Source: MDNR File)

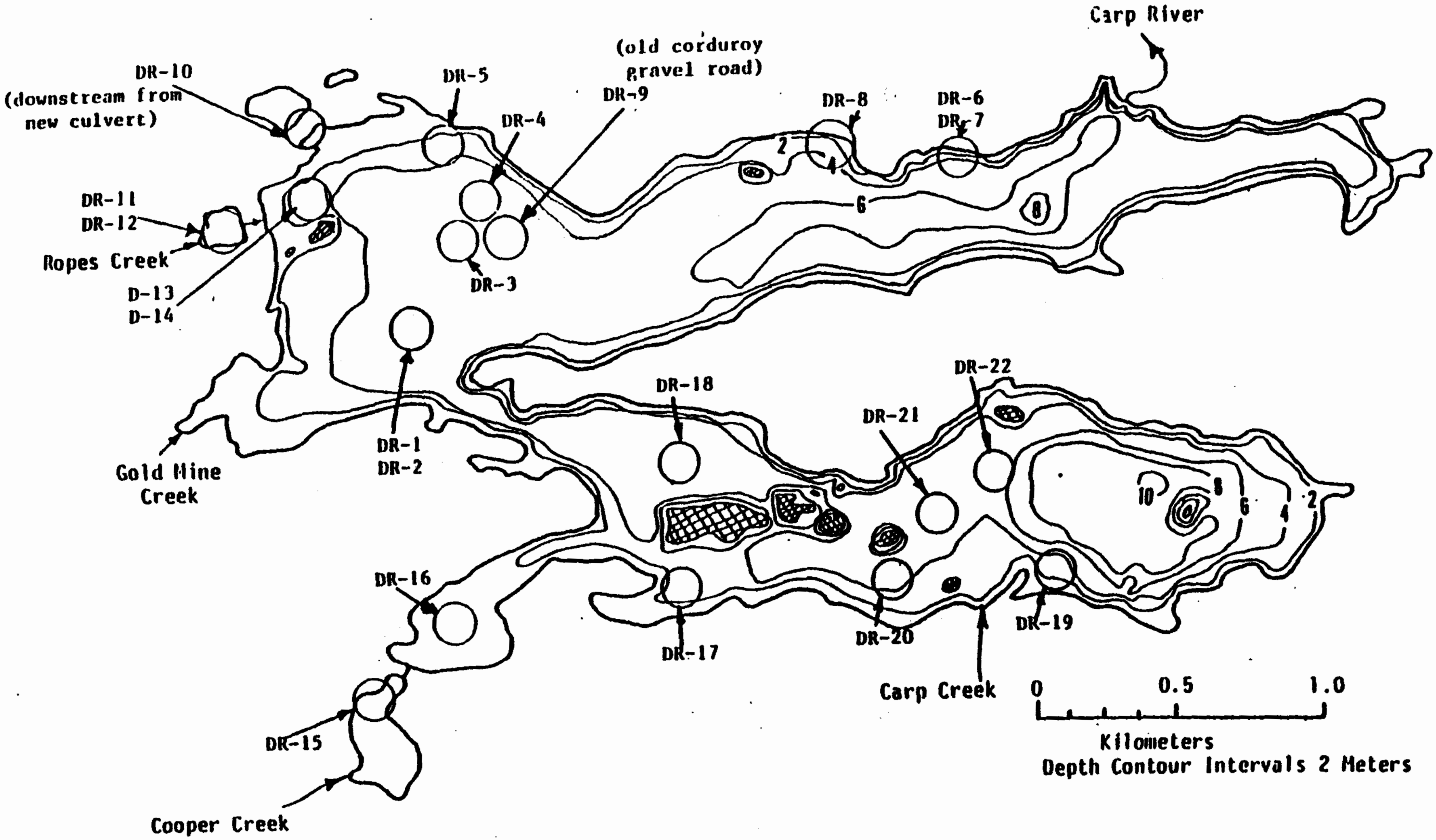


Figure 4-11. Sediment Sampling Locations July 8, 1985

(Source: MDNR File)

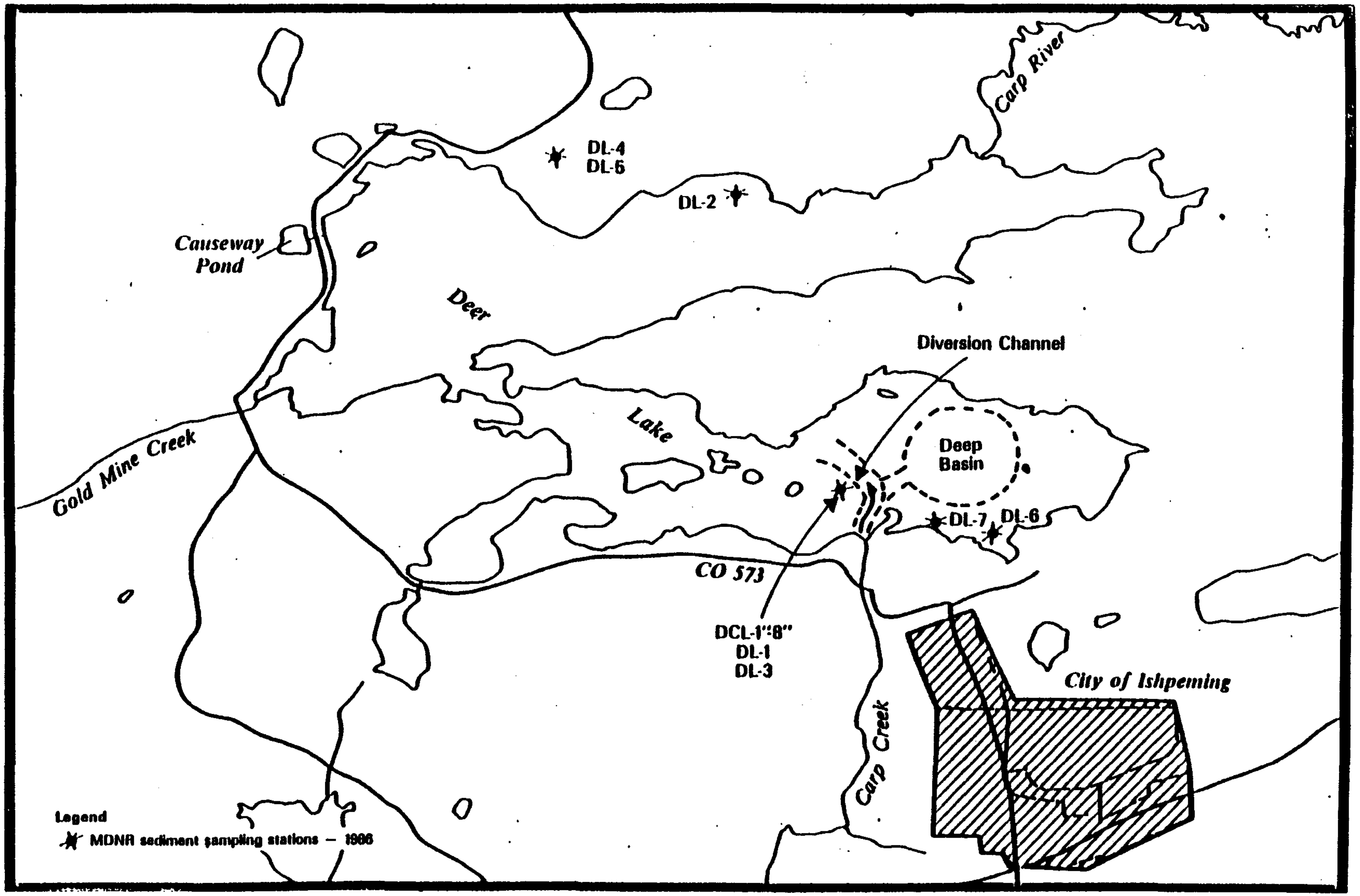


Figure 4-12.
Sediment Sampling Locations of MDNR 1986 Survey

obtained for this report. All data were collected between 1981 and 1986. In Deer Lake the highest concentrations were found in the vicinity of Carp Creek inlet (Figure 4-13). Where sand was a large component of sediment, concentrations were low. Surficial sediment samples from the Causeway Pond had mercury in the range of concentrations found in Deer Lake and ranged from 1.8 to 2.8 mg/kg. Although these concentrations are at the low end of the range found in Deer Lake, they are elevated relative to upland values collected near Deer Lake and to values from other lakes in the Upper Peninsula.

Concentrations at the two locations sampled in Carp Creek were elevated, due to inputs from upstream CSOs (Figure 4-14). Concentrations in Carp River are very much lower than in Deer Lake. The station closest to Deer Lake has an elevated concentration but all other stations have relatively low concentrations (0.2-0.7 mg/kg dry weight) (Figure 4-15).

Summary of Information on Heavy Metals in Deer Lake Sediments

Table 4-15 shows heavy metal concentrations in deep basin lake sediments for Lakes in Michigan's Upper Pennisula and the depositional zone of Lake Superior. Mercury content of Deer Lake sediments exceeds by far that of other inland lakes and Lake Superior. It should be noted, however, that most of the inland lakes appear to contain mercury in greater concentrations than the Lake Superior depositional zone but this is probably due to higher and more variable levels of analytical detectability. Sediment mercury concentrations in Deer Lake did not change significantly due to mercury volatilization following lake draw down.

In March 1982, MDNR sampled surficial sediments nearby in Goldmine Lake and Teal Lake. The sediments were analyzed for mercury concentration. The results are listed below:

Goldmine Lake	0.3 mg/kg dry weight
Teal Lake (west end)	0.3 mg/kg dry weight
Teal Lake (east end)	0.2 mg/kg dry weight

Mercury concentrations in Deer Lake sediments are very much higher than those in adjacent watersheds with much the same geology. The differences in mercury concentration are so great that the significance of natural inputs from geologic sources seems minimal. The available data indicate significant loadings of mercury to Deer Lake probably came from other sources. Other metals in Deer Lake which were substantially higher than the Upper Peninsula average were copper, chromium, and nickel.

Based on available data, it can not be shown that these metals have caused use impairments. Analyses for these metals in fish tissue have shown them not to be at levels of concerns (Appendix A).

Average concentration of lead, arsenic and zinc, in Deer Lake sediments were higher than the Upper Peninsula averages but fell within the first standard deviations for each metal. Average cadmium concentration in Deer lake was approximately equal to the Upper Peninsula average.

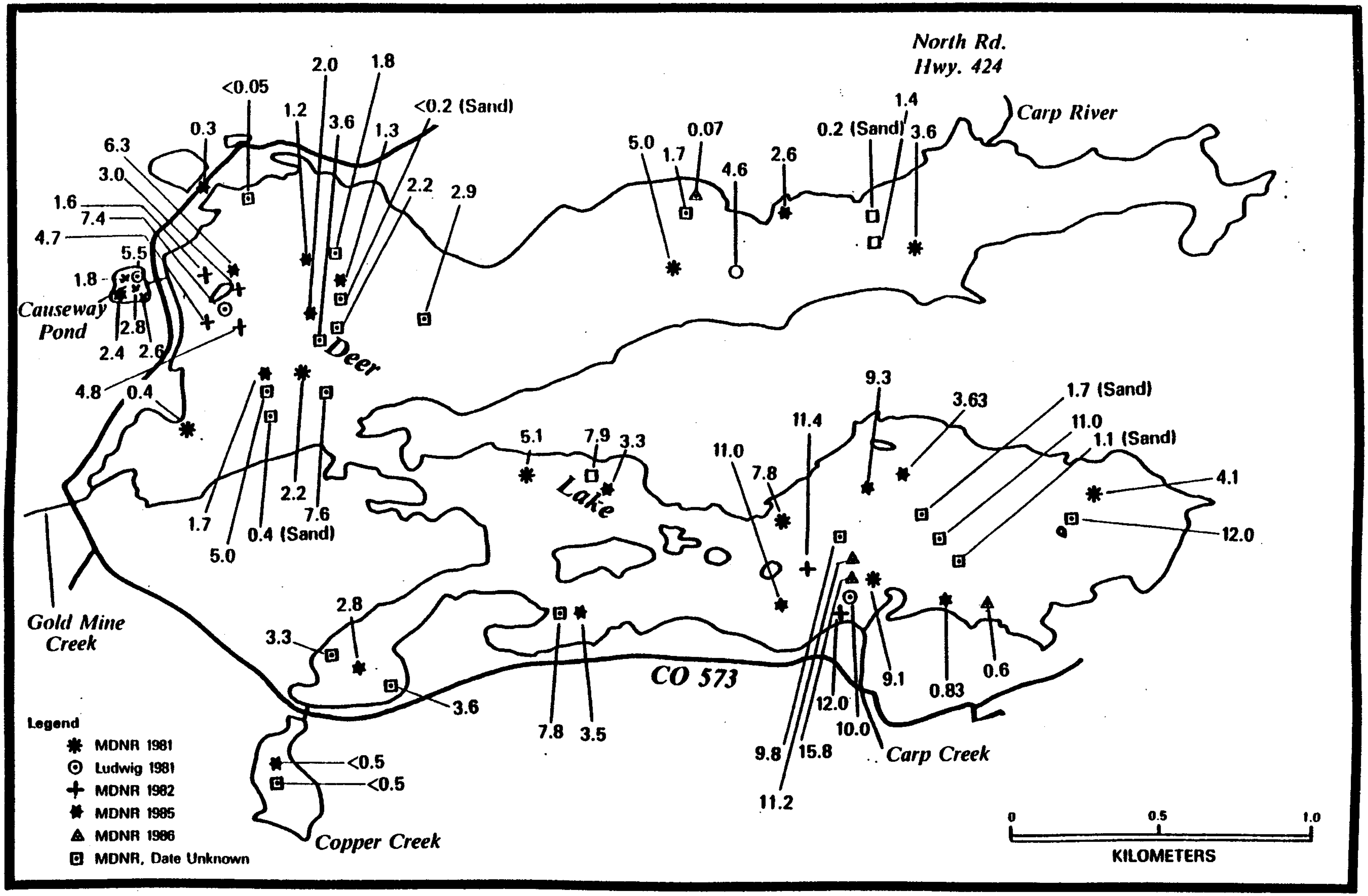


Figure 4-13.
Mercury concentrations (mg/kg dry weight) in surficial sediments of Deer Lake

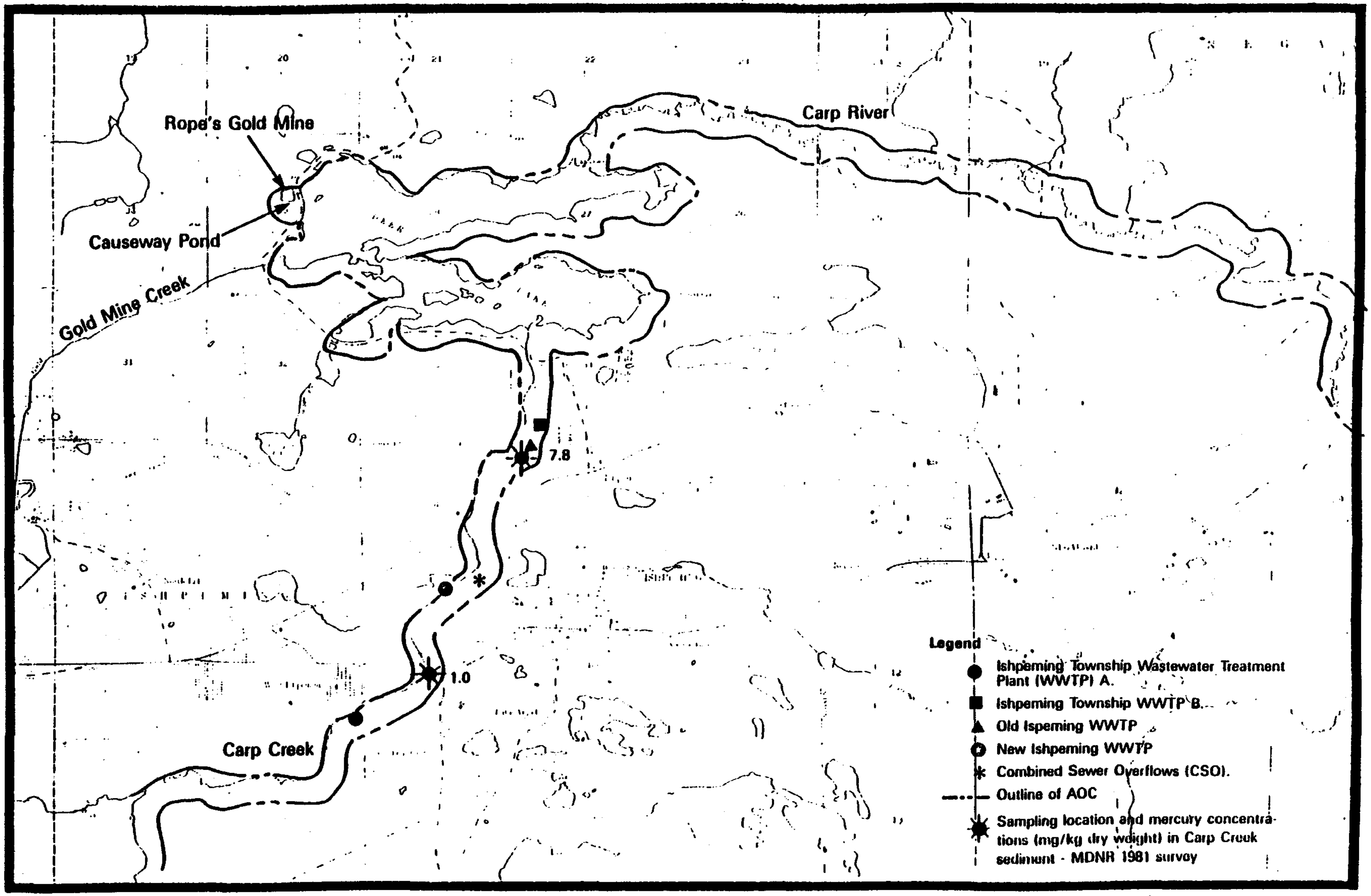


Figure 4-14.

Mercury in Carp Creek sediments - all data. (Units in mg/kg dry weight.)

