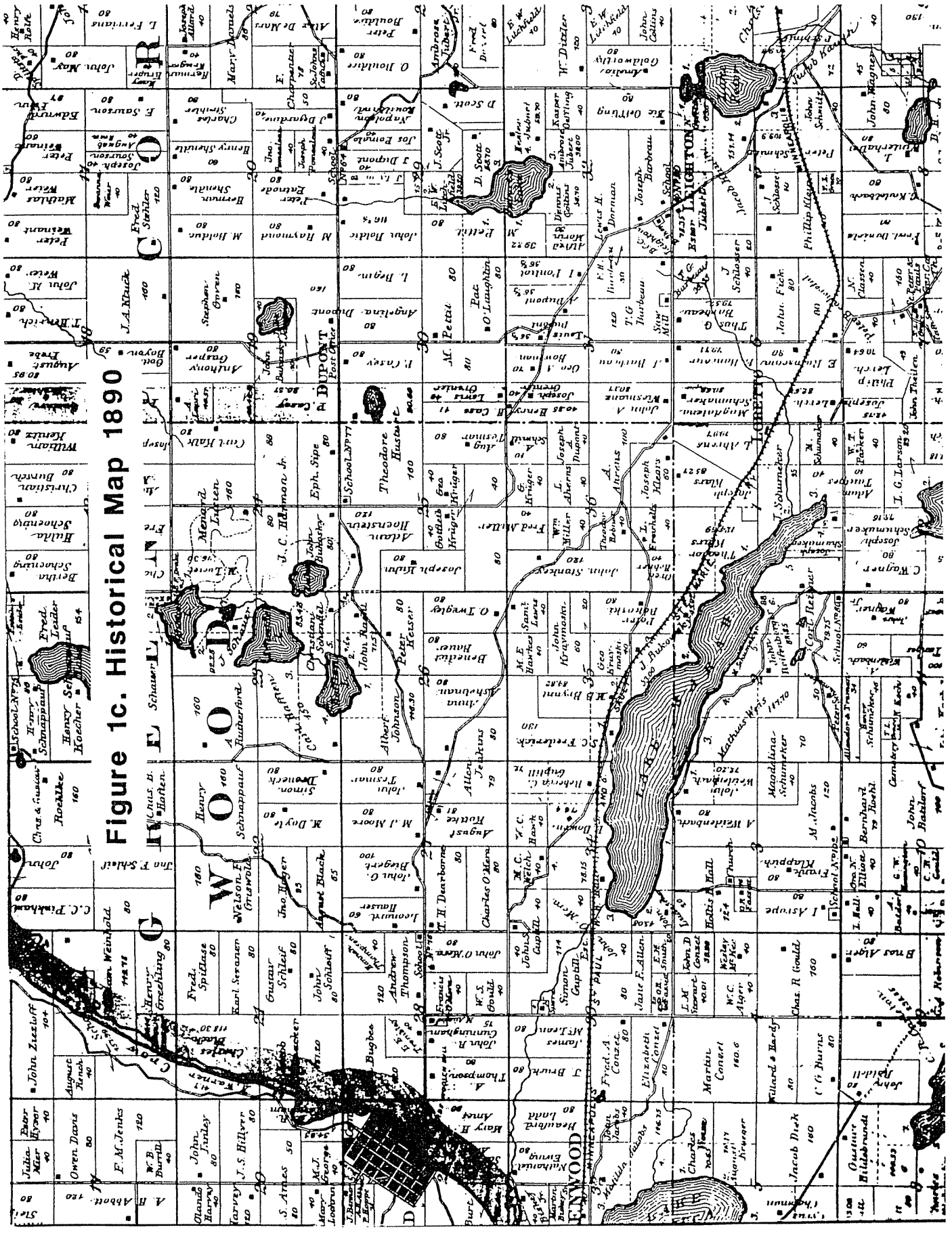


Figure 1c. Historical Map 1890

As a result of the popularity of the lake, this region quickly became a targeted area for railroad development. By 1886 the Minneapolis/St. Paul Sault St. Marie line was constructed along the northern edge of the lake, cutting through eighty acres and continuing for one-half mile (Hennepin County). On an 1860 map, the railroad line is shown on the south side of the lake where County Road 11 now exists. Sidney Mitchell remembers Lake Sarah's bustling community by recalling the busy Lake Sarah train depot which accommodated four train stops a day (Fobbe, 1990).

