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Scientific Investigations Report 2006-5071

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Area	
acre	4,047	square meter (m^2)
square mile (mi^2)	2.59	square kilometer (km^2)
	Distance	
mile (mi)	1.609	kilometer (km)
	Flow rate	
cubic foot per second (ft^3/s)	0.028	cubic meter per second (m^3/s)
	Mass per unit time	
Pound per year (lb/yr)	0.454	kilogram per year (kg/yr)

Concentration of chemical constituents in water is given in milligrams per liter (mg/L). A milligram per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water.

The map projections are in Universal Transverse Mercator of 1983 (UTM 83), zone 17.

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ABSTRACT

The Lake St. Clair Regional Monitoring Project partners planned a 3-year assessment study of the surface water in the Lake St. Clair drainage basins in Michigan. This study included water-quality monitoring and analysis, collection of discrete (grab) and automatic water-quality samples, monitoring of bacteria, and the creation of a database to store all relevant data collected from past and future field-data-collection programs.

In cooperation with the Lake St. Clair Monitoring Project, the U.S. Geological Survey assessed nonpoint-source loads of nutrients and total suspended solids in the Black, Belle, and Pine River basins. The principal tool for the assessment study was the USEPA's PLOAD model, a simplified GIS-based numerical program that generates gross estimates of pollutant loads. In this study, annual loads were computed for each watershed using the USEPA's Simple Method, which is based on scientific studies showing a correlation between different land-use types and loading rates.

The two land-use data sets used in the study (representing 1992 and 2001) show a maximum of 0.02-percent change in any of the 15 land use categories between the two timeframes. This small change in land use is reflected in the PLOAD results of the study area between the two time periods. PLOAD model results for the 2001 land-use data include total-nitrogen loads from the Black, Belle, and Pine River basins of approximately 495,599 lb/yr, 156,561 lb/yr, and 121,212 lb/yr, respectively; total-phosphorus loads of 80,777 lb/yr, 25,493 lb/yr, and 19,655 lb/yr, respectively; and total-suspended-solids loads of 5,613,282 lb/yr, 1,831,045 lb/yr, and 1,480,352 lb/yr, respectively. The subbasins in the Black, Belle, and Pine River basin with comparatively high loads are characterized by comparatively high percentages of industrial, commercial, transportation, or residential land use.

The results from the PLOAD model provide useful information about the approximate average annual loading rates from the three study basins. In particular, the results identify subbasins with comparatively high loading rates per square mile. This could aid water-resources managers and planners in evaluation of the effectiveness of public expenditures for water-quality improvements, assessment of progress towards achieving established water-quality goals, and planning of preventive actions.

INTRODUCTION

The waterway formed by the St. Clair River, Lake St. Clair, and Detroit River connects Lake Huron with Lake Erie and is part of the international boundary between the United States and Canada (fig. 1). Within this waterway, the Detroit River is one of 14 rivers nationwide designated as a National Heritage River because of its historically strategic importance for navigation in the Great Lakes. The waterway provides a water supply for about 4 million people, critical habitat for maintaining biodiversity in the aquatic environment and supporting fisheries, and major recreational opportunities for southeastern Michigan and southern Ontario. Major streams that discharge to the waterway upstream from Belle Isle in Detroit River are the Black, Belle, Pine and Clinton Rivers in the United States, and Thames and Sydenham Rivers in Ontario, Canada.

In an effort to clean up the most polluted areas in the Great Lakes, the Great Lakes Water Quality Board of the International Joint Commission has designated the St. Clair River an Area of Concern (AOC). The AOC designation commits state and provincial governments to developing and implementing Remedial Action Plans (RAPs) as part of their watershed planning efforts. In 2003, as part of the ongoing monitoring, assessment, and remediation efforts in this region, the Lake St. Clair Regional Monitoring Project partners (Macomb County Health Department, Oakland County Drain Commissioner, St. Clair County Health Department, Wayne County Department of the Environment, Macomb County Public Works Department, Environmental Consulting and Technology, Michigan Department of Environmental Quality, and U.S. Geological Survey) developed plans for a 3-year water-quality assessment and monitoring of the basins within the United States that drain to Lake St. Clair (fig. 1). The Lake St. Clair Regional Monitoring Project is a comprehensive assessment of the hydrological, chemical, and physical state of the surface water of the study area. The plan includes water-quality monitoring, collection of discrete (grab) and automatic water-quality samples, and monitoring of bacteria.

The Regional Monitoring Project calls for the creation of a database to store all relevant data collected from the past and from future field-data-collection programs.

