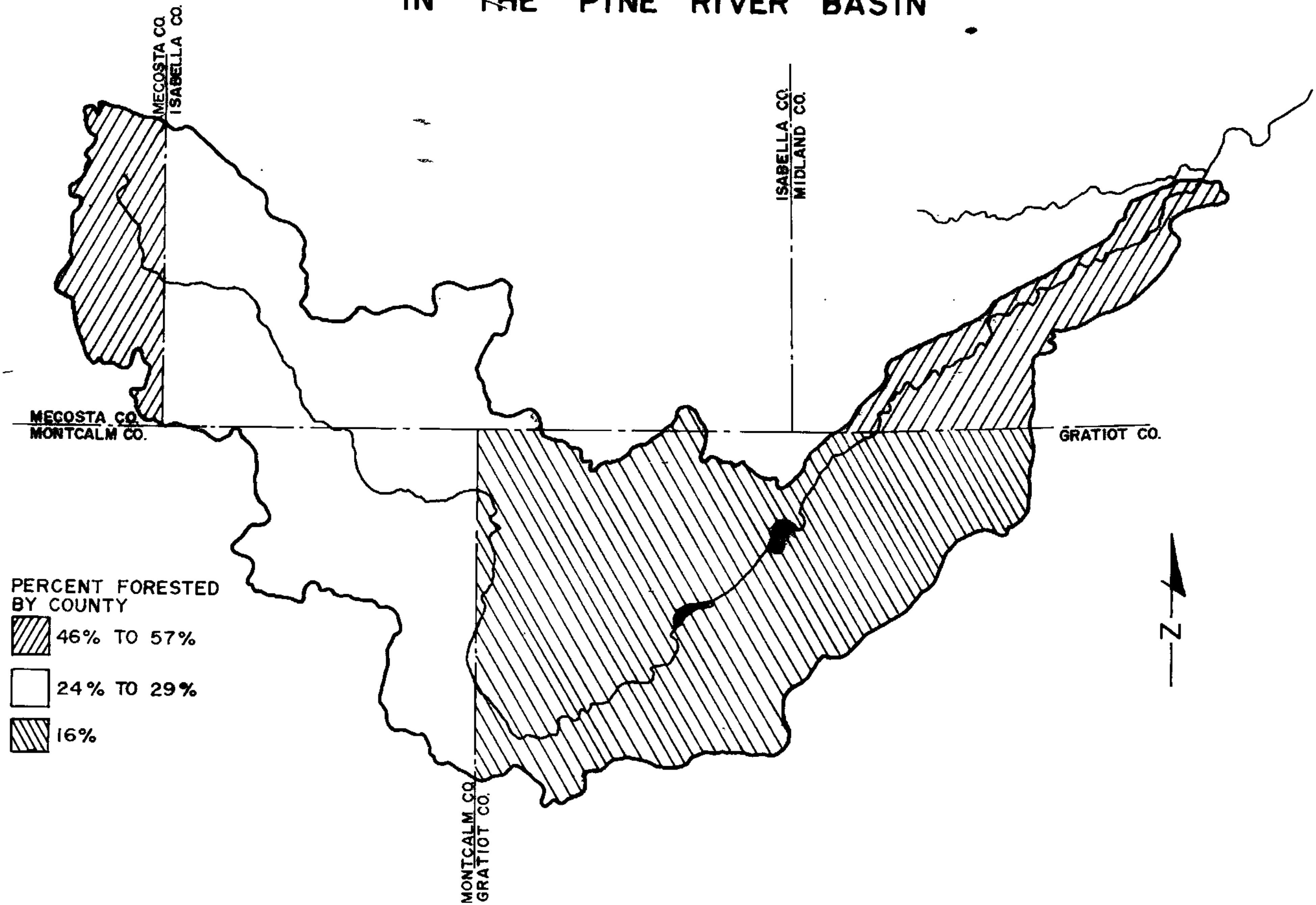
PERCENTAGE OF FORESTED LAND IN THE PINE RIVER BASIN



3. Water Use

Water in the Pine River basin is used for irrigation, municipal and industria water supplies, waste assimilation, power generation, and recreation.

Alma currently supplies an average of 2.5 million gallons per day (mgd) of water to its citizens and industries. For eight to nine months of the year this water is drawn from the Pine River. During summer months approximately one-half of the water is supplied by wells and one-half from the river. St. Louis obtains all of its water from wells. Most industries in both cities use municipal water with the exception of Leonard Refineries which uses its own wells. The Michigan Chemical Company uses water from the St. Louis municipal supply, its own wells, and the Pine River.

Most homeowners in unincorporated areas of the basin use septic tanks and leach fields to dispose of their domestic wastes to the ground waters. The cities of Alma and St. Louis have primary sewage treatment plants with effluents to the Pine River. Industrial wastes from the Lobdell-Emery Manufacturing Company; Leonard Refineries, Inc.; and the Alma Products Company discharge to storm sewerage systems, county drains, or tributaries of the Pine River. Wastes from Michigan Chemical Company discharge directly to the Pine River. Other industrial wastes discharge to city sewerage systems.

There is one hydroelectric power generating station in the basin, located in St. Louis.

Recreational use of water in the Pine River is concentrated in the headwater region of the river. Small lakes and streams as well as the Pine River offer swimming, fishing, and boating activities.

There are presently two impoundments on the main branch of the Pine River, one at Alma and the other at St. Louis. A reservoir on the Pine River near Vestaburg (Montcalm County) has been proposed. This reservoir would be designed to provide supplemental flow during low flow periods.

4. Economic Development

Agriculture is the primary basis of the basin economy. Products include livestock, field crops, vegetables, fruits and nuts, forest products, and greenhouse products. Economically important natural resources include petroleum, salt and brine products, natural gas, sand, gravel, and peat.

The majority of the basin's industry is located in Alma and St. Louis. The major types of industries include: metal working, chemical production, oil refining, and mobile home manufacture.

5. Population

In 1960, approximately 35% of Gratiot County's population of 37,012 resided in Alma and St. Louis. The other 65% lived in rural areas or small communities. The populations in those portions of the Pine River basin located in Mecosta, Isabella, Montcalm, and Midland counties also live in rural areas or in small communities. Table 1 presents the 1960 and preliminary 1970 census figures for all the counties which have portions in the Pine River basin and for the cities of Alma and St. Louis.

TABLE 1

POPULATIONS OF AREAS WITHIN AND NEAR

THE PINE RIVER BASIN

Area	1960 Census Figure	Preliminary 1970 Census Figure	% Change
Mecosta County	21,051	27,080	+ 28.6
Isabella County	35,348	43,770	+ 23.8
Montcalm County	35,795	38,850	+ 8.5
Gratiot County	37,012	38,730	+ 4.4
Midland County	51,450	63,000	+ 22.4
Alma	8,978	Not Available	
St. Louis	3,808	Not Available	

6. Climate

The characteristics of the climate in the Pine River basin are frequent weather changes with extreme seasonal variation in temperatures and fairly even seasonal distribution of precipitation. The average annual precipitation over the basin is 29.4 inches with a normal snowfall of 35 to 40 inches.

In Alma the mean annual temperature is 47.7°F. The all time recorded low is -22°F, and the all time record high is 108°F. The average growing season is 146 days.

B. Geology

1. Topography and Soil Types

The western end of the Pine River basin in Mecosta and southwest Isabella Counties is rolling to hilly with medium relief. This changes to rolling to undulating with low relief in the middle section of the basin in Isabella, Montcalm, and Gratiot counties. As the river flows northeast the topography becomes undulating to flat with low relief. The general topography of the Pine River basin is shown in Figure 4.

Accompanying these changes in topography from rolling and hilly land of medium relief to flat land with low relief is a change in soil types. Soils in the western half of the basin are sands and sandy loams. In Gratiot County the soils grade into clay loam and silty clay loams and then to sandy loam. In Midland County, (flat with low relief), the basin is composed of loams and silty clay loams and wet and dry sands associated with peats. The general soil types found in this basin are shown in Figure 5.

2. Subsurface Geology

All the mineral soils in this watershed have developed from parent material of glacial origin. However, the underlying bedrock is the product of sediment deposition in ancient seas during the Paleozoic era. These sediments were compacted and cemented to form sandstone from sand, shale from mud and silt, and limestone and dolomite from limey mud. Bedrock was worn down by erosion for 200 million years and then by the various glaciers which covered this area.

The bedrock of the western portion of the basin is primarily sandstone with some sandy shale. Bedrock of the central and eastern portion consists of sandstone and shale with some limestone and coal seams. Petroleum is taken from these bedrock deposits in the Pine River basin. The distribution of bedrock formations is shown in Figure 6. The locations of oil and gas wells and gas storage areas are shown in Figure 7. Brine is also obtained from these bedrock deposits. Valuable chemicals such as halogens (bromine, iodine and chlorine) and reactive metal-ions (magnesium, calcium and sodium) are extracted from these brines. The major brine fields in the basin are in Midland and Gratiot counties. Their location is shown in Figure 8.

About one million years ago, the first glacial period began. Glaciers picked up loose soil, rocks, and boulders--collectively called glacial drift--and carried them along, grooving and scouring the bedrock surface. This glacial drift was deposited over the entire lower peninsula of Michigan when the glaciers receded. The thickness of the glacial drift which overlies the bedrock varies from 400 to 600 feet in the western section of the Pine River basin and between 200 to 400 feet in the eastern portion. Today,

