DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
MICHIGAN GEOLOGICAL SURVEY

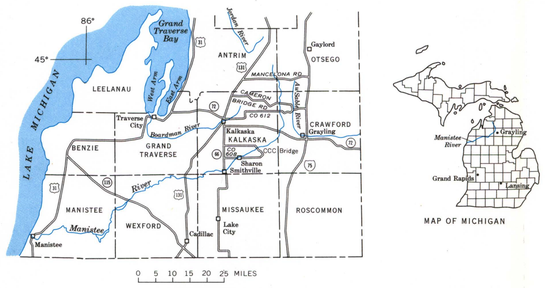
HYDROLOGIC INVESTIGATIONS
ATLAS HA-436 (SHEET 1 OF 2)

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, trout fishing), but expanding recreational needs must be balanced against the growing demand of water for public and industrial supplies, irrigation, and dilution of sewage and other wastes. In order to make intelligent decisions regarding use and management of water resources for recreation and other demands, an analysis of hydrologic factors related to recreation is essential.

The Manistee River is one of Michigan's well-known trout streams—a stream having numerous public access sites and campgrounds. Upstream from Cameron Bridge (see location map) the Manistee is rated as a first-class trout stream but below Cameron Bridge the river is rated only as a fair trout stream by the Michigan Department of Natural Resources. As a Michigan canoe trail it is second only to the AuSable River in popularity. Esthetically, the Manistee is one of Michigan's most attractive rivers, its waters flowing cool and clean, and around each bend a pleasant wilderness scene. This report deals with that part of the river upstream from State Highway M-66 at Smithville. Several hard-surface roads give access to the upper river as shown on the location map. Numerous dirt roads and trails give access to the river at intermediate points. The recreational values of the Manistee depend on its characteristics of streamflow, water quality, and bed and banks. This atlas describes these characteristics and shows how they relate to recreational use.

Much of the information presented here was obtained from basic records of the U.S. Geological Survey's Water Resources Division. Additional information was obtained from field reconnaissance surveys in 1968 and 1969. The study was made in cooperation with the Michigan Geological Survey, Gerald E. Eddy, Chief. Assistance was also obtained from other sections of the Michigan Department of Natural Resources.



LOCATION MAP

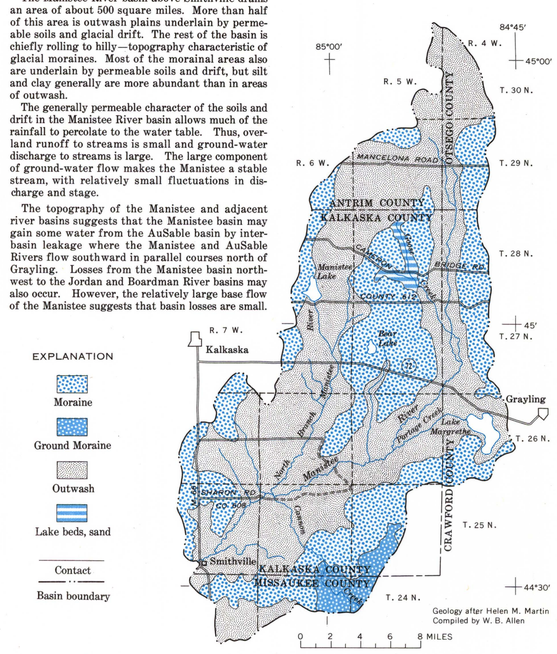
MAP OF MICHIGAN

GEOLOGIC SETTING

The Manistee River basin above Smithville drains an area of about 500 square miles. More than half of this area is outwash plains underlain by permeable soils and glacial drift. The rest of the basin is chiefly rolling to hilly—topography characteristic of glacial moraines. Most of the morainal areas also are underlain by permeable soils and drift, but silt and clay generally are more abundant than in areas of outwash.

The generally permeable character of the soils and drift in the Manistee River basin allows much of the rainfall to percolate to the water table. Thus, overland runoff to streams is small and ground-water discharge to streams is large. The large component of ground-water flow makes the Manistee a stable stream, with relatively small fluctuations in discharge and stage.