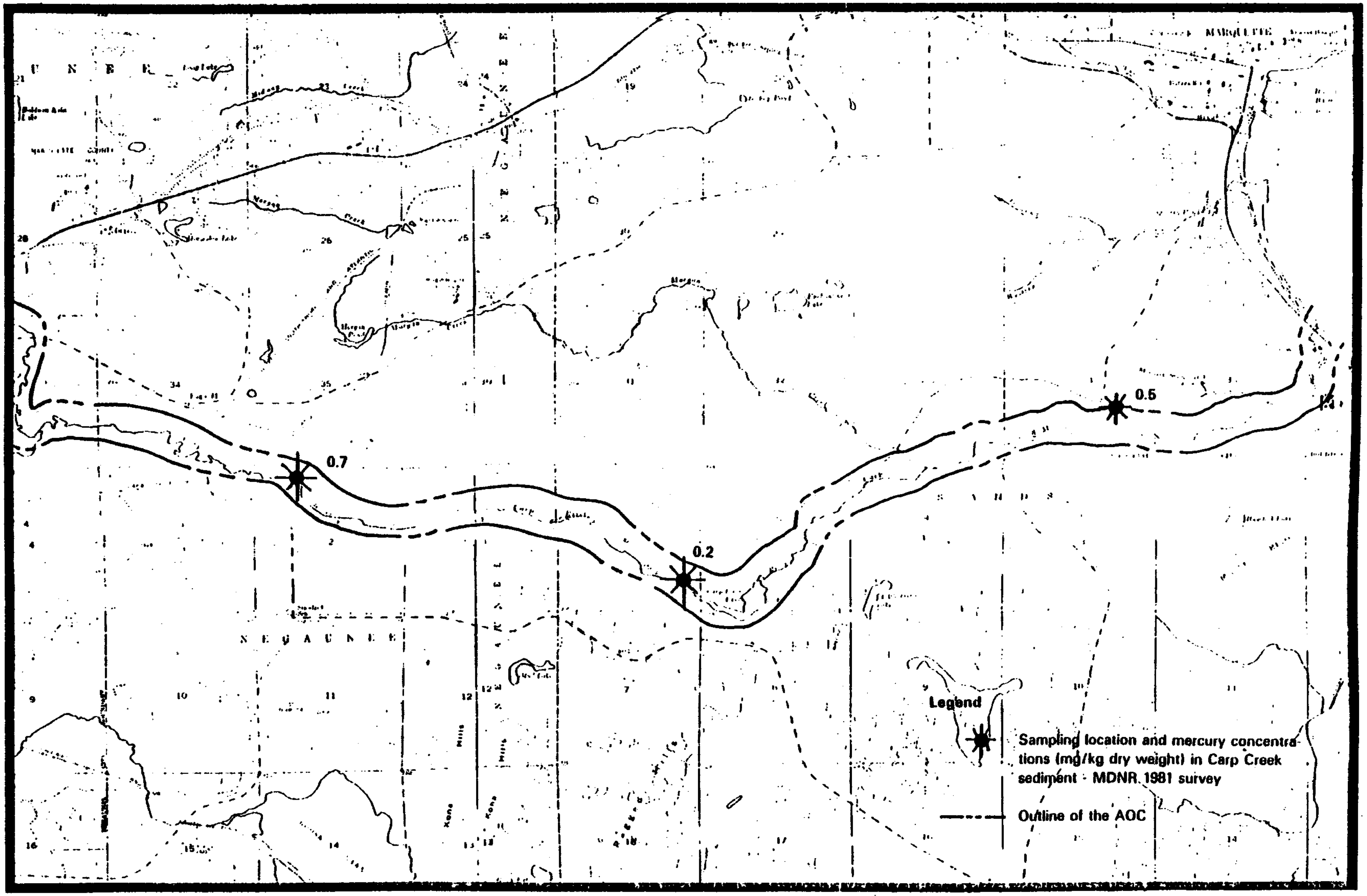


Figure 4-15.
Mercury in Lower Carp River sediments - all data. (units in mg/kg dry weight).

TABLE 4-14. ANALYSIS OF MERCURY IN DEER LAKE SEDIMENTS - 1986

Location	Site Description	Hg[1]	TS%[2]	VS%[3]
DL-1	Surface, composite	11.2	50.5	14
DL-2	Surface, composite	1.0	47.0	11
DL-3	Surface	15.8	37.5	21
DL-4	Upland soil - top 4 inches	0.2	76.5	7
DL-5	Upland Soil - subsurface 12-16 inches	0.2	83.5	2.7
DL-6	Sand surface	0.6	94.0	1.3
DL-7	Sand surface	0.01	96.0	0.6

[1]Mercury concentration in mg/kg dry weight.

[2]Percent total solids.

[3]Percent volatile solids.
(Source: MDNR files)

TABLE 4-15. HEAVY METAL CONCENTRATIONS IN DEEP BASIN LAKE SEDIMENTS IN THE UPPER PENINSULA OF MICHIGAN, 1977-1980.

Lake	County	Metals mg/kg dry weight							
		As	Cu	Hg	Cd	Cr	Zn	Ni	Pb
Long	Iron	72	38	0.14					48
Kaks	Luce	12	15	1.0	2.0	17	570	8	40
Hamilton	Dickinson	9	60	1.0	2.0	15	160	13	55
Edey	Dickinson	4.2	28	0.03					86
Pole Creek	Delta	12	10	1.0	2.0	20	180	4	30
Dodge	Schoolcraft	2.0	12						16
Crelhane	Luce	29	18	0.14					82
Six Mile	Dickinson	4	28	1.0	2.0	17	1100*	10	25
Twin Lakes	Luce	4.0	15	1.0	2.0	16	60	6	60
Island	Schoolcraft	17	20	0.02					130
Boot	Schoolcraft	9.3	20	0.09					130
Fire	Iron	21.1	22	0.02					44
Ellen	Iron	4.2		0.04					56
Bass	Luce	6	15	1.0	4.0	20	170	10	90
Indian	Iron	2.0	14	0.02					5
Kingston	Alger	4.0	18	1.0	2.0	25	120	8	75
Long	Menominee	26	40	0.12					230
Bodi	Luce	5.5	20	0.09					150
Torch	Houghton	30	2500*	0.4	2.0	40	300	75*	200
Lake Superior x's**		1.3	49	0.053	0.8	124	63	72	26
N		19	17	18	8	8	7	7	19
$\bar{x}$		14.4	23.1	0.45	2.25	21.3	223	8.4	81.7
S.D.		16.7	12.7	0.46	0.71	8.2	169	2.9	61.3

*omitted from calculations
**Source: IJC. 1982. Guidelines and Register for Evaluation of Great Lakes Dredging Projects. WAter Quality Board.

On the whole, concentrations of metals in Deer Lake sediments are high when compared with other lakes in the region. Ludwig (1981) also noted that overall concentrations for metals were high in Deer Lake.

Core Samples

MDNR collected sediment cores from Deer Lake for heavy metals in 1981 and 1982 to determine historical deposition patterns. Cores were collected off the Carp Creek inlet and in the deepest part of the lake (the eastern section of the south basin). Core segments were analyzed at intervals to a depth of 40 cm. In addition to sediment analysis, leachate tests for mercury were performed to determine if mercury was readily available. The data are shown in Table 4-16.

Analyses on the deep basin, core revealed that concentrations of heavy metals decreased consistently with depth in the core. This indicates that the deep basin cores at their bottom are probably representative of natural background levels in Deer Lake watershed. The other two cores, collected near the Carp Creek inlet, showed a wider range of concentration changes with core segment depth, but the same pattern of decreasing concentrations of heavy metals was evident. Variability in these cores may be due to the influence of the creek and/or the construction of the dam.

Concentrations of most metals in the deep basin core were generally lower than those in the cores near the Carp Creek inlet. From 0 to 10 cm, metals concentrations were comparable in cores from both locations, but below 10 cm, the deep basin core concentrations were lower for all metals except cadmium and manganese. Manganese concentration decreased steadily in all cores but at the 20-30 in depth, the deep basin core was lowest in concentration. Cadmium concentration measured 2.0 mg/kg dry weight in all samples from all depths.

The deep basin contained the original Deer Lake, so core concentrations at some depth would reflect natural loadings from Carp Creek. Based on this assumption all metals with the exception of cadmium and possibly manganese, are elevated relative to natural levels. The abrupt change in lead concentrations at about 30 cm probably indicates the use of leaded gasolines in the 1920s and 1930s. The sediments from the other two core locations had probably accumulated since the use of leaded gasoline since all core segments have elevated concentrations.

Mercury was measured in each of the core segments obtained off the Carp Creek inlet in March 1982 by the leachate test. Mercury was not found above the level of detection (0.1 ug/l).

Mercury data from core samples taken in 1985 and 1986 are shown in Table 4-17. Subsurface (tailings) samples collected in 1985 from the western side of Deer Lake and Causeway Pond contained substantially more mercury than surficial sediments in the same area or from the central and northern parts of the lake.

The core sample in 1986 was collected near Carp Creek Inlet, as were MDNR's 1982 cores (Table 4-17). No significant change has occurred in surficial sediment mercury concentrations in Deer Lake off the Carp Creek inlet since 1981.

Table 4-16 Sediment core sample data from Deer Lake near Ishpeming, Marquette County, Michigan, March and October, 1982. All heavy metal concentrations are given for dry weight of sediment.

Sample Depth (cm) Beneath Water:	Total Solids (%)			Cadmium (mg/kg)			Chromium (mg/kg)			Copper (mg/kg)			Nickel (mg/kg)			Lead (mg/kg)		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-2.5	14			<2			80			230			27			200		
0-10		12.9	10.5		<2	<2		91	68		220	160		29	25		190	140
7.5-17.5	15			<2			90			210			27			190		
10-20		21.9	22.3		<2	<2		58	43		150	80		28	21		120	80
17.5-26.3	29						53			130			26			120		
20-30		27.0	59.1		<2	<2		56	16		110	8		27	<5		110	10
26.3-35.0	34			<2			55			150			27			120		
30-40		34.0	41.1		<2	<2		54	23		89	4		27	<5		130	<5
35-40 (sawdust >40)	38			<2			51			98			27			110		
$\bar{x}$ concentrations Upper Peninsula Lakes Table					<0.7			21			23			8			82	

1. Station 4 off Carp Creek inlet March 18, 1982
2. Station 4 off Carp Creek inlet October 12, 1982
3. Deep Basin (10m) Station 3 October 13, 1982

(Source: MDNR FILES)

Table 4- 16 (cont.)

Sample Depth (cm) Beneath Water	Zinc (mg/kg) 1	2	3	Iron (mg/kg) 1	2	3	Manganese (mg/kg) 1	2	3	Arsenic (mg/kg) 1	2	3	Mercury (mg/kg) 1	2	3	Mercury Leach (μg/l) 1	2	3
0-7.5	400			49000			800			18			11.4			<0.1		
0-10		410	370		88000	81000		1500	1400		14	17		11	12			
7.5-17.5	190			49000			1000			16			9.8			<0.1		
10-20		340	320		100000	66000		1400	1100		15	18		16	12			
17.5-26.3	120			39000			980			14			10.1			<0.1		
20-30		420	74		120000	37000		1600	590		20	20		16	0.6			
26.3-35	120			54000			1100			14			12.9			<0.1		
30-40		450	49		80000	36000		1200	600		17	12		13	<0.5			
35-40 (Sawbust >40)	110			52000			990			14			11.8					
$\tilde{x}$ concentrations Upper Peninsula Lakes Table		223									14			0.5				

(Source: MDNR FILES)

TABLE 4-17. CORE SAMPLES COLLECTED BY MDNR FROM DEER LAKE IN 1985 AND 1986 FOR MERCURY ANALYSIS. ALL VALUES IN MG?KG DRY WEIGHT.

Core Samples			Year	Location
Sample Number	Conc. of Hg.[1]	Sample Composition		
DR-1	1.67		1985	Central portion of Deer Lake
2	0.02			
DR-13	6.34			West end of Deer Lake
14	1.96			
DR-11	0.56			Causeway Pond
12	2.37			
DR-6	2.57			North basin, eastern section of Deer Lake
7	0.01			
DCL-1"	14.7	silt	1986	Near Carp Creek Inlet
2"	15.9	silt		
3"	10.4	silt		
4"	7.5	silt		
5"	1.0	silt		
6"	1.2	silt and sand		
7"	0.3	sand		
8"	1.1	sand		

Notes:
[1]Mercury concentration in mg/kg dry weight.

Tailings Samples

Tailings in the Ropes' Goldmine were sampled for mercury by Ecological Research Service, Inc. (ERS) in the summer of 1981, by MDNR in March 1982 and 1986, and by CCI in March 1983. CCI also sampled ice and snow above the tailings in March 1983. The results of these studies are described below.

Data sampled by ERS are shown in Table 4-18. These tailings near the Ropes' mine are reported to contain substantially less mercury than the sediments or tailings in the lake (Ludwig 1981).

MDNR reported a value of 4.8 and 9.9 mg/kg dry weight of mercury in tailings from the Ropes' mine tailings deposited in Deer Lake. The corresponding surficial concentration was 4.4 and 3.0 mg/kg dry weight, respectively. Tailings sampled by MDNR in Causeway Pond measured 4.9 mg/kg dry weight. The corresponding surficial value was 2.8 mg/kg dry weight.

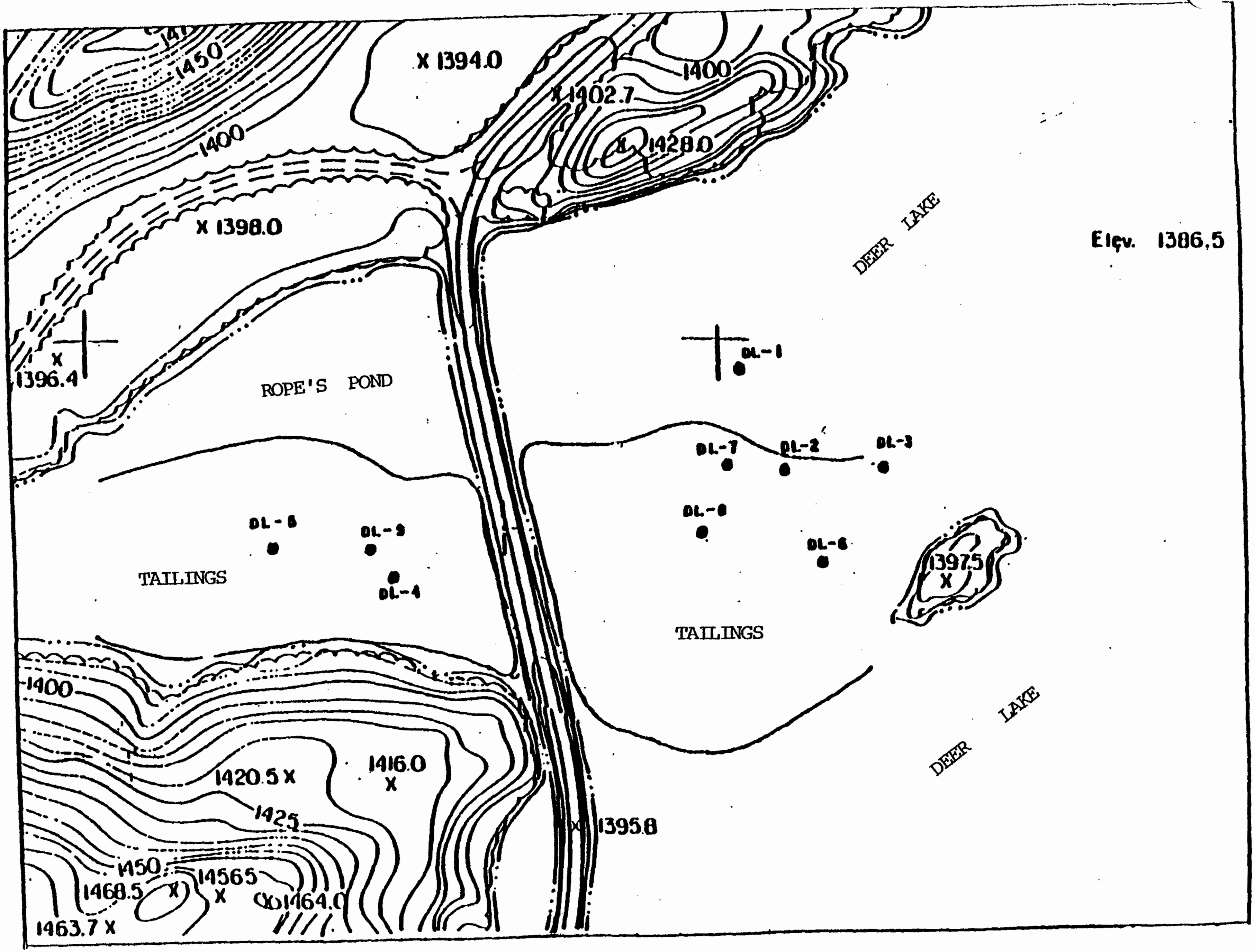
In 1983, CCI sampled tailings in and adjacent to Deer Lake. Sampling locations are shown in Figure 4-16 and data are shown in Table 4-19. Most cores were sampled to a depth of 3 feet; however, two were sampled to a depth of 10 feet. The samples were collected with a 1.5 inch hand sauger. Four of the five 3-foot cores showed concentrations of mercury higher at the 2- to 3-foot depth than at the 1- to 2-foot depth, indicating mercury concentration in tailings was greater at depth than that in surface sediments above the tailings. The 10-foot cores also show subsurface concentrations higher than surface concentrations at depths of 2 to 8-feet.

Sampling of ice and snow above Ropes' mine tailings conducted by CCI in March 1983. In winter, volatile metals may migrate upward from mineralized soils into an overlying ice layer and become concentrated (D'Itri 1983). This may occur through degassing of mercury from sediments and/or capillary movement of water containing various forms of dissolved mercury upward to ice (D'Itri 1983). Aerially transported metals also concentrated in the bottom ice of the snow pack. The results of sampling ice, snow, and tailings are shown in Table 4-20 and the sampling location is illustrated in Figure 4-17. The ice was apparently sampled two times with resulting concentrations that were one order of magnitude different. The sampling of tailings reveals the presence of mercury. Based on information accompanying this data, it is not clear if the sediment was analyzed or if leachate from the sediment was analyzed in samples 1c-1g. The ice may serve as a small intermittent point source of mercury to Deer Lake when it melts and becomes runoff. Mercury from this source does not seem to influence sediment concentrations in Deer Lake.

Ice from an area assumed to be uncontaminated with mercury was sampled as an experimental control. The control site is located near Cedar Lake and is shown in Figure 4-18. The concentration of mercury in the ice at this site, 0.0062 mg/l or ppm, is not considered indicative of uncontaminated areas, and is considered high (D'Itri 1983).

TABLE 4-18. ANALYSIS OF TAILINGS FROM ROPE'S GOLDMINE FROM CORE SAMPLES. (SOURCE: LUDWIG 1981)

Sample Site	Hg mg/kg dry wt.
East Cyanide Tailings Pile 0.5-3.0m deep	1.2
West Tailings Pile, Surface	1.1
West Tailings Pile, 0.5-2.0m deep	1.4



X 1394.0
1450
1400
X 1402.7
1400
X 1428.0
X 1398.0
DEER LAKE
Elev. 1386.5
X
1396.4
ROPE'S POND
DL-1
DL-7
DL-2
DL-3
DL-5
DL-9
DL-8
DL-6
DL-4
TAILINGS
1397.5
X
TAILINGS
1400
DEER LAKE
1420.5 X
1416.0
X
1425
X 1395.8
1450
1468.5
14565
X
1464.0
1463.7 X

TABLE 4-19. CORE SAMPLES OF TAILINGS PILES FROM ROPES' GOLDMINE ANALYZED FOR SILVER AND MERCURY. CORES COLLECTED BY CCI MARCH, 1983.

Sample Location	Depth (feet)	Silver (ppm)	Mercury (ppm)
DL-1	0-2	1.350	4.540
	2-3	1.250	5.000
DL-2	0-2	2.290	1.700
	2-3	2.400	2.100
DL-3	0-2	2.210	2.900
	2-3	2.160	2.800
DL-4	0-2	2.650	1.550
	2-3	2.070	3.500
DL-5	0-2	1.950	3.950
	2-3	2.270	5.000
DL-2	0-2	1.650	1.420
	2.4	1.310	1.550
	4-6	1.990	2.250
	6-8	2.190	1.750
	8-10	1.950	1.550
DL-6	0-2	2.210	2.750
	2-4	2.390	3.200
	4-6	1.750	2.750
	6-8	1.600	2.200
	8-10	1.160	1.550

TABLE 4-20. ANALYSIS OF MERCURY (mg/1) IN SNOW AND ICE ABOVE TAILINGS AND ABOVE AN AREA WITHOUT TAILINGS.