FIGURE 4

TOPOGRAPHY OF PINE RIVER BASIN

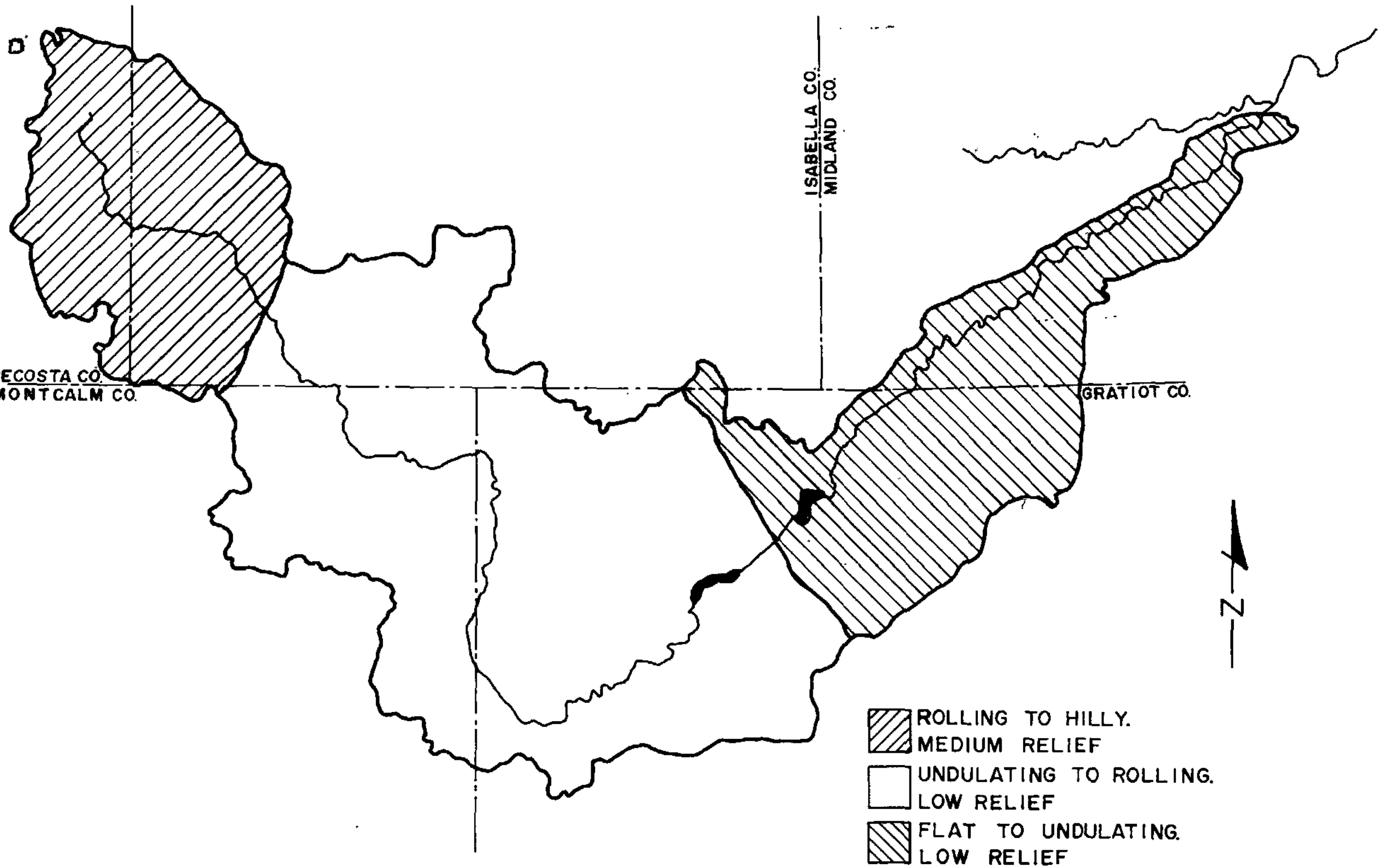


FIGURE 5

SOIL TYPES IN PINE RIVER BASIN

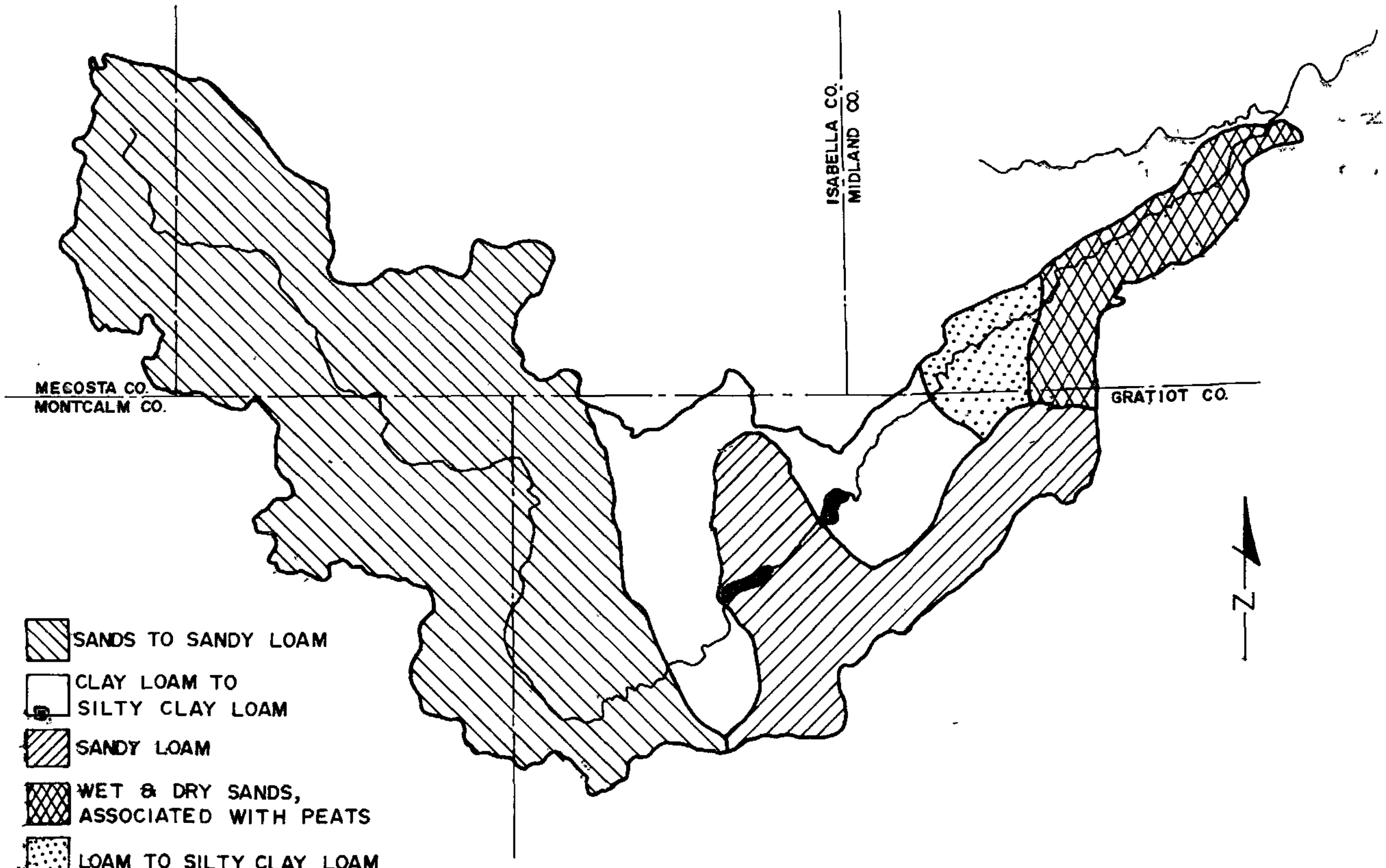


FIGURE 6

BEDROCK FORMATIONS IN PINE RIVER BASIN

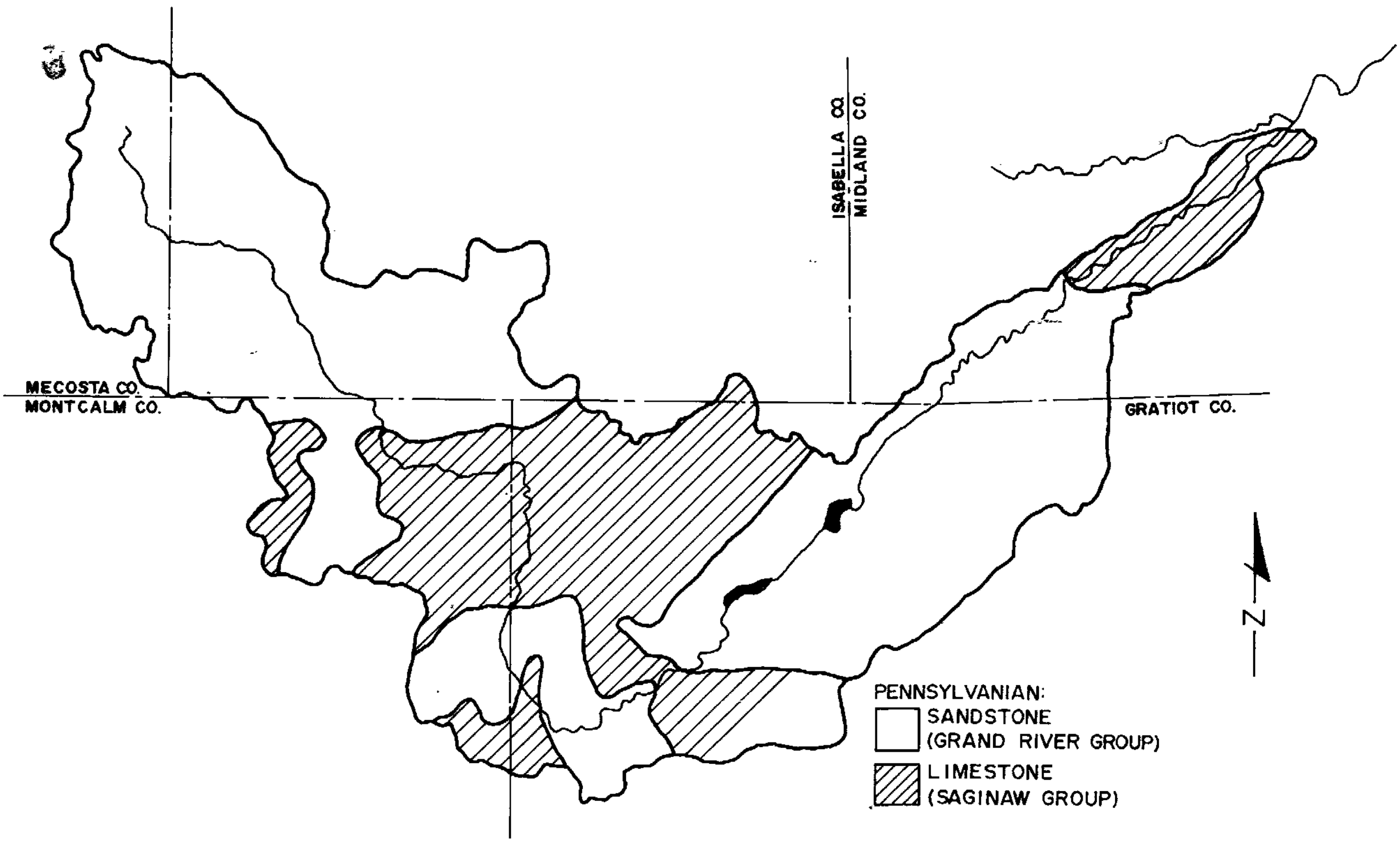


FIGURE 7

OIL AND GAS FIELDS IN PINE RIVER BASIN IN 1967

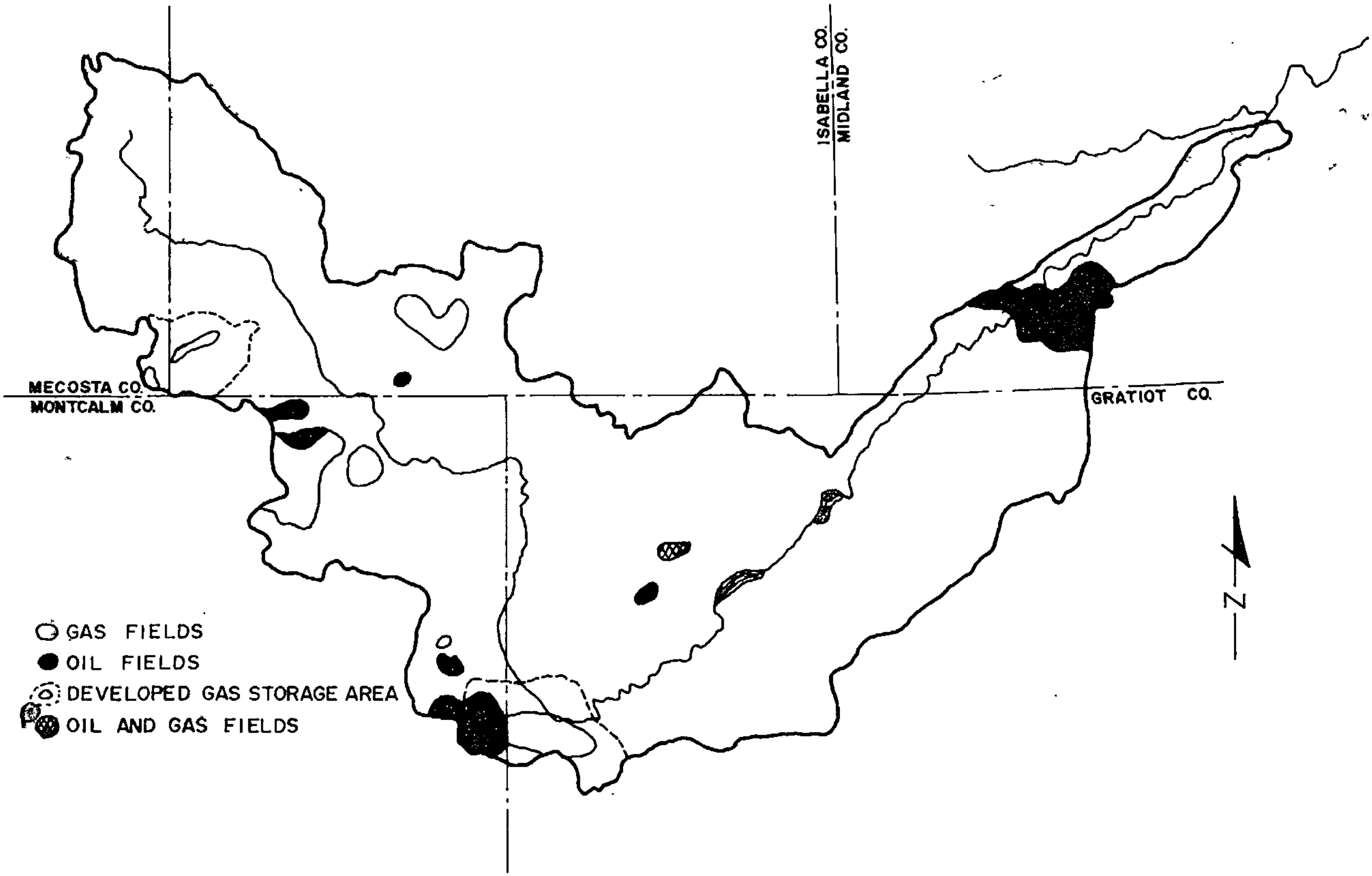


FIGURE 8

LOCATION OF BRINE WELLS IN THE PINE RIVER BASIN 1967

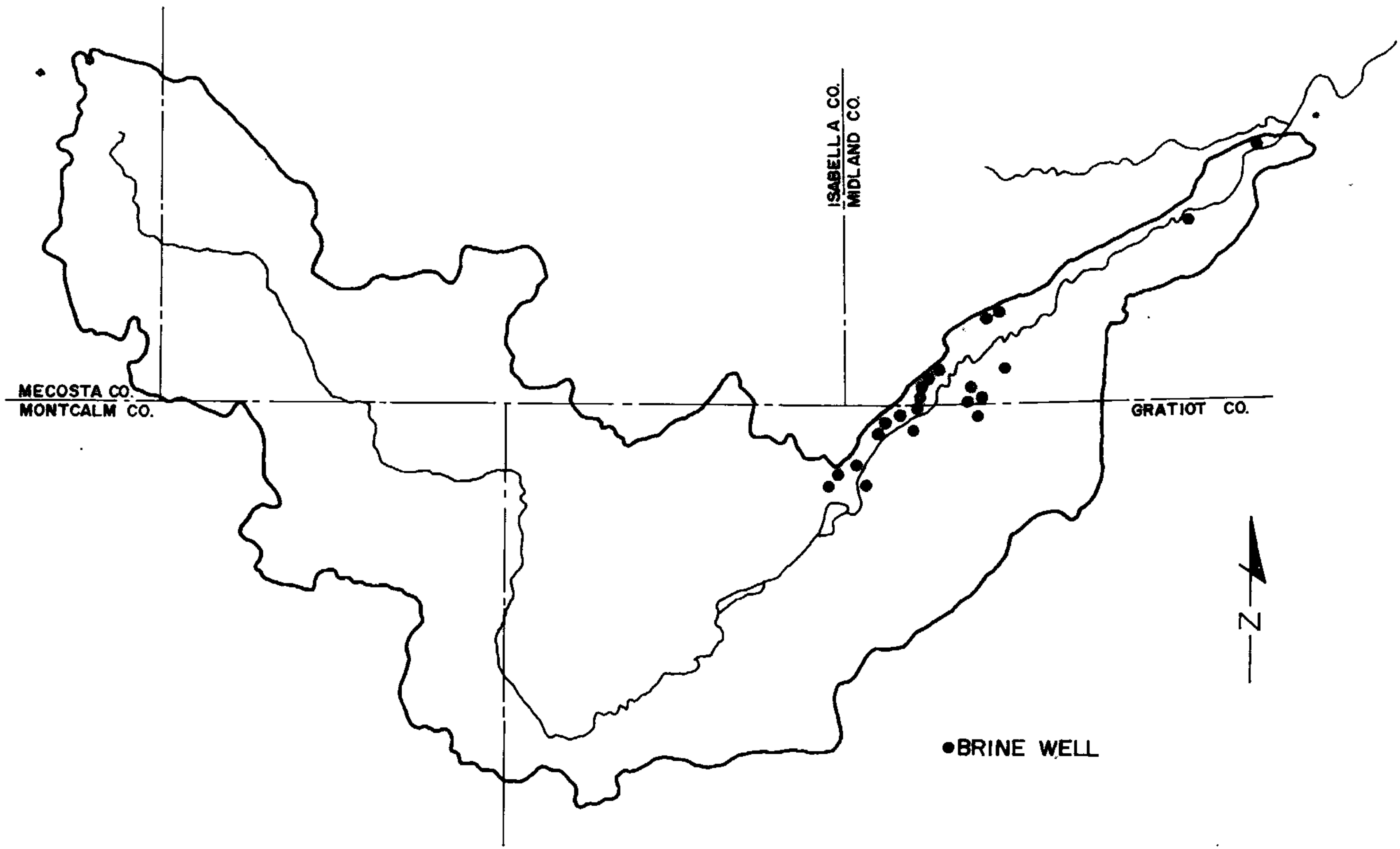


FIGURE 9

GENERAL AVAILABILITY OF GROUNDWATER IN THE GLACIAL DRIFT DEPOSITS IN THE PINE RIVER BASIN

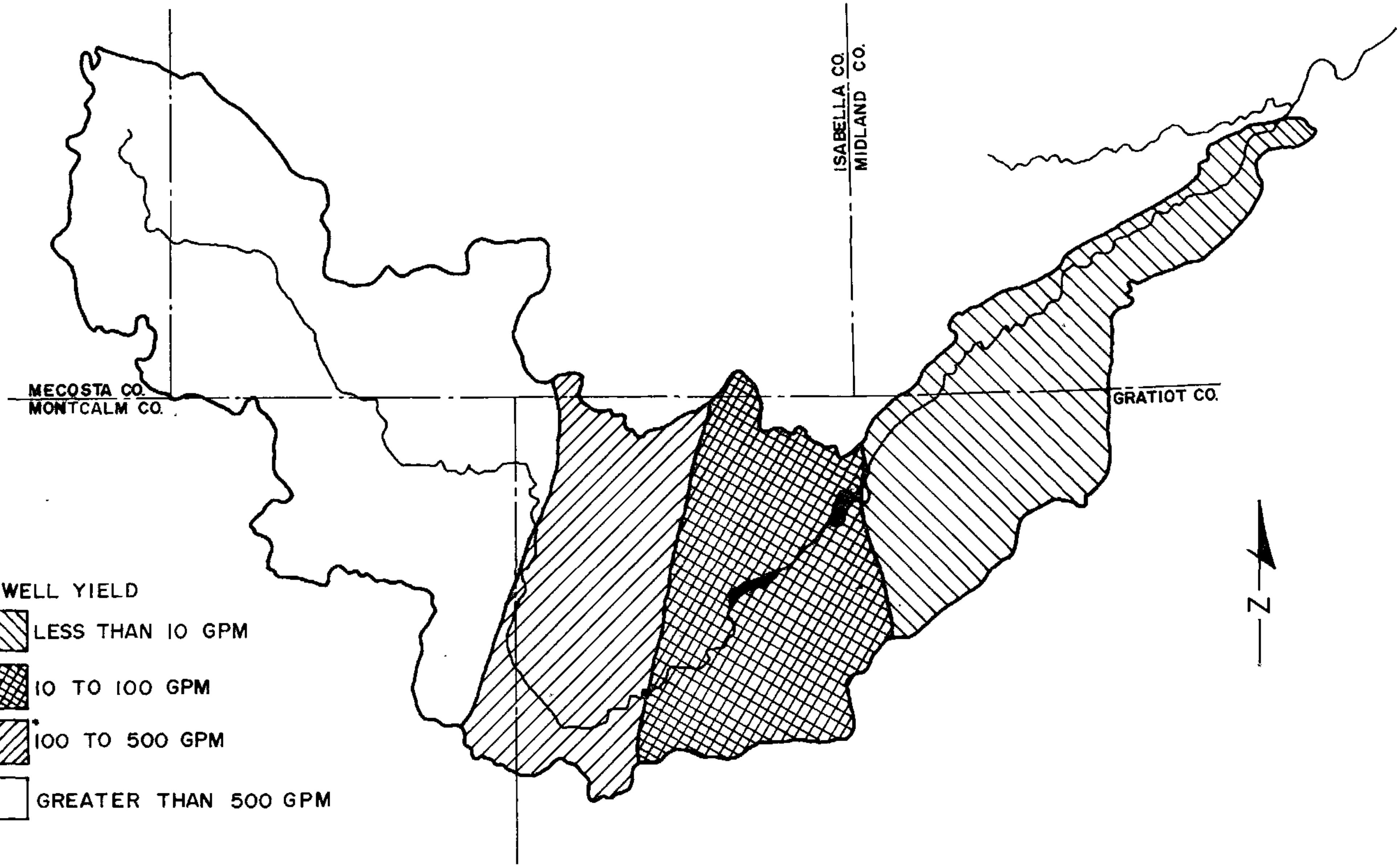
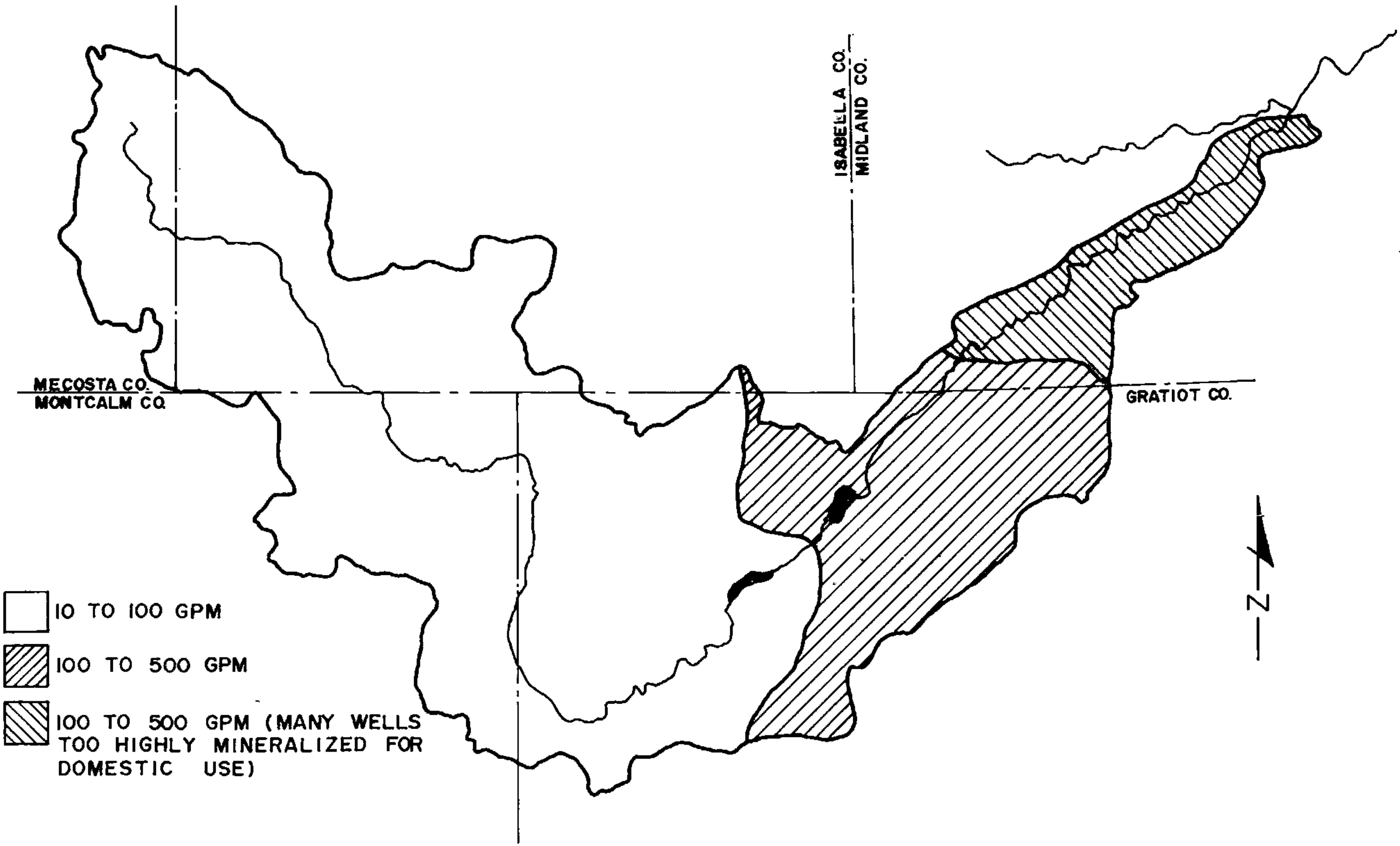


FIGURE 10

GENERAL AVAILABILITY AND QUALITY OF GROUNDWATER IN THE BEDROCK DEPOSITS IN PINE RIVER BASIN



glacial drift is a primary source of groundwater in this area, as shown in Figure 9. The quality of ground water taken from drift is generally good although it may be hard. However, in some local areas the water may be of very poor quality, especially where the drift is underlain by bedrock containing highly mineralized waters as is found in the eastern end of the basin. The general availability and quality of groundwater in the bedrock deposits in the Pine River basin is shown in Figure 10.

C. Hydrology

1. Physical Characteristics

The Pine River upstream from Alma is a shallow, narrow stream with a gravel, rock, and sand bottom. It has relatively moderate meander and a narrow flood plain. The water is normally clear with little visible turbidity or color. Weed and algae growth is sparse.

In Alma and St. Louis the river is impounded at two locations. The first dam is located on the upstream side of the State Street bridge in Alma and the second dam is located approximately 200 yards upstream from the Main Street bridge in St. Louis.

The Alma Reservoir is 2.4 miles long and relatively narrow. During the summer months it contains abundant growths of aquatic plants and algae. The discharge of the Alma dam is not frequently regulated. The 2.6 mile long St. Louis reservoir is also narrow but contains few aquatic plants or algae. The two dams are about 6 miles apart with a free flow of river for approximately 3.4 miles between the reservoirs. A United States Geological Survey (USGS) stream gage is located in this free flowing reach of river near the Superior Street bridge in Alma. Hydroelectric power is produced at the St. Louis dam which is owned and operated by the City. This dam regulates river flow during low flow periods by periodically storing and releasing water for power generation.

Downstream from St. Louis the river broadens slightly, the bottom is primarily sand and gravel, and approximately 30 miles of this shallow reach of the river contain dense masses of aquatic vegetation during summer months. A USGS stream gage is located in this reach, at Meridian Road, Midland County, about eight miles from the mouth of the river.

2. Flow Characteristics

The stream flow of the Pine River is moderately stable. The two reservoirs in the Alma - St. Louis area have a moderating influence on the stream flow, absorbing and temporarily storing excess flows. An indication of the long term stability of a stream is its "variability ratio" which is the ratio of the once in 10 year drought flow to the most probable drought flow. A ratio of unity would describe a stream in which there was no change in drought flow from year to year. Groundwater usually provides a large percentage of the base flow of streams with high variability ratios. A smaller ratio indicates a variable stream subject to more extreme droughts.

The variability ratio for the 7-day low flow of the pine River at the Alma USGS gage is 0.465, about halfway between the two extremes.

Figure 11 is a daily hydrograph of Pine River streamflow at Alma for the months of April through September 1967, the year in which intensive river sampling surveys were conducted. This is a typical hydrograph with high spring flows and low flows in the late summer and fall. The figure also includes the recorded precipitation for the same period. During the late summer heavy precipitation caused only a minor increase in streamflows.

The streamflow below St. Louis is extremely variable during low flow periods because of the operation of the hydroelectric plant in St. Louis. Figure 12 illustrates river stages during two days which typify changes in river levels at points above and below the St. Louis dam. The extreme variation at McGregor Rd. is obvious compared with variations at the Alma gage. A certain minimum water level is maintained in the St. Louis reservoir because the Michigan Chemical Company's water intakes are located in this reservoir. Extremely low flows occur downstream from the dam at times when water is being stored for power generation. The electric power generated at the dam is sold to a public utility firm and is not utilized directly by the City of St. Louis.

3. Drought Flows

Streamflow records are available for the Pine River at the USGS gage in Alma from 1931 to date. This historical flow data was statistically analyzed by the Gumbel Theory of extreme values to allow prediction of drought flows for various "return" periods (i.e. frequency of recurrence.) The results of this analysis are presented in Table 2 and shown graphically in Figures 13 and 14. Michigan's Intrastate Water Quality Standards, designed to protect and enhance water quality, apply at all flows equal to or exceeding the 10-year recurrence of minimum low flow of 7-day duration. Figure 14 indicates that more severe droughts than the 26 cfs design flow occur only 0.3% of the time. If the proposed new dam is constructed on the Pine River near Vestaburg, it will have the effect of maintaining a minimum flow of 60 cfs from May through September and 45 cfs from October through January during most years.

TABLE 2

EXPECTED DROUGHT SEVERITIES vs DROUGHT DURATION, PINE RIVER AT ALMA

(Period of record 1931-1965)

Drought Occurrence	Min. Av. Flow for 1 day cfs	Min. Av. Flow for 7 days cfs	Min. Av. Flow for 14 days cfs	Min. Av. Flow for 30 days cfs
Most Probable	45	56	62	77
Once in 5 Years	20	34	39	46
Once in 10 Years	14.5	26*	31	38
Once in 25 Years	8	19	24	30

* Design flow for Water Quality Standards.