The topography of the Manistee and adjacent river basins suggests that the Manistee basin may gain some water from the AuSable basin by interbasin leakage where the Manistee and AuSable Rivers flow southward in parallel courses north of Grayling. Losses from the Manistee basin northwest to the Jordan and Boardman River basins may also occur. However, the relatively large base flow of the Manistee suggests that basin losses are small.



Geology after Helen M. Martin
Compiled by W. B. Allen

SURFICIAL GEOLOGIC MAP

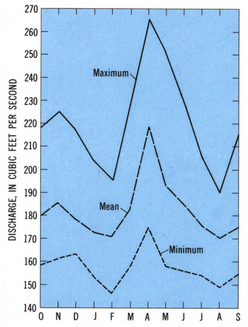
STREAMFLOW

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 flowing 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 having steep gradients than in flatter reaches. Also, velocities are greater in shallow riffles than in deep pools.

DISCHARGE

Continuous records of discharge have been obtained since 1942 on the Manistee River near Grayling. A graphic summary of this record is shown at right. The highest rate of discharge normally occurs during the season of snow melt—usually in April. Subsequently, discharge declines to yearly lows in late summer or early fall and then increases slightly as vegetation uses less water. During the late fall and winter months discharge remains relatively low, until the spring snowmelt completes the annual cycle. The average monthly discharge, in cfsm (cubic feet per second per square mile), at the Grayling gage ranges from 1.37 in April to 1.07 in August. This is the smallest variation in monthly discharge recorded for any stream in Michigan's southern peninsula.



GRAPH OF MEAN MONTHLY DISCHARGE

STREAMFLOW

DISCHARGE (CONTINUED)

Miscellaneous discharge measurements have been made at various times at several points on the Manistee River and its tributaries. A series of measurements made on August 14, 1968, for this study, are listed below. Also listed is the mean discharge for that day at the gaging station near Grayling. These measurements were made after several rainless days, so the discharge was derived entirely from ground water.

The relatively low discharge per unit drainage area (0.40 cfsm) at Mancelona Road Bridge suggests leakage from the upper Manistee basin to the Jordan River to the northwest. The high discharge of the Jordan River (1.55 cfsm at Pinney Bridge on August 12, 1968) supports this view. The higher discharge on the Manistee at the next three stations downstream (1.01 to 1.06 cfsm) is attributed chiefly to a large contribution of ground water from the permeable materials in the upper basin, although leakage from the AuSable River basin to the Manistee may be a contributing factor. Between the CCC Bridge and Sharon the discharge declined from 1.01 cfsm to 0.77 cfsm, suggesting either less permeable materials in this part of the basin or a possible loss of water from the North Branch of the Manistee to the Rapid and Boardman Rivers to the northwest.

Station	Location	Drainage area (sq mi)	Discharge (cfs)	Discharge (cfsm)	Velocity (fps)	
					Maximum	Minimum
Manistee River at Mancelona Road Bridge near Gaylord	N. line sec. 19 T. 29 N., R. 4 W.	43.9	17.6	0.40	1.46	0.19
Manistee River Co. Rd. 612 near Frederic	N. line sec. 6	115	116	1.01	1.82	.16
Manistee River at Gaging station near Grayling	NW¼ sec. 31, T. 27 N., R. 4 W.	159	168	1.06	—	—
Portage Creek near Grayling	SW¼ sec. 22 T. 26 N., R. 5 W.	40.1	26.3	.66	1.25	.16
Manistee River at CCC Bridge near Sharon	SW¼ sec. 25 T. 26 N., R. 6 W.	254	256	1.01	2.12	.52
North Branch Manistee River at Sharon	SE¼ sec. 6	92.9	26.4	.28	1.53	.27
Manistee River at bridge at Sharon	SW¼ sec. 6 T. 25 N., R. 6 W.	434	336	.77	3.06	.36

