

INTRODUCTION

The cold-water streams of the northern states provide unique recreational values to the American people (wilderness or semi-wilderness atmosphere, fast-water canoeing, and trout fishing) but the expanding recreational needs must be balanced against the growing demand of water for public and industrial supplies, for irrigation, and for the dilution of sewage and other wastes. In order to make intelligent decisions regarding use and management of the water resources for recreation and other demands, an analysis of the hydrologic factors related to recreational values is essential.

The Pere Marquette, an outstanding river for brown and steelhead trout fishing, is also a popular canoe trail. Larger boats, some equipped with motors, are common in the lower reaches where the river is wide and deep. Canoes are abundant on the river near Baldwin but are relatively sparse elsewhere. The broad swampy floodplain that borders most of the river between Wabasha and Ludington apparently offers few favorable canoe sites.

The Pere Marquette is located in the west-central part of the Southern Peninsula of Michigan, and flows westward from the headwaters near Chase in Lake County to the mouth at Ludington, in Manistee County. The river is south of, and roughly parallel to, U.S. Highway 10 from Chase to Ludington.

Access to the river is by roads leading south from U.S. 10 at Nirvana, Idlewild, Baldwin, Branch, Wabasha, Scottville, and many intermediate points. The recreational value of the river depends on the streamflow characteristics, quality of water, and character of stream channel and bed and banks. The purpose of this report is to describe these characteristics and show how they relate to recreational uses.

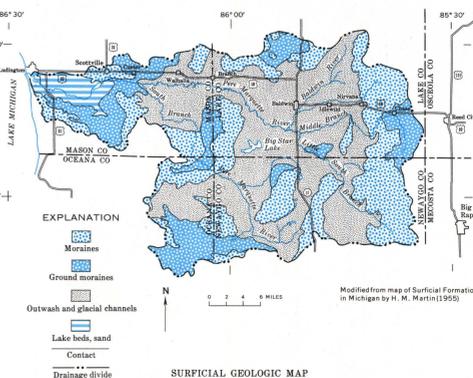
Most of the information presented here was obtained from a field reconnaissance in July and August, 1966, and from basic records of the U.S. Geological Survey's Water Resources Division. The area of field study is limited to the channel, bed, and banks of the Middle Branch and main stem of the Pere Marquette from source to mouth. The study was made in cooperation with the Michigan Geological Survey, Gerald E. Eddy, Chief. Advice and assistance were also obtained from other sections of the Michigan Department of Natural Resources. Sheet 1 of this atlas presents information on streamflow and quality of water. Sheet 2 describes the physical characteristics of the stream channel, bed, and banks, and shows how these characteristics relate to streamflow, water quality, and recreational use.

GEOLOGIC SETTING

The Michigan Lobe of the Pleistocene glaciers deposited a series of moraines with associated ground moraines in the Pere Marquette River basin. These moraine areas form most of the boundary areas of the basin and isolated remnants within the basin. Between the moraines are broad areas of glacial outwash that cover more than half of the drainage basin. The moraine areas are hilly to gently rolling; the outwash areas are relatively flat but dissected in places by streams and pitted with kettle holes formed by melting blocks of glacial ice. Some of the kettle holes are occupied by lakes. West of Scottville the river basin is a broad plain underlain by beds of sand deposited in a glacial lake. The Middle Branch of the Pere Marquette rises in the rolling hills of glacial moraine and ground moraine that form the eastern boundary of the drainage basin. West of this moraine area the river flows across a broad outwash plain that extends westward to Custer. The river crosses a belt

of ground moraine between Custer and Scottville and then crosses a sandy lake plain to the mouth at Ludington.