FIGURE 11

PINE RIVER AT ALMA, MICHIGAN 1967

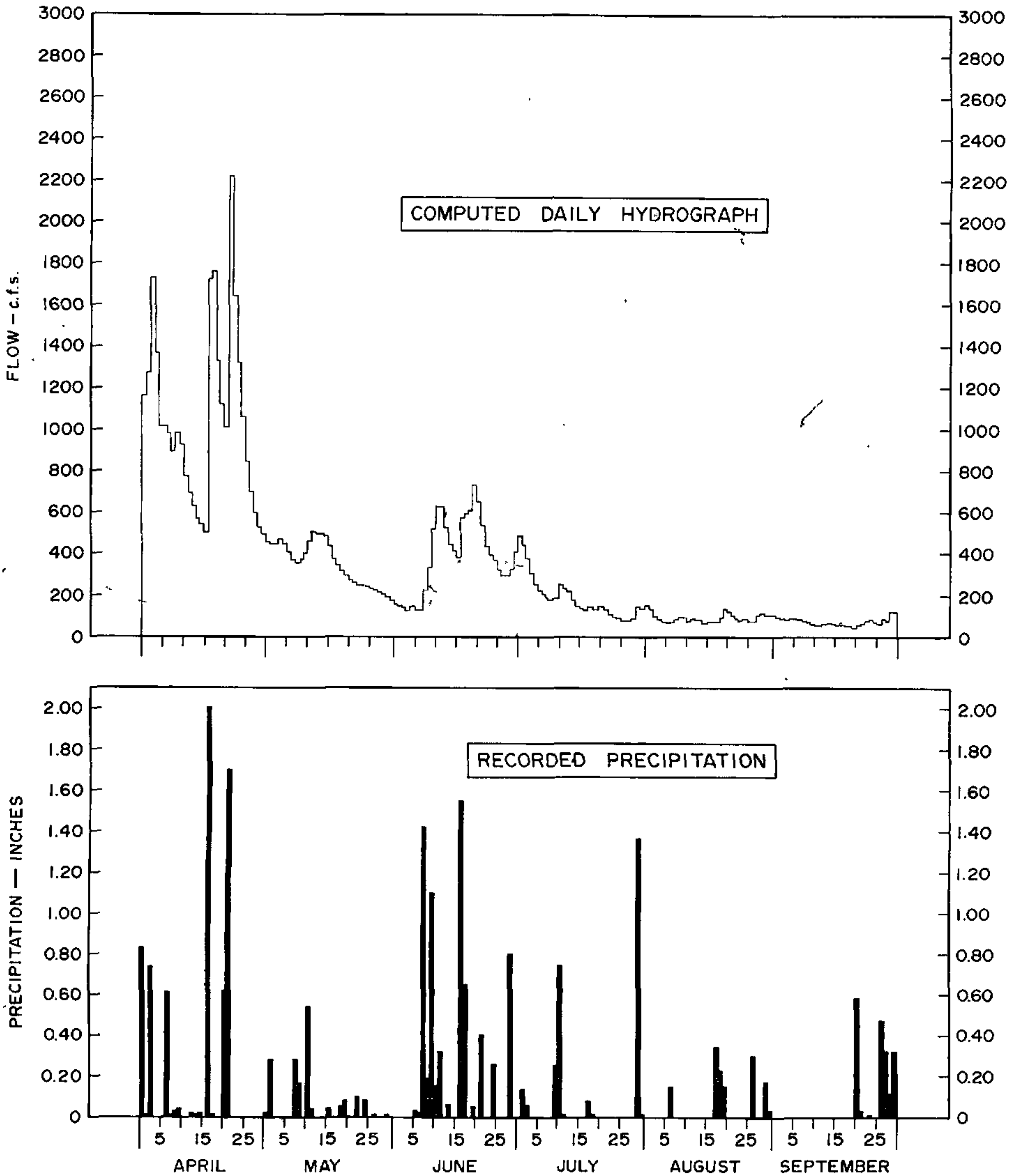


FIGURE 12

TYPICAL CHANGES IN RIVER LEVELS AT VARIOUS PINE RIVER STATIONS

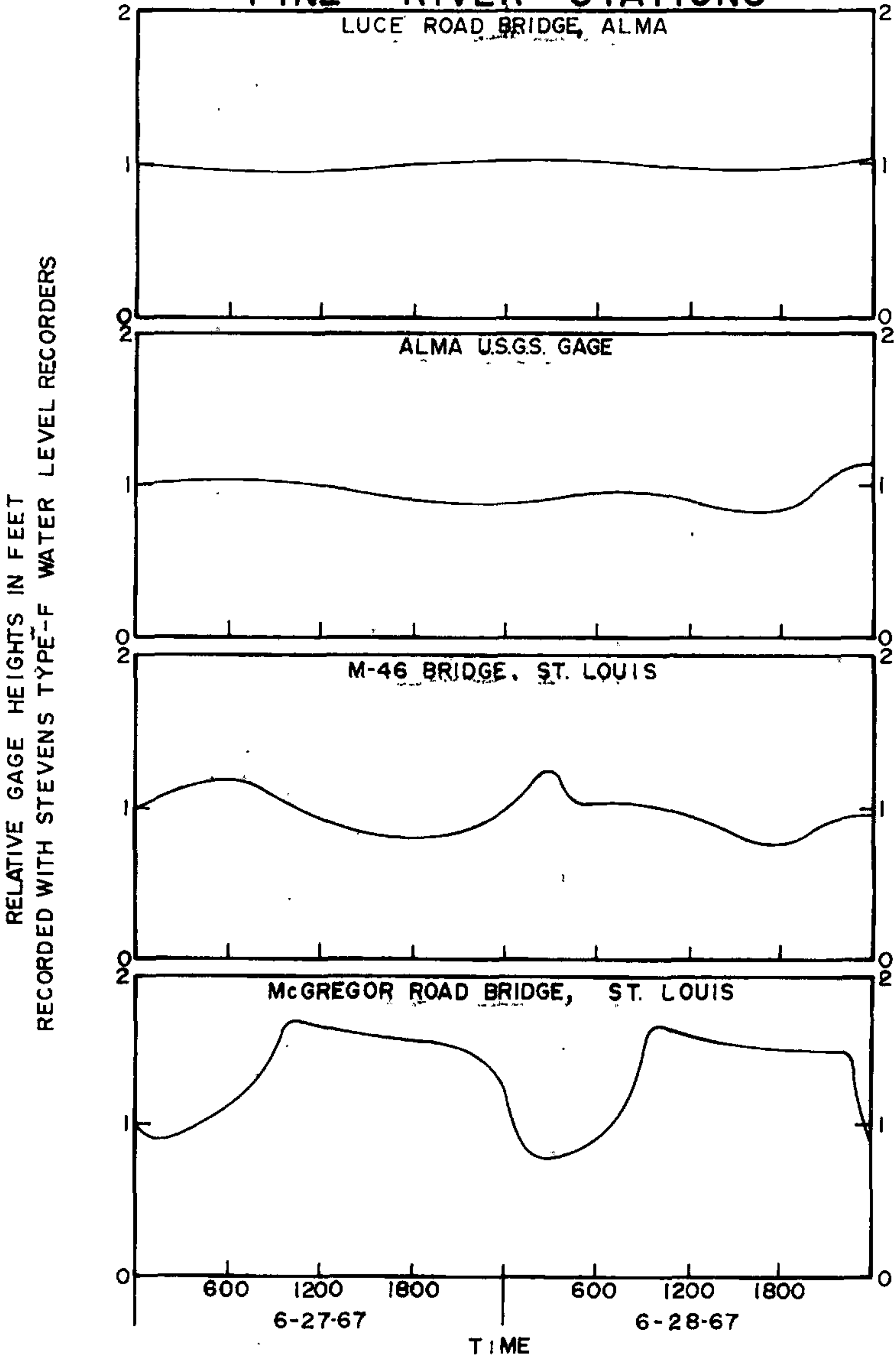


FIGURE 13

DROUGHT DURATION VS. SEVERITY

PINE RIVER AT ALMA

PERIOD OF RECORD 1931 — 1965

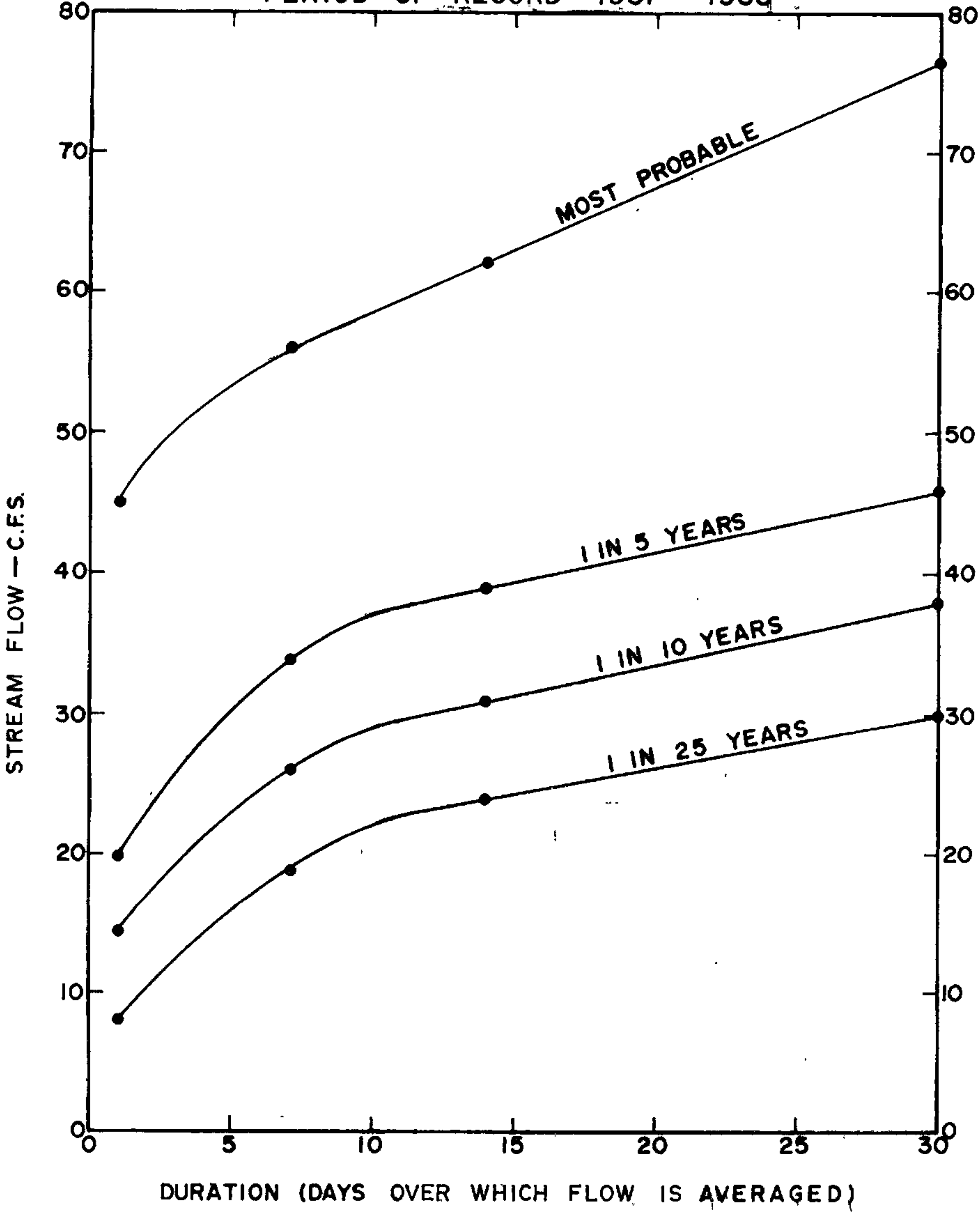


FIGURE 14

DURATION CURVE OF DAILY DISCHARGES

PINE RIVER AT ALMA

PERIOD OF RECORD 1931 — 1966

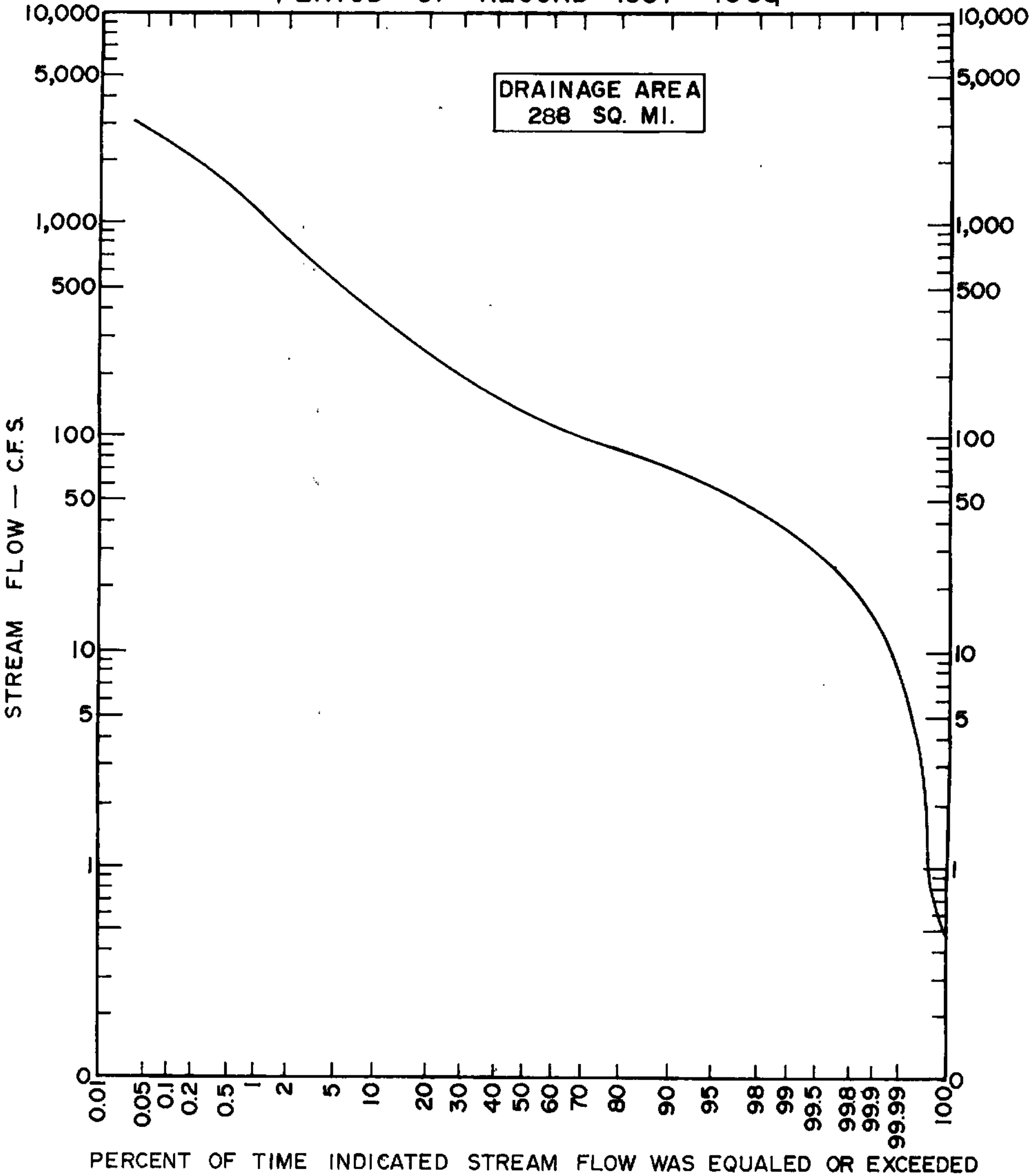


Table 3 indicates the day of each year on which the lowest daily average flow occurred and the month of the year in which the lowest monthly flow occurred. This shows that in over 1/3 of the years the lowest monthly average flow occurred in August. Other months in which low flows frequently occur are September, July, and October.

4. Time of Passage

The time required for a unit of water to travel through a given reach of stream is a function of amount of streamflow, the river volume, and channel characteristics such as slope and roughness. A knowledge of times of passage is necessary to accurately assess the rate of waste assimilation within the reach. The time of passage for various reaches of the Pine River was computed on the basis of occupied channel volume and river flow. Fluorescent tracer dye studies were also conducted to verify the reliability of the calculated times of passage. The dye study results and calculated times of passage agreed closely.

TABLE 3

MINIMUM AVERAGE DAILY AND MONTHLY FLOWS OF THE PINE RIVER AT ALMA

Year	Lowest Daily Average Flow (cfs)	Date of Occurrence	Lowest Monthly Average Flow (cfs)	Month of Occurrence
1931	30.0	July 29	34.8	August
1932	40.0	July 29 & Sept. 22-27	47.5	September
1933	34.0	September 15-17	59.0	September
1934	17.0	July 22	35.6	July
1935	29.0	October 12	62.9	September
1936	14.0	August 16	34.7	August
1937	29.0	September 2	53.5	September
1938	2.0	July 23	66.0	July
1939	44.0	June 4	66.4	October
1940	19.0	February 1	59.6	August
1941	16.0	August 31	42.4	July
1942	47.0	February 22	65.5	August
1943	34.0	August 3	79.4	August
1944	21.0	December 14	51.8	August
1945	40.0	January 16	70.4	October
1946	27.0	July 24	49.6	August
1947	42.0	October 14	66.6	October
1948	7.6	July 17	56.0	September
1949	46.0	July 4 & 5	63.2	September
1950	54.0	October 1 & 2	69.7	October
1951	69.0	August 25	97.4	July
1952	50.0	June 28	112.0	June
1953	57.0	September 18	92.8	October
1954	39.0	October 10	72.3	September
1955	59.0	August 1 & 5	84.6	August
1956	75.0	October 4	92.7	January
1957	40.0	August 8 & 15	75.3	August
1958	51.0	August 15	68.0	August
1959	54.0	September 25	70.4	July
1960	66.0	October 4	91.4	September
1961	57.0	July 2	79.9	July
1962	36.0	September 1	63.6	August
1963	24.0	July 7 & August 6	53.3	July
1964	0.4	September 6	70.1	September
1965	28.0	October 7	47.6	July
1966	39.0	August 10	61.5	August
1967	44.0	September 20	81.2	September
1968	47.0	August 29	78.6	August

NOTE. Some low flows are affected by regulation of the Alma dam, located 1/2 mile above the gage and by variable backwater from the power plant at St. Louis, 5½ miles below the gage. Since 1965 about 3 cfs has been diverted above the station for Alma's water and returned below the gage by way of the Alma Wastewater Treatment Plant.

WASTE DISCHARGES TO THE PINE RIVER

The Pine River in Gratiot and Midland Counties receives the waste discharges of various industries and communities. The principal industrial waste discharges to the Pine River include: the Lobdell-Emery Mfg. Co., Leonard-Refineries, Alma Products Co., and the Michigan Chemical Co. Alma and St. Louis are the principal municipal dischargers.

Table 4 compares the percentages of the wastes discharged daily by industrial and municipal sources during the 1967 surveys. Table 5 illustrates the percentage of each measured contaminant contributed by individual dischargers on a daily basis. Due to the physical arrangement of sewer systems, it was necessary to measure a combined discharge from Lobdell-Emery Mfg. Co., and Alma Products Co.

A. Industrial Waste Discharges

1. Lobdell-Emery Manufacturing Company

This company is a general manufacturer and metal plater located in Alma. In 1967, most of their process wastes were discharged to the City of Alma's Superior Street storm drain with the balance discharged to the Alma sanitary sewerage system. The Superior Street drain empties into a county drain tributary to Horse Creek. This creek joins the Pine River in the St. Louis impoundment, about 35 miles from the mouth of the Pine. The same county drain which received the effluent of the Superior Street storm drain also received wastewater from the Alma Products Company. The location of these industries and their effluents is shown in Figure 15.

Two 24-hour composites were collected in 1967 from the county drain below these effluents. The results of analyses of these samples are listed under Wier #1 in Table 6. The samples contained high concentrations of total solids, total dissolved solids, suspended solids, phosphates, chlorides, sodium, sulfates, hardness, and chloroform extractable substances (oils). During the first survey, this discharge had an extremely low pH of 2.9.

In 1969, that portion of Lobdell-Emery's effluent which discharged to the Alma sanitary sewerage system was removed and is now discharged to a new Alma storm sewer which empties to the Pine River near the intersection of Michigan and Pennsylvania Streets. Grab samples of the discharge from this storm sewer at the Pine River have contained high concentrations of hexavalent chromium. Lobdell-Emery has recently ceased all plating operations. On or before December 31, 1972, the company will pretreat their wastewater and discharge both sanitary and all process wastewater to the Alma sanitary sewerage system.

TABLE 4

PINE RIVER

COMPARISON OF 1967 INDUSTRIAL
& MUNICIPAL WASTE LOADS

Parameters Measured	Percent of Total Load Contributed By Industrial Sources	Percent of Total Load Contributed by Municipal Sources	Total* Load contributed by Both Sources
Flow - MGD	54	46	4.94
BOD-5	36	64	2,005
Total Solids	97	3	587,933
Total Dis. Solids	98	2	574,114
Sus. Solids	92	8	13,672
Total PO_4	90	10	3,808
S.O. PO_4	95	5	5,007
NH_3-N	70	30	894
NO_3-N	98	2	155
Cl	99	1	296,532
Ca	99	1	99,090
Mg	86	14	2,374
Na	97	3	65,745
K	96	4	4,444
SO_4	76	24	10,798
CN	0	0	0
Cr^{+6}	100	0	3.2
Cu	100	0	314

*NOTE: All loads contributed by both sources are expressed as pounds per day except for flow.

TABLE 5

PINE RIVER

PERCENT OF 1967 TOTAL WASTE LOAD
CONTRIBUTED BY INDIVIDUAL WASTE SOURCES

Parameter Measured	Alma WWTP	*Weir #1	*Weir #2	*Michigan Chemical	St. Louis WWTP
Flow	34	15	7	32	12
BOD_5	46	6	1	29	18
Total Solids	2	2	1	94	1
Tot. Dis. Solids	2	1	1	95	1
Sus. Solids	5	23	1	69	2
Total PO_4	7	90	1	-1	3
S.O. PO_4	4	95	0	0	1
NH_3-N	22	3	6	61	8
NO_3-N	1	7	0	91	1
Cl	0.5	0.5	0.5	98	0.5
Ca	0.5	0.5	0.5	98	0.5
Mg	9	14	5	66	6
Na	2	2	1	94	1
K	2	1	1	95	1
SO_4	17	13	13	49	8
CN	0	0	0	0	0
Cr^{+6}	0	100	0	0	0
Cu	---	0	---	100	---

*Note: Weir #1 - Intercepted combined flow from Lobdell-Emery and Alma Products.

Weir #2 - Intercepted discharge from Lagoon System which treated Leonard Refinery process water.

Michigan Chemical - Represents the combined results from 13 discharges minus 2 intakes of the Michigan Chemical Company.