The Department of Natural Resources (DNR) in 1971 determined the land use in the watershed: 10% forest and woodland with mixed hardwoods, 25% agricultural land, mainly pasture, and 65% in lake homes and idle land.

The number of plots bordering the lake diminished as the years progressed. As the need for residential land increased around the immediate vicinity of the lake, agricultural land was divided up and sold as residential property. In 1860 there were 23 lake front plots; by 1913 that number had decreased to 20 plots and included a former agricultural plot (the eastern most portion of Lake Sarah lying in Greenfield) which had been sold, sometime between 1898 and 1913, to Lake Sarah Heights Development creating 13 residential properties (Historical Society).

Lake Sarah has experienced algal blooms for quite some time. The Lake Sarah Improvement Association, an organization formed in 1973 to address problems concerning the lake, has, in the past, treated the lake with copper sulfate as a measure to control this problem. The lake has also received annual herbicide treatments for control of weeds.

Six lake level measurements, taken sporadically from 1942-74, indicate no significant droughts or floods for this region. The low point, recorded in 1958 by the United States Geological Survey, was 978.0'. The lake's high point was recorded by the Division of Water, Soils and Minerals at 979.7' on May 3, 1974 (Hennepin County). In 1973, a petition for a control structure was presented to the Hennepin County Board of Commissioners. The control structure was requested because the water level had dropped in the lake by approximately two feet and many home owners were unable to dock their boats in the shallower water.

Historical water surface elevation records were available for the following years:

Table 1. Water Surface Elevations

Elevation	Date	By
979.32	1/19/42	Water Resources
979.22	2/25/48	Water Resources
978.00	1958	U.S.G.S
978.29	11/19/73	Div. of Waters, Soil & Minerals
979.70	5/3/74	Div. of Waters, Soil & Minerals
978.90	8/5/74	Hennepin County

The runout elevation was determined as 977.3' from a 1942 survey conducted by a Division of Water Resources survey crew. At that time there was an old timber bridge at the now abandoned railroad grade. The bridge had a twelve foot opening. A Hennepin County survey crew found a 1974 runout elevation of 977.9'. The controlling elevation is at the old abandoned railroad crossing 440 feet upstream (south) from the present railroad crossing.

In April 1931 a makeshift fish screen was installed upstream from the old bridge. The screen had rusted out by 1941. A new barrier was installed in 1987.

2.0 PROJECT PURPOSE

Lake Sarah was identified as a critical lake in the Pioneer-Sarah Creek Watershed Management Plan. It is located in the Sarah Creek watershed.

The Lake Sarah Project was initiated due to the gradual eutrophication of the lake. The recreational uses of Lake Sarah have been impaired due to algal blooms which have occurred for a number of years. The lake fishery has also undergone a change. The Department of Natural Resources (DNR) surveys indicated a significant change in the fish population occurred between 1981 and 1986. Lake Sarah has poorer water quality than other lakes in the metropolitan area that have similar morphometric and watershed characteristics.

3.0 PROJECT PARTICIPANTS

The Lake Sarah Project was a cooperative effort among local government and citizens in the area. The project sponsor was the Pioneer-Sarah Creek Watershed Management Commission (Commission). The Commission provided financial and oversight contributions. Other cooperators and responsibilities were: the city of Independence- financial support and clerical and financial coordination; the city of Greenfield- financial support and steering committee secretary; the Lake Sarah Improvement Association- financial support and coordination assistance; the Hennepin Conservation District- in-kind support for project management and technical work; Hennepin Parks- financial and in-kind support for coordinating monitoring activities.

A project steering committee was created at the start of the project. The steering committee met approximately every other month or as needed throughout the project. Their purpose was to oversee the project progress and provide input from a variety of perspectives.