		PPM	
1.	Ropes' Goldmine Tailings Dump		
a.	16" of new and packed snow	0.0006	
b.	2" ice layer directly above tailings	0.0022	(3/1/83)
	(Resampling of above)	0.0006	(3/3/83)
c.	6" of tailings (frozen)	2.0	
d.	Next 12" of tailings	1.5	
e.	Next 12" of tailings	0.87	
f.	Next 12" of tailings	0.91	
g.	Next 12" of tailings	0.77	
2.	Sterile Area - Cedar Lake Area		
a.	14" of snow	0.0005	
b.	3 1/2" of ice	0.0062	
3.	Water Blank		
a.	High-purity, deionized water	0.0005	

(Source: D'Itri 1983)

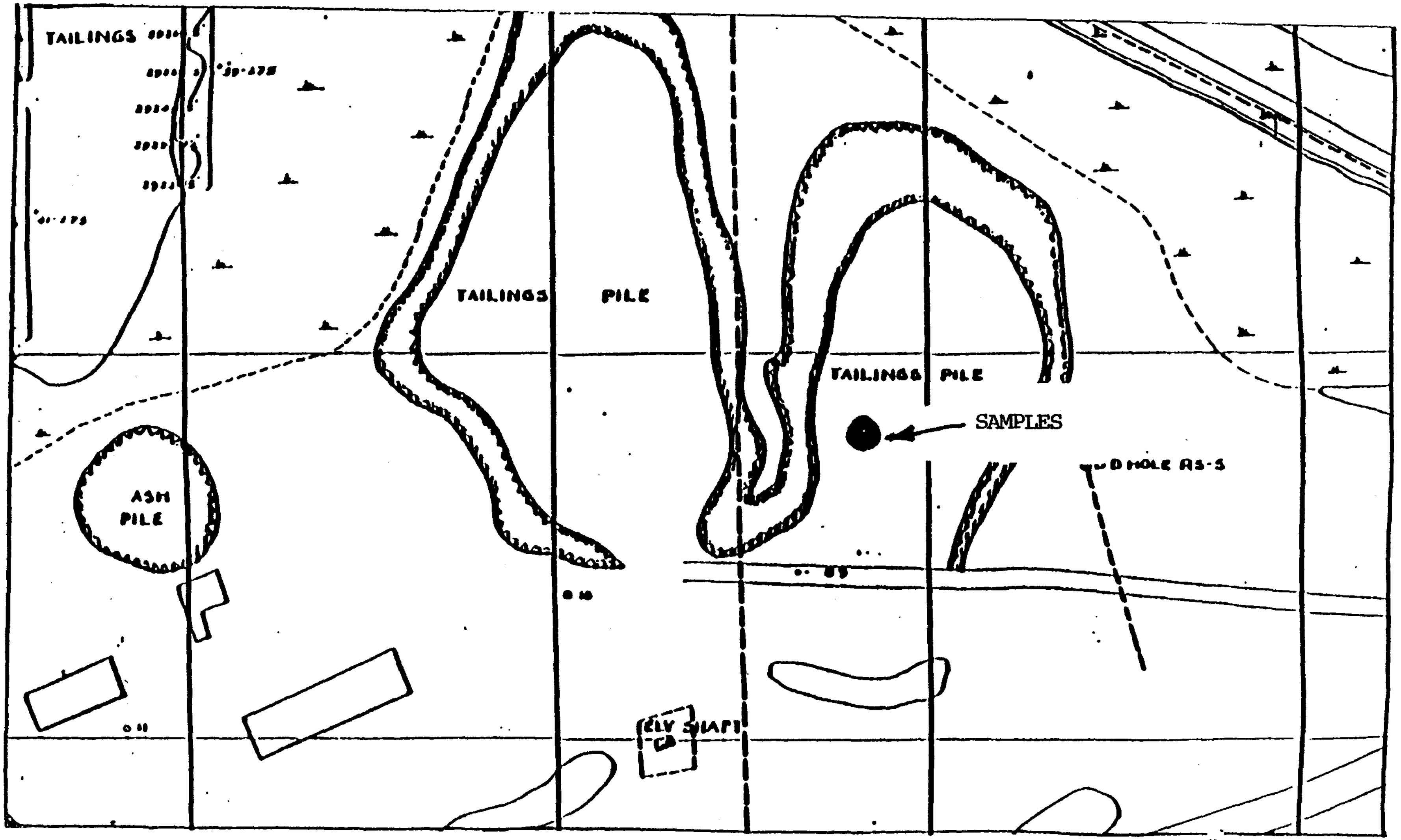


FIGURE 4-17. Location of Ice and Snow Sample, above Rope's Goldmine Tailings, Analyzed for Mercury Content near the West End of Deer (Source: D'Itri 1983)

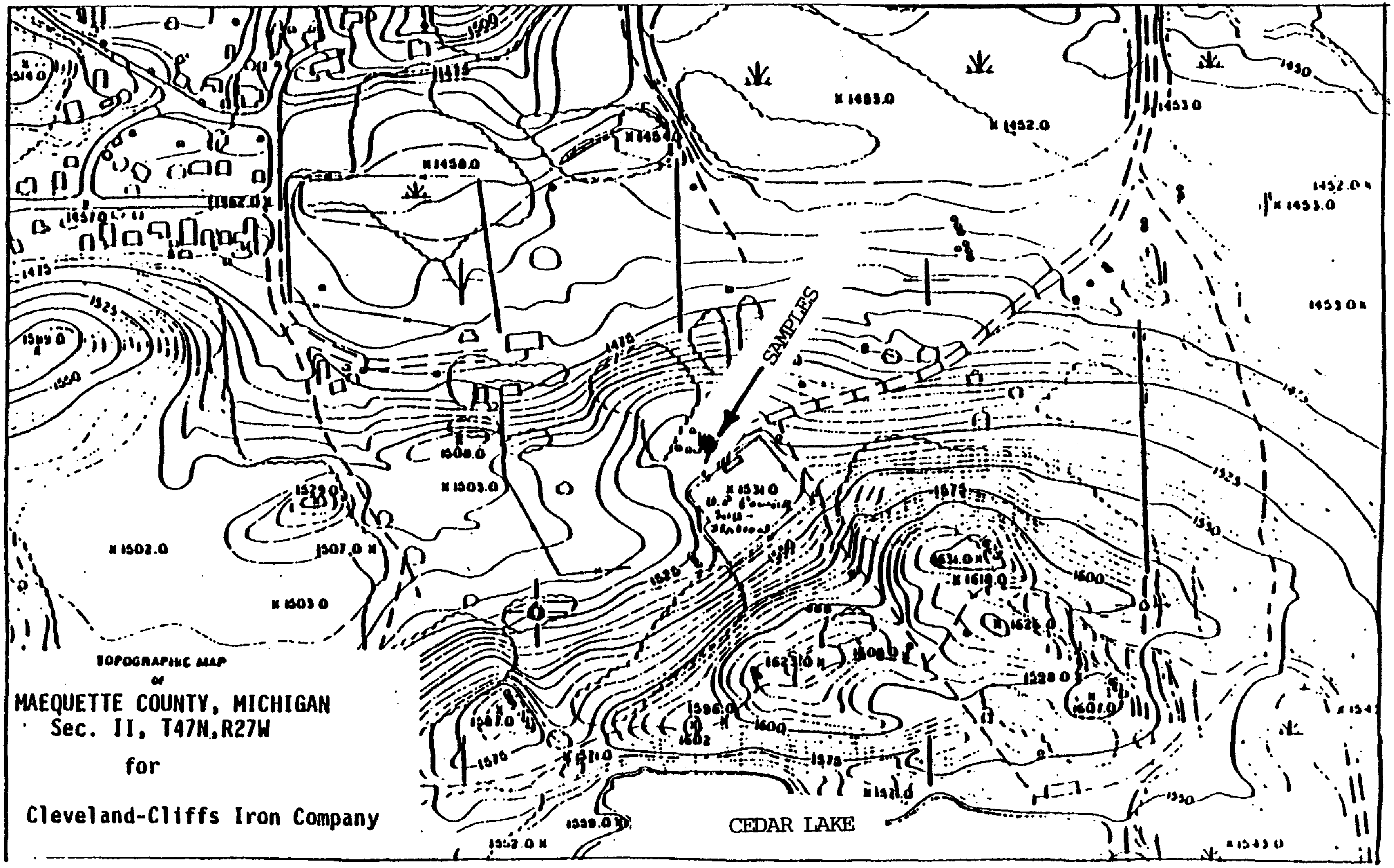


FIGURE 4-18. Sampling Location of Ice and Snow for Mercury Analysis from an Uncontaminated Area near Cedar Lake. (Source: D'Itri 1983)

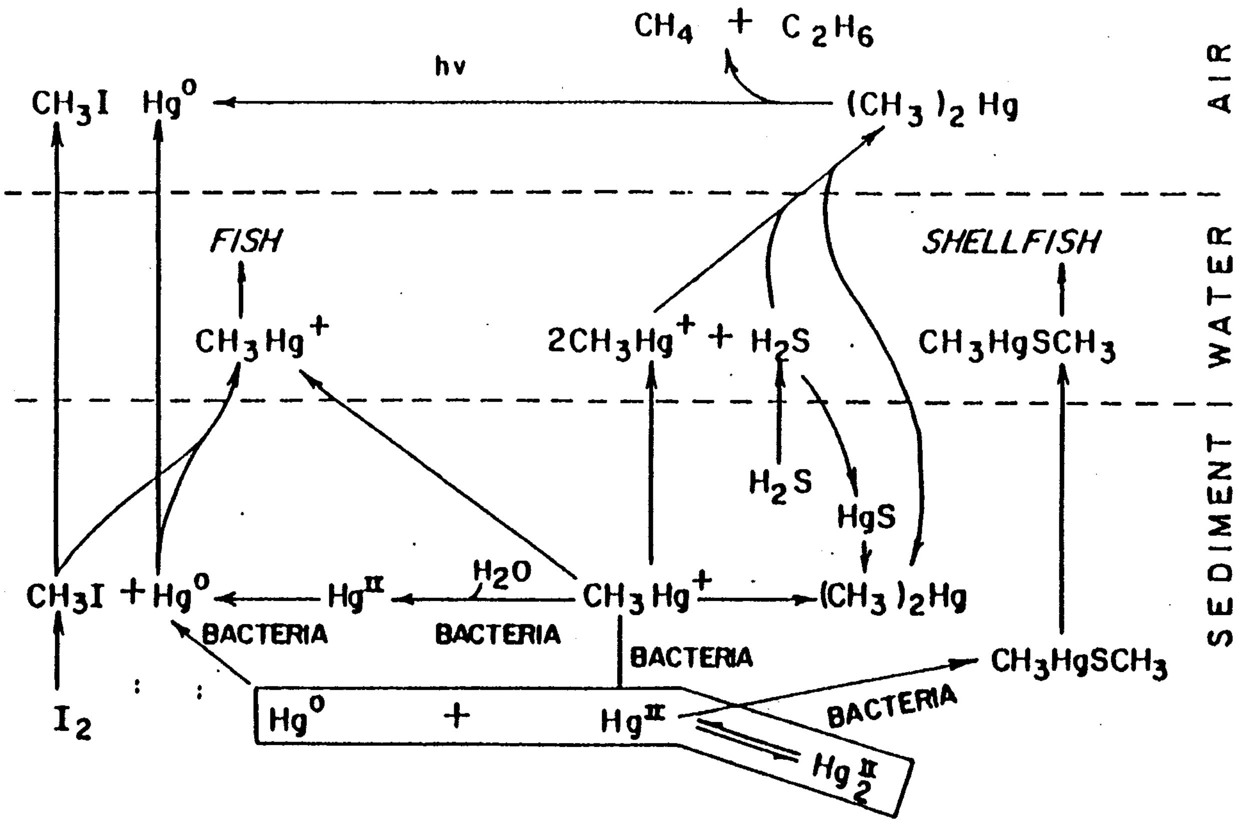


Figure 4-19 The mercury cycle showing those reactions catalyzed by bacteria, chemical disproportionation by H_2S and the photochemistry of organomercury compounds. (Source: Wood 1987)

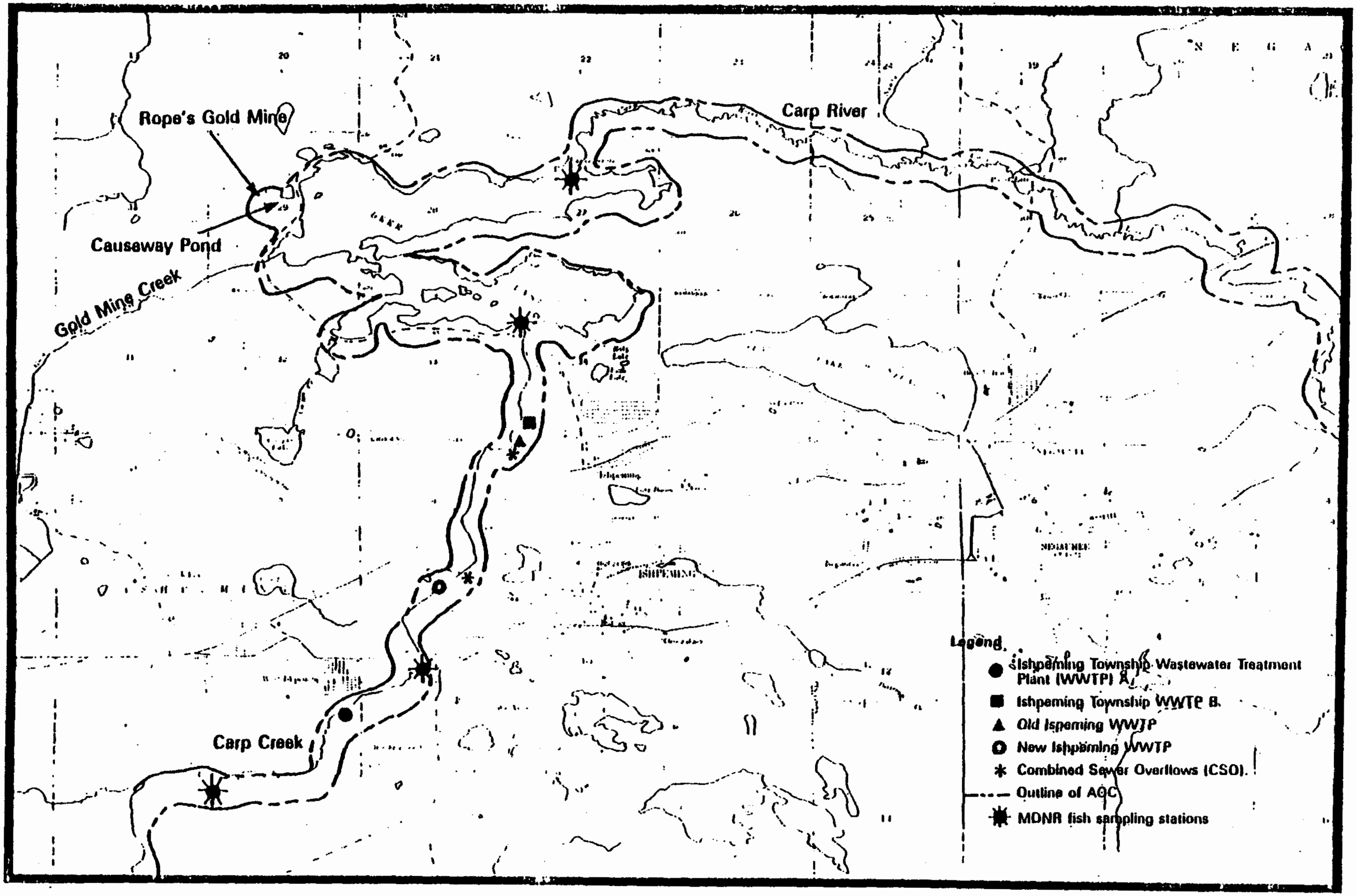


Figure 4-20.

Locations of MDNR fish sampling stations on Carp Creek and Deer Lake

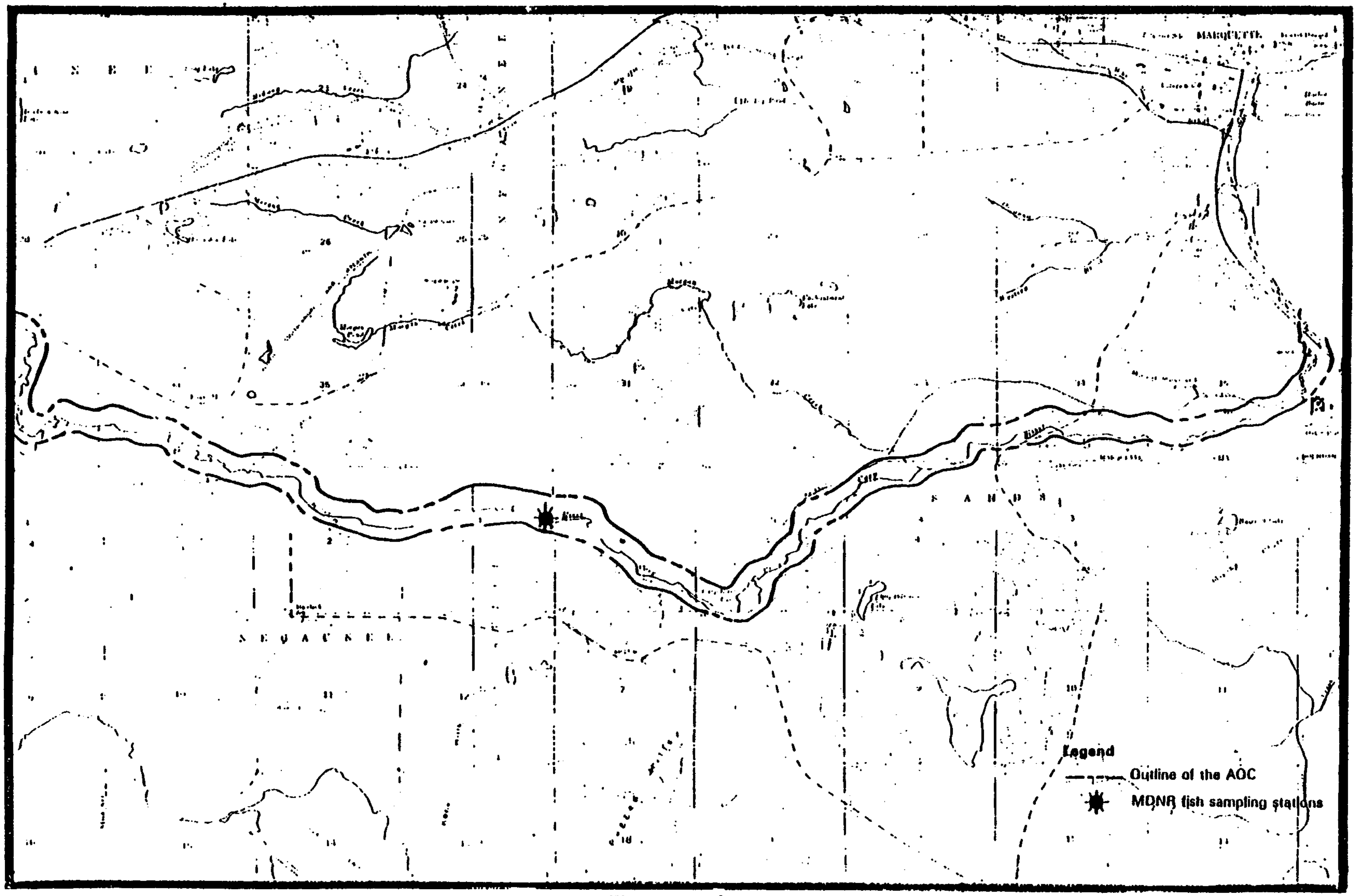


Figure 4-21.