VELOCITY

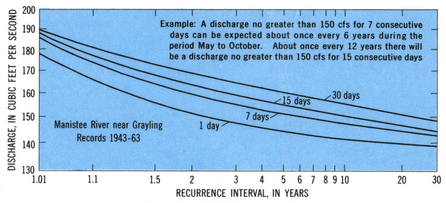
Velocity of flow on the Manistee varies from place to place. Velocity in some of the riffles exceeds 3 feet per second. In pools velocities may be less than 1 foot per second. Velocity usually is faster near the surface at mid-channel than near the bed and banks of the stream. Velocity also varies with discharge at any given cross section. Normally an increase in discharge is accompanied by an increase in velocity.

Maximum and minimum velocities for several cross-sections are shown on the above table. These sites were selected for baseflow measurements, and no attempt was made to measure the fastest reaches in the streams. However, it is unlikely that velocities greater than about 4 feet per second occur on the Manistee, except possibly during periods of high water.

STREAMFLOW

FREQUENCY OF LOW FLOW

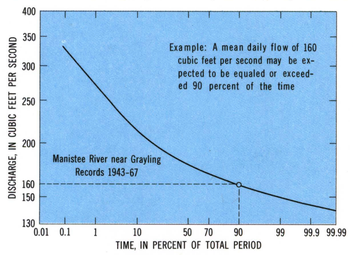
The frequency of low flow on the Manistee is of interest to recreationists because recreational values are influenced by periods of low flow. For example, canoeing on the Manistee above Cameron Bridge generally is slower and more difficult at low flow than at high flow. The effect of wastes is also influenced by low flow, as a stream can assimilate a greater quantity of wastes at higher discharges. However, because the Manistee River is so remarkably uniform in discharge, periods of low flow are less noticeable than on other large rivers in the State.



GRAPH SHOWING FREQUENCY OF LOW FLOW

FLOW DURATION CURVES

Flow duration curves show the percentages of time that specified discharges were equaled or exceeded. The curve at right shows that the Manistee near Grayling discharged at least 160 cfs (cubic feet per second) 90 percent of the time and for 10 percent of the time the discharge was more than 210 cfs. The slope of the flow duration curve for the Manistee near Grayling is flatter than that of any other major stream in Michigan's Southern Peninsula, indicating very uniform flow.

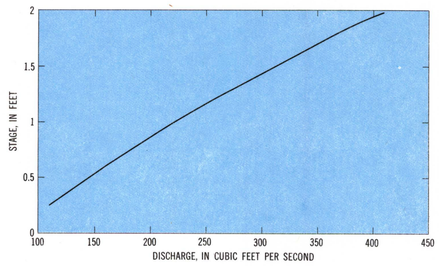


FLOW DURATION CURVE

STREAMFLOW

STAGE

The stage or water level of the Manistee fluctuates with discharge. The relation of stage to discharge for the Manistee River near Grayling is shown graphically below. At the maximum recorded discharge of 388 cfs (cubic feet per second) the gage height was about 1.9 feet. Higher stages than this have occurred at times because of ice jams. At the minimum recorded discharge of 122 cfs the gage height was about 0.4 foot. For most years the range in stage at the Grayling gage is less than 1 foot. The small range in stage contributes to the river's value for recreation. Canoe traffic is not seriously hampered by low stages and there is little if any damage to cabins or campgrounds caused by high stages.



GRAPH SHOWING RELATION OF STAGE TO DISCHARGE

STREAMFLOW

SUMMARY

The following table summarizes the streamflow characteristics of the Manistee 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 Manistee River
Trout fishing	High drought flow helps keep summer water temperatures low. Excessive floodflow removes cover and may cause erosion of banks.	Drought flow in Manistee per unit drainage area, is higher than most Michigan streams. Flood flows are very low, cause little damage.
	A variety of fast and slow reaches adds interest to fishermen. Excessively high velocities make wading dangerous.	Velocity varies in different reaches. Generally not too fast for safe wading where depth is less than 3 feet.
	Abrupt and large increases in stage are a hazard to wading fishermen.	Changes in stage generally are relatively small and are not abrupt in the study area above Smithville. Changes may be abrupt below reservoirs in lower reaches of river.
Boating	Boating season reduced by periods of flood and drought.	Uniform discharges negate problems of floods or droughts. Boating in upper river somewhat easier at high-water season.
	A variety of fast and slow reaches adds interest to boaters.	Alternate riffles and pools make boating interesting. No rapids to challenge the expert in upper river.
	Small velocity makes upstream travel easier.	Velocity too fast for easy upstream travel in riffles.
Camping and cabin living	Streamflow characteristics favorable to fishing and boating also are generally favorable to camping and cabin living.	See descriptions above.

