

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER SUPPLY POTENTIAL OF THE
LAKE SALLY SYSTEM,
MARQUETTE COUNTY, MICHIGAN

Open-File Report 78-1046

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By N. G. Grannemann

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Lansing, Michigan

December 1978

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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DEFINITION OF TERMS

Base flow. Sustained or fair-weather runoff; in most streams it is composed largely of ground-water runoff.

Bedrock. In this report, designates Precambrian consolidated rocks.

Cubic feet per second (ft³/s). A unit expressing rate of discharge. One cubic foot per second is equal to the discharge of a stream through a rectangular cross section 1 foot wide and 1 foot deep at an average velocity of 1 foot per second.

Evapotranspiration. Water withdrawn from a land area by evaporation from water surfaces and moist soil and by plant transpiration.

Fault. A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.

Gaging station. A particular site on a stream, canal, lake or reservoir where systematic observations of gage height or discharge are obtained.

Ground water. Water in the ground that is in the saturated zone from which wells, springs, and ground-water runoff are supplied.

Ground-water runoff. That part of runoff that has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.

Partial-record stations. A site where limited streamflow data are collected systematically over a period of years for use in hydrologic analyses.

Permeability. The measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.

Pleistocene. The period of time between about 2 million and about 10,000 years ago, characterized by extensive glaciation of regions now free from ice.

Precambrian X. The age in earth history representing the time between 1.6 and 2.5 billion years ago.

Runoff. That part of precipitation that appears in streams; the water draining from an area. When expressed in inches, it is the depth to which an area would be covered if all the water draining from it in a given period were uniformly distributed on its surface.

Synclinerium. A broad regional fold in rocks in which the strata dip inward from both sides toward the axis.

CONVERSION FACTORS

Factors for converting Inch-pound units to metric units.

To convert from	To	Multiply by
Length		
inch (in)	centimeter (cm)	2.54
foot (ft)	meter (m)	0.3048
mile (mi)	kilometer (km)	1.609
Area		
mile ² (mi ²)	kilometer ² (km ²)	2.59
Volume per unit time		
foot ³ per second (ft ³ /s)	liter per second (L/s)	28.32
Volume per unit time per area		
foot ³ per second per mile ² (ft ³ /s)/mi ²	liter per second per kilometer ² (L/s)/km ²	10.93
Temperature		
degree Fahrenheit	degree Celsius	<u>1</u> /

$$\underline{1}/ \text{ Temp } ^\circ\text{C} = (\text{temp } ^\circ\text{F} - 32)/1.8$$

WATER SUPPLY POTENTIAL OF THE
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By

Norman G. Grannemann

ABSTRACT

Six lakes in the headwaters of Ely Creek form the Lake Sally system. This system is the source of water for Ishpeming and several small communities in the central part of Michigan's Upper Peninsula. During years of average precipitation, more water is used from the system than is supplied to it, and the quantity of water in lake storage is depleted. Below-normal precipitation in 1976 and early 1977 accelerated depletion and produced significantly lower lake levels, casting doubt on the system's ability to meet water demands. Because precipitation and overland runoff account for 93 percent of the water supplied to the Lake Sally system, the lake levels fluctuate according to precipitation patterns and are particularly sensitive to drought.

Water supplied to the Lake Sally system when precipitation is average is estimated to be 2.57 ft³/s or 13.4 in/yr. Use of water by Ishpeming is about 3.5 ft³/s or 18.27 in/yr. When the Lake Sally system supply is insufficient, the city also obtains some water from Cedar Lake and Lake Angeline outside the Lake Sally system.

Results of a base-flow investigation in 1977 on Ely Creek, the outlet of the Lake Sally system, indicate that ground-water flow to the lake system is between 0.08 and 0.17 ft³/s.

INTRODUCTION

Purpose and Scope

Inland lakes are an important source of water for many communities in Michigan. In Marquette County, Lakes Sally, Ogden, Miller, Tilden, Schoolhouse, and Foster--the Lake Sally system--are the principal water supply for Ishpeming and some nearby communities. Below normal precipitation and increased pumpage by Ishpeming have resulted in low lake levels during several periods in the past two decades. In March 1977, following 11 months of below normal precipitation, the water supply in the lake system was almost depleted. At the request of the Michigan Department of Public Health, data were collected to aid in describing the

hydrologic setting and evaluating the long-term water-supply potential of the lakes. This report provides that information. Although rain and snowmelt since March 1977 added water to the system, the need for an evaluation of the hydrologic situation remained.