4.0 PROJECT COSTS

The project was divided into 8 project elements. The budget for the project was as follows:

Table 2. Program Elements and Budget

Program Element	Activity	Budget
1	Development of Work Plan	$2,871
2	Development of Monitoring Plan and QAPP	$1,264
3	Development of Community Information and Outreach Plan	$237
4	Monitoring	$60,797
5	Community Information and Outreach Program	$6,455
6	Data Analysis and Assessment /Diagnostic Study Report	$8,624
7	Project Administration	$17,287
8	Development of an Implementation Plan	$6,125
Total		$103,660

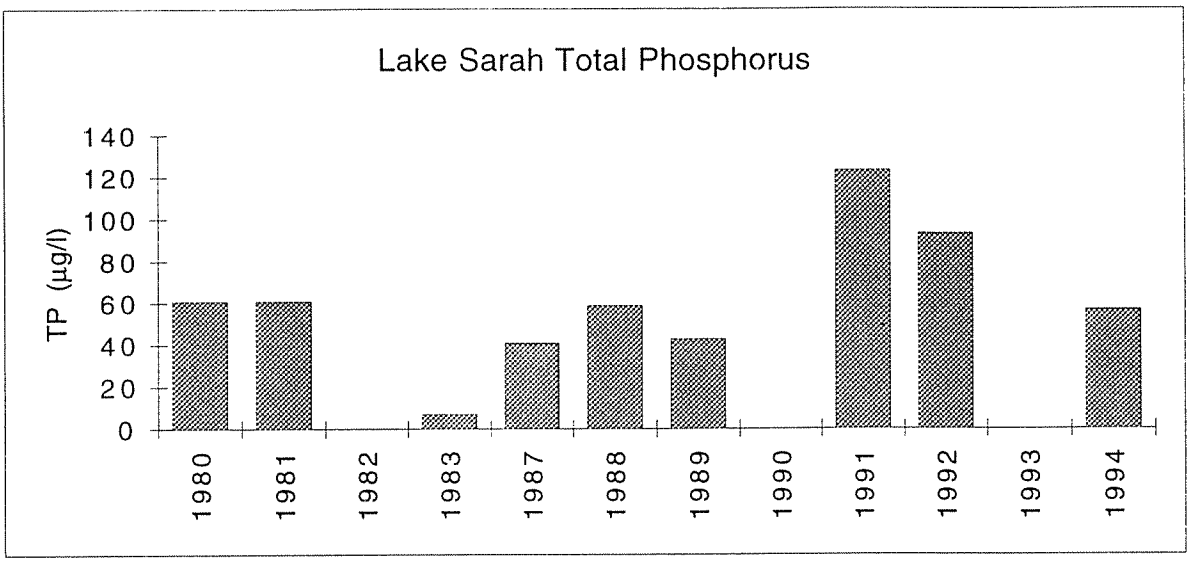
Grant Amount $51,830

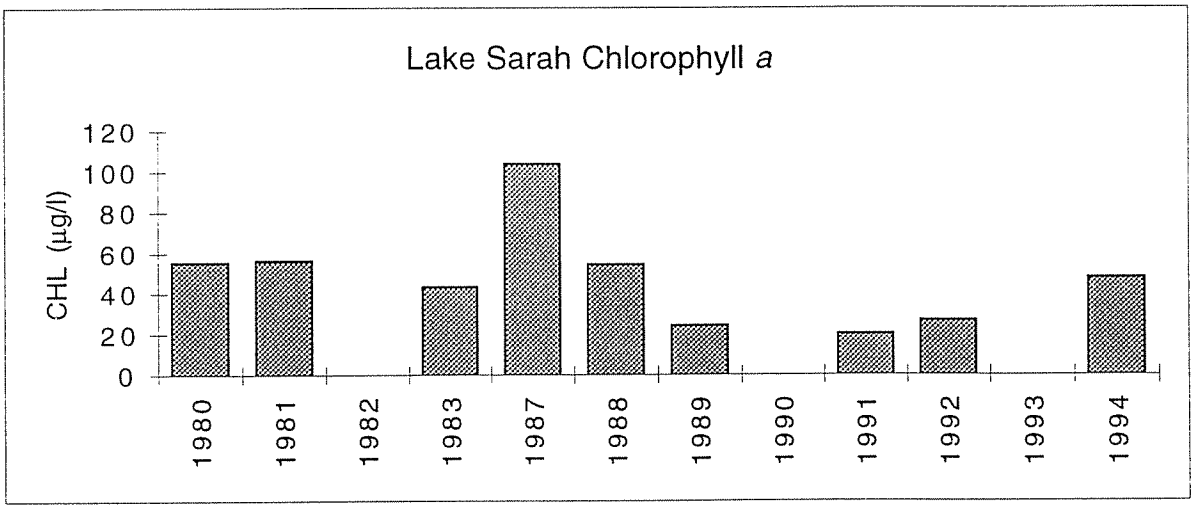
SECTION 2
SUMMARY OF PREVIOUS STUDIES

There is a substantial amount of water quality data for Lake Sarah from various sources. However, there had been no flow measurement of the inflows to the lake until 1991. The Pioneer-Sarah Creek Watershed Management Commission first began monitoring lakes in the watershed in 1988. Lake Sarah was included in this first monitoring effort. Lake Sarah was again monitored in 1989, 1992 and 1994. The Commission's monitoring program consists of monthly sampling from May to September. Samples were collected for total phosphorus, chlorophyll *a*, nitrate and nitrite, ammonia, total Kjeldahl nitrogen, alkalinity and chloride. Measurements of pH, dissolved oxygen, conductivity and Secchi disk transparency were also made.

The Metropolitan Council monitored Lake Sarah in 1980 and 1983. The Hennepin Conservation District has monitored water quality in Lake Sarah since 1980. Hennepin Parks has also monitored transparency and other parameters since 1980. The STORET database contains data from 1972 on for Lake Sarah. A summary of the data from previous studies is presented in Figures 2 and 3. Previous studies indicate a fluctuation in total phosphorus concentrations with a gradual decrease in water quality (Dindorf, 1993a). Chlorophyll *a* concentrations have not changed substantially in recent years. Earlier chlorophyll *a* concentrations were higher than observed in recent years. There was no significant trend detected in the transparency data.