QUALITY OF WATER

INTRODUCTION

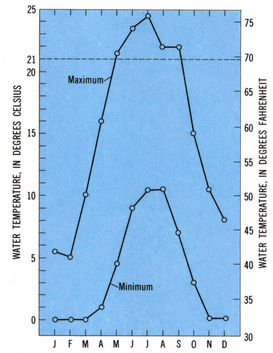
Quality of water is one of the essential factors in determining the recreational value of a river. Quality of water is described in terms of dissolved and suspended substances and the physical properties of the water. Dissolved substances include solids and gasses; the dissolved materials especially important to recreational values are dissolved oxygen, nitrates, and phosphates. Suspended materials include all undissolved materials, chiefly clay, silt, sand, and organic materials moved in the stream. Physical properties important to recreational values are temperature, pH, specific conductance, odor, and color. The following sections discuss each of these parameters of water quality. A summary table describes their relation to recreational use.

TEMPERATURE

Temperature of water is a critical requirement for trout habitat. A record of water temperature has been obtained on the Manistee at the gaging station near Grayling since May, 1957. A part of this record is shown graphically below. Maximum temperature normally occur during hot sunny days in summer—usually in July or August. The highest temperature recorded was 24.4°C(76°F) occurring on July 1, 1963. Temperatures at freezing point are recorded on many days during winter months. Summer water temperatures at the gaging station are cooler than those recorded at most other stations in Michigan. During the period July 15 to August 14, 1968, records of temperature at four additional sites were obtained. Maximum temperatures at these four sites and at the gaging station near Grayling during the same period are listed below.

Cooler water as shown for the upstream reaches is a normal condition in most rivers. The cooler water at the CCC Bridge between Grayling and Sharon may reflect a relatively large inflow of ground water in this reach.

Diurnal fluctuations in water temperatures of the Manistee during the summer months generally range from 1 to 4°C.



GRAPH SHOWING MAXIMUM AND MINIMUM MONTHLY WATER TEMPERATURES, AT GAGING STATION NEAR GRAYLING, OCTOBER 1967 THROUGH SEPTEMBER 1968

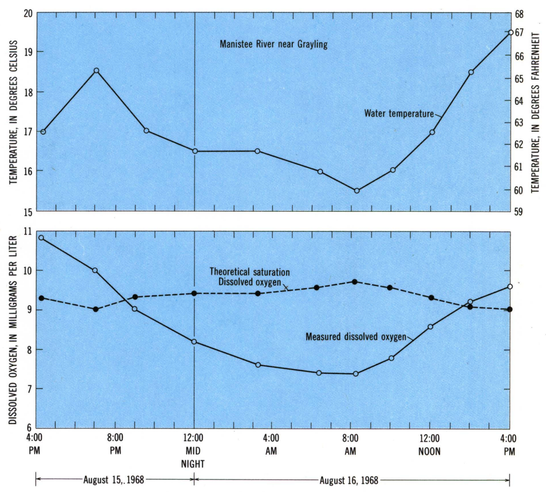
Station	Location	Maximum water temperature	
Mancelona Road Bridge	N. line sec. 19, T. 29 N., R. 4 W.	17.8°C	64.0°F
"Red Bridge" Co. Rd. 612 near Frederic	N. line sec. 6, T. 27 N., R. 4 W.	17.5°C	63.5°F
Gaging station near Grayling	NW¼ sec. 31, T. 27 N., R. 4 W.	23.0°C	73.4°F
CCC Bridge	SW¼ sec. 25, T. 26 N., R. 6 W.	18.8°C	65.8°F
Sharon Bridge	SW¼ sec. 6, T. 25 N., R. 6 W.	23.0°C	73.4°F