FIGURE 15
LOCATION OF LOBDELL EMERY, LEONARD REFINERIES AND ALMA PRODUCTS WASTEWATER DISCHARGES, AUGUST 1967

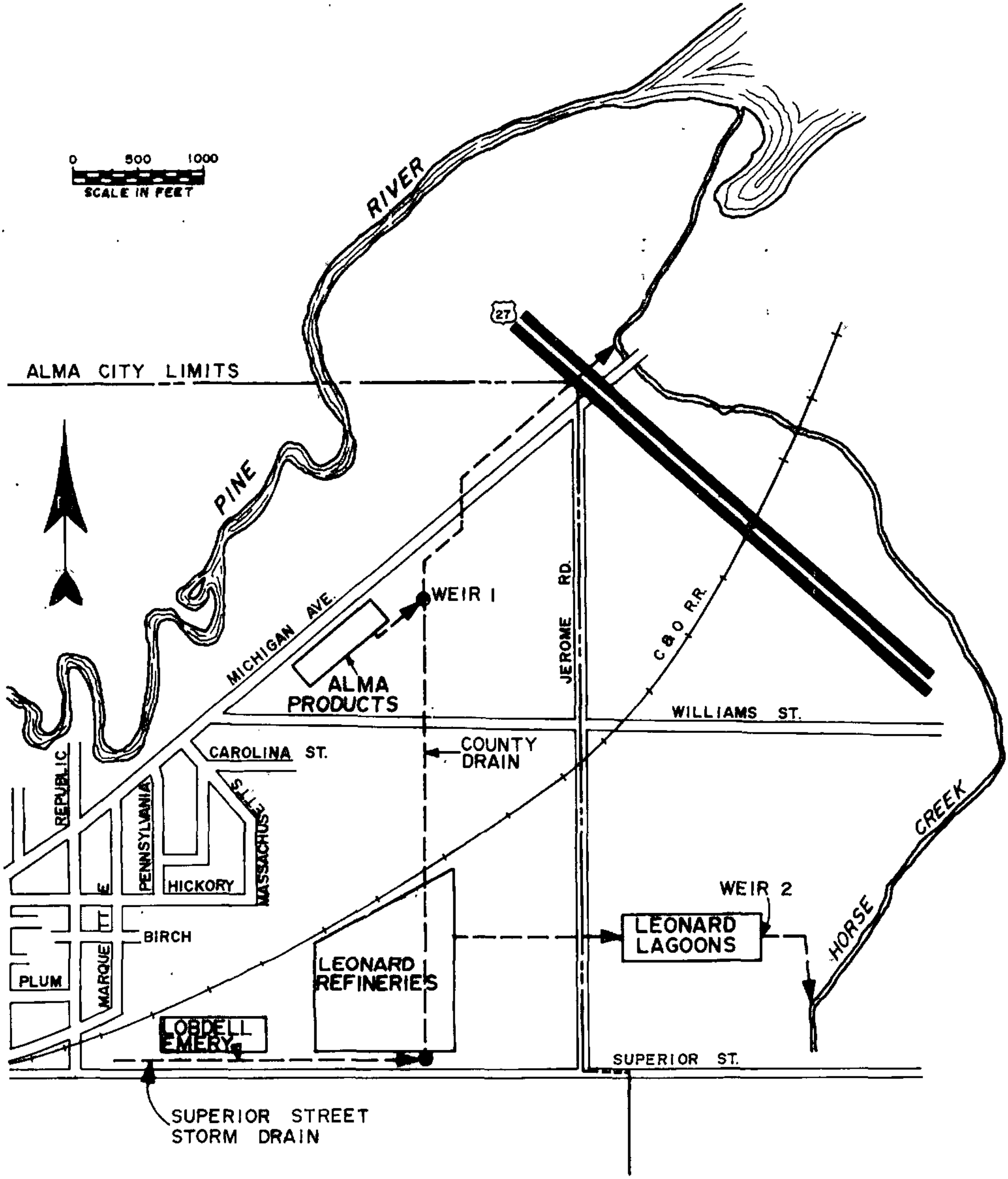


TABLE 6

PINE RIVER
1967 COMPOSITE SAMPLE RESULTS OF INDUSTRIAL WASTE DISCHARGES

Weir #1 — Contains Effluent from Lobdell Emery and Alma Products

Parameter Measured	8/29/67 Conc	8/29/67 lbs/day	8/30/67 Conc	8/30/67 lbs/day	Avg. lbs/day
Flow - MGD	0.763	---	0.704	---	0.734
BOD_5	25	159	12	70	114
Total Solids	1,912	12,162	870	5,112	8,637
Tot. Dis. Solids	1,028	6,542	745	4,374	5,458
Sus. Solids	884	5,623	125	734	3,178
Set. Solids	---	---	---	---	---
pH	2.9	---	6.2	---	---
Total PO_4	940	5,979	155	911	3,445
SO PO_4	750	4,771	---	---	4,771
NH_3-N	8.0	50.9	0.0	0.0	25
NO_3-N	1.7	10.8	1.9	11.1	10.9
Cl	210	1,336	120	705	1,020
Fe	80.0	509	---	---	509
Ca	24.0	153	36.0	212	182
Mg	70.0	445	34.0	199	322
Na	170	1,081	---	---	1,081
K	5.9	37.5	---	---	37.5
SO_4	220	1,399	250	1,469	1,434
CN	0.0	0.0	0.0	0.0	0.0
Cr^{+6}	0.0	0.0	1.1	6.4	3.2
Cu	---	---	0.0	0.0	0.0
Alkalinity	0.0	0.0	---	---	0.0
Hardness ($CaCO_3$)	350	2,226	230	1,351	1,788
$CHCl_3$ Ext.	21.0	134	14.0	82.3	108
CO_3	0.0	0.0	---	---	0.0
H_2SO_4 Acidity	---	---	---	---	---

Weir #2 — Effluent from Lagoon System at Leonard Refinery

Parameter Measured	8/29/67 Conc	8/29/67 lbs/day	8/30/67 Conc	8/30/67 lbs/day	Avg. lbs/day
Flow - MGD	0.331	---	0.386	---	0.358
BOD_5	9	24.8	11	35.4	30
Total Solids	1,544	4,257	1,520	4,892	4,574
Tot. Dis. Solids	1,531	4,226	1,506	4,848	4,537
Sus. Solids	13.0	35.8	14.0	45.1	40.4
Set. Solids	---	---	---	---	---
pH	7.6	---	7.4	---	---
Total PO_4	0.45	1.2	0.6	1.9	1.6
SO PO_4	0.1	0.3	0.1	0.3	0.3
NH_3-N	18.0	49.6	18.0	57.9	53.8
NO_3-N	0.0	0.0	0.0	0.0	0.0
Cl	410	1,131	410	1,319	1,225
Fe	0.3	0.8	0.6	1.9	1.4
Ca	126	347	124	399	373
Mg	39.0	107	39.0	125	116
Na	260	717	260	837	777
K	12.0	33.1	12.0	38.6	35.8
SO_4	460	1,268	500	1,609	1,438
CN	0.0	0.0	0.0	0.0	0.0
Cr^{+6}	0.0	0.0	0.0	0.0	0.0
Cu	---	---	---	---	---
Alkalinity	85.0	234	90	290	262
Hardness ($CaCO_3$)	475	1,310	470	1,513	1,412
$CHCl_3$ Ext.	2.0	5.5	2.0	6.4	5.95
CO_3	0.0	0.0	0.0	0.0	0.0
H_2SO_4 Acidity	---	---	---	---	---

Michigan Chemical Co — Combined Results of 13 Effluents minus loads in 2 water intakes

Parameter Measured	8/30/67 Conc	8/30/67 lbs/day	8/31/67 Conc	8/31/67 lbs/day	Avg. lbs/day
Flow - MGD	1.565	---	1.553	---	1.559
BOD_5	Various	585	Various	---	585
Total Solids	"	461,126	"	657,586	559,356
Tot. Dis. Solids	"		"		549,966
Sus. Solids	"	11,767	"	7,014	9,390
Set. Solids	"	---	"	5,684	5,684
pH	"	---	"	---	---
Total PO_4	"	-58	"	28.8	-14.6
SO PO_4	"	---	"		
NH_3-N	"	602	"	484	543
NO_3-N	"	163	"	119	141
Cl	"	278,502	"	305,024	291,763
Fe	"	29.8	"	---	29.8
Ca	"	97,147	"	---	97,147
Mg	"	1,596	"	---	1,596
Na	"	61,789	"	---	61,789
K	"	4,215	"	---	4,215
SO_4	"	5,303	"	---	5,303
CN	"	---	"	0	0
Cr^{+6}	"	---	"	0	0
Cu	"	221	"	408	314
Alkalinity	"	-1,012	"	---	-1,012
Hardness ($CaCO_3$)	"	245,951	"	---	245,951
$CHCl_3$ Ext.	"	56.9	"	---	56.9
CO_3	"	---	"	---	---
H_2SO_4 Acidity	"	4,882	"	---	4,882

Note: All concentrations are expressed in mg/l except for flow and pH.

2. Leonard Refineries, Inc.

The Alma refinery manufactures many types of petroleum products. Process wastewaters from this plant are treated in a series of aerated stabilization ponds which have a retention time of about 10 days. The effluent is discharged to Horse Creek. These ponds are being expanded so that the retention time will be about 40 days. Caustic wastes and foul condensates are injected into deep wells.

Two 24-hour composite samples of the effluent from the final stabilization pond were collected in 1967. The results of analyses of these samples are listed under Weir #2 in Table 6.

3. Alma Products Company

This company manufactures machined metal parts. All liquid wastes from this plant, except for cooling water, passed through four small waste stabilization ponds and an oil skimmer-separator device before discharging to the county drain. This effluent is included in the sample results listed under Weir #1 in Table 6.

On or before December 31, 1972, Alma Products will further pretreat its wastewater and then discharge it to the Alma sanitary sewerage system, instead of to the county drain.

4. Michigan Chemical Company

This company produces bromine, calcium carbonate, sodium chloride, and other chemical products. The company has two water intakes in the Pine River. There are approximately 20 separate wastewater outfalls from the Michigan Chemical Company to the Pine River. Discharges from some of these outfalls have deposited a visible quantity of solids, which extends approximately 150 feet into the river. Large quantities of total dissolved solids, chlorides, and suspended solids are also discharged.

A detailed wastewater survey of this company was conducted during the week of August 28, 1967 by personnel of the Water Quality Appraisal Section of the Water Resources Commission. The resulting report, entitled "Report of Industrial Survey, Michigan Chemical Company, St. Louis, Michigan," lists specific concentrations and quantities of wastes discharged from the company's many outfalls. Table 6 lists a total load to the Pine River from the 13 effluents measured during the 1967 survey. The loads measured in the water entering the company's two water intakes were subtracted so that the figures in Table 6 represent only the loads added by the Michigan Chemical Company. The results show high total solids, total dissolved solids, suspended solids, settleable solids, chlorides, calcium, sodium, potassium, sulfates, hardness, and sulfuric acid acidity. High biochemical oxygen demand, ammonia-nitrogen, magnesium, and copper loads were also found. One discharge had a low pH of 2.0.

TABLE 7

SUMMARY OF MICHIGAN CHEMICAL CO. WASTE DISCHARGES

September, 1970

Parameter Measured	Measured Net Discharge (lb/day)
BOD_5	2,746
COD	8,723
Total Solids	735,703
Total Volatile Solids	173,997
Total Suspended Solids	16,767
Susp. Vol. Solids	5,392
Total Dissolved Solids	718,943
Diss. Vol. Solids	168,120
Diss. Non-Vol. Solids	550,329
Susp. Non-Vol. Solids	11,375
Sett. Solids	13,660
Total PO_4	152
NH_3-N	528
NO_3-N	36
K	2,227
Ca	82,492
Na	83,291
Mg	1,214
Cl	281,094
SO_4	15,850
Alkalinity (as $CaCO_3$)	-1,533
Hardness (as $CaCO_3$)	213,655

NOTE: The discharges shown are net values from thirteen of Michigan Chemical Company's outfalls and two intakes (lb/day taken in subtracted from lb/day discharged). Twenty-four hour composite samples were collected on 9-9-70 and 9-10-70.

Net discharges shown here cannot be compared with the net discharges shown for the 1967 survey in Table 6 because the 1970 results shown above are more representative of Michigan Chemical Company's total waste load.

A similar survey was conducted during the week of September 6, 1970. As in 1967, a great deal of variation was observed in Michigan Chemical Company's discharges. Table 7 contains a summary of the twenty-four hour survey which is considered most representative. Between 1967 and 1970, the company has accomplished a limited number of changes in its processes to provide waste control. The major change was the installation of a brine disposal well. Operating difficulties have occasionally been experienced with this well. The detailed 1970 data is included in a report entitled, "Report of Wastewater Survey, Michigan Chemical Company Facility Discharges to the Pine River, St. Louis, Michigan."

B. Municipal Waste Loads

1. Alma Wastewater Treatment Plant

This plant has an estimated design capacity of 1.35 mgd and provides primary waste treatment for an estimated population of 9,100. The final effluent is chlorinated. The sewerage system is a combined system which bypasses untreated sewage to the Pine River during periods of heavy precipitation.

Two 24-hour composite samples of the effluent from this treatment plant were collected in August 1967. The results of analyses of these samples are listed in Table 8. These results show that this plant contributed substantial quantities of BOD_5, solids, and nutrients to the Pine River.

Table 9 presents a comparison of monthly averages of volumes of waste treated and BOD_5 loads from this plant for the months of June through September 1967 and 1970. Both the quantity of wastes treated and the BOD_5 load to the Pine River were approximately the same in the summer of 1967 and in the summer of 1970.

The Water Resources Commission at its July 23-24, 1970 meeting authorized the Chairman and Executive Secretary, on behalf of the Commission, to sign a Stipulation (a voluntary but legally binding agreement) developed between the City of Alma and the staff of the Commission. In this Stipulation the city has agreed to the following improvements:

1.) The City shall connect all waste discharges to the wastewater treatment plant, and

2.) The City shall treat or control the sewage and industrial wastes to the extent that when discharged to the Pine River it shall:

a.) Not contain more than 150 pounds per day of oxygen consuming substances as measured by the five-day biochemical oxygen demand test.

b.) Not contain more than twenty-five (25) milligrams per liter of suspended solids.

c.) Not contain more than fifteen (15) milligrams per liter of chloroform extractable substances (oil) or amounts sufficient to cause a visible film on the waters of the state.

TABLE 8

PINE RIVER

1967 COMPOSITE SAMPLE RESULTS OF
MUNICIPAL WASTE DISCHARGES

Parameter Measured	Alma W W T P					St. Louis W W T P				
	8/29/67		8/30/67		Av	8/29/67		8/30/67		Av
	Conc	lbs/day	Conc	lbs/day	lbs/day	Conc	lbs/day	Conc	lbs/day	lbs/day
Flow - MGD	1.83	---	1.53	---	1.68	0.67	---	0.55	---	0.61
BOD_5	62	946	70	893	920	80	447	58	266	356
Total Solids	648	9,890	---	---	9,890	980	5,476	---	---	5,476
Tot. Dis. Solids	592	9,035	---	---	9,035	916	5,118	---	---	5,118
Sus. Solids	56	855	48	612	734	64	358	66	303	330
pH	7.6		7.8			7.7		7.8		
Total PO_4	19	290	18	230	260	25	140	20	92	116
S.O. PO_4	13	198	11	140	169	15	84	11	50	67
NH_3-N	14	214	14	179	196	14	78	16	73	76
NO_3-N	0.1	1.5	0.2	2.6	2.05	0.2	1.1	0.3	1.4	1.25
Cl	90	1,374	130	1,659	1,516	180	1,006	220	1,009	1,008
Ca	60	916	64	817	866	100	559	106	486	522
Mg	13	198	17	217	208	26	145	26	119	132
Na	98	1,496	100	1,276	1,386	140	782	140	642	712
K	7.6	116	7.6	97	106	10	56	9.4	43	50
SO_4	130	1,984	125	1,595	1,790	175	978	150	688	833
CN	0.00	---	0.00	---	---	0.00	---	0.00	---	---
Cr^{+6}	0.00	---	Trace	---	---	0.00	---	0.00	---	---

NOTE: All concentrations except flow and pH are expressed as mg /l.

TABLE 9

COMPARISON OF 1967 AND 1970 AVERAGE FLOWS AND BOD_5 LOADS FROM THE ALMA AND ST. LOUIS WASTEWATER TREATMENT PLANTS (June - September)

	Average Flow (mgd)	Average Effluent BOD_5 Concentration (mg /l.)	Average BOD_5 Load (lbs /day)
ALMA W W T P			
June 1967	2.32	63	1220
July 1967	1.63	69	940
August 1967	1.43	86	1030
September 1967	1.54	105	1350
June 1970	1.70	82	1160
July 1970	1.40	80	930
August 1970	1.40	90	1050
September 1970	1.60	69	920
ST. LOUIS W W T P			
June 1967	1.16	38	370
July 1967	0.81	38	260
August 1967	0.63	48	250
September 1967	0.59	61	300
June 1970	0.65	68	370
July 1970	0.57	72	340
August 1970	0.51	95	400
September 1970	0.83	57	390

NOTE: Data obtained from monthly operating records submitted to the Michigan Department of Public Health.

d.) Not contain more than twenty percent (20%) of the total phosphorus contained in the sewage and wastes prior to treatment.

e.) Not contain more than three tenths (0.3) milligrams per liter of chromium.

f.) Not contain more than one (1.0) milligram per liter of nickel.

g.) Not contain more than two tenths (0.2) milligram per liter of cyanide.

h.) Not have a pH of less than 6.5 nor more than 8.5.

i.) Contain no other substances in amounts sufficient to injuriously affect public health or welfare, or commercial, industrial, recreational and domestic water supply use.

3.) The City shall provide facilities capable of producing the waste effluent quality specified in paragraph one hereof in accordance with the following time schedule:

a.) Submit preliminary engineering study and basis of design for said facilities to the Director of the Michigan Department of Public Health and obtain his approval thereof on or before September 15, 1970.

b.) Submit construction plans and specifications for said faciltiies to the Director of the Michigan Department of Public Health and obtain his approval thereof on or before July 1, 1971.

c.) Award construction contracts and commence construction of said facilities in accordance with plans and specifications approved by the Director of the Michigan Department of Public Health on or before October 1, 1971.

d.) Complete construction of said facilities and place same in continuous operation on or before December 31, 1972.

The preliminary engineering study calling for secondary treatment of wastes and 80% phosphorus removal has been submitted to the Michigan Department of Public Health.

2. St. Louis Wastewater Treatment Plant

This plant has an estimated design capacity of 0.45 mgd and provides primary waste treatment for an estimated population of 4,000. The final effluent is chlorinated. The sewerage system is a combined system which bypasses untreated sewage to the Pine River during periods of heavy precipitation.

The results of analyses of two 24-hour composite samples of the effluent from the treatment plant are listed in Table 8. This plant contributes a substantial BOD_5, solids, and nutrient load to the Pine River. The data in Table 9 shows that the BOD_5 load from this facility was about 27% greater in the summer of 1970 than in the summer of 1967.

WATER QUALITY INVESTIGATIONS (1967)

A. Purpose of Investigations

In August 1967 a continuous 48-hour survey of the water quality of the Pine River was conducted by staff of the Michigan Water Resources Commission. The purpose of the survey was to ascertain river water quality and to relate this quality to existing waste loads being discharged to the river. The natural assimilative capacity of the river downstream from the waste loads was then determined from this information. After definition of these river factors, predictions of improvements in river water quality that would be expected with various degrees of improvement in waste treatment were made.

B. Waste Assimilation

An important characteristic of any river is its ability to assimilate waste without impairing legitimate water uses. Natural purification in a stream occurs when bacteria and other organisms break down organic or other biodegradable materials into stable compounds or elements. These organisms utilize the dissolved oxygen from the water during the waste assimilation process. If large quantities of wastes are added to a stream, so that more oxygen is used than can be replaced, then oxygen depletion occurs. Lowered oxygen levels may deleteriously affect fish and other aquatic life. A complete lack of oxygen causes the development of undesirable conditions, creates noxious odors, and eliminates fish and other desirable aquatic life.

The relationships involved in organic waste assimilation are complex, but can be approximated by the use of a simplified mathematical model. This was done for the Pine River to predict dissolved oxygen concentrations at the design flow. Predictions were made for a 20 mile reach of the river where wastes from the Alma and St. Louis area cause the greatest oxygen depletion. The concentrations of dissolved oxygen predicted at the design flow were not satisfactory to protect the designated uses of the river. Variations of waste loads to the river were substituted in the model to simulate improvement of present treatment practices. The necessary improvements in treatment were then determined when dissolved oxygen predictions met the standards.

1. Background Information Utilized in Predictions

The comprehensive Pine River survey was conducted in August 1967. Additional data were collected in September 1970 to determine if changes in water quality had occurred. Nineteen sampling stations were selected to characterize the river upstream and downstream from major waste discharges. The locations of these stations are shown in Figure 16. The 48-hour grab sampling results from 1967 are listed in Table 10 and the dissolved oxygen results are summarized in Table 11. The 1970 grab sample results are listed in Table 12.