The streamflow characteristics and temperature of the Pere Marquette are strongly influenced by the geology and topography of the basin. The more permeable materials in the basin, especially sand and gravel outwash, contribute a relatively large amount of ground-water discharge to the stream. This ground-water discharge maintains the flow of the stream during rainless periods and helps to keep the water cool during hot summer days. The less permeable materials that compose the moraines and ground moraines generally contribute more surface runoff and less ground-water discharge than is contributed by the outwash deposits. The relatively high ground flow and low summer water temperatures of the Pere Marquette reflect the permeable materials that underlie most of the basin.



SURFICIAL GEOLOGIC MAP

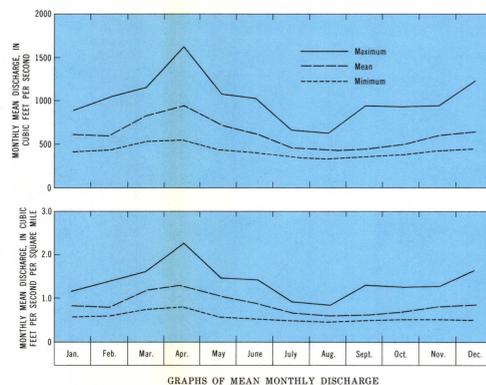
STREAMFLOW

INTRODUCTION

The flow of any uncontrolled river varies from day to day and from year to year. This variation may be measured in units of discharge (volume of water discharged per unit of time), velocity (speed of movement of water), and stage (elevation of water surface). These units are related—a high discharge results in high stages and, usually, in high velocities. Velocity also varies in different reaches of the river, the velocity generally being greater in reaches of steep fall than in the flatter reaches. The gradients of the reaches of the river are shown on the river profile (Sheet 2).

DISCHARGE

Daily discharge on the Pere Marquette is recorded at a gaging station at Scottville. Records of monthly mean discharge for the period October, 1951 through September, 1967, are shown below. Discharge is shown in cubic feet per second (cfs) and cubic feet per second per square mile (cfsm). The highest rates of discharge usually occur during the snowmelt season in April. Discharge generally declines through late spring and summer months and then increases somewhat in the fall when frost kills the vegetation and reduces the amount of evapotranspiration in the basin.



GRAPHS OF MEAN MONTHLY DISCHARGE

DISCHARGE MEASUREMENTS OF PERE MARQUETTE RIVER, SEPTEMBER 19, 1966

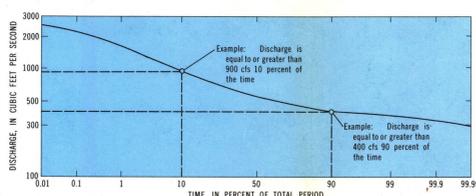
Stream	Location	Drainage area (sq. mi.)	Discharge (cfs)	Discharge (cfsm)
Middle Branch Pere Marquette River	Station 1 SE 1/4 Sec. 10, T. 17 N., R. 12 W., at highway bridge 4 1/2 miles southwest of Chase	30	15.6	0.52
Pere Marquette River	Station 2 SW 1/4 Sec. 15, T. 17 N., R. 13 W., at fishing site 2.7 miles south of Baldwin	200	102	0.51
Pere Marquette River	Station 3 NW 1/4 Sec. 27, T. 18 N., R. 14 W., 3 1/2 miles southeast of Branch	320	210	0.66
Pere Marquette River	Station 4 SW 1/4 Sec. 21, T. 18 N., R. 15 W., 1.4 miles south of Wabasha	380	257	0.68

The discharge per unit drainage area (cfsm) was greater at the two downstream stations than in the two upstream stations. This is attributed to the greater proportion of outwash in the drainage area contributing to the downstream stations.

STREAMFLOW

FLOW-DURATION

Discharge characteristics of streams can be illustrated graphically by flow-duration curves that show the percentage of time that specified discharges are equalled or exceeded. A flow-duration curve for the Pere Marquette at Scottville is shown below. The curve is based on record from 1940 to 1966.