Previous Studies

Iron-ore deposits in Marquette County have prompted numerous studies of the area's bedrock geology, such as that by Van Hise and Bayley (1897), and Gair (1975). Maps compiled by Leverett (1929), Martin (1957), and Doonan and VanAlstine (1978, unpublished) show the area's glacial geology. Water resources of the Marquette Iron Range are described in studies by Stuart, Brown, and Rhodehamel (1954); Wiitala, Newport, and Skinner (1967); and Supina (1974). Data from the above reports and unpublished data in the files of the U.S. Geological Survey and the Geological Survey Division, Michigan Department of Natural Resources, have been used for this study.

Physical Setting and Drainage

The Lake Sally system, defined as the drainage basin of Lakes Sally, Ogden, Miller, Tilden, Schoolhouse, and Foster (fig. 1), is in central Marquette County in the north-central part of Michigan's Upper Peninsula. The lakes are in an upland area of rugged topography. Altitudes range from 1,529 ft above mean sea level at Lake Sally to 1,873 ft at Summit Mountain (fig. 2). The lakes are connected by intermittent streams that, under natural conditions, drain to Ely Creek. The drainage network is not well developed and overland runoff is held in storage in the lakes. Lake Sally's water level and storage capacity are affected by a dam at the lake's outlet. From 1975 until spring 1978, pumpage from Lake Sally lowered the lake's level to the extent that it discharged no surface water to Ely Creek.

Climate

Average annual precipitation at Ishpeming (fig. 3), which is representative of that in the Lake Sally system, is 31.25 inches. The average annual snowfall is 104 inches and the average annual frost-free period is 116 days (Michigan Department of Agriculture, Michigan Weather Service, 1971). Class "A" pan evaporation averages 31 inches annually. This is about 6 inches more than the evaporation from natural water bodies (Kohler, Nordenson, Baker, 1959). The climate of the basin is moderated somewhat by its proximity to Lake Superior. Monthly mean temperatures range from 15°F in January to 66°F in July. Monthly mean temperatures from November to early March average less than 32°F. Precipitation during this period is generally in the form of snow, and there is little or no recharge to streams, aquifers, and lakes. During spring, melting snow may cause monthly runoff to exceed precipitation by as much as two times.