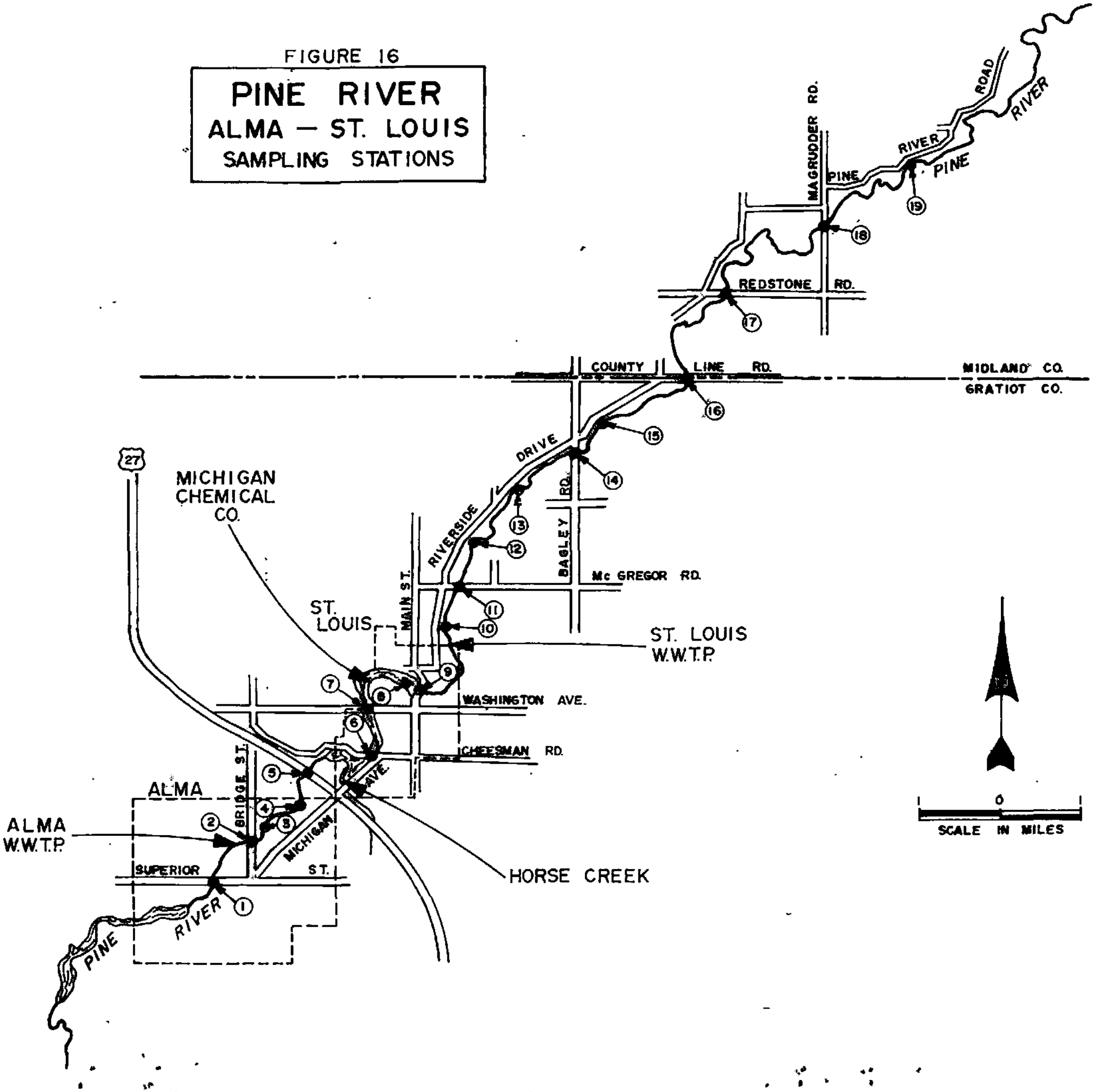


FIGURE 16

PINE RIVER
ALMA — ST. LOUIS
SAMPLING STATIONS

River flows were determined at the USGS gage in Alma during the surveys. Three significant flow rates at this location are:

1) Average flow rate during 1967 comprehensive study = 110 cfs.
2) Average flow rate during 1970 study = 100 cfs.
3) 10-year recurrence of minimum low flow of 7-day duration = 26 cfs. This is the design flow.

Waste loads used in DO calculations are summarized in Table 13.

The DO standards used as the criteria for satisfactory water quality were 1) average daily DO not less than 5 mg/l, and 2) no single value less than 4 mg/l.

The physical, chemical, and biological characteristics of the river affect DO predictions when using a simplified mathematical model. Several unusual characteristics of the Pine River should be listed:

a. The dam in St. Louis is used to supply water power for a municipal hydroelectric plant. This generating plant is used during peak loads. Water is stored in the reservoir at other times. Because the reservoir is also used to supply part of Michigan Chemical Company's water, the reservoir level is kept above these intakes regardless of the river flow. These dam operations can seriously affect downstream water quality, particularly during drought flows. At low flows, with the reservoir level requirement and the storage of water for peak power needs, the flow through the dam can be entirely cut off. The effect on the river water quality would be serious since effective waste assimilation depends on adequate diluting flow. Fluctuations of water level at the McGregor Rd. bridge of almost one foot were observed during the 1967 survey (Figure 12).

b. The river contains large amounts of aquatic vegetation downstream from St. Louis. The effect of photosynthesis and respiration on the river DO concentrations in this area was significant from sampling stations 11 to 18. Supersaturated afternoon DO values (about 15 mg/l) shown in Table 12 were largely caused by the photosynthesis of the aquatic plants, while the low early morning DO values (about 2 mg/l) were partially caused by respiration of the weeds. Consequently, DO concentrations are more critical with regard to meeting the standard of no single value less than 4 mg/l than the standard for daily average DO (5 mg/l or greater). The photosynthesis-respiration effect is dependent on a number of factors, including density of plant growth, type of plant, and light intensity.

c. There is a large ammonia load to the river, principally from Michigan Chemical Company. Certain bacteria convert this ammonia to nitrites and then to nitrates utilizing dissolved oxygen in the process. This places an additional demand on the available dissolved oxygen resources of the river.

TABLE 10

1967 SURVEY

48 HOUR SAMPLING RESULTS

Station	Date	Time	Temp. °C	DO mg/l	5-day BOD mg/l
No. 1	8-29-67	8:00A	19	8.2	1.5
Mile Point - 38.76	8-29-67	11:30A	21	8.6	1.8
Superior Street Bridge,	8-29-67	3:15P	21	8.8	2.3
Alma	8-29-67	7:10P	22	8.2	1.7
	8-29-67	10:12P	20	8.2	2.2
	8-30-67	1:40A	20	8.4	2.0
	8-30-67	5:30A	19	8.0	1.6
	8-30-67	9:30A	20	8.0	1.4
	8-30-67	1:00P	20	7.9	1.2
	8-30-67	4:30P	19	8.4	1.7
	8-30-67	8:00P	18	8.3	1.5
	8-30-67	11:30P	18	8.0	1.4
	8-31-67	3:00A	17	8.4	1.8
	8-31-67	6:40A	16	8.2	1.6
	Arithmetic Average		19.3	8.3	1.7
No. 2	8-29-67	8:25A	20	7.6	2.1
Mile Point - 37.88	8-29-67	11:40A	22	8.2	1.9
Bridge Street Bridge,	8-29-67	3:25P	22	8.6	2.4
Alma	8-29-67	7:17P	22	8.4	2.6
	8-29-67	10:25P	20	7.6	5.6
	8-30-67	1:45A	20	7.8	2.4
	8-30-67	5:40A	19	7.8	2.6
	8-30-67	9:40A	20	7.4	1.4
	8-30-67	1:05P	20	7.8	2.2
	8-30-67	4:41P	19	8.2	3.7
	8-30-67	8:10P	18	7.8	3.8
	8-30-67	11:35P	18	7.8	2.5
	8-31-67	3:05A	17	7.8	2.8
	8-31-67	6:50A	15.5	7.9	2.3
	Arithmetic Average		19.5	7.9	2.7
No. 3	8-29-67	8:35A	19	7.2	1.8
Mile Point - 37.16	8-29-67	11:55A	21	7.6	2.6
Michigan Avenue:	8-29-67	3:35P	22	8.1	3.2
Right Bank at First	8-29-67	7:27P	22	8.2	2.6
Access N.E. of Republic	8-29-67	10:30P	20	7.4	3.4
Street Intersection,	8-30-67	1:55A	19	7.4	3.2
Alma	8-30-67	5:45A	19	7.4	3.2
	8-30-67	9:50A	20	7.0	1.6
	8-30-67	1:15P	20	7.4	2.4
	8-30-67	4:50P	19	7.8	3.0
	8-30-67	8:15P	18	7.6	2.7
	8-30-67	11:43P	18	7.8	3.6
	8-31-67	3:15A	17	7.4	2.4
	8-31-67	7:00A	15.5	7.7	2.1
	Arithmetic Average		19.3	7.6	2.7
No. 4	8-29-67	8:50A	19	6.5	2.6
Mile Point - 36.88	8-29-67	12:20P	21	7.8	3.5
Michigan Avenue:	8-29-67	3:50P	22	7.8	3.2
Right Bank West of	8-29-67	7:35P	22	8.4	2.9
Presbyterian Church	8-29-67	10:42P	20	7.4	3.2
Parking Lot,	8-30-67	2:05A	19	7.0	4.4
Alma	8-30-67	5:57A	19	7.2	4.0
	8-30-67	10:05A	20	7.7	4.1
	8-30-67	1:30P	20	6.4	4.8
	8-30-67	4:54P	19	7.4	3.0
	8-30-67	8:25P	18	7.7	3.2
	8-30-67	11:53P	17	7.4	2.8
	8-31-67	3:25A	16	7.2	2.6
	8-31-67	7:05A	15	7.6	2.4
	Arithmetic Average		19.1	7.4	3.3
No. 5	8-29-67	9:00A	19	6.8	4.1
Mile Point - 35.85	8-29-67	12:35P	21	7.2	3.2
U S.-27 Bridge	8-29-67	4:05P	22	-	-
	8-29-67	7:48P	22	7.8	2.8
	8-29-67	10:54P	21	7.6	2.8
	8-30-67	2:25A	20	7.2	3.0
	8-30-67	6:10A	19	6.4	3.2
	8-30-67	10:15A	20	6.8	3.3
	8-30-67	1:50P	20	6.4	4.8
	8-30-67	5:06P	19	7.0	1.8
	8-30-67	8:35P	18	7.0	2.3
	8-31-67	12:03A	18	7.2	3.2
	8-31-67	3:50A	16	6.9	2.9
	8-31-67	7:15A	16	6.8	2.6
	Arithmetic Average		19.4	7.0	3.1
No. 6	8-29-67	9:15A	20	6.8	2.7
Mile Point - 34.81	8-29-67	12:45P	21	7.1	3.1
Cheesman Road Bridge,	8-29-67	4:18P	22	7.6	2.8
St. Louis	8-29-67	8:00P	22	7.4	2.3
	8-29-67	11:03P	20	7.2	2.8
	8-30-67	2:35A	20	7.0	2.6
	8-30-67	6:20A	20	6.8	2.5
	8-30-67	10:30A	20	7.0	4.8
	8-30-67	2:10P	20	6.2	2.4
	8-30-67	5:15P	19	6.4	2.2
	8-30-67	8:44P	18	6.2	2.2
	8-31-67	12:11A	18	6.4	2.1
	8-31-67	4:00A	16	6.5	2.3
	8-31-67	7:28A	16	6.4	2.4
	Arithmetic Average		19.4	6.8	2.6
No. 7	8-29-67	9:20A	21	7.7	2.9
Mile Point - 34.18	8-29-67	12:55P	21	8.3	3.0
Washington Avenue	8-29-67	4:25P	23	8.4	3.5
Bridge, St. Louis	8-29-67	8:05P	22	7.7	2.7
	8-29-67	11:11P	20	7.2	2.8
	8-30-67	2:40A	20	7.0	2.4
	8-30-67	6:25A	20	7.0	2.5
	8-30-67	10:35A	20	6.6	2.3
	8-30-67	2:20P	20	6.8	2.5
	8-30-67	5:25P	19	6.9	2.3
	8-30-67	8:50P	18	6.6	2.6
	8-31-67	12:16A	18	6.2	2.2
	8-31-67	4:08A	16	6.2	2.2
	8-31-67	7:34A	16	6.2	2.4
	Arithmetic Average		19.6	7.1	2.6
No. 8	8-29-67	9:30A	21	9.4	2.8
Mile Point - 33.20	8-29-67	1:10P	22	11.6	5.0
Mill Street Bridge,	8-29-67	4:45P	23	12.4	6.2
St. Louis	8-29-67	8:12P	22	11.6	5.4
	8-29-67	11:20P	22	10.4	4.4
	8-30-67	2:50A	21	8.6	3.4
	8-30-67	6:35A	21	8.6	3.2
	8-30-67	10:40A	20	7.8	3.0
	8-30-67	2:30P	20	6.8	2.9
	8-30-67	5:33P	21	7.8	2.6
	8-30-67	8:58P	20	7.6	2.8
	8-31-67	12:21A	19	7.2	2.8
	8-31-67	4:17A	17.5	6.5	2.9
	8-31-67	7:40A	17	6.4	2.3
	Arithmetic Average		20.5	8.8	3.6
No. 9	8-29-67	9:35A	21	9.2	3.9
Mile Point - 32.95	8-29-67	1:15P	22	10.8	4.4
Main Street Bridge,	8-29-67	4:35P	23	12.0	5.4
St. Louis	8-29-67	8:20P	22	11.6	6.1
	8-29-67	11:28P	22	10.4	5.6
	8-30-67	2:55A	21	9.2	4.4
	8-30-67	6:55A	21	7.7	3.2
	8-30-67	10:45A	20	8.0	4.0
	8-30-67	2:35P	20	8.0	3.7
	8-30-67	5:39P	21	7.2	2.7
	8-30-67	9:04P	20	7.6	3.0
	8-31-67	12:25A	19	7.2	2.8
	8-31-67	4:23A	17	6.8	3.3
	8-31-67	7:47A	17	6.0	2.2
	Arithmetic Average		20.4	8.7	3.9
No. 10	8-29-67	9:55A	21	7.0	3.3
Mile Point - 31.57	8-29-67	1:30P	22	9.7	5.7
Riverside Drive:	8-29-67	4:50P	23	11.8	6.6
Left Bank .57 miles N. of	8-29-67	8:30P	22	9.0	7.3
Prospect Avenue and	8-29-67	11:37P	22	8.8	6.8
Union Street	8-30-67	3:00A	21	8.4	6.0
	8-30-67	7:05A	20	6.4	4.7
	8-30-67	11:00A	20	6.0	6.0
	8-30-67	2:55P	20	7.8	4.7
	8-30-67	5:45P	21	7.3	4.3
	8-30-67	9:09P	20	6.4	4.0
	8-31-67	12:34A	19	6.0	4.0
	8-31-67	4:33A	17	6.0	3.6
	8-31-67	7:54A	17	5.6	2.8
	Arithmetic Average		20.4	7.6	5.0

TABLE 10 CONTINUED

Station	Date	Time	Temp. °C	DO mg/l	5-day BOD mg/l
No. 11	8-29-67	10:10A	20	6.1	5.3
Mile Point - 30.91	8-29-67	1:40P	22	11.4	6.6
McGregor Road Bridge	8-29-67	4:55P	23	12.8	7.2
	8-29-67	8:40P	22	9.2	5.6
	8-29-67	11:45P	22	8.2	6.2
	8-30-67	3:10A	21	8.0	5.8
	8-30-67	7:10A	20	6.4	4.3
	8-30-67	11:05A	20	5.7	3.3
	8-30-67	3:15P	20	7.9	6.5
	8-30-67	6:50P	21	7.6	4.0
	8-30-67	9:18P	20	5.8	3.6
	8-31-67	12:39A	18	5.8	3.6
	8-31-67	4:40A	17	5.6	2.9
	8-31-67	8:00A	17	5.6	3.0
	Arithmetic Average		20.2	7.6	4.8
No. 12	8-29-67	10:25A	20	8.5	4.8
Mile Point - 30.13	8-29-67	1:50P	22	11.2	7.8
Riverside Drive:	8-29-67	5:03P	24	14.0	8.4
Left Bank 1.1 Miles	8-29-67	8:45P	22	9.0	5.4
North of McGregor Rd.	8-29-67	11:53P	22	6.6	5.2
Intersection	8-30-67	3:20A	21	6.6	5.6
	8-30-67	7:15A	20	6.0	4.2
	8-30-67	11:10A	20	5.8	3.8
	8-30-67	3:25P	20	7.4	4.4
	8-30-67	5:56P	21	7.8	4.0
	8-30-67	9:25P	19	6.4	4.4
	8-31-67	12:47A	18	5.0	3.5
	8-31-67	4:50A	16.5	5.0	3.6
	8-31-67	8:06A	16.5	5.4	3.0
	Arithmetic Average		20.1	7.5	4.9
No. 13	8-29-67	10:35A	20	6.4	6.4
Mile Point - 28.71	8-29-67	2:05P	22	11.6	5.8
Riverside Drive :	8-29-67	5:10P	23	13.5	8.0
Left Bank 1.7 Miles	8-29-67	8:55P	22	9.2	6.6
North of McGregor Rd.	8-30-67	12:03A	21	6.2	5.0
Intersection	8-30-67	3:30A	20	5.6	5.0
	8-30-67	7:20A	20	5.2	4.5
	8-30-67	11:20A	20	5.4	3.4
	8-30-67	3:45P	20	7.6	3.2
	8-30-67	6:01P	20	7.0	3.2
	8-30-67	9:33P	19	6.0	3.0
	8-31-67	12:55A	18	4.4	3.2
	8-31-67	5:00A	16.5	4.1	2.3
	8-31-67	8:10A	16	4.0	2.0
	Arithmetic Average		19.8	6.9	4.4
No. 14	8-29-67	10:45A	20	6.8	2.2
Mile Point - 27.95	8-29-67	2:20P	22	11.4	4.0
Bagley Road Bridge	8-29-67	5:18P	23	13.0	9.0
	8-29-67	9:05P	22	9.4	6.4
	8-30-67	12:10A	21	6.4	5.6
	8-30-67	3:35A	21	5.2	4.8
	8-30-67	7:30A	20	5.1	4.5
	8-30-67	11:30A	20	4.8	3.2
	8-30-67	3:50P	20	6.3	4.7
	8-30-67	6:07P	20	7.8	3.6
	8-30-67	9:41P	19	6.2	3.5
	8-31-67	1:00A	18	4.8	3.2
	8-31-67	5:08A	16.5	3.7	2.2
	8-31-67	8:19A	16	4.2	3.4
	Arithmetic Average		19.9	6.8	4.3
No. 15	8-29-67	11:00A	20	2.4	4.4
Mile Point - 27.33	8-29-67	2:30P	22	13.6	2.4
Riverside Drive:	8-29-67	5:25P	23	12.0	5.2
Left Bank .45 Miles	8-29-67	9:15P	22	8.8	5.6
N.E. of Bagley Rd.	8-30-67	12:20A	21	6.4	5.4
Intersection	8-30-67	3:45A	20	4.4	4.0
	8-30-67	7:35A	20	3.9	4.0
	8-30-67	11:40A	20	5.0	5.0
	8-30-67	4:05P	20	5.8	2.5
	8-30-67	6:15P	20	6.4	2.2
	8-30-67	9:50P	19	5.6	2.4
	8-31-67	1:08A	18	4.4	2.0
	8-31-67	5:18A	16	3.5	2.0
	8-31-67	8:25A	16	3.7	2.2
	Arithmetic Average		19.8	6.1	3.5
No. 16	8-29-67	11:10A	20	5.6	2.0
Mile Point - 26.13	8-29-67	2:45P	22	12.4	7.6
County Line Road	8-29-67	5:30P	24	14.1	5.4
Bridge	8-29-67	9:20P	22	8.6	6.4
	8-30-67	12:27A	22	6.8	6.1
	8-30-67	3:50A	21	4.8	6.0
	8-30-67	7:40A	20	3.7	3.8
	8-30-67	11:50A	20	4.2	3.1
	8-30-67	4:10P	20	6.9	2.9
	8-30-67	6:20P	20	7.7	2.7
	8-30-67	9:57P	19	6.4	2.8
	8-31-67	1:15A	18	5.0	2.5
	8-31-67	5:27A	16	4.2	1.8
	8-31-67	8:30A	16	4.1	2.2
	Arithmetic Average		20.0	6.8	4.0
No. 17	8-29-67	11:20A	--	6.4	2.4
Mile Point - 24.14	8-29-67	2:55P	--	12.6	2.4
Redstone Road Bridge	8-29-67	5:37P	24	15.0	2.4
	8-29-67	9:27P	22	9.6	3.4
	8-30-67	12:35A	22	6.4	4.9
	8-30-67	4:00A	21	5.4	4.2
	8-30-67	7:47A	20	4.1	3.3
	8-30-67	12:05P	20	4.7	3.0
	8-30-67	4:20P	20	7.2	2.9
	8-30-67	6:30P	19	8.0	2.6
	8-30-67	10:07P	18	6.6	2.0
	8-31-67	1:23A	18	5.8	2.2
	8-31-67	5:35A	16	5.1	2.0
	8-31-67	8:38A	16	5.4	1.8
	Arithmetic Average		19.7	7.3	2.8
No. 18	8-29-67	11:25A	--	7.1	2.5
Mile Point - 21.24	8-29-67	3:00P	--	11.4	7.6
Magrudder Road Bridge	8-29-67	5:45P	24	14.6	2.0
	8-29-67	9:38P	22	9.9	2.5
	8-30-67	12:44A	22	7.6	4.8
	8-30-67	4:05A	20	6.0	3.4
	8-30-67	7:55A	21	5.0	3.0
	8-30-67	12:15P	20	5.3	2.7
	8-30-67	4:30P	20	7.4	2.7
	8-30-67	6:36P	19	8.2	2.6
	8-30-67	10:15P	18	7.3	2.0
	8-31-67	1:30A	18	6.4	2.1
	8-31-67	5:43A	16	6.2	1.8
	8-31-67	8:48A	15	6.4	1.8
	Arithmetic Average		19.6	7.8	3.0
No. 19	8-29-67	11:35A	--	7.2	4.0
Mile Point - 19.13	8-29-67	3:15P	--	11.6	3.6
Pine River Road:	8-29-67	5:57P	24	14.0	3.0
Left Bank 1.45 Miles N.E.	8-29-67	9:45P	22	9.9	2.6
of Magrudder Road Bridge	8-30-67	12:55A	22	8.0	2.7
	8-30-67	4:15A	20	6.6	2.9
	8-30-67	8:00A	20	5.4	3.3
	8-30-67	12:30P	20	5.7	3.8
	8-30-67	4:45P	20	7.6	2.8
	8-30-67	6:41P	19	8.0	2.6
	8-30-67	10:24P	18	7.6	2.4
	8-31-67	1:40A	18	7.0	2.2
	8-31-67	5:53A	15	7.0	2.1
	8-31-67	8:55A	15	7.0	1.7
	Arithmetic Average		19.4	8.0	2.8

TABLE 11

SUMMARY OF 1967 PINE RIVER SURVEY

DISSOLVED OXYGEN CONCENTRATIONS

August 29-31, 1967

Station No.	Description	Mile Point	Average DO (mg./l.)	Lowest DO Measured (mg./l.)	Average* Morning DO (mg./l.)
1	Superior Street Bridge	38.76	8.3	7.9	8.2
2	Bridge Street Bridge	37.88	7.9	7.4	7.7
3	Mich. Avenue (Bank)	37.16	7.6	7.0	7.4
4	Mich. Avenue (Bank)	36.88	7.4	6.4	7.4
5	U.S.-27 Bridge	35.85	7.0	6.4	6.7
6	Cheesman Rd. Bridge	34.81	6.8	6.2	6.7
7	Washington Ave. Bridge	34.18	7.1	6.2	6.5
8	Mill Street Bridge	33.20	8.8	6.4	7.3
9	Main Street Bridge	32.95	8.7	6.0	7.1
10	Riverside Drive (Bank)	31.57	7.6	5.6	6.0
11	McGregor Rd. Bridge	30.91	7.6	5.6	5.8
12	Riverside Drive (Bank)	30.13	7.5	5.0	5.6
13	Riverside Drive (Bank)	28.71	6.9	4.0	4.7
14	Bagley Road Bridge	27.95	6.8	3.7	4.5
15	Riverside Drive (Bank)	27.33	6.1	2.4	4.0
16	County Line Rd. Bridge	26.13	6.8	3.7	4.1
17	Redstone Rd. Bridge	24.14	7.3	4.1	4.8
18	Magrudder Rd. Bridge	21.24	7.8	5.0	5.7
19	Pine River Rd. (Bank)	19.13	8.0	5.4	6.3

*Average of the four morning runs when DO was low.