Figure 2. Historical Data 1980-1996





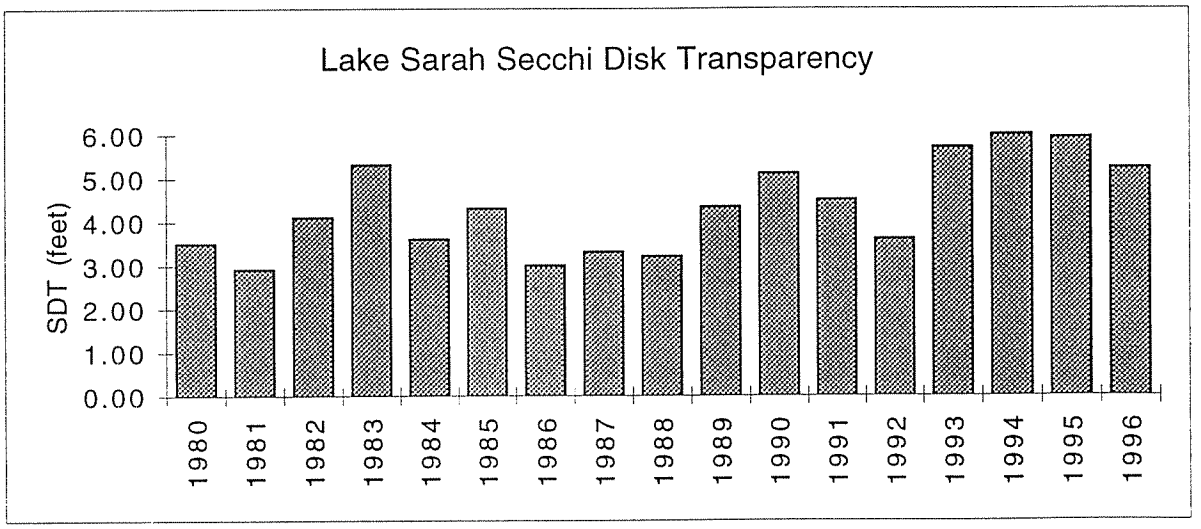
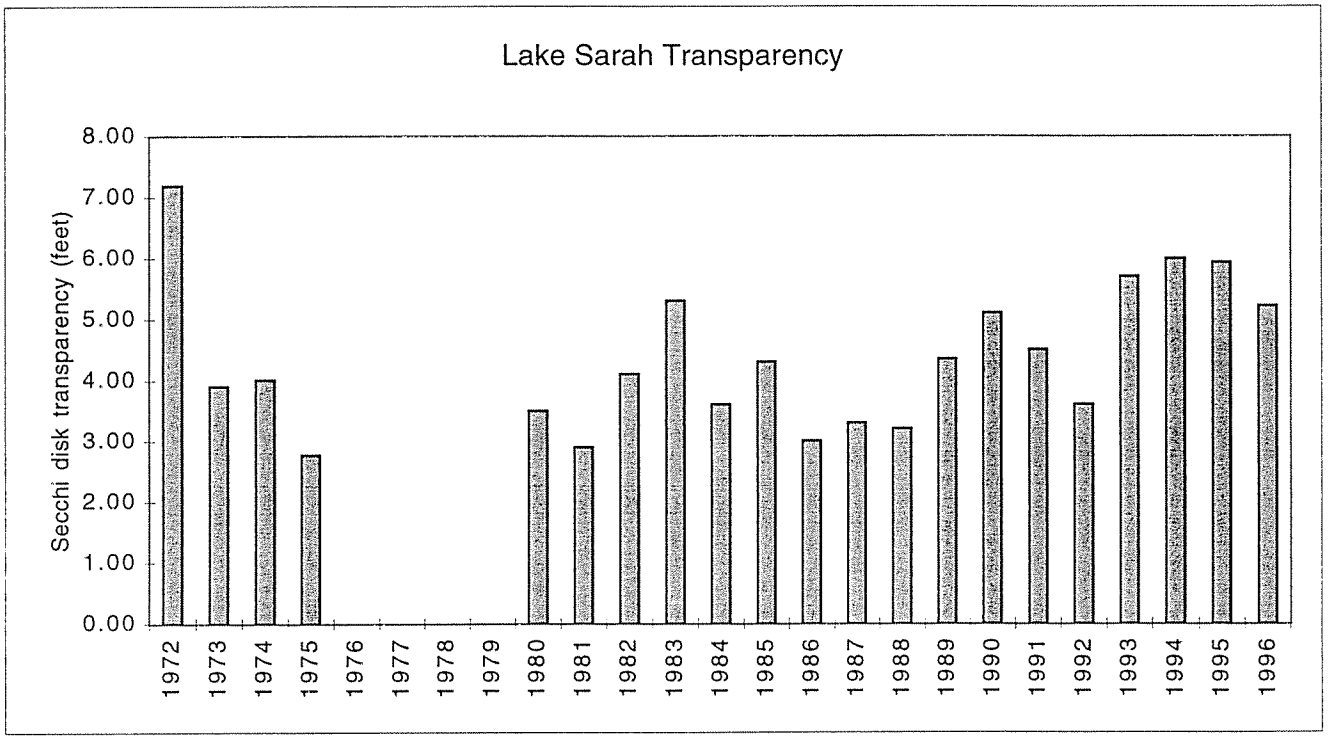