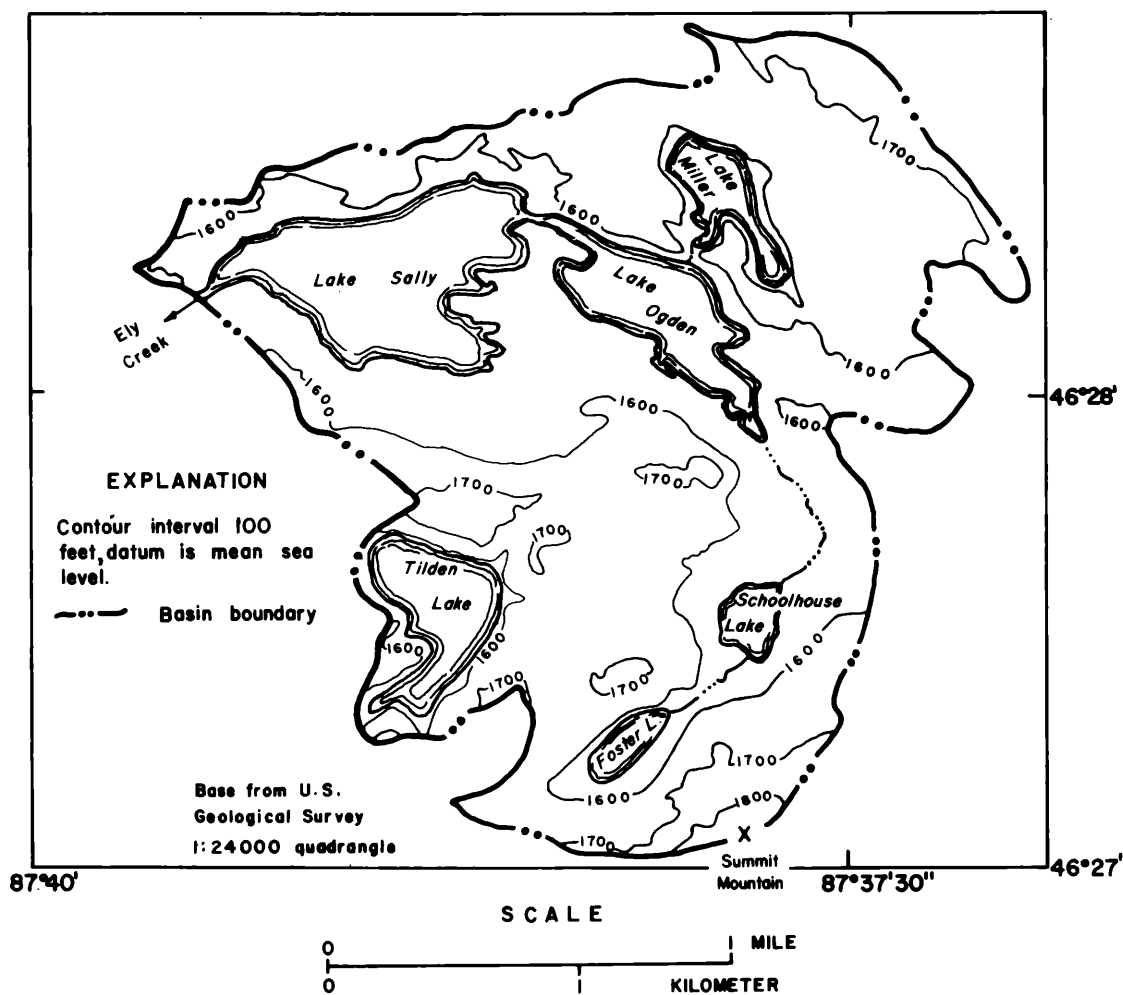


Figure 2.--Topographic map of the Lake Sally system (drainage area is 2.6 mi²; lake area is 0.55 mi²).

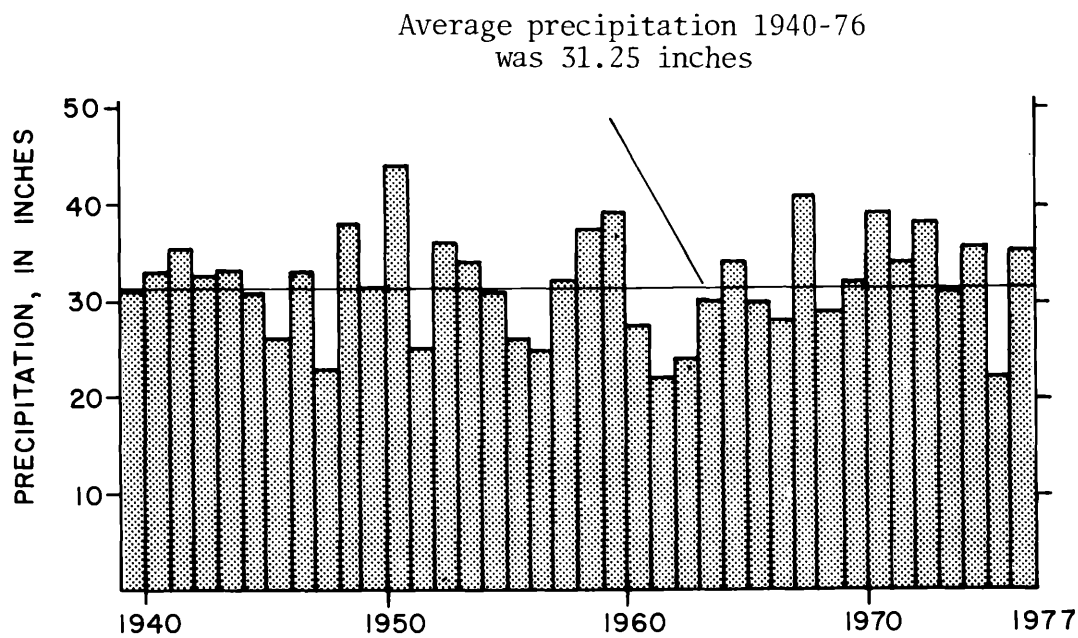


Figure 3.--Annual precipitation at Ishpeming.