TABLE 12

1970 GRAB SAMPLE RESULTS

September 9, 1970

Station No.	Average DO (mg/1)	Morning Samples (6:15 am - 8:15 am) Temp (°C)	pH	DO (mg/1)	Afternoon Samples (2:40 pm - 4:20 pm) Temp (°C)	pH	DO (mg/1)	Composite Samples NH3-N (mg/1)	NO3-N (mg/1)	Cl (mg/1)
1	8.4	20.0	8.10	7.8	23.0	8.30	9.0	.09	.40	32
2	8.3	19.5	8.15	7.6	23.2	8.22	9.0	.37	.40	30
5	7.0	20.0	8.05	6.4	22.0	8.13	7.6	.19	.35	26
6	6.9	20.5	7.95	6.4	24.0	8.05	7.4	.52	.40	34
7	6.4	20.5	7.90	6.0	24.0	8.10	6.8	.35	.30	30
8	8.2	22.0	7.25	8.0	25.5	7.20	8.4	.37	.25	400
9	9.6	22.5	7.00	8.2	24.0	7.40	11.0	.41	.30	530
11	8.4	20.0	7.25	4.6	24.3	7.45	12.2	.37	.45	640
12	8.7	20.0	*	2.8	25.0	7.20	14.6	.37	.45	610
13	8.3	20.0	*	2.0	25.0	7.20	14.6	.22	.50	740
14	8.4	20.0	*	1.8	24.0	7.90	15.0	.24	.50	610
15	7.7	20.0	*	2.2	24.0	7.90	13.2	.17	.60	580
16	9.2	20.0	*	2.8	24.0	8.00	15.6	.13	.60	580
17	9.0	21.0	*	3.8	24.0	8.10	14.2	.11	.55	640
18	8.7	21.0	*	5.4	24.0	7.90	12.0	.19	.60	780

* Equipment malfunction

TABLE 13

WASTE LOADS TO THE PINE RIVER

UTILIZED IN DISSOLVED OXYGEN PREDICTION CALCULATIONS

Waste Source	Flow (cfs)	BOD_5 (lbs/day)	Lo* (Ult. BOD) (lbs/day)	NH_3-N (lbs/day)	No** (O_2 demand from N) (lbs/day)	Total Demand (Lo + No) (lbs/day)
1967:						
Alma WWTP	2.60	920	1,340	196	895	2,235
Horse Creek	1.69	144	211	79	360	571
Michigan Chemical	15.50	585	855	602	2,750	3,605
St. Louis WWTP	0.94	356	520	76	347	867
1970:						
Alma WWTP	2.35	900	1,310	196	895	2,205
Horse Creek	1.53	51	75	29	133	208
Michigan Chemical	15.20	1,565	2,290	481	2,200	4,490
St. Louis WWTP	0.99	380	555	76	347	902

* Calculated assuming K = .10 ($L_o = 1.46\ BOD_5$)
** Oxygen demand from NH_3 = 4.57 lb O_2/lb NH_3-N

The 1967 Michigan Chemical Company BOD_5 and NH_3-N loads were taken from the first 24-hour waste survey (8/30/67 a.m. to 8/31/67 a.m.).

Net waste loads are shown for Michigan Chemical both in 1967 and 1970. These were obtained by subtracting amounts taken out of the river via water intakes from the amounts being discharged into the river. Flow rates shown are for the discharges (water taken in is not subtracted).

Horse Creek includes effluent from Lobdell-Emery and Alma Products (storm drains) and from Leonard Refineries lagoon outfall.

Three assumptions were needed to complete the 1970 Table of Waste Loads:
1) NH3-N from Alma WWTP = 1967 value
2) NH3-N from St. Louis WWTP = 1967 value
3) BOD5 and NH3-N from Leonard Refinery = estimated from the 1967 value.

d. There are four major sources of waste which contribute oxygen-depleting constituents to the river at separate locations.

e. The impoundments at Alma and St. Louis interrupt the free flow of river water and modify many river characteristics. Included are changes in the downstream hydrograph and in times of passage. The decrease in turbulence increases sedimentation rates, reduces reoxygenation rates, and may result in stratification. Such stratification could affect chemical composition and temperature.

The computer model of river DO was modified to consider the weed respiration demand and the nitrogenous (ammonia) oxygen demand. Average daily river flows were used because dam operation is arbitrary and cannot be predicted.

2. Dissolved Oxygen Predictions

Seven cases were considered using the mathematical model of the DO concentrations in the Pine River. Two of these were to match the conditions found during the 1967 and 1970 surveys, and five were to predict DO concentrations with various load reductions. DO predictions are based on the design flow of 26 cfs and water temperature = 25°C.

Three types of improved treatment were simulated to improve dissolved oxygen concentrations in the river at design flow: 1) reduction of carbonaceous BOD_5 loads, 2) reduction of nitrogenous oxygen demand loads, and 3) reduction of nutrient loads.

BOD_5 loads can be decreased in various degrees by wastewater treatment processes. In those cases which specify BOD_5 reduction (Cases 4, 5, and 7), river loads were calculated assuming 90% removal of BOD_5. Where secondary treatment processes are in use or planned (e.g. Leonard Refineries and the City of Alma WWTP), approximations of the actual or planned loads were used. The BOD_5 load from Horse Creek was estimated based on 1967 surveys, known improvements since 1967, and planned Alma sewer revisions. The BOD_5 load from the City of Alma WWTP was assumed equal to the maximum allowable load after completion of improvements specified in the July 1970 stipulation.

Ammonia can be nitrified to nitrate or removed by certain treatment processes. In those cases (4, 6 and 7) in which improved nitrogenous oxygen demand removal was specified, an ammonia nitrogen concentration of 2 mg/l was assumed for the effluents from Alma WWTP, the St. Louis WWTP and the Michigan Chemical Company. The effluent from the Leonard Refinery ponds was estimated.

The aquatic plant respiration demand can be reduced by reducing the density of plants. High levels of nutrients contribute to the profuse aquatic plant growths. The common nutrients phosphorus (as phosphate) and nitrogen (as nitrate) are both present in the affected portion of the river at higher levels than upstream from the waste discharges. Although quantitative relationships between nutrients and plant density are not well known, reductions in nutrients would be expected to reduce the plant growth. Therefore, the plant respiration demand was removed from the model for cases (5, 6, and 7) where 80% phosphorus removal was specified.

The cases considered are discussed in detail below, and summarized in Table 14.

Case 1) Duplication of 1967 survey conditions: (flow = 110 cfs, av. temp. = 19.8°C). Rates of organic waste stabilization and nitrification, flow rates, and temperatures were determined from 1967 survey information. Waste inputs were obtained from industrial and municipal surveys conducted simultaneously with the river survey. This information, along with a weed respiration demand and a reoxygenation coefficient, was used to match the observed data at the low (morning) DO condition. The actual and computed DO profiles are shown in Figure 17. Dissolved oxygen concentrations at the sag point approached the minimum allowable value of 4.0 mg/l.

Case 2) Duplication of observed 1970 survey conditions: (flow = 100 cfs, av. temp. = 22.3°C). A complete survey of the type conducted in 1967 was not conducted in 1970. The observed early morning DO profile, however, was matched by a calculated profile. River flow and waste loads to the river were similar to those observed in 1967. The same reoxygenation coefficient and decay rate factors for carbonaceous and nitrogenous oxygen demand determined for the 1967 case were used in this and all subsequent cases.

Observed morning DO concentrations were lower downstream from St. Louis in the 1970 survey than in 1967, and the afternoon DO concentrations were generally higher, indicating that the aquatic weed photosynthesis-respiration effect had increased between 1967 and 1970. The diurnal range of DO concentrations was too great to be attributed solely to changes in flow rate or waste loads, therefore, increased weed respiration factors were used to more closely simulate the DO sag point. The actual and computed profiles for 1970 are shown in Figure 18. Dissolved oxygen concentrations dropped below 2 mg/l in the reach downstream from St. Louis.

Case 3) Design Flow Conditions with Existing Waste Loads: (flow = 26 cfs, temp. = 25°C). This case is a prediction of dissolved oxygen concentrations at the design flow. Waste loads used in the prediction calculations were loads similar to those measured during the 1970 survey but were modified slightly to represent average conditions.

Using these assumptions, the DO concentration dropped to zero both in the reach between Alma and St. Louis (Station 5) and downstream from St. Louis (Stations 12-19).

Case 4) Design Flow Conditions with Lowered Carbonaceous and Nitrogenous Oxygen Demand Loads: (flow = 26 cfs, temp. = 25°C). The previously discussed decreases in carbonaceous and nitrogenous oxygen demand loads were applied to the model. It was assumed that no phosphorus was removed, therefore the aquatic weed respiration demands remained in the model.

FIGURE 17

DISSOLVED OXYGEN PROFILE AUGUST 1967

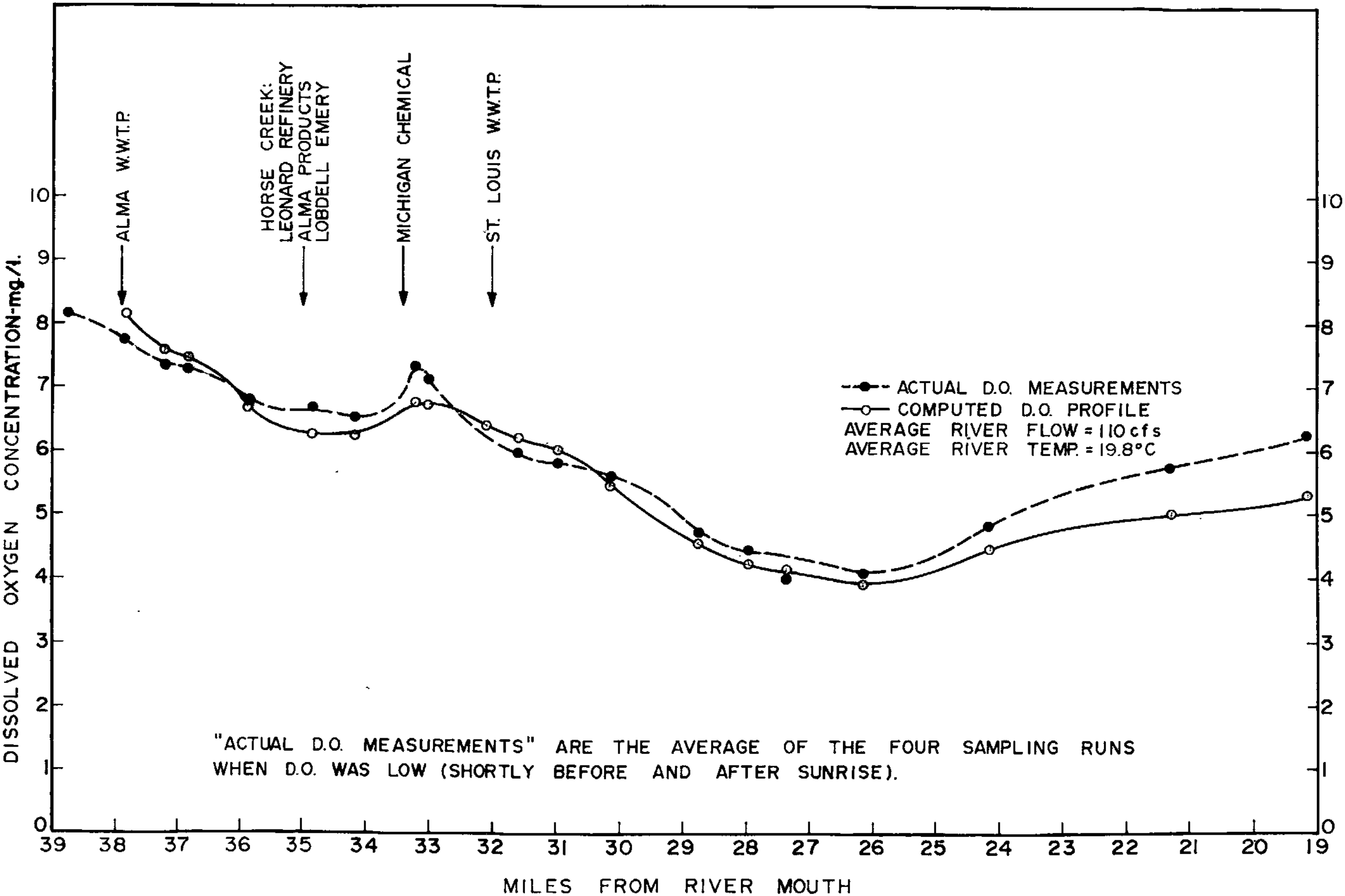


FIGURE 18

DISSOLVED OXYGEN PROFILE SEPTEMBER 1970

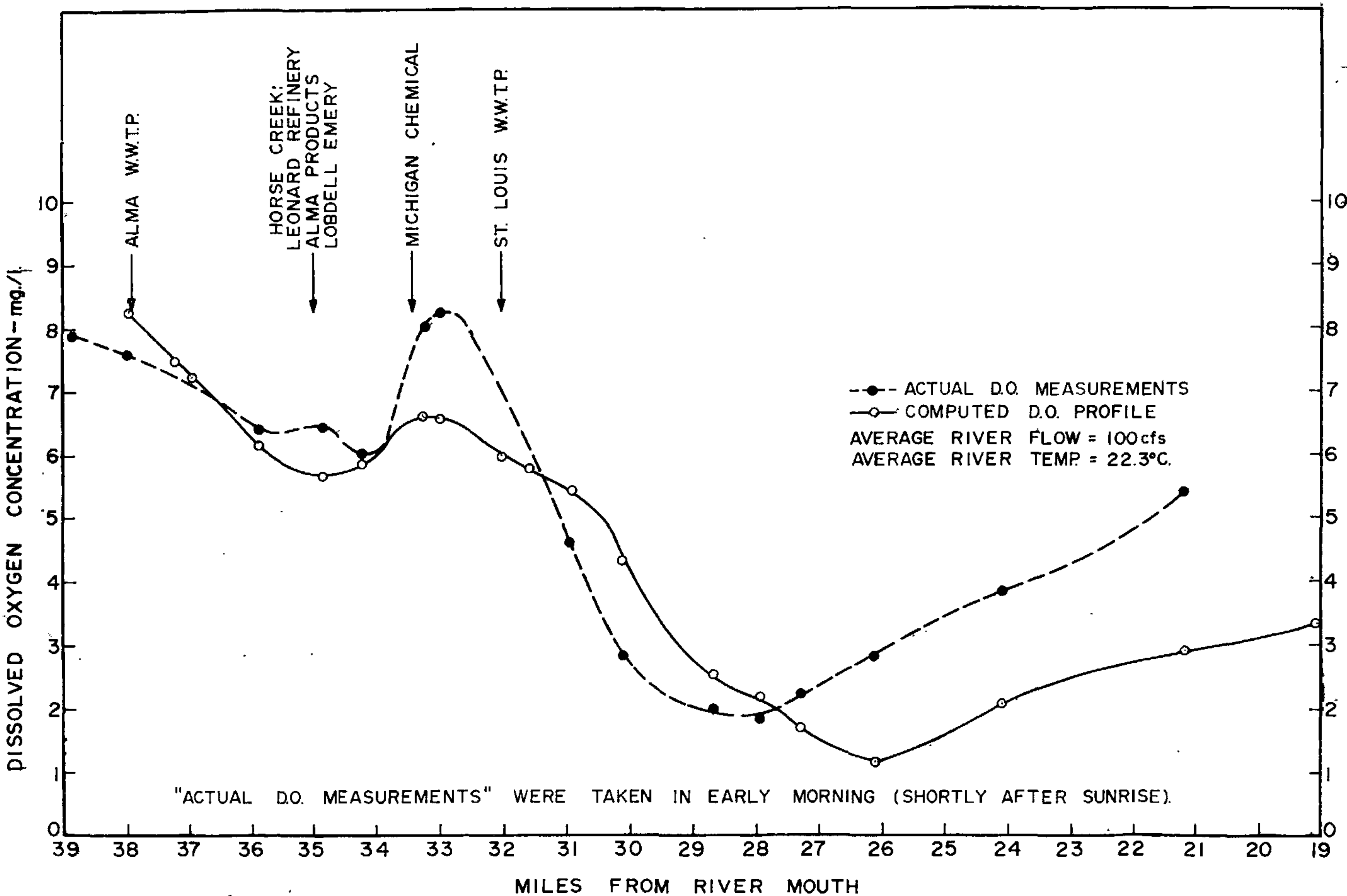


TABLE 14

SUMMARY OF SEVEN DO PREDICTION CASES

Case Number		1	2	3	4	5	6	7
Flow at Alma (cfs)		110	100	26	26	26	26	26
Average Temperature (°C)		19.8	22.3	25	25	25	25	25
<u>Improved Treatment Assumptions:</u>								
Lower BOD_5		NO	NO	NO	YES	YES	NO	YES
Lower NH_3-N		NO	NO	NO	YES	NO	YES	YES
Phosphorus Removal		NO	NO	NO	NO	YES	YES	YES
Waste Loads (lb / day)								
Alma WWTP	BOD_5	920	900	1015	150	150	1015	150
	NH_3-N	196	196	178	25	178	25	25
Horse Creek	BOD_5	144	51	51	15	15	51	15
	NH_3-N	79	29	28	27	28	27	27
Michigan Chemical	BOD_5	585	1565	1564	315	315	1564	315
	NH_3-N	602	481	459	170	459	170	170
St. Louis WWTP	BOD_5	356	380	390	71	71	390	71
	NH_3-N	76	76	80	11	80	11	11
Minimum DO Concentration (mg/l)		3.91	1.16	0	0	1.17	0	4.88
<u>Computed Oxygen Profiles:</u> (All DO Concentrations in mg/l)								
Sampling Station Number								
2		8.15	8.26	7.07	7.07	7.07	7.07	7.07
3		7.63	7.47	1.42	5.86	4.28	3.00	5.86
4		7.46	7.20	0.46	5.71	3.84	2.33	5.71
5		6.70	6.14	0	5.64	3.26	1.33	5.64
6		6.32	5.64	3.96	7.02	5.93	5.05	7.02
7		6.25	5.82	6.14	7.23	6.93	6.45	7.23
8		6.74	6.57	7.70	7.83	7.80	7.74	7.83
9		6.70	6.50	7.20	7.69	7.51	7.38	7.69
--		6.39	5.97	3.70	6.67	5.45	4.93	6.67
10		6.26	5.77	2.78	6.45	4.93	4.30	6.45
11		6.04	5.42	0.49	5.90	3.66	2.73	5.90
12		5.49	4.31	0	2.91	2.79	1.66	5.53
13		4.61	2.54	0	0	1.54	0.12	5.01
14		4.25	2.16	0	0	1.20	0	4.88
15		4.04	1.72	0	0	1.17	0	4.89
16		3.91	1.16	0	0	2.19	0.88	5.39
17		4.46	2.06	0	0	3.12	2.01	5.85
18		5.00	2.89	0	0.90	3.83	2.87	6.20
19		5.31	3.36	0	1.62	4.12	3.22	6.33

The predictions showed that the DO concentrations dropped to zero downstream from St. Louis (Stations 13-17). This indicates that weed respiration must be lowered to meet the DO standard, thus nutrient (phosphorus) reduction is needed.

Case 5) Design Flow Conditions with Removal of Phosphorus and Lowered Carbonaceous Oxygen Demand Loads: (flow = 26 cfs, temp. = 25°C). Carbonaceous oxygen demand loads were decreased while nitrogenous oxygen demand loads remained at the present levels in the model. Weed respiration demands were removed to simulate the effects of phosphorus removal.

While predicted DO concentrations did not drop to zero, they did fall below the minimum allowable value of 4 mg/l both between Alma and St. Louis (Stations 4 & 5) and downstream from St. Louis (Stations 11-18). This unsatisfactory DO prediction indicates that nitrogenous oxygen demand must be lowered to meet the DO standard.