QUALITY OF WATER

DISSOLVED OXYGEN

Dissolved oxygen is another critical requirement of the trout fishery, and is also a general indication of the concentration of organic wastes in water. Water saturated with dissolved oxygen contains about 14 mg/l (milligrams per liter) at temperatures just above freezing. As water is warmed its capacity to hold dissolved oxygen decreases, and at a temperature of 21.1°C (70°F) the saturation capacity is only 9 mg/l. In summer, the effects of dissolved oxygen released by submerged plants usually mask the effect of diurnal variation in temperature.

Dissolved oxygen in the Manistee was measured periodically for 24 hours in August 1968, at the campsite north of the M-72 bridge near Grayling. Oxygen given off by water plants during sunlight hours raised the dissolved oxygen to 1.1 mg/l above saturation on August 14. During the following night dissolved oxygen dropped to 2.6 mg/l below saturation. On August 15 dissolved oxygen increased to only 0.3 mg/l above saturation, probably because partly cloudy skies reduced the activity of water plants. This is a normal range for an unpolluted stream with a moderate amount of bottom vegetation.



GRAPHS SHOWING FLUCTUATION OF DISSOLVED OXYGEN AND WATER TEMPERATURE

QUALITY OF WATER

NUTRIENTS (NITRATES AND PHOSPHATES)

Nutrients, chiefly nitrates and phosphates, influence the amount and variety of plant and animal life in a stream. By stimulating growth of water plants nutrients also strongly influence the amount of dissolved oxygen in the water. An abundance of nutrients may result in abnormally high concentrations of dissolved oxygen during the day and abnormally low concentrations at night. The ultimate decay of the water plants also consumes oxygen. Concentrations of nutrients in stream water normally are low in summer because submerged plants remove these materials from solution.

Chemical analyses of samples of water from the Manistee at the gaging station near Grayling and at a bridge west of Sharon show nitrate concentrations of 0.2 to 0.5 mg/l and phosphates 0.03 to 0.12 mg/l, respectively. These low values are typical of an unpolluted stream in an area where use of fertilizer for farming is essentially nonexistent.

SPECIFIC CONDUCTANCE

The specific conductance of water is an indicator of the concentration of dissolved solids. It is useful in measuring the dissolved load of a stream. Records of specific conductance have been obtained on the Manistee River at the gaging station near Grayling since October 1965. From November, 1965 to September, 1969, specific conductance ranged from 225 to 300 micromhos. The lower values usually are associated with relatively high discharges. Typical values are shown below.

DISCHARGE AND SPECIFIC CONDUCTANCE OF THE MANISTEE RIVER NEAR GRAYLING

Date	Discharge (cfs)	Specific conductance (micromhos at 25°C)
Oct. 3, 1966	168	300
Feb. 1, 1967	195	280
Apr. 5, 1967	252	270
Aug. 4, 1967	184	300
Apr. 1, 1968	211	260
Sept. 3, 1968	174	290
May 1, 1969	217	260
July 1, 1969	260	225

QUALITY OF WATER

OTHER DISSOLVED SOLIDS

The chemical analyses tabulated below are typical of an unpolluted river in a forested basin underlain by permeable glacial drift. The water is of the calcium-bicarbonate type, moderately hard, and low in sulfates and chlorides.

pH

The pH of water is an indicator of its acidity or alkalinity. Waters with a pH of 7.0 are said to be neutral. A pH lower than 7.0 indicates acid water; a pH higher than 7.0 indicates alkaline water. The water in the Manistee River is slightly alkaline, with pH values in the study area ranging from 7.2 to 7.6.