Bedrock Geology

Bedrock in the Lake Sally system consists of the Negaunee Iron-formation (metamorphosed sedimentary rock) and intrusive bodies of greenstone (metamorphosed diabase), both of Precambrian X age (fig. 4). The Negaunee Iron-formation, characterized by parallel laminae of chert and iron minerals (Puffet, 1974), is the principal source of iron ore throughout the Marquette Iron Range. Mineral composition and fracturing make the Negaunee Iron-formation less resistant to erosion than the greenstone bodies.

Greenstone bodies intrude the Negaunee Iron-formation in about half of the Lake Sally system (fig. 4) and are more abundant within the system than elsewhere in the iron range. Greenstone is the most erosion-resistant rock in the iron range and forms the rough terrain around Lake Sally.

The Negaunee Iron-formation and the greenstone bodies are not good aquifers. In general, these rocks yield water only where faults and fractures provide storage and pathways for flow of ground water.

Bedrock Structure

The Marquette Synclinorium, a large canoe-shaped feature, extends from Lake Superior, 11 miles east of the Lake Sally system, into Baraga County, 22 miles west of the lake system. It is the predominant bedrock structure in the study area. The synclinorium is east-west trending and is composed of deformed and metamorphosed Precambrian sedimentary rock.

Several major faults are shown in figure 4. Many minor faults and joints occur throughout the study area. The boundaries of all greenstone intrusive bodies are faulted.

Faulting and other fracturing has altered the weathering patterns of the rock, affecting topography and drainage. Tilden Lake is at the intersection of two faults, and Ely Creek, in places, follows a fault. Erosion along faults produced bedrock depressions that are now the sites of Foster and Schoolhouse Lakes.

Glacial Geology

The general direction of ice movement in Marquette County during the Pleistocene was northeast to southwest (Martin, 1957). Glaciers advanced and retreated through the study area several times; however, only a few, thin deposits of unconsolidated material remain in the Lake Sally system. Because the deposits are thin and discontinuous, little ground water is held in storage, and only small amounts are contributed to the Lake Sally system during droughts.