Case 6) Design Flow Conditions with Removal of Phosphorus and Lowered Nitrogenous Oxygen Demand Loads: (flow = 26 cfs, temp. = 25°C). Nitrogneous oxygen demand loads were decreased while carbonaceous oxygen demand loads remained at the present levels in the model. Weed respiration demands were removed to simulate the effects of phosphorus removal.

Predicted DO concentrations fell below 4 mg/l between Alma and St. Louis (Stations 3-5) and downstream from St. Louis (Stations 11-18) and were zero at Stations 14 and 15. This unsatisfactory DO prediction indicates that carbonaceous oxygen demand must be lowered to meet the DO standard.

Case 7) Design Flow Conditions with Removal of Phosphorus and Lowered Carbonaceous and Nitrogenous Oxygen Demand Loads: (flow = 26 cfs, temp. = 25°C). Lowered oxygen demands from all three effects were incorporated into the model. The prediction shows that dissolved oxygen concentrations at all stations remain above the minimum allowable concentration.

3. Suggested Improvements to Maintain Allowable DO Concentrations

The preceeding discussion has shown that oxygen demands from all three effects must be lowered to maintain the minimum allowable dissolved oxygen concentration of 4 mg/l required by Michigan's Intrastate Water Quality Standards. Elimination or reduction of one or even two of these factors is not sufficient to assure meeting the standards at the design flow.

C. Chemical and Physical Characteristics

A great variety of chemical impurities are added to surface waters by industrial and municipal waste discharges and other human activities. Most of these dissolved impurities are not subject to waste assimilation as is organic material. All can be considered pollutants if they are sufficiently concentrated, but when sufficiently diluted, they may not adversely affect water quality.

1. Suspended, Colloidal, and Settleable Materials

The presence of excess suspended, colloidal and settleable materials in surface waters will impair clearness and affect aesthetic value. They may settle in sufficient quantities to form undesirable deposits which can interfere with fish spawning and destroy the habitat of fish and fish food organisms.

Michigan's Intrastate Water Quality Standards state that there shall be "no objectionable unnatural turbidity, color, or deposits in quantities sufficient to interfere with the designated use." This standard is not presently being met in the St. Louis impoundment near the Michigan Chemical Company's waste outfalls.

2. Residues

Residues such as oils, floating solids, and debris of man-made origin constitute a type of pollution that is often most readily apparent to the public at large. Floating oil is extremely hazardous to waterfowl and aquatic furbearers. It can sink and create an unfavorable habitat for benthic organisms.

Michigan's Interstate Water Quality Standards state that there should be no evidence of residues except of natural origin; no visible film of oil, gasoline or related materials; and no globules of grease present on surface waters. In the past, oil has covered the surface of the Pine River on many occasions. The bottom of the St. Louis impoundment below its confluence with Horse Creek contained large quantities of oil. This problem has been, or is in the process of being, corrected by new and improved industrial wastewater treatment facilities.

3. Toxic and Deleterious Substances

The entire reach of the Pine River under study will be designated for Agricultural use effective January 1, 1974. This use includes livestock watering. Limited data are available concerning the tolerances of livestock and poultry to toxic materials in water, however, there are many substances which adversely affect animal metabolism when present above critical concentrations. Certain heavy metals are toxic to plants irrigated with water containing these substances.

To protect these agricultural uses, the standards state that the water should, "conform to current United States Public Health Service (USPHS) Drinking Water Standards as related to toxicants."

TABLE 15
RESULTS OF ANALYSES
OF AUGUST 1967
COMPOSITE SAMPLES OF PINE RIVER WATER QUALITY

No.	Sampling Location	T.S.	S.S.	pH	NO_3-N	Cl	NH_3-N	$SOPO_4$	TPO_4	Fe	Ca	Mg	Na	K	SO_4	Alkal.	CO_3	Hardness	AD	Phenol	CN	Cr+6	As	Mn	Cu	F	Zn
1	Superior St. Bridge in Alma (mp 38.76)	340	15	8.3	0.20	26	0.0	0.05	0.30	0.5	70	22	12	1.1	48	205	0	265	0.0	0.00	0.00	0.00		0.0	0.0	0.30	0.0
2	Bridge St. Bridge in Alma (N. side of channel) (mp 37.88)	350	15	8.3	0.15	26	0.0	0.30	0.60	0.5	70	22	14	1.3	50	205	0	265	0.0	0.00	0.00	0.00		0 0	0.0	0.30	0 0
3	Michigan Ave. - First Access N. E. of Rep. St. Intersection (mp 37.16)	350	17	8.3	0.20	26	0.0	0.30	0.60	0.5	70	22	14	1.3	50	205	0	265	0.0	0.00	0.00	0.00		0.0	0.0	0.35	0.0
4	Michigan Ave. - behind Presbyterian Church (mp 36.88)	370	34	8.3	0.25	26	0.0	0.40	0.85	0.9	70	22	15	1.3	50	205	0	265	0.0	0.00	0.00	0.00		0.0	0.0	0.30	0.0
5	U.S.-27 Bridge, downstream side (mp. 35.85)	350	21	8.3	0.20	26	0.0	0.45	0.80	0.5	70	22	15	1.4	54	205	0	265	0.0	0.00	0.00	0.00		0.0	0.0	0.35	0.0
6	Cheesman Rd. Bridge (mp 34.81)	360	23	8.2	0.20	30	0.0	3.0	4.4	0.9	72	22	17	1.6	58	205	0	270	0.0	0.00	0.00	0.00		0.0	0.0	0.45	0.0
7	Washington Ave. M-46 Bridge in St. Louis (mp 34.18)	370	17	8.2	0.20	34	0.0	1.6	2.0	0.6	74	22	18	1.8	58	205	0	275	0.0	0.00	0.00	0.00	0.00	0.0	0.0	0.40	0.0
8	Mill St. Bridge in St. Louis (mp 33.20)	1280	19	8.0	0.35	410	1.0	0.30	1.1	0.5	204	24	99	7.4	74	175	0	610	0.0	0.00	0.00	0.00	0.00	0.0	0.30	0.50	0.0
9	Main St. Bridge in St. Louis (mp 32.95)	2000	19	7.9	0.30	770	1.1	0.40	1.1	0.4	344	32	150	14	74	175	0	990	0.0	0.00	0.00	0.00	0.00	0.0	0.30	0.50	0.0
10	Riverside Dr. - W. Bank 0.57 mi. N. of Prospect & Union in St. Louis (mp 31.57)	2000	22	7.9	0.50	820	1.1	0.55	1.2	0.4	364	32	160	15	78	175	0	1040	0.0	0.00	0.00	0.00		0.0	0.30	0.50	0.0
11	McGregor Rd. Bridge (mp 30.91)	2000	20	7.9	0.65	830	1.0	0.50	1.1	0.5	370	31	160	16	76	170	0	1050	0.0	0.00	0.00	0.00		0.0	0.30	0.50	0.0
12	Riverside Dr. - W. Bank 1.1 mi. N. of McGregor Rd. intersection (mp 30.31)	2000	19	7.9	0.75	820	0.6	0.45	1.1	0.3	370	31	160	15	74	170	0	1050	0.0	0.00	0.00	0.00		0.0	0.30	0.50	0.0
13	Riverside Dr. - W. Bank 1.7 mi N. of McGregor Rd. intersection (mp 28.71)	2000	19	7.9	0.90	800	0.0	0.55	1.0	0.4	350	36	160	16	74	170	0	1030	0.0	0.00	0.00	0.00		0.00	0.30	0.50	0.0
14	Bagley Rd. Bridge (mp 27.95)	2040	24	7.9	0.95	830	0.0	0.45	1.1	0.4	370	31	170	16	76	170	0	1050	0.0	0.00	0.00	0.00		0.00	0.30	0.50	0.0
15	Riverside Dr. N Bank 0.45 mi. N. E. of Bagley Rd. intersection (mp 27.33)	2250	18	7.9	1.0	980	0.0	0.55	0.95	0.2	430	36	180	18	76	165	0	1230	0.0	0.00	0.00	0.00		0.00	0.30	0.50	0.0
16	North Co. Line Rd. Bridge (mp 26.13)	2250	25	7.9	1.1	980	0.0	0.55	1.3	0.3	420	36	180	18	76	165	0	1200	0.0	0.00	0.00	0.00		0.00	0.30	0.55	0.0
17	Redstone Rd. Bridge (mp 24.14)	2400	21	8.1	1.1	1050	0.0	0.60	1.0	0.2	450	31	200	19	76	165	0	1250	0.0	0.00	0.00	0.00		0.00	0.30	0.50	0.0
18	Magrudder Rd. Bridge (mp 21.24)	2470	22	8.1	1.3	1050	0.0	0.70	1.0	0.3	470	36	200	20	78	165	0	1330	0.0	0.00	0.00	0.00		0.00	0.30	0.50	0.0
19	Pine River Rd. - Sample from W. Bank approx. 1.45 Road miles N. E. of Magrudder Rd. Bridge (mp 19.13)	2300	37	8.2	1.3	1020	0.0	0.75	1.1	0.5	440	31	200	18	80	165	0	1230	0.0	0.00	0.00	0.00		0.00	0.30	0.55	0.0

Note: 1) All sample results except pH are expressed as mg /1 (Hardness and alkalinity are expressed as equivalent mg /1 of $CaCO_3$. SOPO4 and TPO4 are expressed as mg /1 of PO_4.)
2) Results are from 24-hour composite samples taken August 29 and 30, 1967.
3) Streamflow as measured at U S G S -Alma gage average 114 cfs on August 29 and 107 cfs on August 30.
4) Seven-day once in ten year flow at Alma is 26 cfs.

Composite water quality samples of the Pine River were collected at all sampling stations during the first 24 hour survey. The results of analyses of these samples are listed in Table 15. Concentrations of the toxicants analyzed (cyanide, hexavalent chromium, and arsenic) were zero. Concentrations of phenol and zinc were also zero. Concentrations of copper were zero upstream from the effluents of the Michigan Chemical Company but were 0.30 mg/l at all stations downstream from these discharges. No health hazard would be expected at these low levels.

4. Total Dissolved Solids

Dissolved solids at high concentrations may affect uses of water because of their corrosive properties. Examples include chlorides which can cause scaling and pitting of metals and hardness which can form deposits in pipes and boilers. High salt concentrations in irrigation water may be deleterious to plants directly or indirectly because of their chemical and physical effects on soil. Soils absorb sodium from irrigation waters, adversely affecting aeration of and drainage from the soil.

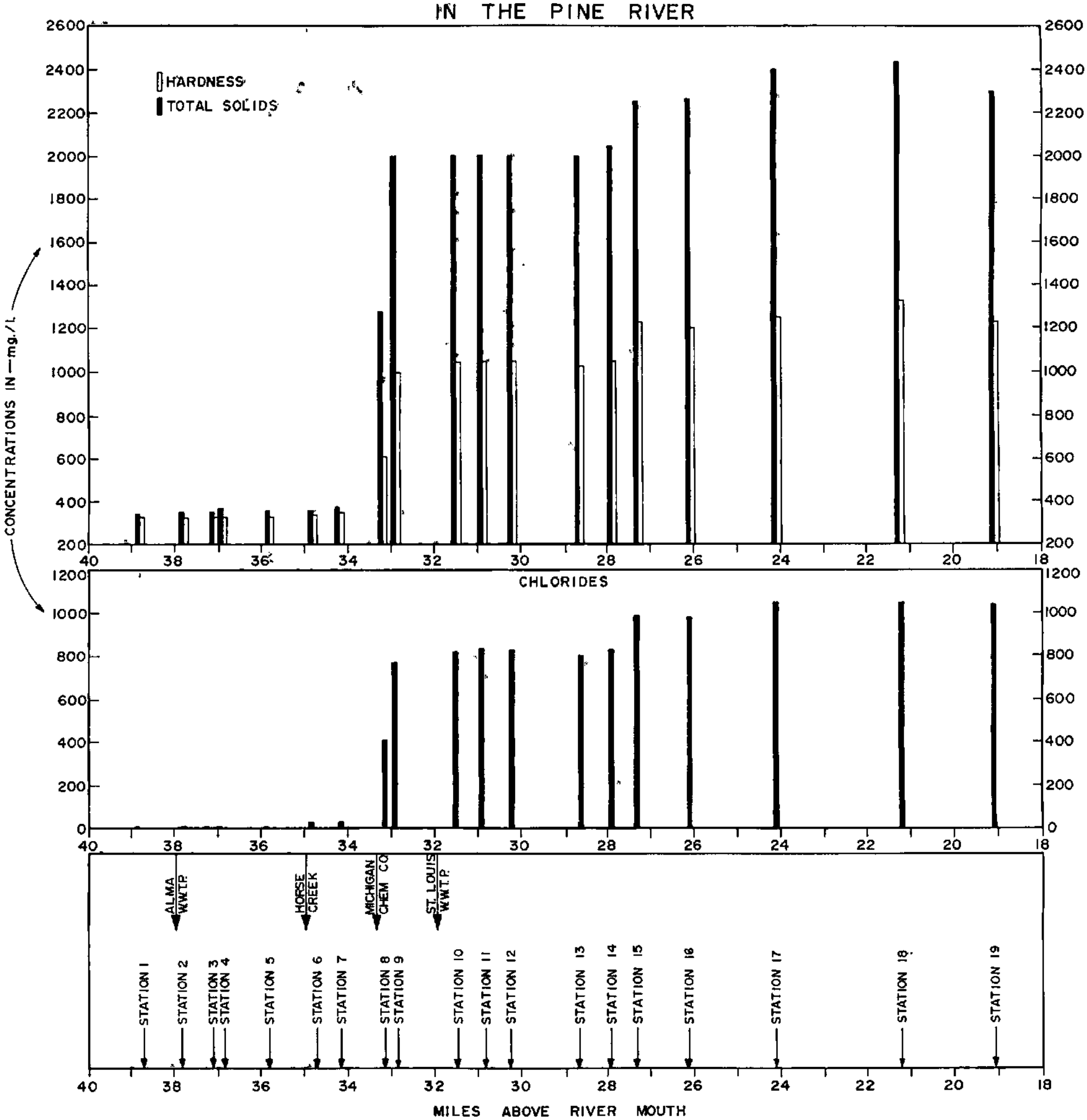
The present standards state that the total dissolved solids concentration shall not exceed a monthly average of 500 mg/l nor exceed 750 mg/l at any time, and chlorides shall not exceed 125 mg/l in streams designated for Industrial use. This use applies to the Pine River upstream from the M-46 bridge in St. Louis. The values in Table 15 show that total dissolved solids and chloride concentrations in this portion of the Pine River were well under the maximum allowable limit.

The standards also state that total dissolved solids shall not exceed 700 mg/l for streams designated for Agricultural use. The Pine River downstream from M-46 in St. Louis will be designated for agricultural use after January 1, 1974. At the time of the 1967 survey the water in the lower reach of the Pine River greatly exceeded the maximum allowable limit of 700 mg/l of total dissolved solids. Figure 19 shows the concentrations of total solids, hardness and chloride in the Pine River during one of the 1967 surveys. The large increase in all of these constituents occurs downstream from the effluents of the Michigan Chemical Company. The maximum dissolved solids concentration of 2,448 mg/l was more than three times greater than the allowable limit. To meet the standard, the total dissolved solids entering the river from the Alma and St. Louis area should not exceed 75,000 lb/day.

The Intrastate Water Quality Standards for water designated for Agricultural use include the provision that the maximum percentage of sodium should be 40% as determined by the formula (Na x 100) ÷ (Na + Ca + Mg + K) when the bases are expressed as milliequivalents per liter. The percentage of sodium in the Pine River immediately upstream from the Michigan Chemical Company (Station 7) was 12% in 1967. Downstream from the company the sodium percentage doubled to approximately 24%.

FIGURE 19

CONCENTRATIONS OF TOTAL SOLIDS, HARDNESS & CHLORIDES IN THE PINE RIVER



5. Nutrients

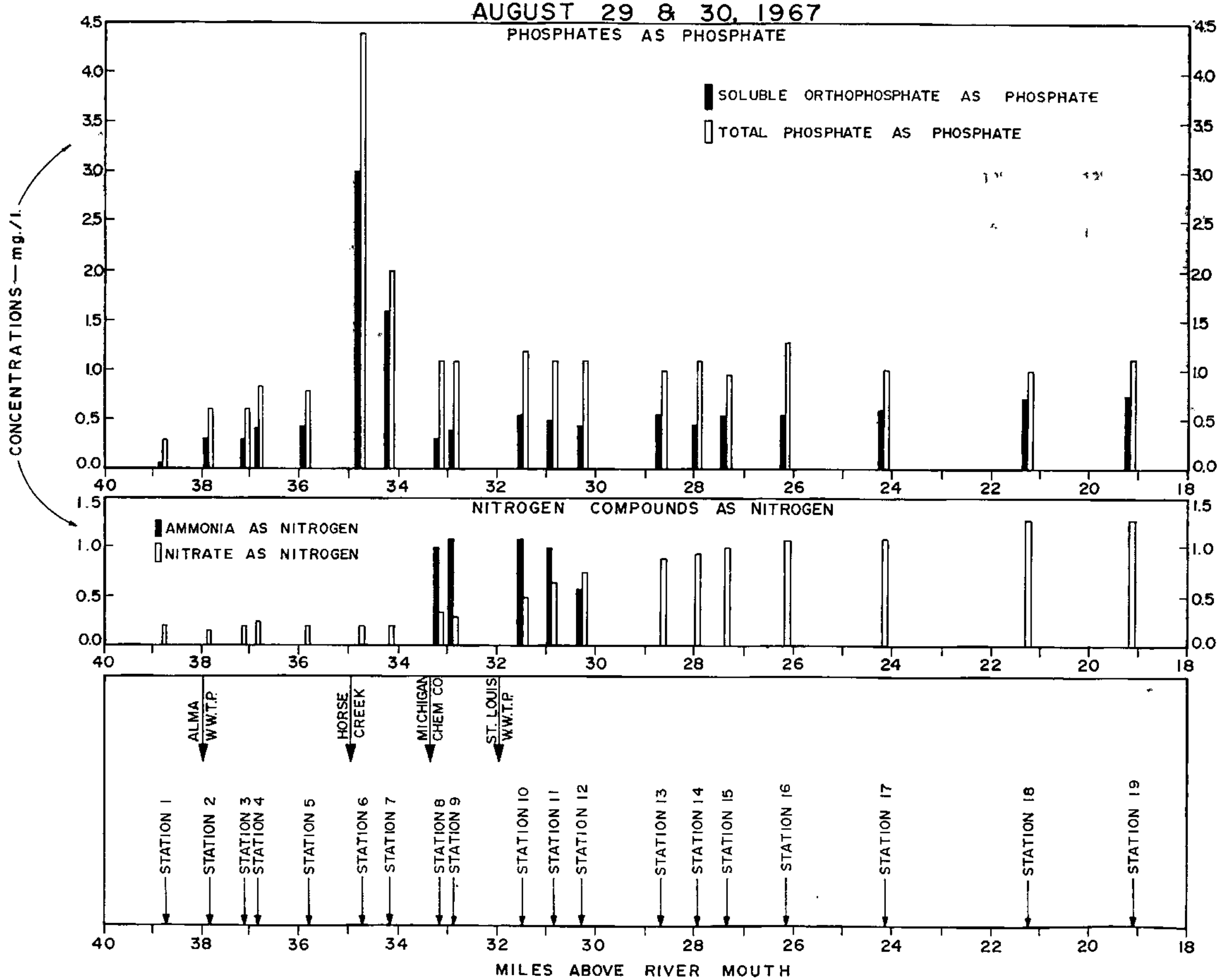
Excess quantities of nutrients such as sugars, phosphorus, and nitrogen promote the growth of algae, attached plants, or slime. These growths can cause obnoxious odors, impart undesirable tastes, alter dissolved oxygen concentrations, and create nuisance conditions in waterways and on beaches.

Nuisance conditions are dependent on many variables such as temperature, the combination of nutrients present, etc. The standards for nutrients have been written as a general statement which says, "Nutrients originating from industrial, municipal or domestic animal sources shall be limited to the extent necessary to prevent the stimulation of growths of algae, weeds and slimes which are or may become injurious to the designated use." In addition, those waters designated for Agricultural use include the statement that nitrate concentrations shall conform to USPHS Drinking Water Standards. The maximum allowable concentration in the standards is 10 mg/l nitrate-nitrogen.

The concentration of phosphorus and nitrogen compunds found in the composite samples of the Pine River are shown in Figure 20. Low concentration of these nutrients were found at the control station at Superior Street in Alma. Only 0.05 mg/l of the 0.30 mg/l of total phosphates present at this location were soluble orthophosphates, the form most readily available for use by aquatic plants. Downstream from the discharge of the Alma Wastewater Treatment Plant, the total phosphate concentration doubled to 0.60 mg/l and the soluble orthophosphate concentration increased to 0.30 mg/l. A large increase in the concentrations of both total and soluble orthophosphate occurred immediately downstream from the confluence with Horse Creek. In 1967 this tributary contained industrial waste effluents high in phosphoric acid. Composite samples of flow in the county drain which contains the wastes of these industries had concentrations of 940 mg/l of total phosphates and 750 mg/l of soluble orthophosphate during the 1967 survey. The concentration declined rapidly in the St. Louis impoundment. High concentrations of phosphates were found in the fourteen miles of river downstream from the St. Louis dam. Little or no decline in concentrations occurred in this reach, indicating that there was more phosphorus available than required by the aquatic plants present. In the future, industrial wastes from Alma (except for Leonard Refineries) will be treated by the Alma WWTP. Phosphorus removal will be required at the Alma Wastewater Treatment Plant by December 31, 1972.