Locations of MDNR fish sampling stations on Lower Carp River and Deer Lake

TABLE 4-21. SUMMARY OF FISH SURVEYS CONDUCTED IN DEER LAKE FROM 1981 TO 1985.

Organization	Date of Sampling; Types of Analyses	Location
Ecological Research Services, Inc.	Summer 1981; mercury, other metals	Deer Lake
MDNR	October 1-2, 1981; mercury, other metals, chlorinated organics	Deer Lake
MDNR	May 8 and August 7, 1982; Mercury	Carp River
	October, 1982; Mercury	Deer Lake
	May and October, 1982; Mercury	Carp Creek
	March 12, 1982; Mercury, other metals	Teal Lake
MDNR	August 1984, Mercury	Carp River
	June 1984, Mercury	Deer Lake
MDNR	February through March 1985, Mercury	Deer Lake

TABLE 4-22. AVERAGE CONCENTRATIONS OF MERCURY OF FISH FROM DEER LAKE, CARP CREEK, AND CARP RIVER, 1981-1985.

	Whole x^1 [n]^2 (range)	Scaled x^1 [n]^2 (range)	Skinned x^1 [n]^2 (range)	Composites of Whole
<u>Carp Creek</u>				
Brook Trout MDNR 1982	0.22 [16] (0.10-0.43)			9 fish =0.42 3 fish =0.27
White Suckers MDNR 1982	0.54 [9] (0.25-0.86)			
Golden Shiners				5 fish =0.57
Bluegills				4 fish =0.21
<u>Deer Lake</u>				
Perch Ludwig 1981	1.29 [12] (0.6-1.7)			
MDNR 1981		1.08 [15] (0.4-2.1)	1.62 [5] (1.0-2.2)	
MDNR 1982	1.56 [17] (0.46-2.3)			6 fish = 0.54
MDNR 1984	0.95 [2] (0.5-1.4)		1.17 [20] (0.6-2.2)	6 fish = 0.50 (0.30-0.60)
MDNR 1985	1.56 [50] (0.96-2.60)			
Northern Pike Ludwig 1981	1.47 [3] (0.8-1.8)			
MDNR 1981		2.24 [10] (1.4-2.9)	2.46 [5] (2.1-2.8)	
MDNR 1982	2.26 [24] (0.71-4.70)			
MDNR 1984	0.97 [3] (0.8-1.1)		1.70 [16] (0.9-3.2)	

TABLE 4-22 CONTINUED

	Whole x^1 [n][2] (range)	Scaled x^1 [n][2] (range)	Skinned x^1 [n][2] (range)	Composites of Whole
MDNR 1985	2.12 [50] (0.99-4.07)			
White Sucker MDNR 1981		0.92 [5] (0.9-1.0)		
MDNR 1984			0.52 [5] (0.4-0.8)	
MDNR 1985	0.65 [13] (0.09-2.03)			
Black Bullheads MDNR 1981	0.54 [10] (0.4-1.1)			
<u>Carp River</u>				
Brook Trout MDNR 1982	0.39 [2] (0.25-0.54)			3 fish =0.17 5 fish =0.23
MDNR 1984				4 fish =0.2 4 fish =0.1
White Suckers MDNR 1982	0.85 [11] (0.5 - 1.2)			
MDNR 1984				6 fish = 0.10 3 fish = 0.10

1 - statistical mean
2 - number of observations

Table 4-23 presents data from fish collected from Teal Lake in 1982. Mercury concentrations ranged from 0.1 to 0.2 mg/kg, which was considerably less than concentrations in Deer Lake fish and below the MDPH advisory limit of 0.5 mg/kg.

4.2.3.2 Bird Contamination

Since fish were contaminated at relative high levels with mercury in Deer Lake and its tributaries, other important animals in this ecosystem were sampled to determine their degree of contamination.

In June of 1982, tissues of several species of birds in or around Deer Lake were collected and analyzed for mercury by the MDNR (Table 4-24). Among nine puddle ducks, muscle tissue averaged 0.36 mg/kg mercury (range 0.1 to 0.65 mg/kg), liver averaged 0.86 mg/kg (range 0.2 to 1.4 mg/kg) and kidney averaged 0.82 mg/kg (range 0.3 to 1.4 mg/kg). The tenth duck had very high concentrations for this type of duck and had 4.9 mg/kg in muscle, 40.0 mg/kg in its liver and 17 mg/kg in its kidney. These concentrations closely paralleled concentrations found in a great blue heron that prey on fish and other aquatic animals. The heron had 6.3 mg/kg in its muscle, 40.0 mg/kg in its liver and 17.0 mg/kg in its kidney. MDNR wildlife biologists indicated that a puddle duck will eat small fish on occasion instead of their normal diet consisting plant materials.

Mallard duck eggs had 0.57 mg/kg mercury in their whites and 0.27 mg/kg in the yolks of a five egg composite sample.

Bald eagles normally prefer a fish diet and were attracted to the rich supply that existed in Deer Lake. Since heavy metals are excreted into hair and feathers by warm blooded animals, feathers from bald eagles near the lake were collected and analyzed for mercury. Feathers from adult bald eagles had mercury concentrations ranging from 1.9 mg/kg mercury in body feathers to 10.0 mg/kg in down to 6.2 to 34.0 mg/kg mercury in primary wing feathers. A primary feather collected from an immature migrant eagle, killed at the nearby Marquette airport by an airplane, had 4.5 mg/kg. Muscle tissue from this bird had 5.6 mg/kg mercury. Eagle feathers usually have mercury concentrations about seven times greater than muscle concentrations. If this immature bird had grown another wing feather while its body burden of mercury was 5.6 mg/kg, the new feather probably would have approached 40.0 mg/kg mercury. Berg, et al. 1966, reported that sea eagles in Scandanavia that have 40 to 65 mg/kg of mercury in their features have eggs that seldom hatch.

Bald eagles have attempted to reproduce near Deer Lake since 1964. The original nest was abandoned in 1976 and another nest was constructed close to the shoreline. The nest history is shown in Table 4-25. No eagle offspring have been produced from the Deer Lake area since records were first kept beginning in 1963 and continuing to the present. In contrast, overall nesting success of bald eagles in Michigan's Upper Peninsula has been excellent. Michigan DNR surveyed reproductive success of bald eagles in the Upper Peninsula and determined that a "normal" pair had a 0.9966 probability of successfully reproducing offspring between 1975 and 1980.

TABLE 4-23. HEAVY METALS IN SKINLESS, BONELESS FISH FILLETS COLLECTED IN TEAL LAKE, MARQUETTE COUNTY, MICHIGAN, MARCH 12, 1982.

Species	Sex	Length (cm)	Zinc (mg/kg wet wt.)	Mercury (mg/kg wet wt.
Yellow Perch	F	30.0	5	0.1
	F	26.3	5	0.1
	M	28.1	6	0.2
	F	25.0	5	0.1
	M	23.1	4	0.1
	F	22.5	5	0.2
	F	22.5	6	0.1
	F	20.6	5	0.1
	F	22.5	6	0.1
	F	24.4	6	0.1
White Sucker	F	46.3	5	0.1
	F	46.3	7	0.1
	F	52.5	5	0.1
	F	8.8	5	0.1
	F	51.3	4	0.1

NOTES: Cadmium, chromium, nickel, copper and lead were less than the 1.0-mg/kg level of detection and arsenic was less than the 0.5-mg/kg level of detection.

TABLE 4-24. CONCENTRATIONS OF MERCURY IN TISSUES OF VARIOUS ANIMALS COLLECTED IN DEER LAKE OR NEARBY, JUNE 1982.

Ducks	Tissue: Muscle	Liver	Kidney	Feathers	
Adult	0.5	1.3	1.4		
Duckling	0.1	0.4	0.4		
Immature	0.1	0.2	0.3		
Immature	0.44	0.96	1.0		
Immature	0.29	0.50	0.52		
Immature	0.65	1.40	1.40		
Immature	0.29	0.78	0.62		
Immature	0.44	1.20	0.84		
Immature	0.46	0.98	0.92		
Immature	4.90*	40.00*	17.00*		
Average (n=9)	0.36	0.86	0.82		
Mallard eggs (5 composite) whites 0.57 mg/kg, yolks 0.27 mg/kg					
Great Blue Heron	6.3	40.0	14.0		
Bald Eagle	--	--	--	Primary	34.0
	--	--	--	Primary	6.2
	--	--	--	Down	10.0
	--	--	--	Body	1.9
Immature migrant**	5.6	--	--	Primary	4.5

*not included in average
**killed at nearby Marquette airport

Turtle eggs	0.8

Source: MDNR Files

TABLE 4-25. BALD EAGLE NEST HISTORY IN THE VICINITY OF DEER LAKE

Year	Nest Condition
1963	Nest site not occupied
1964-1969	Nest occupied, but failed
1970	Uncertain whether occupied
1971	Occupied, outcome uncertain
1972	Nest site not occupied.
1973-1975	Nest occupied, but failed
1976 (new location)	
1976-1980	Nest occupied, but failed
1981	One adult occupied territory

Source: MDNR 1985

Although mercury contamination of eagles appears to be the primary cause of reproductive failure around Deer Lake, other substances, such as DDT, PCB and other pesticides, might have influenced past failures. Analysis of fish from Deer Lake in 1982 by the MDNR, did not reveal significant levels of the above contaminants, however (Appendix A).

4.2.3.3 Other Contaminated Animals

Turtle eggs were also collected along Deer Lake in 1982 by the MDNR and analyzed for mercury. Mercury concentrations were measured at 0.8 mg/kg (Table 4.25). The hatchability rate of turtle eggs with this concentration of mercury is unknown.

4.3 SUMMARY

The one impaired designated identified in the Deer Lake AOC is a degraded fishery due to mercury contamination. A fish consumption advisory has been in effect since 1981 for all species of fish in Deer Lake and since 1982 in Carp Creek and the Carp River. Other animals found to be contaminated to varying degrees with mercury in the Deer Lake AOC were, ducks, duck eggs, great blue heron, bald eagles and turtle eggs. Mercury concentrations in bald eagles were at high concentrations and have probably prevented, in large part, successful reproduction for many years.

The primary sources of mercury were two laboratories of CCI in Ishpeming which used mercury in iron ore analysis. Spent reagents were discharged to the sewer system and eventually reached Carp Creek and Deer Lake. Deer Lake was a highly productive lake due to the loadings of nutrients from three old WWTP's on Carp Creek. A new WWTP replaced the old facilities in 1985 and the combined storm sewers have also been separated at a total cost of about $20 million. In the past, the classic problem with excessive nutrient loads to lakes were evident in Deer Lake: algal blooms, odors, dissolved oxygen depletion in the water column in both winter and summer, and fish kills. Phosphorus loadings have been decreased to a third of the former loadings to the lake and phosphorus is less than 1.0 mg/l in the new WWTP discharge. The future water quality in Deer Lake should be improved considerably but due to the required stabilization of the impoundments volume, comparison with previous studies may not be very meaningful.

Sediments in Deer Lake have elevated concentrations of several heavy metals (zinc, chromium, copper, lead, nickel, and mercury. Of these metals, mercury is of greatest concern because it may serve as a source of contamination of the biota for a period or time. The highest concentration of these metals is near their point of input to Deer Lake via Carp Creek. Mercury from 10 to 15 mg/kg can be found off the Carp Creek inlet. Sediment mercury concentrations near the Deer Lake discharge to the Carp River are less than 3 mg/kg and are usually less than 1.0 mg/kg in the sediments of the Carp River.

Core samples of Deer Lake sediments clearly show that all the heavy metals of concern have been enriched due to man's activities and that mercury was not present at elevated concentrations before lead and other heavy metal began to increase. Sediment heavy metals concentrations were much lower in nearby Teal Lake and Goldmine Lake compared to Deer Lake, even though they have similar soils and subsurface geology.

Mercury from other sources, such as precipitation, mercury trapped in ice and snow during degassing or loads from the Ropes' Goldmine tailings, appear to be insignificant potential sources compared to the surficial sediments in Deer Lake at this time.

5.0 SOURCES OF POLLUTION

The pollutants known to have caused the use impairment that serves as the basis for the AOC in Deer Lake is mercury. The Cleveland Cliffs Iron Company (CCI) maintained two laboratories in the City of Ishpeming and both used mercury compounds. An assay lab, built in 1929, used mercuric chloride in an ore assay process. A research lab, which began operating in 1974, also used mercuric chloride but to a lesser extent. Both labs disposed of the compound through the Ishpeming sewer system (MDNR File). In September 1981, this method of disposal was ceased.

Future potential sources include Deer Lake sediments, aerial transport, runoff of meltwater from tailings, leachate from tailings and natural geologic formations. Data on runoff of ice above tailings is limited to one small survey, yet the results indicate this would be a insignificant intermittent source. Data on leachate from tailings is also limited and indicates that this is not a major source. Information on natural inputs from geologic sources is the most limited, but core sample data indicate it is not great.

These sources of pollutants are discussed in greater detail below.

5.1 PRIMARY SOURCES OF POLLUTION

5.1.1 Point Sources

5.1.1.1 Ishpeming Wastewater Treatment Plants

In 1964, three primary sewage treatment plants were constructed to serve the City of Ishpeming, the northern portion of Ishpeming Township, and the western portion of Ishpeming Township. The location of these plants are shown in Figure 4-4. Information on flow and level of treatment of these plants, as well as for the current Marquette and Negaunee WWTPs which also discharge to the Carp River, is shown in Table 5-1.

The three WWTPs were subject to routine combined sewage overflows (MDNR File). The Ishpeming Plant experienced high rates of infiltration/inflow to the system. Based on the design flow (2.0 MGD) and population served (7,375), expected wastewater flows would be approximately 0.8 MGD (D'Itri 1983). The actual flow into the plant ranged from 1.6 MGD to 4.0 MGD.

Data from effluent analyses at the Ishpeming WWTP are shown in Tables 5-2. Concentrations of mercury in effluent show a considerable decrease from 1981 to 1984, which is likely related to the discontinuance of CCI's disposal of mercury via the sewer system. Concentrations of copper and zinc also showed large decreases. Silver and cadmium were quantified in 1984 but not in 1981. Other metals that were tested for but not detected in either year were chromium, nickel, and lead. Mercury, lead, zinc and silver were elevated in sludge in 1981.

TABLE 5-1. DESIGN FLOW AND LEVEL OF TREATMENT OF MUNICIPAL WASTEWATER TREATMENT PLANTS DISCHARGING TO CARP CREEK AND CARP RIVER.

WWTP	Population SERVED	Design Flow (MGD)	Level of Treatment	Receiving Water
Ishpeming	7,375	2.0	Primary 1964-1985	Carp Creek
Ishpeming Twp. Plant A	1,400	0.2	Primary 1965-1985	Carp Creek
Ishpeming Twp. Plant B	270	0.07	Primary 1964-1985	Carp Creek
Marquette*	44,100	6.2	Secondary with phosphorus removal	Carp River
Negaunee*	5,450	1.2	Secondary with phosphorus removal	Carp River

*Located below Deer Lake outlet; on line facilities.

TABLE 5-2 ISHPEMING WWTP EFFLUENT SURVEY RESULTS OF COMPOSITE WATER SAMPLES COLLECTED OVER A 24-48 HOUR PERIOD. NM - Not Measured.

Date	Flow (MPG)	Tot. P (mg/1)	Amm-N (mg/1)	5-Day BOD (mg/1)	Metals	Organic Contaminants
9/8-10/70	1.6	2.5	5.2	40.0	NM	NM
8/21-22/79	2.5	0.9	4.6	33.0	NM	NM
10/12-13/81	1.8	1.9	7.2	59.0	1.6 ug/1 Hg 100 ug/1 Cu 95 ug/1 Zn Other metals less than detection levels	NM
5/15-16/84	2.5	1.2	3.9	30.0	0.5 ug/1 Hg 25 ug/1 Cu 4.0 ug/1 Ag 0.9 ug/1 Cd Other metals less than detection levels	4.9 ug/1 chloroform 5.6 ug/1 toluene All other organic contaminants less than detection levels

Source: MDNR File

Copper and zinc were found in the WWTP sludge at elevated concentrations in 1984 (Table 5-3). The decrease in mercury concentrations in effluent from 1981 to 1984 was paralleled by a drop in sludge concentrations.

In 1981, Michigan State University (MSU) completed a study of WWTP sludge in Michigan. Sludge from the Ishpeming WWTP was sampled and contained 27 mg/kg dry weight of mercury. The average mercury concentration for all WWTPs sampled was approximately 5 mg/kg dry weight. Other WWTPs in the Area of Concern (AOC), which were sampled in the study, are listed below along with their associated sludge mercury concentrations.

WWTP	Mercury (mg/kg dry weight)
Ishpeming Township A	2.1
Ishpeming Township B	1.5
Negaunee	4.3
Marquette	8.0

The Marquette WWTP sludge contained a relatively high concentration of mercury. This facility discharges to the Carp River and may act as another minor source of mercury to the system below Deer Lake. The Negaunee STP may also act as another minor source. The concentration of mercury in the sludge is dependent on the quantity in the effluent and the ability of the WWTP to remove solids. Concentrations of mercury in sludge are approximately 100 to 1,000 times higher than in effluent (D'Itri 1983).

In 1981, the concentration of lead in Ishpeming WWTP sludge (200 mg/kg dry weight) was below the MSU survey average (400 mg/kg dry weight). The concentration of zinc at Ishpeming (350.0 mg/kg dry weight) was well below the MSU Survey Average (3,000 mg/kg dry weight). The concentration of silver at Ishpeming (15 mg/kg dry weight) exceeded slightly the average reported by MSU (10 mg/kg dry weight). Silver concentrations in sludge at Marquette (38 mg/kg dry weight) and Negaunee (28 mg/kg dry weight) were considerably higher than the MSU survey average.

Table 5-4 shows 1985 sampling results from the old Ishpeming WWTP. Mercury was present in influent and effluent. Mercury in sludge was higher in 1985 (12.42 mg/kg dry weight) than 1984 (1.1 mg/kg dry weight), but the 1985 concentration was lower than the 1981 concentration. In 1982 the sludge digester was cleaned. Approximately 120,000 gallons of digester effluent were recycled into the influent at the plant for treatment and then released (pers. comm., Jack Rydquist, MDNR, August 1987).

Results of sampling effluent and sludge at the old Ishpeming Township plants are shown in Tables 5-5 and 5-6, respectively. The samples were collected on October 12 and 13, 1981.

The new Ishpeming WWTP began operating in April 1986. Construction began in 1984. The new plant serves the total areas previously served by the three separate plants. In addition to the new WWTP, the combined sewers in the area have been eliminated. This should result in fewer sewage overflows to Carp Creek (MDNR File).

TABLE 5-3 HEAVY METAL CONCENTRATIONS (mg/kg dry weight) IN RAW SLUDGE SAMPLES COLLECTED FROM THE ISHPEMING WWTP. ORGANIC CONTAMINANTS DATA WERE NOT AVAILABLE. MN - Not measured.

	Al	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Ag
10/13/81	NM	NM	NM	NM	NM	33.0	NM	15.0	200.0	350.0	15.0
5/15/84	1600	2.5	24.0	130.0	7200.0	1.1	130.0	8.0	27.0	130.0	NM

Source: MDNR File

TABLE 5-4. TOTAL MERCURY ANALYSIS OF EFFLUENT FROM ISHPEMING SEWAGE TREATMENT PLANT (ISTP).