Figure 3. Secchi Disk Transparency 1972-1996



SECTION 3
DIAGNOSTIC STUDY

1.0 METHODS

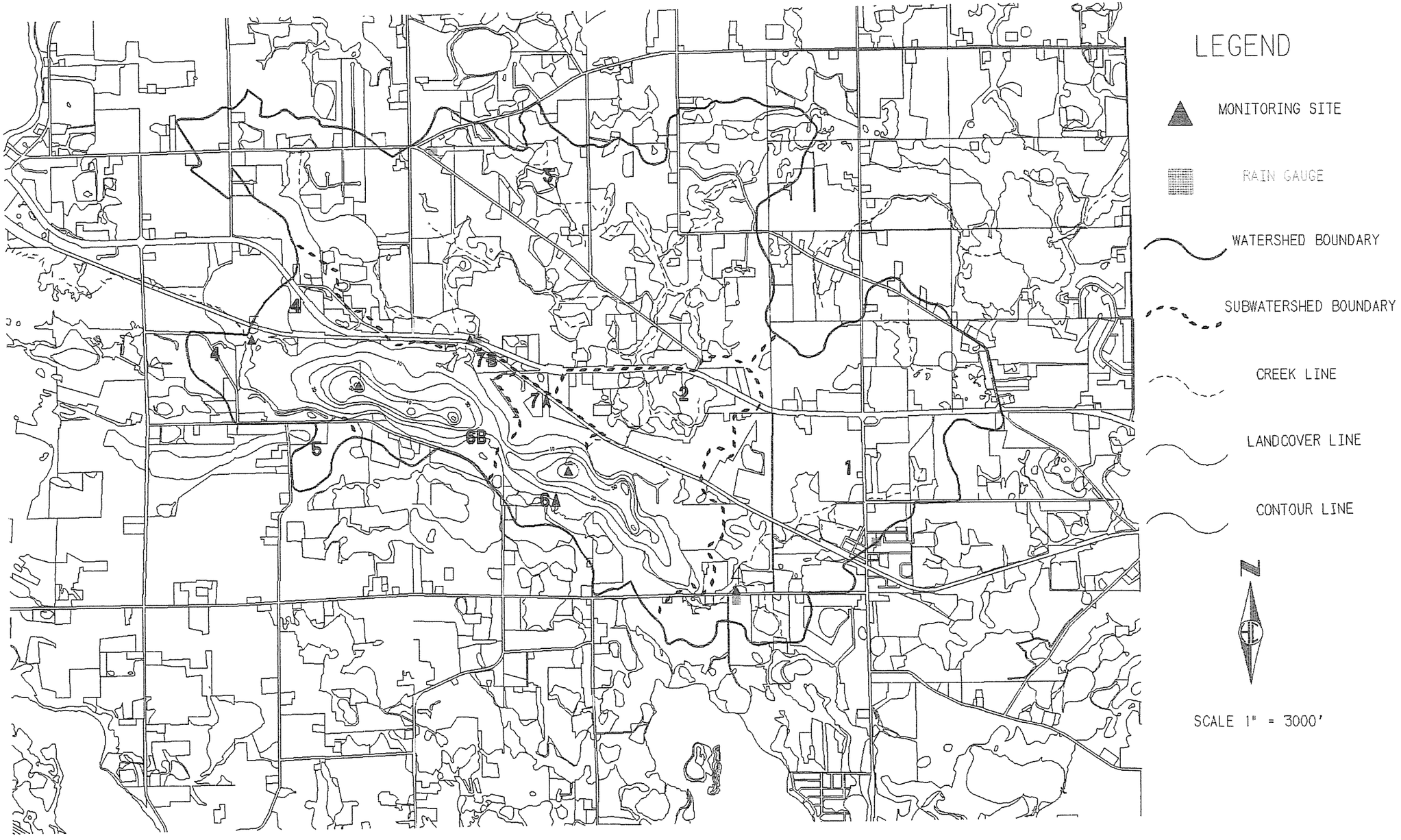
1.1 Water Quality Monitoring

1.1.1 Lake Monitoring

The water quality monitoring portion of the project was managed by John Barten, Project Monitoring Coordinator. The monitoring plan was modeled after the Clean Water Partnership guidance documents. Water samples were collected in accordance to the approved monitoring plan and were analyzed using methods listed in the approved QAPP plan from the laboratory, Instrumental Research. Specifically, samples were collected at two sites in the lake (see Figure 4a). Station number 1 was located in the lower basin over the deepest spot in the lake (50 to 60 feet). This site was the primary site where the majority of the samples were collected. Dissolved oxygen and temperature profiles were measured at each sampling date. Water samples were collected from the upper 2 meters using a composite sampler made from PVC pipe. Samples were also collected in the metalimnion and hypolimnion using a Kemmerer sampler. The water samples were stored in plastic bottles on ice in a cooler until delivered to the laboratory. Phytoplankton samples were taken from the surface composite sample and preserved with Lugol's solution. Zooplankton samples were prepared using a Wisconsin plankton net with a Minnesota bucket. A vertical tow from the bottom to the surface was collected. The zooplankton were identified and enumerated using Sedgewick rafter cells and a Bausch and Laumb microscope. Phytoplankton samples were analyzed using the membrane filter method. Aliquots were filtered onto a 0.45 µm membrane filter. The filters were treated according to the method and mounted onto slides. The slides were examined under the Bausch and Lomb microscope. Phytoplankton species were identified and biomass and was determined using an estimation method (Swain & Dindorf, unpublished). This method was approved for use by MPCA staff. Chlorophyll *a* samples were collected from the surface composite, filtered in the field onto 0.45 µm filters and stored in cellophane envelopes in a desiccator until delivered to the laboratory. Samples were analyzed for pH using a Beckman model PHI 11 pH meter. Conductivity was measured using a YSI model 3000 Temperature-Level-Conductivity meter. Station number 2 was located in the upper basin over the deepest area in the basin (40 feet).