Concentrations of nitrogen compounds were low upstream from the Michigan Chemical Company and high downstream from this waste source. The discharges of this company added an average of 543 pounds per day of ammonia-nitrogen and 141 pounds per day of nitrate-nitrogen to the Pine River during the 1967 survey. The concentration of ammonia-nitrogen increased from 0.0 mg/l in the river above the company to 1.1 mg/l below the company. Much of the ammonia-nitrogen was nitrified to nitrate-nitrogen in the first five miles of river downstream from the Michigan Chemical Company. Such nitrification has a significant demand on the oxygen resources of a river. The aquatic plants present in this reach of stream utilize and store these nutrients. The nutrients are released again to the river when these plants die and decompose.

FIGURE 20
CONCENTRATIONS OF NUTRIENTS IN THE PINE RIVER
AUGUST 29 & 30, 1967



6. Taste and Odor Producing Substances

Taste and odor can be imparted to water by many substances such as phenols, organic growths and certain inorganics. The standards state that concentrations of these substances of unnatural origin shall be less than "those which are causing or may cause taint in the flesh of fish or game."

No extensive work was done to determine if taste and odor producing substances were present in the Pine River. Phenols, a strong taste and odor causing substance, were not present at any of the river sampling stations.

7. Temperature

Surface water temperatures should be maintained as near the natural level as possible. Increased water temperatures affect industrial cooling, stimulate organic growths, intensify taste and odor problems, lower DO concentrations and may adversely affect fish and other aquatic life.

The standards state that the maximum water temperature shall be 85°F (intolerant fish, warm-water species) and that the maximum natural water temperature shall not be increased by more than 10°F. Measured temperatures on the Pine River were well within the standards.

8. Hydrogen Ion (pH)

The pH of water affects its corrosiveness and the efficiency of water treatment processes. Excessive or rapid changes in water pH will cause a shift in the alkalinity and acidity, which causes an imbalance in the natural environment that can be deleterious to plant and animal life.

The standards state that pH must be, "maintained within the range 6.5 - 8.8, with a maximum induced variation of 0.5 unit within this range."

The pH of the composite samples of the Pine River ranged between 7.9 and 8.3 in 1967, and were therefore satisfactory at that time.

D. Bacterial Densities

Total and fecal coliform bacteria in water indicate the possibility that pathogenic (disease causing) bacteria and/or viruses may also be present in the water. Coliform bacteria are normally present in the intestinal tracts of humans and other warm-blooded animals and are excreted in large numbers in fecal wastes. These bacteria may also be present in soils and on plants. Fecal coliform bacteria provide positive correlation with recent contamination from the fecal material of warm blooded animals. The presence of either total or fecal organisms, above certain limits is a warning of potential health hazards to those who use the water for recreation or other purposes.

TABLE 16

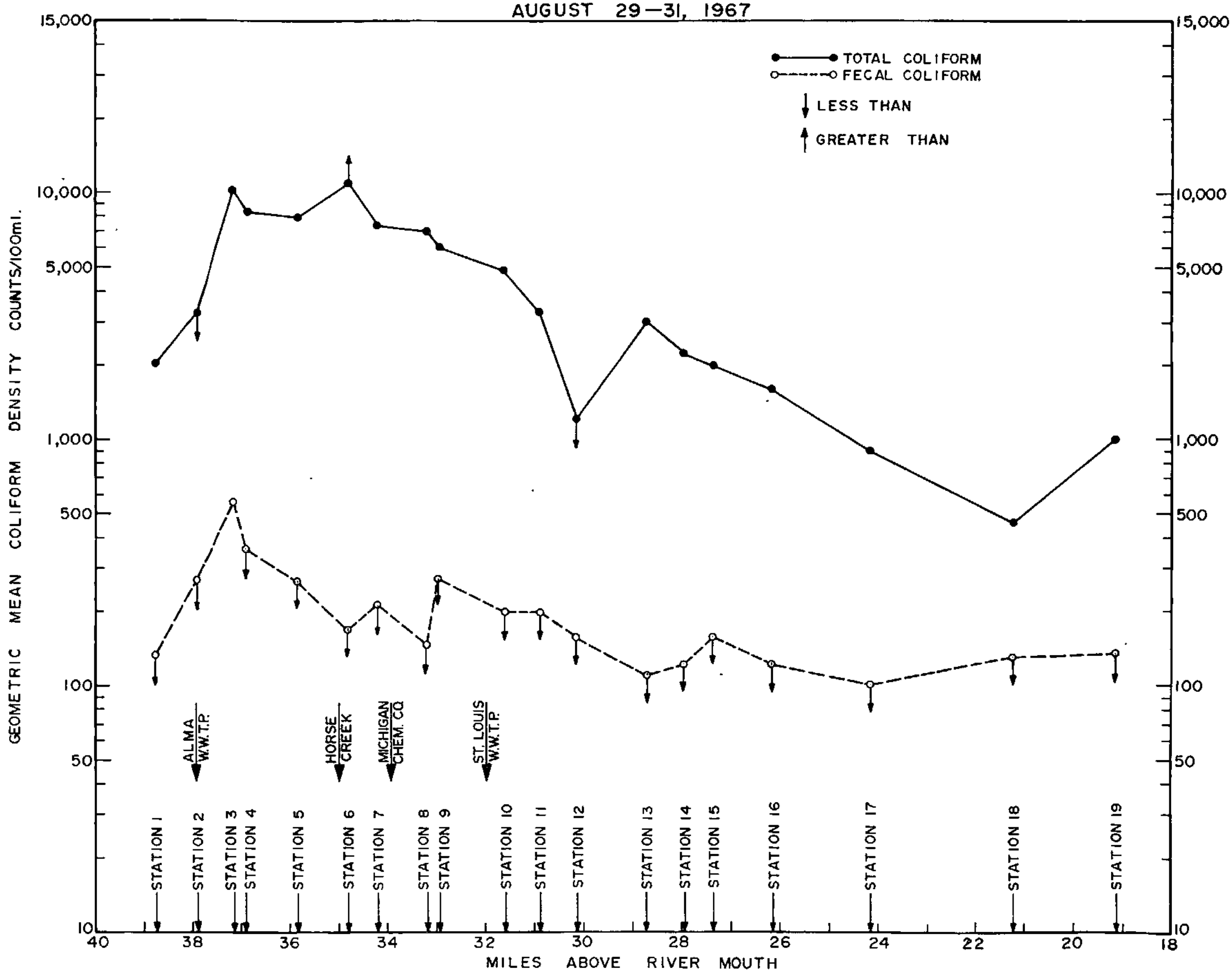
COLIFORM BACTERIA DENSITIES IN THE PINE RIVER

AUGUST 1967

Sampling Location	Date	Time	Total Coliform (counts/100 ml.)	Fecal Coliform (counts/100 ml.)
1. Superior St., Alma	8/29	0800	2,200	<100
	8/29	1515	600	<100
	8/29	2212	9,000	100
	8/30	0530	4,700	700
	8/30	1300	1,600	<100
	8/30	2000	1,100	<100
	8/31	0300	1,600	<100
Geometric Mean			2,059	<132
2. Bridge St., Alma	8/29	0825	<100	<100
	8/29	1525	5,300	<100
	8/29	2225	24,000	900
	8/30	0540	8,600	2,000
	8/30	1305	10,000	200
	8/30	2010	2,400	300
	8/31	0305	1,600	<100
Geometric Mean			<3,293	<271
3. Michigan Ave., First Access N.E. of Republic Street	8/29	0835	5,600	200
	8/29	1535	4,100	100
	8/29	2230	10,000	500
	8/30	0545	300,000	13,000
	8/30	1315	12,000	1,100
	8/30	2015	3,000	400
	8/31	0315	4,400	200
Geometric Mean			10,126	528
4. Michigan Ave., behind Presbyterian Church	8/29	0850	50,000	100
	8/29	1550	6,500	<100
	8/29	2242	6,400	1,400
	8/30	0557	5,600	2,700
	8/30	1330	8,400	200
	8/30	2025	7,200	200
	8/31	0325	4,000	500
Geometric Mean			8,344	<358
5. U.S.-27 Bridge	8/29	0900	32,000	600
	8/29	1605	2,800	200
	8/29	2254	8,500	400
	8/30	0610	7,700	900
	8/30	1350	19,000	100
	8/30	2035	4,200	200
	8/31	0350	4,000	<100
Geometric Mean			7,870	<263
6. Cheesman Rd Bridge	8/29	0915	>100,000	<100
	8/29	1618	---	200
	8/29	2303	11,000	300
	8/30	0620	4,400	<100
	8/30	1410	12,000	100
	8/30	2244	6,400	200
	8/31	0400	4,700	300
Geometric Mean			>10,975	<167
7. Washington Ave., M-46 in St. Louis	8/29	0920	9,600	600
	8/29	1625	11,000	300
	8/29	2311	30,000	580
	8/30	0625	3,000	<100
	8/30	1420	4,800	<100
	8/30	2050	5,000	200
	8/31	0408	5,500	100
Geometric Mean			7,433	<210
8. Mill St. Bridge, St. Louis	8/29	0930	11,500	700
	8/29	1645	9,000	200
	8/29	2320	6,000	100
	8/30	0635	7,300	<100
	8/30	1430	8,700	<100
	8/30	2058	4,200	<100
	8/31	0417	5,600	<100
Geometric Mean			7,119	<146
9. Main St. Bridge, St. Louis	8/29	0935	14,000	700
	8/29	1635	7,600	600
	8/29	2328	4,500	200
	8/30	0655	6,300	<100
	8/30	1435	3,600	200
	8/30	2104	4,600	200
	8/31	0423	6,000	300
Geometric Mean			6,054	<269
10. Riverside Drive N. of Prospect Ave. Union St. in St. Louis	8/29	0955	9,000	400
	8/29	1650	5,800	500
	8/29	2337	3,700	100
	8/30	0705	11,000	400
	8/30	1455	2,600	<100
	8/30	2109	3,500	400
	8/31	0433	3,300	<100
Geometric Mean			4,858	<198
11. McGregor Rd. Bridge	8/29	1010	3,000	500
	8/29	1655	3,200	400
	8/29	2345	4,000	200
	8/30	0710	5,200	300
	8/30	1515	4,200	<100
	8/30	2118	2,200	100
	8/31	0440	2,200	<100
Geometric Mean			3,276	<198
12. Riverside Drive 1.1 Miles N. of McGregor Rd. Intersection	8/29	1025	4,200	300
	8/29	1703	4,600	<100
	8/29	2353	1,600	100
	8/30	0715	<100	<100
	8/30	1525	400	100
	8/30	2127	1,600	400
	8/31	0450	2,000	200
Geometric Mean			<1,217	<157
13. Riverside Drive 1.7 Miles N. of McGregor Rd. Intersection	8/29	1035	16,000	200
	8/29	1710	2,200	100
	8/30	0003	1,500	<100
	8/30	0720	5,700	100
	8/30	1545	2,000	100
	8/30	2133	1,600	<100
	8/31	0500	2,200	100
Geometric Mean			2,986	<110
14. Bagley Rd. Bridge	8/29	1045	2,000	100
	8/29	1718	6,000	<100
	8/30	0010	3,400	<100
	8/30	0730	2,200	<100
	8/30	1550	1,100	100
	8/30	2141	3,200	<100
	8/31	0508	900	400
Geometric Mean			2,242	<122

Sampling Location	Date	Time	Total Coliform (counts/100 ml.)	Fecal Coliform (counts/100 ml.)
15. Riverside Drive 0.45 Mi. N. E. of Bagley Rd. Intersection	8/29	1100	8,000	<100
	8/29	1725	2,000	300
	8/30	0020	1,700	100
	8/30	0735	2,100	200
	8/30	1605	1,600	200
	8/30	2150	1,000	200
	8/31	0518	1,600	100
Geometric Mean			2,038	<157
16. N. County Line Rd. Bridge	8/29	1110	1,200	<100
	8/29	1730	700	<100
	8/30	0027	6,000	<100
	8/30	0740	2,000	200
	8/30	1610	3,000	200
	8/30	2157	1,000	100
	8/31	0527	1,000	100
Geometric Mean			1,627	<122
17. Redstone Rd. Bridge	8/29	1120	1,800	<100
	8/29	1737	800	<100
	8/30	0035	800	<100
	8/30	0747	1,700	100
	8/30	1620	400	<100
	8/30	2207	1,200	100
	8/31	0535	500	100
Geometric Mean			898	<100
18. Magrudder Rd. Bridge	8/29	1125	1,800	<100
	8/29	1745	600	<100
	8/30	0044	1,200	200
	8/30	0755	1,500	300
	8/30	1630	100	<100
	8/30	2215	100	<100
	8/31	0543	200	100
Geometric Mean			452	<129
19. Pine River Rd. 1.45 Mi. N.E. of Magrudder Rd. Bridge	8/29	1135	2,100	200
	8/29	1757	1,000	100
	8/30	0055	1,800	200
	8/30	0800	2,000	200
	8/30	1645	500	<100
	8/30	2224	400	<100
	8/31	0553	600	100
Geometric Mean			986	<135

FIGURE 21
GEOMETRIC MEAN COLIFORM BACTERIA DENSITIES IN THE PINE RIVER
AUGUST 29—31, 1967



Michigan's Intrastate Water Quality Standards to protect the uses designated for the Pine River state that, "the geometric average of any series of 10 consecutive samples shall not exceed 5,000 nor shall 20% of the samples examined exceed 10,000. The fecal coliform geometric average for the same 10 consecutive samples shall not exceed 1,000".

Grab samples were collected at each sampling station for bacterial analysis on every other sampling run during the two 24-hour surveys. Coliform densities were determined by the membrane filter technique. A tabulation of the results is listed in Table 16 and the geometric means of total and fecal coliform densities at each station are shown in Figure 21. These results show that the highest coliform densities were found downstream from the Alma Wastewater Treatment Plant. Geometric means of the seven samples collected at each station show that a total coliform density of 5,000 per 100 ml. was exceeded at stations 3 through 9 (north of Michigan Avenue to Main Street in St. Louis). The two peak values, both greater than 10,000 total coliform per 100 ml., were found just north of Michigan Avenue in Alma and at Cheesman Road in St. Louis. Two or more densities greater than 10,000 total coliform per 100 ml. were found at stations 3, 5, 6 and 7. The geometric means of fecal coliforms were less than 1,000 per 100 ml. at all sampling stations.

E. Biological Investigations

Intensive biological surveys of the Pine River were conducted in 1967 and in 1970 by staff biologists of the Water Quality Appraisal Section, Michigan Water Resources Commission. Both surveys show that a clean water environment existed in the river upstream from Alma but a severly degraded environment existed below Alma and St. Louis.

The effluent from the Alma Wastewater Treatment Plant changes the environment so that only limited biological activity occurs. The bottom of the St. Louis impoundment (below the confluence with Horse Creek) contained large quantities of oil and no bottom dwelling invertebrates. The impoundment bottom below the Michigan Chemical Company was coated with a hard, white precipitate. Below the St. Louis dam, quantities of aquatic plant growths occurred in the river. These growths were still present 30 miles downstream from St. Louis. Only sludgeworms, midges and other air breathing animals survived in the six river miles immediately downstream from St. Louis. Only slight improvement was observed in the next 20 river miles.

Detailed information on these biological surveys are found in a Water Resources Commission report entitled, "Biological Survey of the Pine River, Vicinity of Alma and St. Louis, 1967 and 1970."

WATER QUALITY INVESTIGATIONS (1970)

A limited number of samples were collected from the Pine River in September 1970 to detect any gross changes in water quality that had occurred since the 1967 comprehensive study. The most significant change was in dissolved oxygen concentrations. This was previously discussed in the Waste Assimilation section of this report. Included with that discussion are the results of the 1970 analyses of grab samples. These results, listed in Table 12, include values for temperature, pH, DO, NH_3-N, NO_3-N, and Cl. Additional chemical results from 1970 are listed in Table 17. 1970 bacterial results are similar to those found in 1967 and are listed in Table 18. Parameters whose concentrations include significant changes in water quality between 1967 and 1970 are discussed in the following sections; those without significant changes are not discussed.

A. Toxic and Deleterious Substances

In 1970, as in 1967, all analyses for toxic substances showed concentrations within the USPHS Drinking Water Standards and concentrations of other deleterious substances were also low. Concentrations of cyanide, hexavalent chromium, arsenic, and zinc were found to be zero in 1967 and 1970. Phenol concentrations were not determined in 1970 (zero in 1967). Concentrations of lead, mercury, and cadmium which were not determined in 1967, were found to be zero in 1970. Copper was found at all the stations in 1970, but at a low concentration (0.01 mg/l). In 1967, concentrations as high as 0.3 mg/l were found at all stations downstream from the M-46 bridge in St. Louis.

B. Total Dissolved Solids

The concentrations of total dissolved solids, as well as hardness, calcium, and chloride, were found to be approximately 30% lower at Stations 9 and 18 in 1970 than in 1967. However, the concentrations of total dissolved solids were still significantly higher than the 700 mg/l limit allowed for streams with the Agricultural use designation.

The percentage of sodium downstream from Michigan Chemical Company, as determined by the formula $(Na \times 100) \div (Na + Ca + Mg + K)$ when the bases are expressed as milliequivalents per liter, increased from about 24% in 1967 to about 34% in 1970. In both years the percentage was about 9% upstream from all major waste discharges (Station 1) and about 12% just above the Michigan Chemical Company (Station 7). The maximum allowable value for waters designated for Agricultural use is 40%. Thus, any reduction in the calcium, magnesium or potassium concentration should be accompanied by a reduction in the sodium concentration if the limit is to continue to be met.

TABLE 17

1970 CHEMICAL SAMPLING RESULTS

All samples collected on September 9, 1970

Station No.	1	1	7	7	9	9	18	18
Time	6:15 am	2:50 pm	7:15 am	3:40 pm	8:00 am	4:05 pm	7:15 am	4:10 pm
TS	334.	340.	362.	348.	1640.	1382.	1940.	1578.
SS	12.	6.	18.	11.	11.	12.	14.	8.
SVS	7.	---	5.	9.	11.	9.	14.	---
Turb.	7.	7.	11.	9.	5.	6.	3.	2.
$SOPO_4$	0.09	0.03	0.64	0.64	0.18	0.25	0.61	0.61
TPO_4	0.18	0.09	1.29	0.98	1.04	1.04	1.22	1.10
CO_3	0.	0.	0.	0.	0.	0.	0.	0.
SO_4	32.	33.	46.	44.	85.	67.	100.	78.
Hardness	250.	260.	260.	260.	780.	700.	880.	800.
Alkalinity	205.	210.	195.	200.	150.	165.	150.	160.
AD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04
Ca	68.	68.	68.	68.	256.	224.	292.	268.
Mg	19.	22.	22.	22.	34.	34.	37.	32.
Na	12.	11.	15.	15.	210.	140.	210.	180.
K	2.0	2.0	2.0	2.0	1.6	1.3	1.6	1.6
Pb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr^{+6}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
As	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cu	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
F	0.20	0.20	0.25	0.25	0.30	0.30	0.30	0.30
Zn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

All concentrations shown in mg/l except turbidity which is expressed as jcu. Hardness and alkalinity are expressed as equivalent mg/l of $CaCO_3$. $SOPO_4$ and TPO_4 are expressed as mg/l of PO_4.

TABLE 18

1970 BACTERIAL RESULTS

All samples collected on September 9, 1970

Station No.	Time	Total Coliform (org./100 ml.)	Fecal Coliform (org./100 ml.)
1	6:15 a.m.	4,300	150
	2:50 p.m.	1,900	30
2	6:30 a.m.	5,500	60
	2:58 p.m.	28,000	30
5	7:00 a.m.	22,000	520
	3:12 p.m.	5,300	90
6	6:45 a.m.	10,000	160
	3:27 p.m.	10,000	80
7	7:15 a.m.	7,200	70
	3:40 p.m.	9,300	70
8	7:30 a.m.	9,000	90
	3:55 p.m.	2,900	20
9	8:00 a.m.	3,900	20
	4:05 p.m.	1,800	30
11	8:15 a.m.	2,700	70
	2:20 p.m.	4,700	70
12	6:15 a.m.	2,600	220
	2:40 p.m.	5,200	60
13	6:20 a.m.	700	20
	3:00 p.m.	600	10
14	6:30 a.m.	100	10
	3:10 p.m.	300	40
15	6:40 a.m.	600	20
	3:25 p.m.	2,500	20
16	6:50 a.m.	500	<10
	3:40 p.m.	4,100	10
17	7:00 a.m.	1,400	70
	3:55 p.m.	4,100	20
18	7:15 a.m.	3,100	70
	4:10 p.m.	800	50

C. Nutrients

Nutrients are present in the Pine River below St. Louis. They promote aquatic plant growths in this portion of the river which, in turn, cause diurnal fluctuations in DO concentrations. Figure 22 graphically illustrates these fluctuations. 1970 concentrations of phosphate in the river were similar to those found in 1967, whereas nitrate concentrations were somewhat lower in 1970. More nitrogen was being added to the river from the various waste inputs than was measured at Station 18. This may indicate that more nitrate was accumulating in the biomass of aquatic weeds downstream from St. Louis in 1970 than in 1967.

D. Hydrogen Ion (pH)

Results from the 1970 analyses show a variation of more than 0.5 units of pH occurred between stations located immediately above and below the Michigan Chemical Company. In the morning, this variation (between stations 7 and 8) was 0.65 and in the afternoon was 0.90. This exceeds the allowable change of 0.5 units listed in Michigan's Intrastate Water Quality Standards.

FIGURE 22

DIURNAL FLUCTUATIONS IN DISSOLVED OXYGEN CONCENTRATIONS
PINE RIVER