FLOW-DURATION CURVE, PERE MARQUETTE AT SCOTTVILLE

The ratio of 90 percent to 10 percent discharge on Michigan streams varies from as great as 0.75 to less than 0.05. The higher ratios generally indicate a relatively large contribution of ground-water discharge to the stream. The Pere Marquette, with a ratio of 0.44, has a large contribution from ground-water, but not so great as some other rivers in the area, such as the Manistee.

VELOCITY

Velocity of flow on the Pere Marquette varies in time and place. Increased discharge generally is accompanied by increased velocity. Velocity normally is faster near the surface at mid-channel than near the bottom or banks of a river. Velocity in rapids and riffles is obviously faster than in deep pools. Measured velocities in the Pere Marquette ranged from less than 1 foot per second in the pools to more than 5 feet per second at Rainbow Rapids. The velocity and depth of a stream are limiting factors in safe wading. Generally it is not safe to wade a stream where the depth, in feet, multiplied

by velocity, in feet per second, is greater than 10. For example, if the velocity is 5 feet per second, the water should not enter water more than 2 feet deep. This assumes a firm footing and a strong wader. If bottom material is slippery, even 1 foot may be too deep.

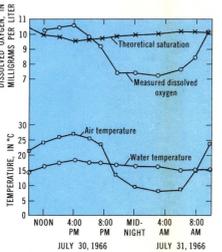
Velocity is a limiting factor in safe wading on the Pere Marquette in the faster riffles and rapids. In most reaches wading is restricted chiefly by the depth of the water in relation to height of the wader's boots.

QUALITY OF WATER

DISSOLVED OXYGEN

Dissolved oxygen is another critical requirement of recreational rivers. The amount of dissolved oxygen in water is very small. At temperatures just above freezing, water saturated with dissolved oxygen contains about 14 mg/l (milligrams per liter) of oxygen. As water temperatures increase the capacity to retain oxygen decreases, and at water temperatures above 21°C (70°F) saturation is reached at concentrations less than 9 mg/l. In summer the effect of temperature may be masked by effects of photosynthesis and respiration of aquatic plants.

Dissolved oxygen was measured periodically for 24 hours at the campsite above Rainbow Rapids in the NW 1/4 Sec. 27, T. 18 N., R. 14 W. (see graph below). Dissolved oxygen was slightly above saturation during most of the daylight hours and dropped to 2 to 3 mg/l below saturation at night. Measured dissolved oxygen ranged from 12 to 10.4 mg/l. This is a normal range for an unpolluted cold-water stream with moderate bottom vegetation.

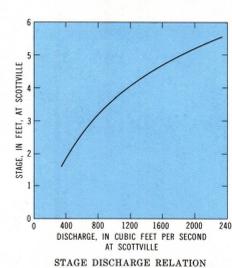


DISSOLVED OXYGEN AND TEMPERATURES PERE MARQUETTE ABOVE RAINBOW RAPIDS

STREAMFLOW

STAGE

The stage, or water level, of the Pere Marquette fluctuates with discharge. The relation of stage to discharge is used to determine the discharge of the river between measurements. The relation between discharge and stage is shown on the graph at the right.



STAGE DISCHARGE RELATION AT SCOTTVILLE

The relation varies in different reaches of the river. In general, for a given change in discharge, fluctuations in stage are relatively large where the river channel is narrow and banks are high, and relatively small where the channel is broad and banks are low. Channel width and bank heights are shown on maps 1 and 3 on sheet 2.

Fluctuations in stage influence the amount of cover available to trout and the wadability of some reaches of the river. Extremely low stages make boating difficult in some shoal reaches, and extremely high stages may cause damage to cabins and campgrounds.

In a normal year, the stage of the Pere Marquette at the gaging station at Scottville fluctuates only about 3 to 4 feet. Stage is usually lowest in late summer and highest in early spring. Fluctuations in stage on the Pere Marquette usually are not abrupt, except during time of snowmelt or exceptionally heavy rains. At such times the changes in stage from day to day may be great enough to restrict wading in some reaches of the river.