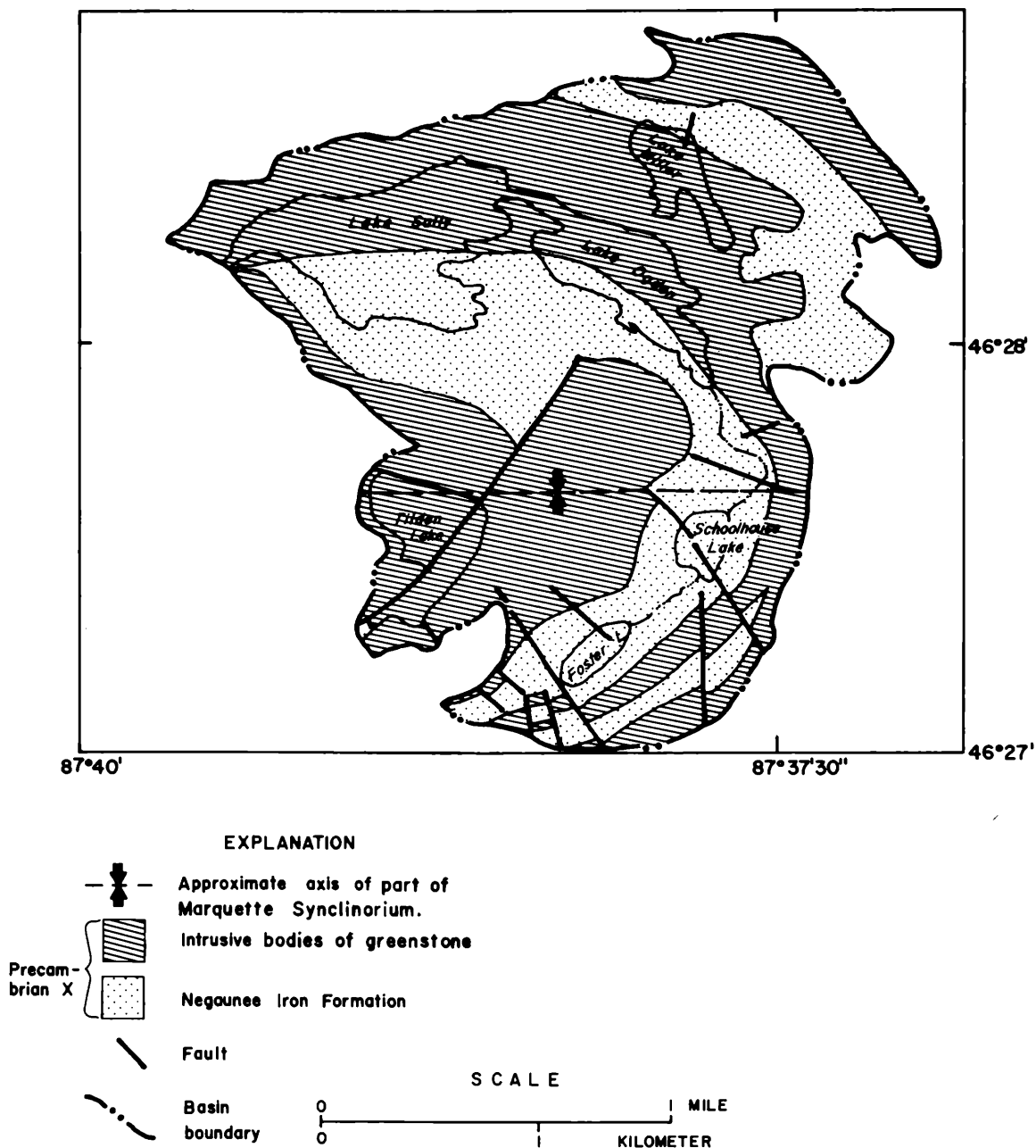


Figure 4.--Bedrock geology of the Lake Sally system (adapted from Boyum, 1975).

Erosional Features

The Lake Sally system lies in a glacially deepened valley, formed in a zone of faulting along the contact of the Negaunee Iron-formation and greenstone bodies (fig. 4). Resistant greenstone, such as that forming Summit Mountain and Suicide Hill, diverted the ice, funnelling it into weaker bedrock zones and promoting valley formation.

WATER AVAILABILITY IN THE LAKE SALLY SYSTEM

Water in lakes of the Lake Sally system is supplied directly by precipitation on the lakes, by runoff, and by ground-water flow from the unconsolidated glacial deposits and bedrock. Steep slopes, abundant bedrock outcrops, and thin unconsolidated deposits in the system make runoff the major source of water to the lakes.

Runoff

Runoff is determined from gaging stations at selected sites or through correlation of discharge measurements with records obtained at gaging stations having similar hydrologic settings. Streamflow data have not been collected continuously at any site in the Lake Sally system or on Ely Creek. However, numerous discharge measurements at site 5 on Ely Creek (fig. 5) provide a basis for evaluating runoff. Correlation of these measurements with records for gaging stations on nearby Warner Creek indicates that the average runoff at site 5 is $0.6 \text{ (ft}^3\text{/s)/mi}^2$. Runoff is variable, however, and ranges from 1.12 to $0.37 \text{ (ft}^3\text{/s)/mi}^2$.

Analysis of the Ely Creek discharge measurements shows that, on the average, once in 10 years the runoff for a 7-day period may be $0.06 \text{ (ft}^3\text{/s)/mi}^2$ or less. The lowest of 18 discharge measurements at site 5 was $0.46 \text{ ft}^3\text{/s}$. Runoff characteristics at site 5 were used in conjunction with a base-flow investigation of Ely Creek to evaluate the surface and ground-water contributions to the Lake Sally system.

Ground-water Flow

Bedrock and glacial deposits are minor sources of water in the Lake Sally system. Bedrock in the system is generally impermeable; however, faulting and other fracturing has created small openings in the rock for storage and movement of water. Most water from ground-water sources in the Lake Sally system flows from glacial deposits. These deposits, although not mapped for this report, occur along intermittent stream valleys and lakes. They are relatively thin, discontinuous, and poor aquifers. No wells are located within the Lake Sally system; consequently, direct study of the water-yielding properties of the glacial material is difficult. Stuart, Brown, and Rhodehamel (1954) describe the glacial deposits around Summit Mountain as till with large amounts of red clay--materials that transmit little water.