Source	Sample Type	Collection Date 1985	Hg (ug/1)
ISTP Influent	Grab	April 3	0.22
ISTP Influent	Composite	May 8	0.36
ISTP Digestor Effluent	Grab	April 3	0.47
ISTP Digestor Effluent	Composite	May 8	0.29
ISTP Final Effluent	Grab	April 3	0.11
ISTP Final Effluent	Composite	May 8	0.25
ISTP Digestor Sludge	Grab	April 3	12.42*

*mg/kg on a dry weight basis

Source: MDNR

TABLE 5-5. EFFLUENT SURVEY RESULTS OF COMPOSITE WATER SAMPLES COLLECTED FROM THE TWO ISHPEMING TOWNSHIP WWTPs (Plants A and B) IN OCTOBER 1981.

	Flow (MGD)	Tot. P (mg/l)	Amm-N (mg/l)	5-day BOD (mg/l)	Metals
Plant A	0.2	5.5	21.0	170.0	20 ug/l Cd
					50 ug/l Cr
					65 ug/l Cu
					50 ug/l Ni
					100 ug/l Pb
					85 ug/l Zn
					1 ug/l Hg
Plant B	0.1	7.3	30.0	270.0	20 ug/l Cd
					50 ug/l Cr
					310 ug/l Cu
					50 ug/l Ni
					50 ug/l Pb
					140 ug/l Zn
					1 ug/l Hg

Source: MDNR File

TABLE 5-6. HEAVY METAL CONCENTRATIONS (mg/kg dry weight) IN SLUDGE SAMPLES COLLECTED FROM THE TWO ISHPEMING TOWNSHIP WWTPs. ORGANIC CONTAMINANTS DATA WERE NOT AVAILABLE. NM = Not measured. (Date collected October 1981)

	Cd	Cr	Cu	Ni	Pb	Zn	Hg
Plant A	3.0	20.0	650.0	14.0	130.0	NM	3.3
Plant B	2.0	20.0	240.0	8.0	70.0	430.0	NM

Source: MDNR File

The new plant has a design flow of 2.34 MGD and phosphorous and nitrogen removal capabilities.

Effluent and sludge data collected from the plant are shown in Tables 5-7 and 5-8, respectively. The effluent was sampled on three days during the time period from December 1986 to January 1987 (pers. comm., Fred Minnich, Director, Ishpeming WWTP, August 14, 1987). The sludge was sampled on October 29, 1986 (letter from Dale G. Brockway, Groundwater Quality Division to Fred Minnich, Director, Ishpeming WWTP, February 5, 1987). In addition, the final effluent and aerobic digester sludge were sampled for organic contaminants in winter 1986-87. No organics were present in concentrations high enough to be quantified.

The effluent was monitored for contaminants found in the sludge in order to determine if the plant's NPDES permit should contain limits for the sampled materials. Based on the results, the WWTP does not need to set limits for these materials (Michigan Water Resources Commission, NPDES Permit No. MI 0044423; pers. comm., Jack Rydquist, MDNR, August 1987).

Mercury (7.8 mg/kg) and copper (1770 mg/kg) concentrations were considered elevated in sludge (pers. comm., Letter from Dale G. Brockway, Groundwater Quality Division, to Fred Minnich, Director, Ishpeming WWTP, February 5, 1987). The 1986 mercury concentration is lower than those reported at the old Ishpeming plant in 1981 (33 mg/kg) and 1985 (12.42 mg/kg), but higher than the 1984 sample (1.1 mg/kg). The 1986 concentration (7.8 mg/kg dry weight) somewhat exceeds the average determined in the MSU 1981 survey (5.0 mg/kg dry weight). Continued sludge monitoring is necessary to determine the variation in mercury sludge concentrations.

Copper concentration in a single sludge sample was higher than 1984 (130 mg/kg dry weight) to 1986 (1,770 mg/kg dry weight). The reason for the increase is not known at this time. Again, additional monitoring of sludge is needed to determine copper variations in sludge. As with mercury, if concentrations of copper remain elevated, possible sources should be determined.

Despite elevated levels of mercury and copper, the sludge is considered acceptable for land application (pers. comm., Letter from Dale G. Brockway, Groundwater Quality Division to Fred Minnich, Director, Ishpeming WWTP, February 5, 1987).

According to MDNR, other point source dischargers in the Deer Lake area, aside from the Ishpeming WWTP, are not believed to significantly impact the AOC (personal communication, Jack Rydquist, MDNR, August 1987).

5.1.1.2 Indirect Dischargers

Several industries discharge process and sanitary wastewater to the Ishpeming WWTP. The industries discharging to the WWTP are Cleveland Cliffs Iron Co. (2 facilities), Globe Printing, and Armco Inc. Tables 5-9 through 5-12 present information on use and disposal of critical materials for all companies listed above as reported in the Michigan Critical Materials Register. In addition, the Empire Iron Mining partnership is known to store and/or use critical material(s) but more specific information was not available.

TABLE 5-7. CONCENTRATIONS OF METALS IN FINAL EFFLUENT OF THE ISHPEMING WWTP - THREE DAYS IN DECEMBER 1986 - JANUARY 1987

Parameter	Final Effluent Concentration (mg/l)			Detection Limit (mg/l)
Arsenic	0.002	0.002	0.002	0.050
Cadmium	0.0002	0.0002	0.0002	0.0002
Chromium (total)	0.005	0.005	0.005	0.050
Chromium (hex)	0.005	0.005	0.005	0.0010
Copper	0.04	0.03	0.04	0.010
Lead	0.002	0.006	0.003	0.0005
Mercury	0.0002	0.0002	0.0002	0.0002
Nickel	0.05	0.05	0.05	0.050
Silver	0.0004	0.002	0.0009	0.0002
Zinc	0.04	0.07	0.08	0.050
Cyanide (Amenable)	0.027	0.012	0.08	0.001

TABLE 5-8. ANALYSES OF SLUDGE FROM THE NEW ISHPEMING WWTP-SAMPLE COLLECTED OCTOBER 29, 1986. All values on a dry weight basis.

Constituent	Concentration	Units
Total solids	8.2	%
TKN	4.7	%
P	4.1	%
K	1,680	mg/kg
Na	735	mg/kg
Ca	1.85	%
Mg	5,000	mg/kg
Al	1.24	%
Cd	5.3	mg/kg
Cr	77.4	mg/kg
Cu	1,770	mg/kg
Hg	7.8	mg/kg
Mo	25.4	mg/kg
Ni	27.0	mg/kg
Pb	316.0	mg/kg
Se	3.7	mg/kg
Zn	1,100	mg/kg
As	7.0	mg/kg
Be	2.0	mg/kg
Fe	3.9	%
Mn	2,200	mg/kg
Ti	31.8	mg/kg
V	11.1	mg/kg

Source: Letter to Fred Minnich, Director, Ishpeming WWTP, from Dale G. Brockway, Groundwater Division, MDNR, February 5, 1987)

TABLE 5-9. WASTE DISPOSAL INFORMATION FROM THE CLEVELAND CLIFFS IRON CO. (FACILITY 880456)

Discharger:	Cleveland Cliffs Iron Co.
Facility:	880456
SIC No.:	1081

Critical Materials[1]	Use[2]	Dis[3]	Res[4]
Chloroform	1-10	1-10	0
Chromium	1	1	0
Mercury	1	0	1

Effluent Characteristics:

% Process:	70
% Cooling:	0
% Sanitary:	30
Average daily flow:	0.043 MGD
Maximum daily flow:	0.045 MGD
Total annual flow:	1119.7 MGY

Wastewater Residual Characteristics:

Critical Material[5]:	Mercury
Physical State:	Liquid
Solvent:	Water
Residual results from:	(not available)
Amount of residue:	4 gallons

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[1]Hazardous materials used in production and/or storage.

[2]Amount of material used in pounds/year.

[3]Amount of material discharged to WWTP in pounds/year.

[4]Amount of material left in residual waste in pounds/year.

[5]Critical material present in residue.

(Source: MDNR printout of Critical Materials Register entries to Ishpeming WWTP, dated 4/23/85).

TABLE 5-10. WASTE DISPOSAL INFORMATION FROM THE CLEVELAND CLIFFS IRON CO. (FACILITY 932572)

Discharger: Cleveland Cliffs Iron Co.
Facility: 932572
SIC No.: 1081

Critical Materials[1]	Use[2]	Dis[3]	Res[4]
Chloroform	11-100	11-100	
Chromium	11-100	0	11-100
Mercury	11-100	0	11-100

Effluent Characteristics:

% Process:	95
% Cooling:	0
% Sanitary:	5
Average daily flow:	0.052 MGD
Maximum daily flow:	0.070 MGD
Total annual flow:	1263.3 MGY

Wastewater Residual Characteristics:

Critical Material[5]:	Mercury
Physical State:	Liquid
Solvent:	Water
Residual results from:	(not available)
Amount of residue:	1,056 gallons
Disposal:	(not available)
Storage:	

[1] Hazardous materials used in production and/or storage.

[2] Amount of material used in pounds/year.

[3] Amount of material discharged to WWTP in pounds/year.

[4] Amount of material left in residual waste in pounds/year.

[5] Critical material present in residue.

(Source: MDNR printout of Critical Materials Register entries to Ishpeming WWTP, dated 4/23/85).

TABLE 5-11. WASTE DISPOSAL INFORMATION FOR GLOBE PRINTING

Discharger: Globe Printing
Facility: 939249
SIC No.: 2750

Critical Materials[1]	Use[2]	Dis[3]	Res[4]
Silver	1-10	1-10	0

Effluent Characteristics:

% Process: 1
% Cooling: 0
% Sanitary: 99
Average daily flow: 0.001 MGD
Maximum daily flow: 0.002 MGD
Total annual flow: 0.0 MGY

Wastewater Residual Characteristics:
No residuals generated.

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[1]Hazardous materials used in production and/or storage.

[2]Amount of material used in pounds/year.

[3]Amount of material discharged to WWTP in pounds/year.

[4]Amount of material left in residual waste in pounds/year.

(Source: MDNR printout of Critical Materials Register entries to Ishpeming WWTP, dated 4/23/85).

TABLE 5-12. WASTE DISPOSAL INFORMATION FOR ARMCO, INC.

Discharger: Armco Inc.
Facility: 520012
SIC No.: 3320

Critical Materials[1]	Use[2]	Dis[3]	Res[4]
Nickel	X[5]	0	101-500
Chromium	X[5]	0	15,648

Effluent Characteristics:

% Process:	33
% Cooling:	66
% Sanitary:	0
Average daily flow:	0.8550 MGD
Maximum daily flow:	0.8550 MGD
Total annual flow:	300.0 MGY

Wastewater Residual Characteristics:
No information.

[1]Hazardous materials used in production and/or storage.

[2]Amount of material used in pounds/year.

[3]Amount of material discharged to WWTP in pounds/year.

[4]Amount of material left in residual waste in pounds/year.

(Source: MDNR printout of Critical Materials Register entries to Ishpeming WWTP, dated 4/23/85).

The critical materials discharged directly to the Ishpeming WWTP in limited amounts are chloroform (by CCI), zinc (by CCI), and silver (by Globe Printing). Other critical materials used by the industries are mercury (by CCI), chromium (by CCI and Armco Inc.), and nickel (by Armco, Inc.). Mercury, chromium, and nickel containing wastes are not discharged into effluent by the users, but are disposed of as residual waste.

Effluent from indirect dischargers has been evaluated in order to determine the need for a pretreatment program at the Ishpeming WWTP. It was determined that a pretreatment program was not necessary (pers. comm., Steve Casey, MDNR, August 18, 1987).

D'Itri (1983), citing the MSU sewage sludge survey conducted in 1981, noted several sources of mercury to WWTPs that may go undocumented. These potential sources include inputs from hospitals, schools, the agricultural industry, and the disposal of consumer goods. It was noted that ammonia and TKN analyses conducted at WWTPs may be performed with reagents containing mercury. Most WWTPs sampled in the MSU survey had no known sources of mercury input, yet average sludge concentration was 5 mg/kg.

Cleveland Cliffs Iron Company

As was mentioned earlier, Cleveland Cliffs Iron Company (CCI) disposed of mercuric chloride through drains in its labs which fed into the Ishpeming combined sewer system. An estimated 40 pounds of mercuric chloride, equal to about 30 pounds of mercury, was disposed of annually (D'Itri 1983). This amount approximates the total amount found in the yearly volume of sludge (memo from Jack Rydquist to Ishpeming File, October 13, 1981).

When the problem of mercury contamination in fish became apparent in 1981, CCI immediately stopped washing mercuric chloride down the drains. Information was not available on quantity or the number of years CCI was disposing of mercury in this way, however, two labs used the substance and one lab opened in 1929 and the other in 1947.

Combined Sewer Overflows

Prior to 1986, the sewer system of Ishpeming was combined. By 1986, the sewers were separated and Ishpeming WWTP completed storm and sanitary sewers are currently separated.

The discharge points of the new storm sewer system are the same as those of the old combined sewer system. The system has two points of discharge to Carp Creek. A 72-inch sewer outfall which receives stormwater from most of the City of Ishpeming, is located at Lakeshore Drive between U.S. 41 and Greenwood Street. Two smaller sewers, 24 inches and 36 inches, have outfalls located 600 to 700 yards upstream of the old Ishpeming WWTP (personal communication, Ed Dobson, Department of Public Works, August 14, 1987).

The effluent from these sewers has not been sampled (pers. comm., Ed Dobson, Department of Public Works, August 14, 1987), however MDNR sampled sediment near these outfalls in 1981 (Table 4-12, Figure 4-9). The mercury concentration in sediments near the 72 inch outfall was 1 mg/kg dry weight. Sediment mercury concentrations near the 36 inch outfall was 7.8 mg/kg.

5.2 SECONDARY SOURCES OF POLLUTION

Secondary sources of pollution to Deer Lake include leachate from tailings, potential groundwater inputs, aerial transport and deposition and runoff from snow and ice.

In 1982, the Michigan Department of Natural Resources (MDNR) used the elutriate test to determine if mercury in surface sediments and tailings in the vicinity of Ropes' Goldmine was readily available. Elutriates contained less than 0.1 ug/l mercury.

Natural geologic formations in the area are probably a minor source of mercury for surface waters. Neither the quantity of mercury which enters the system from this source nor the method of transport have been documented.

Data presented in Chapter 4 of this report show detectable concentrations of mercury in ice and snow. Runoff, upon melting, may be an intermittent source of mercury to the system.

6.0 POLLUTANT TRANSPORT MECHANISMS AND LOADINGS

Prior to 1981 the major source of mercury to the AOC was the effluent of the wastewater treatment plant at Ishpeming. Ishpeming WWTP received mercury contaminated liquid waste from the Cleveland Cliffs Iron Company (CCI) test laboratories through the municipal sewerage system. The effluent from the WWTP went directly to Carp Creek near the entrance to Deer Lake. MDNR determined that approximately 30 pounds of mercury (13.6 kg) per year were being discharged to the sewer system by CCI.

6.1 MAJOR LOADINGS

6.1.1 Nutrients from WWTPS

In 1972, the U. S. Environmental Protection Agency (USEPA) calculated phosphorous (P) and nitrogen (N) loadings to Deer Lake from wastewater treatment plants (WWTPs) as part of a nutrient budget for Deer Lake. The yearly loading of total P from all WWTPs combined to Carp Creek was 15,960 pounds. The yearly loading of total N from all WWTPs was 69,090 pounds.

Table 6-1 shows loadings of BOD-5, suspended solids (SS), and total P from the new Ishpeming WWTP to Carp Creek over the 12 month period of July 1986 to June 1987. The data were obtained from Monthly Operating Reports of the plant. The annual loading of total P was 2,100 pounds, a substantial reduction from 1972.

A similar budget will be completed in the future for comparison to determine the effects of the new WWTP or phosphorus loadings. Limnological investigations of the lake will be undertaken once it becomes stabilized.

Mercury

Little information on mercury loadings from the Ishpeming WWTP to Carp Creek is available. D'Itri (1983) estimated a daily and yearly loading based on a sample obtained from effluent in 1981 (Table 5-2) and average flows from the WWTP. The mercury concentration of the sample was 1.6 ug/l. Assuming a daily average concentration of 1.6 ug/l and a flow of 1.8 MGD, the daily average loading of mercury to Carp Creek would be 11 grams (gm) per day or approximately 4 kilograms (kg) per year.

6.2 SECONDARY LOADINGS

As was stated in Chapter 5, secondary sources of mercury to Deer Lake include sediments, leachate from aerial loadings, tailings, runoff from ice and snow, and geologic formations. The loadings of mercury from these sources to Deer Lake have not been investigated. D'Itri (1983), however, estimated the loadings from meltwaters.

The ice layer above Ropes' Gold Mine tailings contained 2.2 ug/l mercury (see Chapter 4). D'Itri (1983) assumed the concentration was typical of ice throughout the Deer Lake watershed. Given the surface areas of the

TABLE 6-1. LOADINGS OF BOD-5, SUSPENDED SOLIDS, AND TOTAL PHOSPHORUS TO CARP CREEK FROM THE ISHPEMING WWTP. JULY 1986 - JUNE 1987[1]

Month[4]	BOD-5	SS[2]	TP[3]	Range of Percent P-Removal
July 1986	3,600	5,574	435	11-77
August4	1,925	2,510	283	36-93
September	1,753	2,355	123	69-94
October	2,812	2,102	155	63-87
November	2,051	1,783	122	67-91
December	2,047	1,697	134	76-92
January 1987	2,049	2,218	112	74-92
February	2,127	3,366	139	78-90
March	2,901	4,864	161	39-91
April	3,124	3,124	153	75-89
May	2,506	3,139	154	69-88
June	1,823	2,376	129	74-90
Pounds per year	29,018	35,108	2,100	

[1]Monthly loadings are in pounds per month. Yearly loadings are in pounds per year. Monthly loadings are sums of 22 days of data per month.

[2]SS is suspended solids

[3]TP is total phosphorus

[4]All months are missing 9 days of data.

entire watershed, approximately 23,250 acres (9,413 hectares), D'Itri (1983) calculated a potential loading of about 114.4 pounds (52 kg) of mercury annually for the lake. These estimates should be considered highly speculative.

Information reviewed for this report did not contain data on loadings of other metals to Deer Lake.

6.3 IN-PLACE POLLUTANTS

The in place pollutant of primary concern in Deer Lake is mercury where concentrations range from about 2.0 mg/kg to 15 mg/kg in depositional of areas of the lake. Carp Creek and the Carp River downstream of Deer Lake have concentrations of mercury in their sediments of about 1.0 mg/kg or less. The mechanism by which the sediment bound mercury could become available were discussed in Section 4.2.2.1 and shown in Figure 4-19. Most of the sediments containing elevated concentrations of mercury will be in deep water when the impoundment is filled and maintained at maximum capacity. The lake will be productive enough to maintain anoxic conditions in sediments during the warm seasons of the year, at least. Thus, sediment bound mercury may be largely unavailable in this system and recovery may proceed more rapidly than in less productive mercury contaminated lakes and streams.

6.4 DEER LAKE AOC IMPACTS ON THE LAKE SUPERIOR ECOSYSTEM

Mercury in the water column of the Carp River downstream of Deer Lake has seldom been measured above the detection limit of 0.1 ug/l nor above the IJC 0.2 ug/l in a filtered sample. Annual loadings estimated for the Carp River based on half the level of detection (0.05 ug/l), 0.1 ug/l and 0.2 ug/l with a mean annual discharge of 88.8 cts are: 4, 8 and 16 kg/yr.

The Marquette coal fired power plants on Lake Superior burn approximately 1,328,000 metric tons of coal per year. Assuming an average concentration of 1 mg/kg in the coal, almost all of which is gassed to the atmosphere when the coal is burned, a load of 1328 kg/yr of mercury is discharged. Additional potential mercury loads to Lake Superior of a similar magnitude from this area would result from the combustion of oil (1 mg/kg), wood (0.02 mg/kg), paints and from other mercury uses. Clearly, the mercury loading to Lake Superior from the deer Lake AOC is insignificant.