Figure 4a

LAKE SARAH MONITORING SITES



LEGEND

- MONITORING SITE
- RAIN GAUGE
- WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY
- CREEK LINE
- LANDCOVER LINE
- CONTOUR LINE

N

SCALE 1" = 3000'

Samples from station #1 were analyzed for:

Secchi disk transparency (SDT)
Temperature (Temp)
Dissolved oxygen (DO)
Total phosphorus (TP)
Soluble reactive phosphorus (SRP)
Total Kjeldahl nitrogen (TKN)
Nitrate plus nitrite nitrogen ($NO_2 + NO_3$)
Ammonia nitrogen (NH_3)
Total suspended solids (TSS)
Total suspended volatile solids (TSVS)
Total alkalinity (ALK)
Chloride (CL)
Color
pH
Conductivity (COND)
Chlorophyll *a* (CHL)
Phytoplankton
Zooplankton
Fecal coliform bacteria
Organic nitrogen (ON) value calculated
Inorganic nitrogen (IN) value calculated
Total nitrogen (TN) calculated

Samples from station #2 were analyzed for:

Total phosphorus
Soluble reactive phosphorus
Secchi disk transparency
Dissolved oxygen
Temperature
Chlorophyll *a*
Total Kjeldahl nitrogen

The lab work was initially contracted with Twin City Testing. Due to dissatisfaction with the laboratory work, the contract was canceled and was awarded to Instrumental Research for the remainder of the project. The results from the first laboratory will not be used in the analysis.

Samples were collected according to the schedule listed in Table 3.

1.1.2 Stream monitoring

Stream monitoring was conducted at 3 sites around the lake (Figure 4a). Station #3 was located at the mouth of Dance Hall Creek (a.k.a. Rush Creek) as it enters the lake through a 48-inch corrugated metal pipe. A v-notch weir was constructed in the culvert to regulate flow from the site and provide for accurate flow measurements. This site is located on the north side of the lake and drains the majority of the watershed. The legal description of the site is S 1/2 of Sec. 35, T119N, R24W. Monitoring equipment placed at the site included an ISCO model 3220 flow meter with submerged probe level sensor and ISCO model 2900 automatic sampler. The samplers were equipped with 24-500 ml polypropylene bottles. The flow meters were set to read instantaneous flow at 15 minute intervals. A staff gauge was also installed at the site and read weekly. A tipping bucket rain gauge was used to measure precipitation at this site. Flow measurements were collected from March 12 to October 31, 1991.

Station #4 was located at Loretto Creek, a small stream entering the southeast end of the easterly bay of the lake. Samples were collected on the upstream side of a concrete box culvert which passes under County Road 11 near Ihduhapi Trail about 2/10 mile from the lake. The legal description of the site is the S 1/2 of Sec. 1, T118N, R24W. A v-notch weir was constructed in the culvert to regulate flow from the site and provide for accurate flow measurements. This station was equipped with an ISCO flow meter and samples were collected using an ISCO automatic sampler. A tipping bucket rain gauge was also placed at this site and a staff gauge was installed on the upstream side of the culvert.

Station #5 is the outlet of the lake, Sarah Creek, which is located on the northwest end of the western bay. Flow measurements were collected at an opening in the former railroad bed. This site was equipped with an ISCO flow meter and staff gauge. The outlet channel had to be periodically cleaned out due to beaver activity. Prior to March 21, 1991 velocity was measured using the floating chip method. The channel was not clearly defined due to the beaver activity and organic soils. Samples from the lake station were used to estimate water quality at the outlet.

One additional substantial inlet was not monitored. With the two monitoring sites, 77 percent of the watershed area runoff was monitored.

The sampling schedule for the stream sites is listed in Table 4.