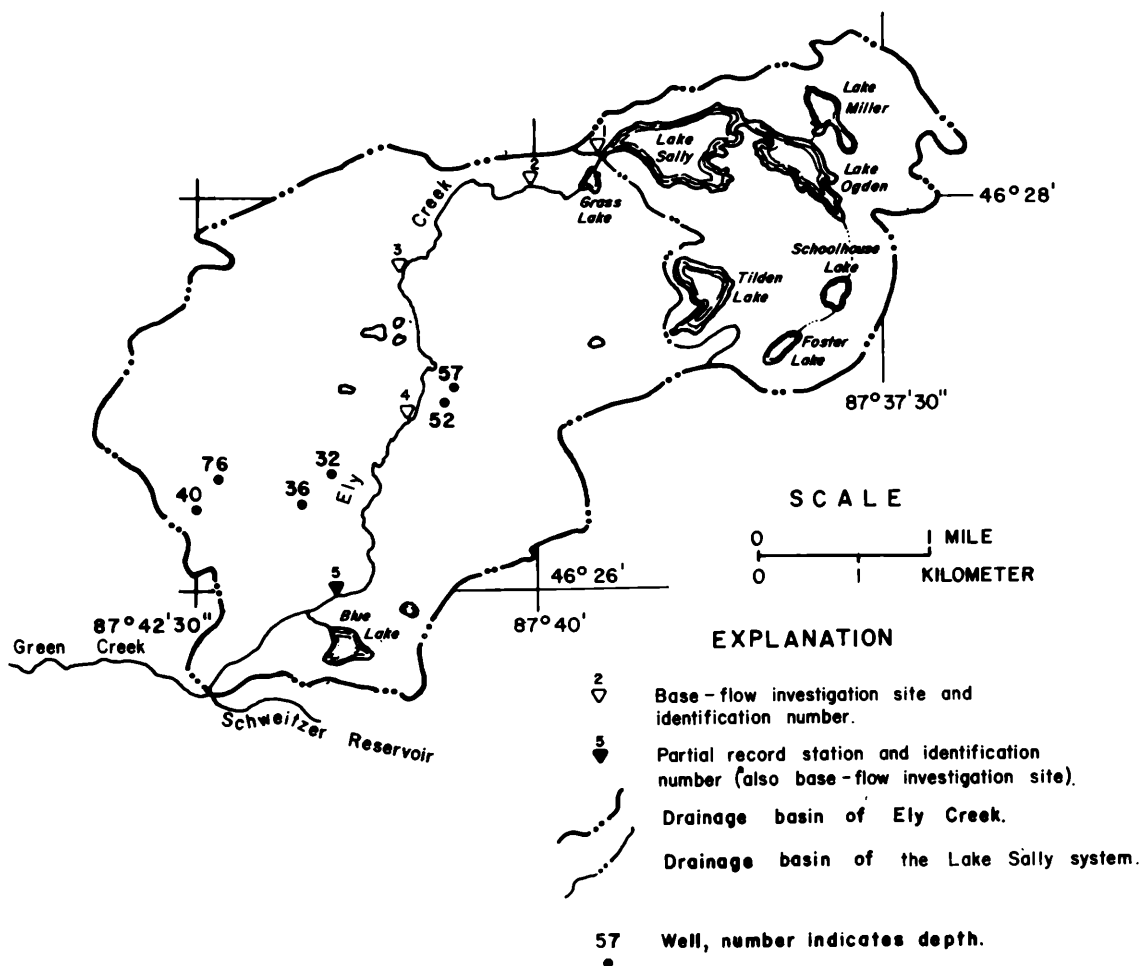


Figure 5.--Ely Creek drainage area (total area of the Ely Creek drainage basin is 9.85 mi²; area of the Lake Sally system drainage basin is 2.6 mi²).

The nearest wells are located southwest of Lake Sally in the vicinity of Ely Creek (fig. 5). Two wells, 52 and 57 feet deep, are in a buried valley and penetrate good aquifer material. Several wells west of Ely Creek are in glacial deposits which have large amounts of clay.

Because the Lake Sally system overlies the fault contact of the Negaunee Iron-formation and greenstone intrusive bodies, and because lakes in the system are situated at high elevations, it is likely that some water from the lakes migrates from the lake system along the fault and its associated fractures. However, no direct evidence of this has been found.