7.0 HISTORICAL RECORD OF REMEDIAL ACTIONS

The following sections provide an overview of completed activities and is or activities currently underway to improve environmental conditions and restore beneficial uses in the Deer Lake system.

7.1 COMPLETED ACTIONS

Construction of a new WWTP and separation of CSOs in the City of Ishpeming was undertaken to meet the requirements of both State and Federal laws. The City was ordered to upgrade its wastewater management by the Michigan Water Resources Commission in 1970.

When it became apparent, in 1981, that fish were heavily contaminated with mercury, a health advisory was issued by the MDPH. Fishing continued in the lake and a program was undertaken to eradicate fish and thus limit human and wildlife exposure. The eradication occurred in 3 stages. First (in the fall of 1984), the lake was drawn down to its lowest level and a sharpened grate was placed across the outlet pipe at the Carp River dam, to kill the fish. The dead fish were not removed from the system. Removal was not deemed necessary for two reasons: 1) when fish contaminated with methylmercury decompose under aerobic conditions (which were assumed present in Carp River) most of the methylmercury is converted to dimethyl mercury and released to the atmosphere, and 2) it was felt that any additional input of mercury from decomposing fish would be insignificant in light of the historic loadings (pers. comm., Elwin Evans, MDNR, August 19, 1987).

In the winter of 1985-1986, MDNR netted and killed 1,500 pounds of fish in the remaining Deer Lake. The fish were not removed from the lake because the mercury input was deemed insignificant relative to historic loadings (pers. comm., Elwin Evans, MDNR, August 19, 1987). The final action taken to eradicate fish occurred in the winter of 1986-1987. The MDNR asked CCI to construct a channel to divert flows from Carp Creek around the lake. This prevented dilution and downstream transport of rotenone. Fish remaining in the deepest portion of the lake were then killed with rotenone. The dead fish were not removed.

During the time the lake was drawn down, the WWTPs along Carp Creek did not alter their effluent quality. Water quality in the lake appeared to deteriorate somewhat during drawdown (pers. comm., Elwin Evans, MDNR, August 19, 1987).

Stabilization of water level in Deer lake will be undertaken as a method of natural restoration. According to D'Itri, 1983, CCI's consultant, stabilization will minimize production and release of methylmercury to the water column.

As a result of lake level stabilization, sediments will not be agitated and exposure to oxygenated water in spring, which could result in transformation of inorganic mercury to methylmercury. Reductions in nutrient loadings may result in reducing the duration and extent of anoxia in sediments. The MDNR estimates that in the first 3-5 years, restocked fish will show elevated concentrations of mercury in their tissue. Within 5-8 years after refilling of the lake, MDNR estimates that mercury in bottom sediments of the lake will be buried and not available. Subsequently, concentrations of mercury in fish tissue should decrease (Consent Judgment 1984; pers. comm., Elwin Evans, MDNR, August 19, 1987).

Summary Table of Remedial Actions

Date	Event
1964	Three primary wastewater treatment plants commenced operation in the City of Ishpeming and the two Ishpeming Townships.
1970	Michigan Water Resources Commission ordered the City of Ishpeming and the two Townships to begin removing phosphorus from their wastewater.
1981	Ropes' Goldmine environmental impact assessment identified mercury contamination in Deer Lake fish and sediments.
1981	CCI terminated mercury discharge to Ishpeming WWTP.
1984 Fall	A Consent Judgment was signed between the State of Michigan and CCI which identifies a restoration plan for mercury contamination in Deer Lake and monitoring requirements (Appendix E). The Consent Judgment mandated that: 1. CCI grant MDNR ownership of surface rights to a parcel of land (1000 ft lake frontage) abutting Brocky Lake in Marquette County for a fee of $1.00; 2. CCI grant MDNR a twenty year lease to surface rights on land (200 ft lake frontage) abutting Lake Angeline in Marquette County. MDNR paid CCI $1.00 for the 20 year lease and may pay $1.00 for any future renewal; and 3. CCI grant a 20 year lease to the surface rights on land (250 ft lake frontage) abutting Goose Lake in Marquette County. MDNR paid CCI $1.00 for the 20 year lease and may pay $1.00 for any future renewal. These grants were mandated to replace the loss of beneficial uses of Deer Lake by the public during restoration.

1984 Fall	Deer Lake was drawn down to its lowest level in order to eradicate fish and minimize human and wildlife exposure. Fish were killed in a grate placed at the outlet pipe of Carp River dam but were not removed from the system.
1984-1985 Winter	Fisheries Division of MDNR netted 1500 pounds of fish under ice in Deer Lake. This was part of the fish eradication effort. The fish were killed in the net and returned to Deer Lake.
1986 Spring	New secondary WWTP (with phosphorus and nitrogen removal) commenced operation and replaced the three primary WWTPs.
1986 Fall	Flow of Carp Creek was diverted around the remaining lake through a channel constructed by CCI. Fish remaining in isolated Deer Lake were then killed with rotenone. This was the last action taken to eradicate mercury contaminated fish in the lake. The fish were not removed from the lake.
1987 Spring	Gates to the dam were partially closed and Deer Lake was allowed to refill. The lake was restocked with 15,000 adult yellow perch transported from nearby Silver Lake; 900,000 - 1,000,000 walleye fry; 19,500 fingerling walleye. A similar stocking program will be carried out in 1988-1990. Fingerling walleye may be stocked at higher rates if warranted.

Restoration Plan for Mercury Contamination in Deer Lake

As was mentioned in Chapter 2, after a suit was filed against CCI in 1982, the company hired a consultant to make recommendations for abatement of mercury contamination. The consultant recommended a method of natural rehabilitation augmented by frequent monitoring of fish, sediments and Ishpeming WWTP digester effluent, final effluent and digestor sludge. The consultant reviewed a number of methods of decontamination including dredging, covering contaminated sediments with inert materials, covering sediments with nylon polymer or plastic films, and raising the pH of the lake through application of calcium carbonate. With the exception of dredging, most methods of mercury remediation have only been attempted in aquaria or in limited field experiments. Dredging was not recommended primarily because of the high probability of resuspending buried contaminated sediments and tailings, engineering difficulties, complications associated with disposal of dredge spoil, and because the scientific literature reviewed included only one dredging study of a lake. The most commonly employed and well documented restoration process for removing mercury from natural waters is natural attenuation. In order for natural restoration to occur, mercury loadings to the lake must cease and, based on the consultant's report, the water level should remain stable (D'Itri 1983).

The seasonal fluctuation of water level in Deer Lake exposed anaerobic bottom sediments. Agitation of sediments by draining and refilling the lake was believed to create conditions which allowed transformations of sediment bound mercury into methylmercury. The methylmercury subsequently released to the water column, may be available for bioacumulation (D'Itri 1983). In spring, when oxygenated water refilled the lake, sediment bound mercury may become oxidized and converted to methylmercury. This occurs as long as the mud-water interface is oxygenated. Once oxygen is depleted, the transformation is greatly reduced (pers. comm., Elwin Evans, MDNR, August 19, 1987).

The Consent Judgment states that CCI shall operate the dam at Carp River to stabilize water level in the lake for 10 years. The MDNR and CCI believe that Deer Lake stabilization will not necessitate an alteration in discharges from the Negaunee WWTP, located on Carp River downstream of Deer Lake. If, however, flows in the Carp River prove to be inadequate, MDNR will recommend to the Michigan Water Resources Commission (MWRC) and USEPA a modification of discharge requirements for the Negaunee WWTP for the duration of the restoration program. If the MWRC or USEPA do not agree with MDNR recommendations, the issue will be brought before the court which issued the Consent Judgment (Consent Judgment 1984). The recommended monitoring program in the consultant's report (D'Itri 1983) is the same as that appearing in the Consent Judgment, except the Consent Judgment added a date when fish monitoring should begin and that the monitoring program should continue for 10 years.

Table 7-1 shows the monitoring program. The Consent Judgment states that within 60 days of the entry of the Judgment, CCI shall submit a more detailed monitoring program and schedule to MDNR for review and approval. A revised report was submitted (pers. comm., Elwin Evans, MDNR, August 19, 1987) but not included in the information reviewed for this report.

Monitoring of fish and sediment in Deer Lake, and effluent and sludge at the new Ishpeming WWTP has continued (per. comm., Elwin Evans, MDNR, August 19, 1987). However, in 1986, CCI and MDNR agreed to use part of the monitoring funds to divert Carp Creek so that fish in the remaining impoundment could be rotenoned (pers. comm., Elwin Evans, MDNR, August 19, 1987).

CCI agreed to pay Michigan DNR $10,000 for past and future field costs, research and laboratory fees. They have paid an additional $10,000 to MDNR for eradication and restocking Deer Lake. These monies were paid within 30 days after the consent judgment was signed in November 1984.

7.2 ACTIONS CURRENTLY IN PROGRESS

The remedial actions currently in progress include stabilization of water level in Deer Lake, restocking of the lake and monitoring to determine if the lake is actually undergoing natural restoration.

TABLE 7-1. TEN YEAR MONITORING PROGRAM FOR DEER LAKE CONSENT JUDGMENT 1984

I. Fish--monitor (to begin in 1985) once per year in three size classes:
   A. Pike (Small, Medium, and Large) 10 each
   B. Perch (Small, Medium, and Large) 10 each
   C. Suckers (Small, Medium, and Large) 10 each (This will monitor the benthic uptake)

   There is no need to monitor bullheads, snails, and algae because they always seem to contain relatively low levels of mercury.

II. SEDIMENTS

   Use sediment traps to collect samples of the particulate matter in the water column which are being directed to the sediments. Suggested locations would be in the lake near the mouth of Carp Creek and immediately before the spillway at the dam. These sediment traps can be left in place 1 to 6 months depending on the sedimentation rates.

III. The Ishpeming Sewage Treatment Plant
   A. STP influent--24 hour composites once a month
   B. STP Digestor effluent--24 hours composites once a month
   C. STP Final effluent--24 hour composites once a month
   D. STP Digestor Sludge--Two times per year, i.e., early March and August or September to coincide with low flow conditions in the plant.

IV. MISCELLANEOUS
   A. Ice cover in tailings deposits area--once per year before spring melt--3 sampling sites
   B. Ice cover in Deer Lake watershed area--once a year before spring melt--6-10 sampling sites

8.0 SPECIFIC GOALS, OBJECTIVES, AND MILESTONES FOR RESTORATION

The main goal of the Deer Lake remedial actions is to restore the impaired sport fishery and thus reduce the potential for toxic impacts to human health and wildlife from eating contaminated fish. The specific remedial objectives are to erradicate contaminated fish and then allow the lake to restore itself naturally, as the mercury contaminated sediments become buried under uncontaminated sediments. Fish were eradicated by 1987 and recovery has begun. It is not certain to what extent natural restoration will reduce the bioavailability of mercury. It is also difficult to predict how much time will be needed to reduce mercury levels in the fish tissue and sediments to acceptable levels (pers. comm., Elwin Evans, MDNR, August 1987).

Studies done on mercury contamination at other lakes (Lake St. Clair, Lake Paijanne) have shown that, after mercury sources have been eliminated, levels of mercury in fish tissue gradually decrease (Nearly 1981; Paasivirta 1981). Variations in lake productivity, sedimentation rates, organic fractions in the sediments and hydraulic retention may all be significant in reducing the bioavailability of mercury over time.

MDNR suspects that restocked young-of-the-year fish will accumulate a body burden of mercury in the first few years and then, after 5 - 8 years, will show a decline in mercury concentration (pers. comm., E. Evans, MDNR 1986). The fish consumption advisory, however, will not be rescinded by the MDPH until fish tissue analyses show mercury concentrations to be less than the 0.5 mg/kg action level.

When the MDPH determines that Deer Lake fish are safe for human consumption, CCI will grant to MDNR a lease on property abutting Deer Lake for the purpose of providing public access. This lease will continue as long as CCI operates the dam (for at least 30 years, as agreed to in the Consent Judgment). To compensate for the temporary loss of the Deer Lake fishery, CCI granted MDNR leases or ownership of surface rights to land adjacent to nearby lakes, so residents would have access to fishing. The lakes where accessibility was increased are Brocky Lake, Goose Lake, and Lake Angeline.

9.0 PROGRAMS AND PARTICIPANTS

This section discusses the environmental programs currently in effect which directly and indirectly control or manage the environmental resources of the Carp Creek - Deer Lake - Carp River system. Binding agreements and responsible parties are identified.

9.1 REGULATORY AND ADMINISTRATIVE PROGRAMS

9.1.1 Water Quality Standards, Guidelines, and Objectives

The mechanism that Michigan uses to protect existing and future uses of State waters are the Water Quality Standards, Part 4 of the General Rules of the Water Resources Commission. All waters of the State are protected for agricultural uses, navigation, industrial and public water supplies, partial body contact recreation and fish and other aquatic life and wildlife (MWRC 1986). Michigan's standards are updated or refined as new information becomes available. The Clean Water Act requires that all states perform a review of water quality standards every three years and modify or revise them as appropriate. The State has recently amended the water quality standards (November 1986) to include: higher minimum dissolved oxygen requirements for waters supporting warm and cold water fish, total body contact recreation during warmwater months in all State waters, and a stronger antidegradation rule.

9.1.2 Compliance Status of Point Source Controls

The NPDES Program

The Surface Water Quality Division (SWQD) of MDNR is responsible for nearly all water pollution control programs in the State. SWQD's main program elements include waste load allocations, chemical and biological monitoring, industrial and municipal discharger compliance monitoring, industrial pretreatment program development, discharge permit issuance and support of escalated enforcement actions (MDNR 1984). NPDES permits are issued by the Michigan Water Resources Commission; the EPA having delegated this authority to MWRC.

Pretreatment Programs

Indirect industrial discharges to the Ishpeming WWTP are not believed to interfere with the operation of the treatment works (pers. comm. Steve Casey, MDNR, August 18, 1987). Under its NPDES permit, the Plant is not required to develop, in the immediate future, an industrial pretreatment program in accordance with Section 307 of the CWA. If the SWQD learns that the Ishpeming WWTP receives or is about to receive industrial wastes, the permit will be modified.

9.1.3 Sources of Superfund and State Hazardous Site Cleanup

There are no CERCLA or 307 sites in the region which impact Deer Lake.

9.1.4 Status of Urban Stormwater Pollution Control Efforts

All Ishpeming urban area represents a minor segment of the total of the combined sewers have been separated. At present, stormwater runoff from Ishpeming is not considered to have a significant impact on the water quality of Deer Lake. However, stormwater control is a concern that will gain more emphasis as the area grows (pers. comm., Jack Rydquist, MDNR, 1986).

9.1.5 Status of Nonpoint Source Control Effort or Incentives

Most of the land in the Deer Lake watershed is forested and non-agricultural in nature, and has not had a demonstrated negative impact on Deer Lake water quality. Carp Creek, above Ishpeming, has no significant BOD loads or suspended solids, and is a designated trout stream.

9.1.6 Status of COE Projects/Other Agency Actions

There are no current COE projects connected with the Carp Creek - Deer Lake - Carp River System.

9.1.7 Public Participation

Two public meetings were held to inform the interested public about the Deer Lake AOC. The first meeting was held in May 1986 to explain the RAP process and the basis for Deer Lake being an IJC area of concern. The history of the Deer Lake mercury contamination problems beginning in 1981 was reviewed. Actions taken by the MDNR and the State Attorney General's Office to correct the problem were discussed.

Attendees were asked to give their names and addresses, if they were interested in receiving additional information and notification of a future meeting on Deer Lake. About 45 people attended this meeting, including MDNR staff. A mailing list of about 75 persons has been created by adding names of organizations or government agencies that were interested but were unable to attend.

Both meetings were announced twice in the weekend newspaper prior to the meeting dates. For the second meeting, held in August 1987, all local parties interested in this AOC were also contacted by telephone. Local news media covered both meetings.

The second meeting on the Deer Lake AOC attracted less than 25 people. The status of the RAP was reviewed. Unfortunately, copies of the RAP were not available from the U.S. EPA consultant (SAIC), for public review prior to the meeting. However, 85 copies were distributed to all interested parties for review in mid-September. Comments were to be received by October 15, 1987. No comments have been received from the public.

10.0 REMEDIAL ACTION STEPS

10.1 REQUIRED PLANS AND STUDIES

A ten year monitoring program for Deer Lake was mandated in the Consent Judgment (1984). Cleveland Cliffs Iron Company is required to monitor, at their own expense; fish tissue, sedimentation rates and sediment quality, sewage treatment plant influent, effluent and sludge, and ice cover in the tailings deposit area and in the Deer Lake watershed (Consent Judgement 1984, Appendix B). They are required to report their findings to the MDNR Surface Water Quality Division. The MDPH will not lift the fish consumption advisory until fish tissue analyses show mercury concentrations to be less than the MDPH action level of 0.5 mg/kg wet weight. Table 10-1 summarizes the cause, sources and remedial actions associated with the problem of degraded fishery in Deer Lake. Figure 10.1 shows the implementation of remedial actions for the Deer Lake AOC. Figure 10.1 shows the implementation of remedial actions for the Deer Lake AOC.

10.2 SPECIFIC REMEDIAL ACTIONS

Discharges from the CCI labs were believed to be the major source of mercury to Deer Lake. Discharges were curtailed in 1981. Other sources of additional mercury to the system might include leachate from Ropes' Goldmine tailings, aerial deposition, runoff from ice melting over the tailings and natural geologic formations. Remedial actions for Deer Lake have been planned on the basis of known inputs from Cleveland Cliffs Iron Company as the major source of mercury to the system.

The 10 year program of environmental monitoring, outlined in Table 7-1 provides a mechanism for gauging the progress of natural restoration. Monitoring is scheduled to resume in October 1987 (pers. comm., Elwin Evans, MDNR, August 1987). Annual meeting have been held between the various parties involved in restoring the designated uses of Deer Lake. These meetings will continue to be held in order to review progress. The monitoring program may be altered if appropriate, but changes must not exceed the level of funding specified in the Consent Judgment (pers. comm., Elwin Evans, MDNR, August 1987).

The goal of the remedial actions is to restore the sport fishery of Deer Lake. Specific completed and ongoing remedial actions have been outlined in Section 7.1 and shown in Figure 10-1. These actions focus on decreasing nutrient loads to Deer Lake, erradicating the contaminated fish population in Deer Lake, stabilizing the water level in the lake and restocking the lake with yellow perch and walleye.

TABLE 10-1. DEER LAKE REMEDIAL ACTION SUMMARY CHART

Use Impairment	Cause	Sources	Remedial Actions
Degraded Fishery	Mercury Contamination of fish in exceedance of the MDPH action	1. Discharges of mercury to the Ishpeming WWTP (from Cleveland Cliffs Iron Company). Heavy nutrient loading from untreated and primary treated sewage discharged into Carp Creek.	1. Construction of new WWTP with secondary treatment and phosphorus and nitrogen removal. Separation of combined sewer system.
			2. Elimination of industrial discharge of mercury to the Ishpeming WWTP.
		2. Contaminated bottom sediments in Deer Lake.	3. Signing of Consent Judgment between MDNR and CCI, which established a restoration and monitoring program for the lake for a 10 year period.
		3. Possible historic loading from Ropes' Goldmine when it was operating in the late 1800's.	4. Eradication of mercury contaminated fish in Deer Lake.
		4. Potential input from Ropes' Goldmine tailings: a. leachate from tailings, b. runoff from melting of ice over the tailings	5. Stabilization of water level in Deer Lake for a 10 year period after signing of the Consent Judgment.
			6. Restocking fish in Deer Lake
		5. Possible input from natural geologic formations in the area.	