QUALITY OF WATER

PH

The pH of water is an indicator of its acidity or alkalinity. Waters with a pH of 7 are said to be neutral. A pH lower than 7 indicates acid water; a pH higher than 7 indicates alkaline water. The water in the Pere Marquette is slightly alkaline with pH values ranging from 7.3 to 7.8.

SUSPENDED AND FLOATING SOLIDS

No direct measurements of suspended solids were in this study. Turbidity was apparently fairly low during most of the summer season, as the bottom was clearly visible most times at depths up to 3 feet. After heavy summer rains the water became slightly cloudy, and during the spring snowmelt the water appeared to be moderately turbid. Floating materials, such as organic trash, detergent foam, and oil slicks were not observed on the river.

	Station 1 SE 1/4 Sec. 10, T. 17 N., R. 12 W., 9-19-66	Station 2 SW 1/4 Sec. 15, T. 17 N., R. 13 W., 9-19-66	Station 3 NW 1/4 Sec. 27, T. 18 N., R. 14 W., 9-19-66	Station 4 SW 1/4 Sec. 21, T. 18 N., R. 15 W., 9-19-66
Calcium (Ca) mg/l	42	42	42	42
Magnesium (Mg) mg/l	16	14	14	14
Sodium (Na) mg/l	2.5	5.8	6.1	7.9
Potassium (K) mg/l	.4	.3	.5	.4
Bicarbonate (HCO ₃) mg/l	206	197	172	174
Carbonate (CO ₃) mg/l	0	0	0	0
Sulfate (SO ₄) mg/l	9.2	12	24	23
Chloride (Cl) mg/l	1.0	8.0	8.5	14
Fluoride (F) mg/l	.1	.1	.1	.1
Nitrate (NO ₃) mg/l	.1	.1	.2	0
Phosphorus as PO ₄ mg/l	.33	1.6	.07	.34
Dissolved Solids*, mg/l	182	193	187	195
Hardness as CaCO ₃ mg/l	171	179	163	168
Specific Conductance**	331	331	337	350
pH	7.5	7.5	7.4	7.5
Color	8	5	8	5

* Calculated
** micromhos at 25°C

STREAMFLOW

SUMMARY

The following table summarizes the streamflow characteristics of the Pere Marquette River and shows how these characteristics are related to recreational uses.

Recreational use	Relation of streamflow to recreational use (Prepared by the Michigan Department of Natural Resources)	Characteristics of Pere Marquette River
Trout fishing	High drought flow helps keep summer water temperature low. Excessive flood flow removes cover and may cause erosion of banks.	Drought flow of Pere Marquette is relatively high. Floodflows cause some bank erosion, but damage appears to be slight.
Boating	A variety of fast and slow reaches adds interest for boaters.	Velocity varies in different reaches. Generally not too fast for safe wading except in a few of the larger rapids. Velocity at flood time may be too fast in much of river.
Camping and cabin living	Streamflow characteristics favorable to fishing and boating also are generally favorable to camping and cabin living.	Rise in stage may be great enough to make some reaches unswimable. Increases in stage generally are not abrupt. A rise of more than 1 foot in 24 hours is uncommon.

QUALITY OF WATER

SUMMARY

The following table summarizes the quality of water characteristics of the Pere Marquette River and shows how these characteristics are related to recreational uses.