To determine the capacity of bedrock and glacial deposits to transmit water, base-flow measurements of Ely Creek were made on August 9, 1977, when its flow was unaffected by antecedent rains. Streamflow at this time was derived primarily from ground-water sources and reflected the potential of bedrock and glacial deposits to transmit stored water to the stream. Because the upper reaches of Ely Creek are geologically similar to the Lake Sally system, base-flow measurements of the creek provide a basis for defining ground-water flow to the lake system. Locations of discharge-measuring sites and results of the base-flow investigation are shown in figures 5 and 6, respectively. There was no discharge from Lake Sally (site 1) at the time of the investigation; diversions having lowered the lake level below the crest of the outlet dam. Discharge at site 4 was significantly higher than at site 3, which indicates that ground-water inflow occurs within this reach. Stream temperatures were appreciably lower at site 4 (fig. 6), reflecting the inflow of colder ground water, probably from a buried valley upstream from the site (Stuart, Brown, and Rhodehamel, 1954). Some water may also be transmitted to Ely Creek along a fault that trends westward from the north side of Tilden Lake (fig. 4). The base-flow study data indicate that Ely Creek is a gaining stream between sites 2 and 4. Because of the geologic similarities between the Ely Creek area and the Lake Sally study area, it is likely that glacial deposits and bedrock in the lake system contribute some water to the lakes during droughts.

The August 9, 1977, base-flow measurement at site 5 on Ely Creek was $1.33 \text{ ft}^3/\text{s}$. When this measurement is correlated with long-term records collected at gaging stations on Warner Creek, the 7-day 10-year low flow at site 5 is determined to be $0.54 \text{ ft}^3/\text{s}$. This low-flow discharge is representative of streamflow during droughts. Using a flow of $0.54 \text{ ft}^3/\text{s}$ at site 5, and assuming that baseflow in Ely Creek under drought conditions decreases upstream at the same percentage rate as it did on August 9, 1977, the discharge at site 3 would be 25 percent of the site 5 value or $0.14 \text{ ft}^3/\text{s}$. The discharge at site 2 would be 2 percent of the site 5 value or $0.01 \text{ ft}^3/\text{s}$. Based on the drought flows at sites 2 and 3, the ground-water contribution to the lake system is estimated to be $0.08 \text{ ft}^3/\text{s}$ or 7 percent of the total inflow. During periods of average precipitation, estimated ground-water flow to the lakes is $0.17 \text{ ft}^3/\text{s}$.