SUSPENDED AND FLOATING SOLIDS

No measurements were made of suspended sediment or floating solids in the Manistee River. However, water in the Manistee usually appears clear and even at high water flows it is only moderately cloudy, indicating that the stream carries only small amounts of suspended sediment. Floating solids are also rare except for some leaves and decaying organic material which occasionally appear. There appears to be considerable transportation of sand along the stream bed in some reaches, but this material would not be picked up in normal sediment sampling procedures.

QUALITY OF WATER

CHEMICAL QUALITY OF WATER IN THE UPPER MANISTEE RIVER

	Gaging Station near Grayling		Bridge near Sharon
	4-28-66	2-1-67	4-28-66
Silica (SiO_2) mg/l	6.2	7.0	5.2
Calcium (Ca) mg/l	44	4.3	36
Magnesium (Mg) mg/l	8.6	9.2	6.7
Sodium (Na) mg/l	2.8	2.2	2.0
Potassiam (K) mg/l	.4	.3	.4
Bicarbonate (HCO_3) mg/l	172	170	132
Carbonate (CO_3) mg/l	0	0	0
Sulfate (SO_4) mg/l	7.6	8.6	11
Chloride (Cl) mg/l	3.0	3.0	1.0
Flouride (F) mg/l	.1	.1	.1
Nitrate (NO_3) mg/l	.5	.2	.2
Phosphorous (as PO_4) mg/l	.03	.12	.04
Dissolved solids (calculated) mg/l	157	158	128
Hardness (as $CaCO_3$) mg/l	146	145	118
Specific conductance (micromhos at 25°C)	284	286	228
pH	7.6	7.2	7.3

QUALITY OF WATER

The following table summarizes the quality of water characteristics of the Manistee 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 Manistee River
Trout fishing	Temperature Criteria for intrastate waters, as established January, 1968, by the Water Resources Commission Michigan Department of Natural Resources (1968) specify 70°F (21.1°C) as the maximum limit for intolerant fish (cold-water species).	Maximum temperatures on the Manistee at gaging station near Grayling exceed 70°F (21.1°C) for a few days of most years. Maximum temperatures in most of the river downstream from Grayling probably also exceed 70°F most years. Upstream from Frederic water temperatures are generally cooler and probably exceed 70° only occasionally.
	Dissolved Oxygen The Water Resources Commission (1968) specifies a minimum of 6 ppm (mg/l). At water temperatures above 20°C (68°F), Tarzwell (1957) indicated full air saturation is required for the full range of activity for brook trout.	Dissolved oxygen on the upper Manistee probably does not go 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 8.8.	pH of the Manistee ranges between 7.2 and 7.6.
	Nutrients (chiefly nitrates and phosphates) 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.	Upper Manistee is free of undesirable weeds, algae, and slime. Bottom vegetation is sparse to moderate. Nitrate and phosphate content probably low at all times.
Trout fishing, boating, camping, and cabin-living	Floating, Settleable, 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.	Upper Manistee generally is free of floating solids and residues of unnatural origin. Turbidity usually is low.

SELECTED REFERENCES

Knutilla, R. L., 1967, Flow characteristics of Michigan streams: U.S. Geological Survey Open-file report, pp. 168-169.

Martin, H. M., 1955, Map of the surface formations of the Southern Peninsula of Michigan. Michigan Geol. Survey, Pub. 49.

Michigan Department of Natural Resources, Water Resources Commission 1968, Water quality standards for Michigan intrastate waters: Jan. 31, 1968.

Tarzwell, C. M., 1957, Water quality criteria for aquatic life *in* Biology of Water Pollution: U.S. Department of Health, Education, and Welfare, pp. 246-272.

U.S. Geological Survey, 1968, Water resources data for Michigan: U.S. Geol. Survey annual rept., pt. 1, Surface Water Records, pt. 2, Water Quality Records.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1972—W71080

RECONNAISSANCE OF THE MANISTEE RIVER, A COLD-WATER RIVER IN THE NORTHWESTERN PART OF MICHIGAN'S SOUTHERN PENINSULA

By

G. E. Hendrickson and C.J. Doonan

1972

For sale by the U.S. Geological Survey, price $1.00 per set