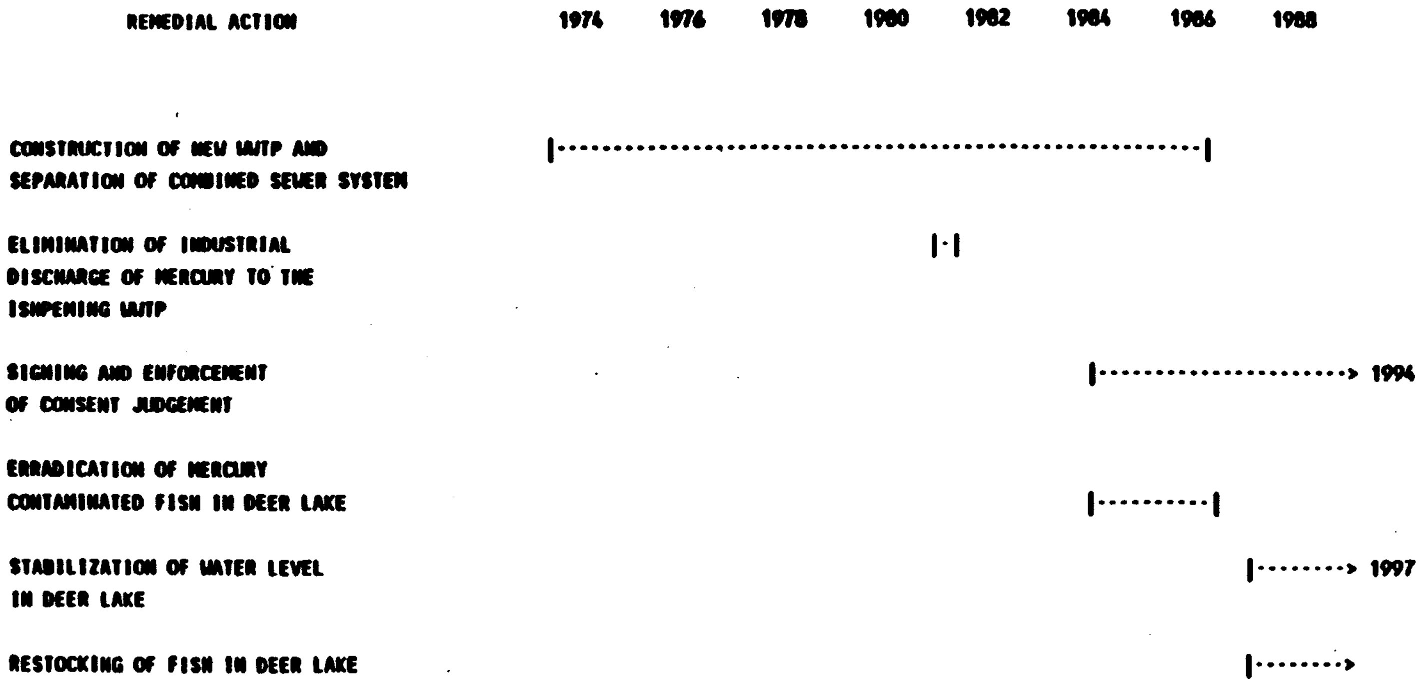

Figure 10-1. Schedule for Implementation of Remedial Actions: Deer Lake AOC.

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APPENDIX A
DEER LAKE FISHERIES SURVEYS AND
FISH CONTAMINANT DATA
1981-1985

Mercury concentrations in fish collected from Deer Lake near Ishpeming, Michigan, October 1-2, 1981

Near Carp River Outlet

Sample Number	Fish Species	Type of Sample	Length (cm)	Hg (mg/kg wet wt.)
305	Yellow Perch	scaled, boneless fillets	21.6	0.9
306	Yellow Perch	scaled, boneless fillets	22.9	0.65
307	Yellow Perch	scaled, boneless fillets	21.6	1.0
308	Yellow Perch	scaled, boneless fillets	22.9	0.45
309	Yellow Perch	scaled, boneless fillets	20.3	0.4
400 SF	Northern Pike	scaled, boneless fillets	56.5	1.9
401 SF	Northern Pike	scaled, boneless fillet	65.3	1.9
402 SF	Northern Pike	scaled, boneless fillet	61.2	1.4
403 SF	Northern Pike	scaled, boneless fillet	71.3	2.9
404 SF	Northern Pike	scaled, boneless fillet	69.5	2.3
400	Northern Pike	skinned, boneless fillet	56.5	2.1
401	Northern Pike	skinned, boneless fillet	65.3	?
402	Northern Pike	skinned, boneless fillet	61.2	2.4

Near Carp Creek Outlet

Sample Number	Fish Species	Type of Sample	Length (cm)	Hg (mg/kg wet wt.)
403	Northern Pike	skinned, boneless fillet	73.1	2.8
404	Northern Pike	skinned, boneless fillet	69.5	2.2
400 X	Northern Pike	livers (5) composite	-	3.3
500	Black Bullheads	skin on, boneless fillets	27.9	0.7
501	Black Bullheads	skin on, boneless fillets	27.3	0.5
502	Black Bullheads	skin on, boneless fillets	27.9	0.3
503	Black Bullheads	skin on, boneless fillets	26.7	0.4
504	Black Bullheads	skin on, boneless fillets	25.4	0.4

$\bar{x}$ 1.35
S.D. 0.91
range 0.3 - 2.9

N = 19

13 $\geq$ 0.5 mg = 68%
10 $\geq$ 1.0 mg = 53%

Table Chlorinated synthetic organic compounds in fish from Deer Lake, Marquette County, Michigan, October 1-2, 1981. Values in milligrams per kilograms wet weight. PCB 1242 and 1260 (0.1-0.2), DDD-p,p′ (0.1), DDT-p,p′ (0.1) and dieldrin (0.01) were not detected above their levels of detection indicated in parenthesis. Samples are boneless fillets and were skinned or scaled as designated.

Station	Species	Type Sample	Sex	Length (cm)	Percent Fat	PCB 1254	DDE p,p'
4- near Carp R. inlet	Northern pike	Skinned	♀	66.3	0.99	0.10	<0.01
	Northern pike	Scaled	♀	63.5	0.85	0.22	0.018
	Yellow perch	Scaled	composite 6-fish	21.6-24.1	0.74	<0.1	<0.01
10-near Carp R. outlet	Northern pike	Scaled	♀	70.2	1.3	0.24	0.022
	Northern pike	Skinned	♀	70.2	1.4	0.36	0.026
	White sucker		♀	47.0	3.0	0.33	0.012
	Black bullhead		-	29.2	3.5	0.46	0.016
	Yellow perch	Scaled	composite 5-fish	20.5-24.0	0.6	<0.1	<0.01
	Yellow perch	Skinned	composite 5-fish	20.5-24.0	0.37	<0.1	<0.01

Table (con't)

Station	Species	Sex	Length (cm)	Type of Sample	Copper	Zinc	Mercury
10-near Carp R. outlet	Yellow perch	♀	21.6	Scaled	<1	11	0.9
		♀	22.9	Scaled	<1	12	0.65
		♀	21.6	Scaled	<1	11	1.0
		♀	22.9	Scaled	<1	11	0.45
		♂	20.3	Scaled	<1	11	0.4
	Northern pike	♂	56.5	Scaled	<1	7	1.9
		♀	65.3	Scaled	<1	5	1.9
		♀	61.2	Scaled	<1	6	1.4
		♀	71.3	Scaled	<1	7	2.9
		♀	69.5	Scaled	<1	6	2.3
		♂	56.5	Skinned	<1	5	2.1
		♀	65.3	Skinned	<1	4	2.8
		♀	61.2	Skinned	<1	4	2.4
		♀	73.1	Skinned	<1	5	2.8
		♀	69.5	Skinned	<1	5	2.2
		-	---	livers, composite 5-fish	3	24	3.3
	Black bullheads	♀	27.9	-	<1	7	0.7
		♀	27.3	-	<1	9	0.5
		♀	27.9	-	<1	6	0.3
		♀	26.7	-	<1	7	0.4
		♂	25.4	-	<1	6	0.4

Table Heavy metals in boneless fillets from fish collected in Deer Lake, Marquette County, Michigan, October 1-2, 1981. All values are in milligrams per kilograms wet weight. Cadmium (0.5), chromium (1.0), nickel (1.0), lead (1.0), and arsenic (1.0) were equal to or less than their respective levels of detection given in parenthesis.

Station	Species	Sex	Length (cm)	Type of Sample	Copper	Zinc	Mercury
4 near Carp R. inlet	Yellow perch	♂	21.6	Scaled	<1	8	2.1
		♂	22.9	Scaled	<1	9	2.1
		♀	25.4	Scaled	<1	9	1.8
		♀	25.4	Scaled	<1	10	1.0
		♀	22.9	Scaled	<1	9	0.4
		♀	21.6	Skinned	<1	6	1.5
		♀	21.6	Skinned	<1	7	2.2
		♀	21.6	Skinned	<1	7	2.2
		♀	21.6	Skinned	<1	6	1.0
		♀	21.6	Skinned	<1	6	1.2
	White sucker	♀	33.0	Scaled	<1	6	0.9
		♀	43.2	Scaled	<1	6	1.0
		♀	40.6	Scaled	<1	9	0.9
		♀	43.2	Scaled	<1	9	0.9
		♂	40.6	Scaled	<1	10	0.9
	Northern pike	♀	66.3	Scaled	<1	7	2.8
		♂	58.4	Scaled	<1	7	2.4
		♀	61.0	Scaled	<1	9	2.6
		♂	58.4	Scaled	<1	6	2.1
		♀	66.0	Scaled	<1	11	2.1
			---	livers, composite 5-fish	3	25	2.9
	Black bullheads	♀	22.2		<1	9	0.6
		♀	27.9		<1	9	1.1
		♀	29.2		<1	10	0.55
		♀	24.1		<1	10	0.4
		♂	21.6		<1	8	0.4

Table Heavy metals in skinless, boneless fish fillets collected in Teal Lake, Marquette County, Michigan, March 12, 1982. All values in milligrams per kilograms wet weight. Cadmium, chromium, nickel, copper and lead were less than the 1.0 mg/kg level of detection and arsenic was less than the 0.5 mg/kg level of detection.

Species	Sex	Length (cm)	Zinc	Mercury
Yellow perch	♀	30.0	5	<0.1
	♀	26.3	5	<0.1
	♂	28.1	6	0.2
	♀	25.0	5	<0.1
	♂	23.1	4	<0.1
	♀	22.5	5	0.2
	♀	22.5	6	<0.1
	♀	20.6	5	<0.1
	♀	22.5	6	<0.1
	♀	24.4	6	<0.1
White sucker	♀	46.3	5	<0.1
	♀	46.3	7	<0.1
	♀	52.5	5	<0.1
	♀	8.8	5	<0.1
	♀	51.3	4	<0.1

Table Mercury in fish collected from Carp Creek upstream of Deer Lake, Marquette County, Michigan, May and October, 1982.

Species & Location	Sex	Length (cm)	Mercury (Hg) wet wt. mg/kg
Brook Trout	♀	25.4	0.24
T47N, R25W, Sec. 17-18 May 8, 1982	♂	20.3	0.16
	♀	20.3	0.14
	♀	21.6	0.21
	♂	21.0	0.20
	♀	20.3	0.14
	♂	22.2	0.10
	♀	19.1	0.10
	♀	22.2	0.43
	♀	19.7	0.24
T48N, R27W, Sec. 9 October 10, 1982, Station -	♂	19.1	0.20
	♀	15.9	0.26
	♀	14.6	0.24
	♂	14.6	0.33
	♀	14.6	0.33
	♂	14.6	0.20
Whole fish 9 fish composite	-	7.6-10.2	0.42
White suckers T47N, R25W, Sec. 17-18 May 8, 1982	♂	31.8	0.46
	♂	31.8	0.60
	♂	29.2	0.63
White suckers	♂	30.5	0.86
	♂	29.2	0.86
	?	21.6	0.61
	?	20.4	0.31
	?	22.2	0.25
	?	21.6	0.25

?=fish young & decomposed internally

Table Mercury in fish collected from Deer Lake, Marquette County, Michigan, October, 1982 near the Carp Creek inlet. T48N, R27W, Sec. 3.

Species	Sex	Length (cm)	Year Class	Mercury (Hg) wet wt. mg/kg
Yellow Perch	♀	23.0	IV	0.92
	♀	25.0	V	1.1
	♀	25.5	V	2.0
	♀	25.5	V	1.8
	♀	23.5	IV	2.0
	♀	23.5	IV	1.7
	♂	21.5	IV	2.2
	6 fish composite Whole fish	~7.5	0	9.54
Northern Pike	♀	56.0	I	2.0
	♀	55.5	I	1.5
	♀	52.0	I	2.2
	♀	51.0	I	1.6
	♀	51.0	I	1.8
	♀	54.0	I	1.6
	♀	56.0	I	1.4
	♀	54.0	I	0.71
	♂	69.0	III	3.5
	♀	72.0	III	3.6
	♀	70.5	III	3.4
	♀	79.0	III	4.7
	♀	43.2	I	1.6
	♀	47.5	I	1.6

Mercury in fish collected from Deer Lake, Marquette County, Michigan, October, 1982 near the Carp River outlet. T48N, R27W, Sec. 27.

Species	Sex	Length (cm)	Year Class	Mercury (Hg) wet wt. mg/kg
Yellow perch	♀	26.0	IV	2.3
	♀	23.5	V	0.62
	♀	24.5	IV	0.46
	♀	22.5	V	1.9
	♀	23.5	V	1.8
	♀	25.0	IV	2.3
	♀	25.0	IV	2.3
	♀	24.0	V	1.6
	♂	23.0	IV	0.71
	♀	25.5	V	0.87
Northern pike	♂	46.0	I	1.2
	♀	55.5	I	1.5
	♀	47.0	I	1.5
	♂	55.0	I	1.8
	♀	54.5	I	1.7
	♀	63.0	II	3.3
	♀	59.0	I	2.1
	♂	72.0	III	4.6
	♀	71.0	III	2.0
	♀	71.0	III	3.4

Table Heavy metals in minnows, snails and algae taken from Deer Lake, Marquette, Michigan, October 10-11, 1982. All values in milligrams per kilograms dry weight unless indicated otherwise.

Station	Species	Percent Solids	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Iron	Manganese	Mercury
Inlet	Minnows - Golden shiners, Fatheads; <6.0 cm[1]	25	<1	<1	1	<1	<1	32	72	19	0.4
Outlet	Minnows - Mostly Fatheads, <6.0 cm [1]	27	<1	<1	1	<1	<1	28	52	10	0.2
Inlet	Snails - <u>Physella</u>, <u>Helisoma</u>[2]	33	<1	<1	2	<1	<1	6	400	140	<0.1
Outlet	Snails - <u>Helisoma</u>[2]	35	<1	<1	1	<1	<1	5	270	90	<0.1
Inlet	Filamentous algae <u>Cladophora</u>	15	<1	2	3	<1	<1	8	1000	1100	<0.1
Outlet	Filamentous Algae <u>Cladophora</u>	16	<1	2	2	<1	<1	6	1200	980	<0.1
Inlet	Phytoplankton, mostly <u>Aphanazominon</u>	5	<1	<1	2	<1	<1	1	41	37	<0.1
Outlet	Phytoplankton, mostly <u>Aphanazominon</u>	2.8	<1	<1	1	<1	<1	3	27	22	<0.1

[1] Whole fish composite samples
[2] Includes shells

Mercury in Fish Collected from the Carp River Downstream of Deer Lake,
T47N, R25W, Sec. 5, Marquette County, Michigan, August 20, 1984.

Species	Sample Type	Mercury (Hg) mg/gk wet wt.
White Sucker	6 fish composite, whole fish, avg. length 5.3 in.	<0.1
White Sucker	3 fish composite, whole fish, avg. length 8.3 in.	<0.1
White Sucker	skinless, boneless fillet 11.1 in.	0.3
Yellow Perch*	skinless, boneless fillet 8.0 in.	1.0
Brook Trout	skinless, boneless fillet 9.5 in.	0.4
Brook Trout	4 fish composite, whole fish avg. length 6.2 in.	0.2
Brook Trout	4 fish composite, whole fish avg. length 5.6 in.	0.1

*Deer Lake Fish??

Table Total mercury analysis of perch (Perca flavescens) collected on February 25, 1985, from Deer Lake, Michigan.

Number	Length (cm)	Weight (g)	Sex	Hg Content (ug/g)
1	20.3	104	F	1.26
2	24.8	144	F	1.74
3	22.2	106	M	1.03
4	21.0	99	F	1.43
5	22.9	129	F	1.26
6	20.3	90	F	1.05
7	19.0	86	F	1.11
8	19.0	89	F	1.09
9	20.3	92	F	1.00
10	21.6	111	M	1.40
11	18.7	87	F	0.98
12	20.3	107	F	1.22
13	20.0	91	F	1.44
14	18.4	79	M	1.94
15	20.3	102	F	1.04
16	22.2	119	F	2.18
17	20.3	91	F	1.85
18	22.5	131	F	1.57
19	21.6	111	M	2.08
20	21.3	97	F	1.99
21	21.0	109	F	1.60
22	22.2	105	F	1.43
23	19.4	91	F	1.04
24	21.6	90	F	2.00
25	18.7	91	F	1.49
26	21.0	103	F	2.28
27	22.5	115	F	3.58
28	20.6	111	F	1.68
29	18.7	85	F	2.13
30	19.4	93	F	2.07
31	22.9	108	F	2.27
32	19.0	90	F	1.62
33	19.7	91	F	1.64
34	20.3	94	F	2.60
35	20.3	89	F	1.95
36	20.6	97	F	1.65
37	22.9	114	M	2.12
38	21.3	106	F	1.23
39	23.5	121	F	2.41
40	21.0	98	F	1.14

(Source: H. Kurita 1987)

Table (continued)

Number	Length	Weight (cm)	Sex (g)	Hg Content (ug/g)
41	21.0	89	F	1.41
42	23.2	109	F	0.96
43	20.3	74	F	1.04
44	21.6	91	F	1.24
45	21.0	101	F	1.17
46	23.2	108	F	0.97
47	22.5	123	M	1.25
48	21.0	90	M	1.01
49	20.0	93	F	1.39
50	19.7	95	F	1.08

(Source: H. Kurita 1987)

Table   Total mercury analysis of northern pike (*Esox lucius*) collected from Deer Lake, Michigan.