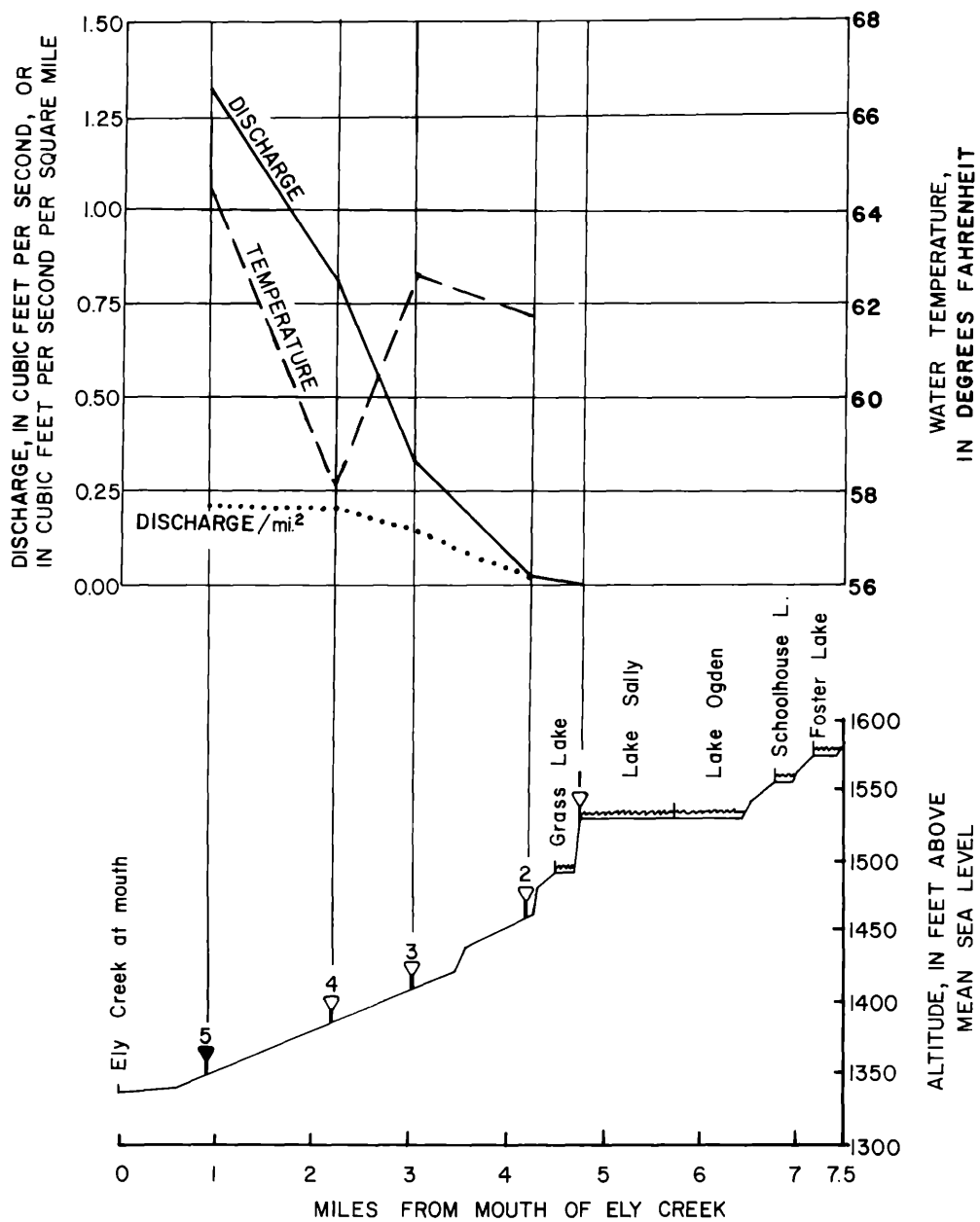


Figure 6.--Results of the August 9, 1977, base-flow investigation of Ely Creek.

Estimates of Water Available

Estimates of the total amount of water available to the Lake Sally system are shown in table 1. These estimates are based on rainfall and runoff in the adjacent Warner Creek basin (fig. 1), which is similar geologically and topographically to the Lake Sally system. Similar evapotranspiration losses were assumed for both the Warner Creek basin and the Lake Sally system.

Table 1.--Estimates of water available to the Lake Sally system
(Drainage area of the Lake Sally system is 2.6 mi²;
combined area of its lakes is 0.55 mi²).

Relative precipitation	Precipitation	<u>ft³/s</u>	Estimated runoff	
	<u>in/yr</u>		<u>in/yr</u>	<u>Mgal/d</u> ^{1/}
Low	21.26	1.10	5.8	0.71
Average	31.25	2.57	13.4	1.66
High	40.79	4.71	24.6	3.04

^{1/} Million gallons per day.

Runoff under low, average, and high conditions is estimated to be 39, 49, and 66 percent of precipitation, respectively. Precipitation values used are the lowest, average, and highest for the period 1940-76. Evaporation from the lake surfaces is assumed to be constant at 25 in/yr for all estimates.

Current water use by Ishpeming is about 3.5 ft³/s; this is 2.3 million gallons per day, or 18.27 in/yr. Annual precipitation (fig. 3) during 1970-75 averaged 34.33 inches or about 3 inches more than the long-term average. Precipitation during 1976 was the lowest recorded (21.26 inches) since 1940. During January and February 1977, precipitation was below normal, but it was above average for the calendar year 1977. Several years of average or below-average precipitation, or an increase in population, would require Ishpeming to have another source of supply available. At present, the city uses Lake Angeline and Cedar Lake for supplemental supply.

CONCLUSIONS

Lakes in the headwaters of Ely Creek--the Lake Sally system--are the source of most water for Ishpeming and some nearby communities. Supplemental supplies are derived from Lake Angeline and Cedar Lake. Deficient precipitation in 1976 and early 1977 caused water used from the Lake Sally system to exceed water supplied to it, thus lowering lake levels significantly. The long-term supply of water to the Lake Sally system is estimated to average $2.57 \text{ ft}^3/\text{s}$ or 13.4 in/yr . Because direct precipitation and overland runoff account for 93 percent of the water supplied to it, the system is sensitive to precipitation patterns and particularly sensitive to drought. Because water use by Ishpeming is about $3.5 \text{ ft}^3/\text{s}$ or 18.27 in/yr , several years of average or below-average precipitation would require the use of water from another source on a regular basis.

Ground-water flow to the lakes is insignificant in the total water budget. It ranges from about 0.08 to $0.17 \text{ ft}^3/\text{s}$ and comes mainly from glacial deposits in the drainage area of the Lake Sally system. Bedrock near the lakes is poorly permeable, except locally along faults, and contributes little water to the lakes.

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