Recreational use	Relation of quality of water to recreational use	Quality of water in Pere Marquette River
Trout fishing	Temperature Criteria for intrastate waters, as established January, 1968, by the Water Resources Commission, Michigan Department of Natural Resources (1968) specify 21.1°C (70°F) as the maximum limit for intolerant fish (cold-water species).	Maximum temperatures in the upper reaches of the Pere Marquette probably exceed 21.1°C (70°F) only rarely. Maximum temperatures below Scottville probably exceed 21.1°C (70°F) a few days of most years.
	Dissolved Oxygen The Water Resources Commission (1968) specifies a minimum of 6 mg/l. At water temperatures above 20°C (68°F), Tarzwell (1957) indicates full air saturation is required for the full range of activity for brook trout.	Dissolved oxygen on the Pere Marquette above Scottville probably does not drop below 6 mg/l at any time. At night may drop 2 to 3 mg/l below saturation.
	Hydrogen Ion Concentration (pH) Water Resources Commission (1968) specifies limits of 6.5 and 8.5.	pH of the Pere Marquette generally ranges from 7.3 to 7.8.
	Nutrients (chiefly nitrate and phosphate) Water Resources Commission (1968) requires nutrients to be limited to the extent necessary to prevent stimulation of growths of algae, weeds, and slime, which are or may become injurious to the designated use. Because these nutrients are rather quickly taken up by plants, exact limits of desirable concentrations are difficult to determine.	Pere Marquette is generally free from undesirable weeds, algae, and slime. A few analyses indicate relatively high phosphate content.
Trout fishing, boating, camping, and cabin living	Floating, Settling, and Suspended Solids Water Resources Commission (1968) specifies no objectionable unnatural turbidity, color, or deposits sufficient to interfere with designated use; no floating solids, or evidence of residues of unnatural origin.	Pere Marquette appears to be generally free of floating solids and residues of unnatural origin. Turbidity during spring flood flows may be moderately high.

QUALITY OF WATER

INTRODUCTION

The quality of water in a river is expressed in terms of dissolved and suspended substances and in physical properties of the water. Dissolved substances are the solids (salts) and gases in the water. Suspended materials include all undissolved materials, chiefly clay, silt, sand, and organic material moved in the stream. Physical properties important to recreational values are temperature, pH, specific conductance, odor, and color.

TEMPERATURE

Temperature of water is a critical requirement for trout propagation. No long-term records of water temperature of the Pere Marquette are available. However, correlation of monthly temperature readings at Scottville with the recording station on the Little Manistee near Friesland indicates that maximum summer water temperatures of the Pere Marquette at this station usually are about 22°C (72°F). Maximum temperatures in upstream reaches generally are lower than at the Scottville gage. A continuous record of water temperatures was obtained at four stations (Map 1, Sheet 2) during the period July 28 through August 2, 1966. Daily high and low readings at the four stations are listed below. Record was lost on station 2 for the period July 31-August 2 because recording water left the thermograph exposed to the air.

Date	Station 1 SE 1/4 Sec. 10 T. 17 N., R. 12 W.		Station 2 SW 1/4 Sec. 15 T. 17 N., R. 13 W.		Station 3 NW 1/4 Sec. 27 T. 18 N., R. 14 W.		Station 4 SW 1/4 Sec. 21 T. 18 N., R. 15 W.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
July 28	15.5	13.0	17.5	16.5	18.0	17.0	19.0	18.0
29	13.0	12.5	17.0	15.5	18.0	15.5	19.0	17.0
30	13.0	12.0	17.0	14.5	18.0	15.5	19.0	16.5
31	13.5	12.0	--	--	18.0	16.0	19.5	16.5
Aug. 1	12.0	12.0	--	--	17.5	15.5	18.5	16.5
2	13.0	11.0	--	--	16.5	15.0	18.0	16.0

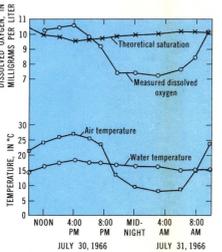
These records show a general increase in summer water temperatures downstream which is a normal situation in most rivers. However, local variations in the amount of ground-water inflow may produce a variety of temperature conditions in different reaches of the river. Local variations in the amount of sunlight may also influence water temperatures. The Pere Marquette is well shaded over most of its length, but the greater width of river below Custer exposes a relatively large surface to sunlight. The generally low summer water temperatures in the Pere Marquette are favorable to trout propagation.

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