Number	Date Collected 1985	Length (cm)	Weight (g)	Sex	Hg Content (ug/g)
1	Feb. 25	33.0	221	M	a
2	Feb. 25	39.4	399	M	a
3	Feb. 25	41.3	406	M	a
4	Feb. 25	40.0	335	M	a
5	Feb. 25	40.6	399	M	a
6	Feb. 25	40.0	368	M	a
7	Feb. 25	31.7	193	M	a
8	Feb. 25	34.3	210	M	a
9	Feb. 25	50.8	779	M	1.81
10	Feb. 25	64.8	1562	M	2.05
11	Feb. 25	44.5	639	M	a
12	Feb. 25	64.8	1521	F	3.30
13	Feb. 25	58.4	1262	M	2.08
14	Feb. 25	58.4	1319	M	1.92
15	Feb. 25	64.8	1776	F	4.07
16	Feb. 25	71.1	2455	M	4.06
17	Feb. 25	69.8	2156	M	1.99
18	Feb. 25	61.0	1366	F	2.17
19	Feb. 25	49.5	896	F	a
20	Feb. 25	62.2	1480	M	1.96
21	Feb. 25	73.7	2245	M	1.02
22	Feb. 25	68.6	2130	F	3.62
23	Feb. 25	40.6	352	M	a
24	Feb. 25	33.0	208	M	a
25	Feb. 25	39.4	290	M	a
26	Feb. 25	40.6	443	F	2.66
27	Feb. 25	36.8	270	F	a
28	Feb. 25	35.6	214	M	1.11
29	Feb. 25	39.4	381	M	a
30	Feb. 25	35.6	218	M	1.23
31	Feb. 25	34.3	229	M	0.99
32	Feb. 25	33.0	193	F	1.14
33	Feb. 25	33.0	233	F	1.20
34	Feb. 25	49.5	768	F	1.59
35	Feb. 25	64.8	1718	M	1.74
36	Feb. 25	36.8	244	M	a
37	Feb. 25	31.8	161	M	a
38	Feb. 25	35.6	239	M	a
39	Feb. 25	33.0	197	M	a
40	Feb. 25	31.8	180	M	a
41	Feb. 25	39.4	379	M	1.15
42	Feb. 25	43.2	508	M	1.09
43	Feb. 25	41.9	515	M	1.30
44	Feb. 25	68.6	2042	M	4.21

(Source: H. Kurita 1987)

Table (continued)

Number	Date Collected 1985	Length (cm)	Weight (g)	Sex	Hg Content (ug/g)
45	Feb. 25	63.5	1763	M	2.09
46	Mar. 14	63.5	1563	M	2.33
47	Mar. 14	66.0	1758	M	2.63
48	Mar. 14	68.6	1853	F	2.64
49	Mar. 14	69.8	2017	M	2.84
50	Mar. 14	73.7	2587	F	2.14
51	Mar. 14	76.2	2906	F	2.26
52	Mar. 19	68.6	2200	F	2.11
53	Mar. 19	72.4	2884	F	1.88
54	Mar. 19	74.9	2806	F	2.27
55	Mar. 19	69.8	2410	F	2.30
56	Mar. 19	72.4	2128	F	2.62
57	Mar. 19	81.3	3037	F	2.59
58	Mar. 19	63.5	1540	M	1.74
59	Mar. 19	61.0	1456	M	2.27
60	Mar. 19	69.8	2143	F	2.06
61	Mar. 19	57.1	1300	F	2.21
62	Mar. 19	69.8	2193	M	1.81
63	Mar. 19	69.8	2479	F	1.95
64	Mar. 19	67.3	1925	F	1.89
65	Mar. 19	59.7	1285	F	1.93
66	Mar. 19	61.0	1511	F	1.44
67	Mar. 19	66.0	2025	F	2.05
68	Mar. 19	62.2	1493	F	1.72
69	Mar. 19	68.6	1876	F	2.49
70	Mar. 19	71.1	2381	M	2.44

a = Fish sample that was collected but not included for analysis at MSU

(Source: H. Kurita 1987)

Table Total mercury analysis of white sucker (*Catostomus commersoni*) collected on March 14, 1985, from Deer Lake, Michigan.

Number	Length (cm)	Weight (g)	Sex	Hg Content (ug/g)
1	40.6	969	F	0.20
2	41.9	883	F	0.59
3	44.4	1183	F	0.84
4	48.3	1287	F	0.86
5	48.3	1353	F	0.61
6	27.9	236	M	0.19
7	29.2	283	M	0.33
8	27.3	210	F	0.09
9	31.7	374	F	0.24
10	34.3	529	M	0.31
11	39.4	678	M	0.84
12	47.0	1167	F	1.29
13	47.0	1390	F	2.03

(Source: H. Kurita 1987)

Mercury in Northern Pike from Deer Lake, Marquette County, Michigan, February 1985. Concentrations in milligrams per kilogram (mg/kg) wet weight from Skinless, Boneless Fillets.

	Length	Hg
1	81.3	5.0
2	80.0	3.6
3	74.9	3.9
4	78.7	3.6
5	71.1	4.0

(Source: MDNR)

APPENDIX B

CONSENT JUDGEMENT

STATE OF MICHIGAN

IN THE CIRCUIT COURT FOR THE COUNTY OF MARQUETTE

* * * * * * * *

FRANK J. KELLEY, Attorney General,
FRANK J. KELLEY, ex rel MICHIGAN
DEPARTMENT OF NATURAL RESOURCES,
and RONALD O. SKOOG, Director,
Michigan Department of Natural
Resources,

Plaintiffs

v

Civil Action No. 82-14767

THE CLEVELAND-CLIFFS IRON COMPANY,
an Ohio corporation, doing business
in Michigan,

Defendant.

A TRUE COPY:

* * * * * * * *

CONSENT JUDGMENT

In 1982, State-Plaintiffs filed this civil action against The Cleveland-Cliffs Iron Company seeking injunctive and other relief to remedy mercury pollution of Deer Lake, a reservoir located in Marquette County, Michigan.[1] Mercury was found in fish from the Deer Lake Reservoir and in fish downstream of the reservoir outlet pipe to the Carp River. Since the time the suit was filed, the parties have been working to analyze the nature of the mercury contamination and develop a plan of restoration. In order to constructively resolve the pending civil action and assure protection of the public health and natural resources, the State of Michigan and The Cleveland-Cliffs Iron Company have agreed to enter into this Consent Judgment which commits the parties to a program for restoration of the Deer Lake Reservoir and its waters and provides the People of the State of Michigan with continued access to comparable fishing resources. Accordingly, the parties, by their respective attorneys, have consented to entry of the Judgment set forth herein.

1/ A 90 acre natural lake which in 1912 was expanded into a reservoir that now covers approximately 900 acres.

NOW THEREFORE, before the taking of any testimony upon the pleadings, and without adjudication of any issues of fact or law, and upon consent of parties, it is ORDERED, ADJUDGED and DECREED as follows:

Jurisdiction

1. This Court has jurisdiction over the subject matter and the parties to this civil action. The Court shall retain jurisdiction to supervise compliance with the terms of this Judgment and to make such further orders as may be necessary.

Reasonableness of Restoration Plan

2. The Court determines that the terms and conditions contained herein are reasonable, adequately resolve the environmental issues raised in this action, constitute an appropriate restorative program for the lands, fish, wildlife, and waters of this State, and properly protect the interest of the People of the State of Michigan.

The Restoration Plan

3. The Cleveland-Cliffs Iron Company has retained Dr. Frank D'Itri to investigate mercury contamination of the Deer Lake Reservoir and to make recommendations for abatement of the mercury pollution. The Department of Natural Resources has also studied the ecological circumstances at the Deer Lake Reservoir and evaluated the recommendations of Dr. D'Itri. The parties are informed and believe that annual fluctuations in the water level of the Deer Lake Reservoir create ecological conditions which chemically transform any available inorganic mercury into the methylated form which is biologically available for uptake by fish and other organisms which live in the water or which feed on aquatic organisms. Stabilization of the water level of the reservoir is necessary to reduce mercury contamination of the reservoir and associated contamination of the fish to acceptable levels.

4. The Cleveland-Cliffs Iron Company owns and operates the

dam located at the outlet of the reservoir to the Carp River. In the fall of 1984, The Cleveland-Cliffs Iron Company will lower the water level in the reservoir to the lowest level which can be achieved with the present impoundment and available outlet. When the water level has been lowered to an elevation of 1,377 feet above sea level, The Cleveland-Cliffs Iron Company will, if feasible, install a fish grate on the outlet pipe of the Deer Lake impoundment. The parties anticipate that the complete lowering of the water level can be accomplished prior to winter freeze up in 1984.

5. Despite posted warnings, the public continues to fish in the reservoir. In order to minimize public exposure to mercury contaminated fish, and to allow the parties to monitor and evaluate the efficacy of the restoration program described in this Consent Judgment, the Department of Natural Resources will undertake a fish eradication program ~~after the water level in the reservoir has been~~ lowered to the maximum extent possible and 1984 winter freeze up has occurred. The parties expect that this fish eradication program will remove approximately ninety (90%) percent of the fish population.

6. The Cleveland-Cliffs Iron Company will then fill the Deer Lake Reservoir in the spring of 1985 or as soon thereafter as is operationally feasible. For a period of ten (10) years thereafter, The Cleveland-Cliffs Iron Company shall operate the dam so as to stabilize the level of the Deer Lake Reservoir and accomplish the objectives of this Consent Judgment. In 1985, the Department of Natural Resources plans to restock the reservoir with some adult fish taken from other inland lakes in the area. This restocking is an experimental program and the extent of restocking to be done, if any, shall be determined by the Department of Natural Resources. The fish which are restocked in the reservoir shall be monitored for mercury uptake by the Department of Natural Resources, and will be available to fishermen.

7. The Cleveland-Cliffs Iron Company will pay the State of Michigan the sum of Ten Thousand ($10,000.00) Dollars for the fish eradication program and any fish restocking undertaken by the Department

of Natural Resources. A check in the amount of Ten Thousand ($10,000.00) Dollars, payable to the STATE OF MICHIGAN, shall be issued, and mailed to the Assistant Attorney General in Charge, Environmental Protection Division, for deposit in the General Fund within thirty (30) days of entry of this Consent Judgment.

8. The parties acknowledge that The Cleveland-Cliffs Iron Company currently has a contractual arrangement with the City of Negaunee, which has its wastewater treatment plant located on the Carp River, regarding the restriction of the flow of the water in the Carp River from the Deer Lake impoundment. The parties believe the impact of the Deer Lake Reservoir stabilization on the City of Negaunee treatment plant discharge will be minimal. However, in the event that the water flow of Carp River does not meet the levels described in the aforesaid water flowage agreement, the Department of Natural Resources will recommend to the Michigan Water Resources Commission and to the United States Environmental Protection Agency a modification of discharge requirements for the Negaunee treatment plant for the duration of the restoration program described in this Consent Judgment. If refusal of either governmental unit to follow the recommendations of the Department of Natural Resources in this regard prohibits or impedes the implementation of the restoration plan set forth herein, the matter will be brought before this Court for further proceedings to enable the terms of this Consent Judgment to be carried out or grant such relief as is appropriate under the circumstances then existing.

9. The Cleveland-Cliffs Iron Company shall defend and hold harmless the State of Michigan against any and all claims by riparian property owners or persons claiming to be riparian property owners for damage to their riparian rights arising out of the raising, lowering and stabilization of the water level in the impoundment. The State of Michigan assumes no liability to third parties for downstream damage resulting from operation of the Cleveland-Cliffs Iron Company Dam at the outlet of the Deer Lake Reservoir.

10. Within thirty (30) days of the entry of this Consent

Judgment, The Cleveland-Cliffs Iron Company shall post signs along the shore of the Deer Lake Reservoir near Marquette County Road 573, warning the public about the mercury problem. The obligation of The Cleveland-Cliffs Iron Company to maintain this posting shall continue only so long as mercury levels in the fish taken from the reservoir exceed 1.0 p.p.m.(mg/kg) total mercury on a wet weight basis, but in any event, for no longer than the ten (10) year period of water level stabilization provided for herein. A copy of the Notice to be posted is attached hereto as Appendix A. The Marquette County Health Department may also continue to post similar warnings until the restoration program has been completed.

Monitoring

11. The Cleveland-Cliffs Iron Company will, at its sole expense, conduct a monitoring program as described in Appendix B to this Consent Judgment, for a period of ten (10) years. Within sixty (60) days of the entry of this Consent Judgment, The Cleveland-Cliffs Iron Company shall submit a more detailed monitoring program and schedule to the Department of Natural Resources for review and approval. The Cleveland-Cliffs Iron Company shall promptly report the results of all analyses conducted pursuant to the monitoring program to the Department of Natural Resources. The Cleveland-Cliffs Iron Company estimates that the annual cost of this monitoring program will be approximately Eighteen Thousand ($18,000.00) Dollars.

State Costs

12. Within thirty (30) days of entry of this Consent Judgment, The Cleveland-Cliffs Iron Company will pay to the STATE OF MICHIGAN the sum of Ten Thousand ($10,000.00) Dollars to compensate the State of Michigan for past and future field costs, research and laboratory fees associated with the Deer Lake Reservoir mercury pollution problem. Except as provided in paragraphs 7 and 18 of this Consent Judgment, this payment will be the sole payment required from The Cleveland-Cliffs Iron Company for these expenses. The check, made payable to the State of Michigan, shall be forwarded to

the Assistant Attorney General in Charge, Environmental Protection Division, Department of Attorney General, 720 Law Building, Lansing, Michigan 48913.

Deer Lake Reservoir Access Site

13. The parties anticipate that it will take a minimum of five (5) years before it can be reasonably determined whether the restoration program described in this Consent Judgment will be successful in reducing mercury contamination in the Deer Lake Reservoir to acceptable levels. The parties anticipate that within five (5) to eight (8) years mercury now in the waters of the reservoir will adsorb onto particulate matter which will settle out and be buried in reservoir sediments. When the Michigan Department of Public Health determines that fish from the Deer Lake Reservoir are no longer unsafe for human consumption due to mercury contamination, The Cleveland-Cliffs Iron Company shall grant to the Department of Natural Resources a lease on property located on the Deer Lake Reservoir shoreline for the purpose of providing public access. Said lease shall continue until the obligations of The Cleveland-Cliffs Iron Company to maintain the dam under Paragraph 14 hereof terminate. Thereafter, the lease may be renewed annually while The Cleveland-Cliffs Iron Company continues to maintain the dam. Consideration to be paid by the Department of Natural Resources for the lease of said public access site shall be One ($1.00) Dollar for the lease and each annual renewal.

Restitution

In order to provide the People of the State of Michigan with continued access to comparable fishing resources, The Cleveland-Cliffs Iron Company agrees to provide the following assurances and properties:

14. To insure preservation of the potential public fishing resource in the Deer Lake Reservoir, The Cleveland-Cliffs Iron Company agrees to continue to maintain the Deer Lake Reservoir impoundment for a period of thirty (30) years.

15. Within thirty (30) days of entry of this Consent Judgment, The Cleveland-Cliffs Iron Company shall convey to the Department of Natural Resources its ownership in the surface rights on a parcel of land abutting Brocky Lake, consisting of approximately the Western Half (W1/2) of Government Lot One (1), in the Southwest Quarter of the Southeast Quarter (SW1/4 SE1/4), of Section Six (6), Township Forty-eight (48) North, Range Twenty-eight (28) West, of Marquette County. This parcel has approximately 1,000 feet of water frontage. The Department of Natural Resources shall pay One ($1.00) Dollar as consideration for the conveyance.

16. Within thirty (30) days of entry of this Consent Judgment, The Cleveland-Cliffs Iron Company shall grant to the Department of Natural Resources a twenty (20) year lease to the surface rights held by The Cleveland-Cliffs Iron Company on a parcel of land abutting Lake Angeline found in Government Lot Three (3) of Section Ten (10), Township Forty-seven (47) North, Range Twenty-seven (27) West, Marquette County, Michigan, more particularly described as follows: The East Two Hundred (200') feet of the West Two Hundred and Eighty (280') feet lying south of the U.P. Power Company power line right of way. This parcel contains approximately 200 feet of water frontage. Thereafter, the lease may be renewed annually at the discretion of the parties. The Department of Natural Resources shall pay One ($1.00) Dollar as consideration for this lease and any renewal.

17. Within thirty (30) days of entry of this Consent Judgment, The Cleveland-Cliffs Iron Company shall grant to the Department of Natural Resources a twenty (20) year lease to the surface rights held by The Cleveland-Cliffs Iron Company on a parcel of land abutting Goose Lake found in the Northeast Quarter of the Northwest Quarter (NE1/4 NW1/4), of Section Twenty-four (24), Township Forty-seven (47) North, Range Twenty-six (26) West, Marquette County, Michigan, more particularly described as follows: Beginning at the intersection of the south line of said Northeast Quarter of the

Northwest Quarter (NE1/4 NW1/4) with Goose Lake; thence East 250.00 feet; thence North 250.00 feet; thence West 200 feet more or less to the shore of Goose Lake; thence Southerly along shore line to point of beginning. This parcel contains approximately 250 feet of water frontage. Thereafter, the lease may be renewed annually at the discretion of the parties. The Department of Natural Resources shall pay One ($1.00) Dollar as consideration for this lease and any renewal.

18. The Cleveland-Cliffs Iron Company shall pay the sum of Ten Thousand ($10,000.00) Dollars to the Department of Natural Resources, payable in the amount of One Thousand ($1,000.00) Dollars per year, each year, for a period of ten (10) years, commencing upon entry of this Consent Judgment, and thereafter payable on or before October 1 of each succeeding year, for ten (10) years. Such payment shall be earmarked or set aside for stream habitat improvement work in Marquette County, to be performed under the direction of the Marquette District fish biologist, of the Department of Natural Resources. <u>Provided</u>, however, that the obligation of the Company to pay the One Thousand ($1,000.00) Dollars shall be suspended during any year when the expenditure of the One Thousand ($1,000.00) Dollars is not authorized by legislative appropriation of such funds. See 1977-1978 OAG, No. 5393, pp 693-695 (November 28, 1978). As used in this paragraph, "stream habitat improvement work" means activities on the Carp River, Dead River, and Escanaba River systems, including but not limited to, stabilization of stream banks, construction of sediment traps, and installation of gravel riffles.

19. This Court retains jurisdiction to enforce this Consent Judgment until the parties have fully complied with its terms. Either party may, in the event of any change in the facts or circumstances upon which this Consent Judgment is premised, or in the event of newly discovered evidence, petition the Court for modification of this Consent Judgment.

STATE OF MICHIGAN
Plaintiffs

FRANK J. KELLEY
Attorney General

By: [signature]
Stewart H. Freeman
Assistant Attorney
General in Charge

By: [signature]
Elizabeth L. Valentine
Assistant Attorney General

Environmental Protection Division
720 Law Building
Lansing, Michigan 48913

THE CLEVELAND-CLIFFS IRON COMPANY
Defendant

Clancey, Hansen, Chilman,
Graybill & Greenlee, P.C.
Peninsula Bank Building
Ishpeming, Michigan 49849

By: [signature]
Ronald E. Greenlee

JUDGMENT ENTERED IN ACCORDANCE WITH THE FOREGOING CONSENT JUDGMENT ON THIS 26 DAY OF October, 1984.

[signature]
Honorable Raymond J. Jason
Circuit Court Judge
Marquette County Circuit Court

APPENDIX A

HEALTH WARNING

Fish from these waters have been found to contain potentially dangerous levels of mercury which can cause serious illness if the fish are eaten regularly over a long period of time.

Fishermen are advised not to consume fish taken from these waters.

For more information contact Marquette County Health Department - 906-475-9977.

APPENDIX B

TEN YEAR MONITORING PROGRAM FOR DEER LAKE

I. Fish--monitor (to begin in 1985) once per year in three size classes:

A. Pike (Small, Medium, and Large) 10 each

B. Perch (Small, Medium, and Large) 10 each

C. Suckers (Small, Medium, and Large) 10 each

(This will monitor the benthic uptake)

There is no need to monitor bullheads, snails, and algae because they always seem to contain relatively low levels of mercury.

II. SEDIMENTS

Use sediment traps to collect samples of the particulate matter in the water column which are being directed to the sediments. Suggested locations would be in the lake near the mouth of Carp Creek and immediately before the spillway at the dam. These sediment traps can be left in place 1 to 6 months depending on the sedimentation rates.

III. The Ishpeming Sewage Treatment Plant

A. STP influent--24 hour composites once a month

B. STP Digestor effluent--24 hours composites once a month

C. STP Final effluent--24 hour composites once a month

D. STP Digestor Sludge--Two times per year, i.e., early March and August or September to coincide with low flow conditions in the plant.

IV. MISCELLANEOUS

A. Ice cover in tailings deposits area--once per year before spring melt--3 sampling sites

B. Ice cover in Deer Lake watershed area--once a year before spring melt--6-10 sampling sites