In cooperation with the Lake St. Clair Regional Monitoring Project, the U.S. Geological Survey (USGS) assessed nonpoint-source loads of nutrients and total-suspended solids in the Black, Belle, and Pine River basins as part of the overall Regional Monitoring effort. This study builds on previous work that the USGS Michigan Water Science Center has done related to the hydrology and water quality in the St. Clair and Detroit Rivers. The principal tool for the assessment study was the USEPA's PLOAD model, a simplified GIS based numerical program that generates gross estimates of pollutant loads (CH2M HILL, 2001). Using the USEPA's Simple Method in the PLOAD model, annual loads were computed for each watershed, which has its basis on scientific studies showing a correlation between different land-use types and loading rates (Panuska and Lillie, 1995). The land-use/land-cover data (referred to hereafter as "land-use data") used in the study represent conditions in 1992 and 2001.

The land-use data show a maximum of 0.02-percent change in any of the 15 landuse categories between the two timeframes. For example, in the Black River basin, there was only a slight decrease in cropland and pasture and woody wetlands and a 0.01-percent increase in deciduous forest between 1992 and 2001. Similarly, in the Belle River basin, the land-use data show only a 0.01-percent reduction in deciduous forest and woody wetlands between 1992 and 2001. For the Pine River basin, data show approximately a 0.02-percent increase in residential and commercial land use, and the same extent of reduction in deciduous forest, mixed forest, and woody wetlands between 1992 and 2001. This small change in land use is reflected in the PLOAD results in the study area between the two time periods. Because the difference in load rates is so slight between the two time periods, only the model results for the current (2001) land-use data set are discussed in detail in this report.

Purpose and Scope

This report describes (1) the methods and procedures used for the computation of nonpoint-sources of total-nitrogen, total-phosphorus and total-suspended-solids loads in the Black, Belle, and Pine River basins; (2) total loads from the three study basins with comparison of subbasin loads based on the 2001 land-use data; and (3) identification of subbasins with comparatively high loading rates.

Because the PLOAD model broadly addresses pollutant loads by land-use categories and subbasins, it cannot be used to investigate individual nonpoint sources or specific pollutant fate and transport processes. However, some supporting information is presented herein to provide perspective on the interpretation of computed nutrient loads in relation to the basin characteristics.

Study Basins

Site selection for this study was based on data availability, land-use characteristics, and site priority for the Lake St. Clair Regional Monitoring Project. On the basis of these criteria, the Black, Belle, and Pine River basins, which are within the Lake St. Clair drainage basin, were chosen for estimation of nonpoint-source loads. These three study basins discharge into the St. Clair River (fig. 1), which flows southward about 40 mi and connects the southern tip of Lake Huron to Lake St. Clair. The river is part of the boundary between the United States and Canada. A brief description of each basin studied is given below.

Black River Basin

The Black River flows southeastward in Michigan's eastern Lower Peninsula, draining approximately 710 mi^2 into the St. Clair River (fig. 2). The Black River drains parts of Huron, Lapeer, Sanilac, and St. Clair Counties. The basin was divided into 34 subbasins for use in the PLOAD model. Agriculture is the predominant land use, with approximately 78 percent of the land covered by cropland and pasture; however, intensive development has occurred in the last 20 years in and near the city of Port Huron. The 1992 and 2001 land-use data do not show much change in most of the land-use categories except for a slight decrease in cropland and pasture and woody wetlands and an increase in deciduous forest (table 1).

Belle River Basin

The Belle River drains an area of approximately 227 mi^2. This basin was divided into 12 subbasins for use in the PLOAD model (fig. 3). This basin drains parts of Lapeer, Macomb, Oakland, and St. Clair Counties. The main branch of the Belle River rises from marshy areas in Lapeer, St. Clair, and Oakland Counties. Before its final discharge into St. Clair River at Marine City, the Belle flows parallel to the St. Clair River for about half a mile. Agriculture is the predominant land use in this basin, with approximately 70 percent of the land covered by cropland and pasture. About 19 percent of the basin is in deciduous forest and about 6 percent in woody wetlands. The land-use data show a 0.01-percent reduction in deciduous forest and woody wetlands between 1992 and 2001 (table 2).

Pine River Basin

The Pine River basin is the smallest of the three study basins and drains an area of approximately 195 mi^2 in St. Clair County (fig. 4). This basin was divided into six subbasins for use in the PLOAD model. The predominant land uses/land covers within the Pine River basin are (1) cropland and pasture and (2) deciduous forest, constituting about 60 percent and

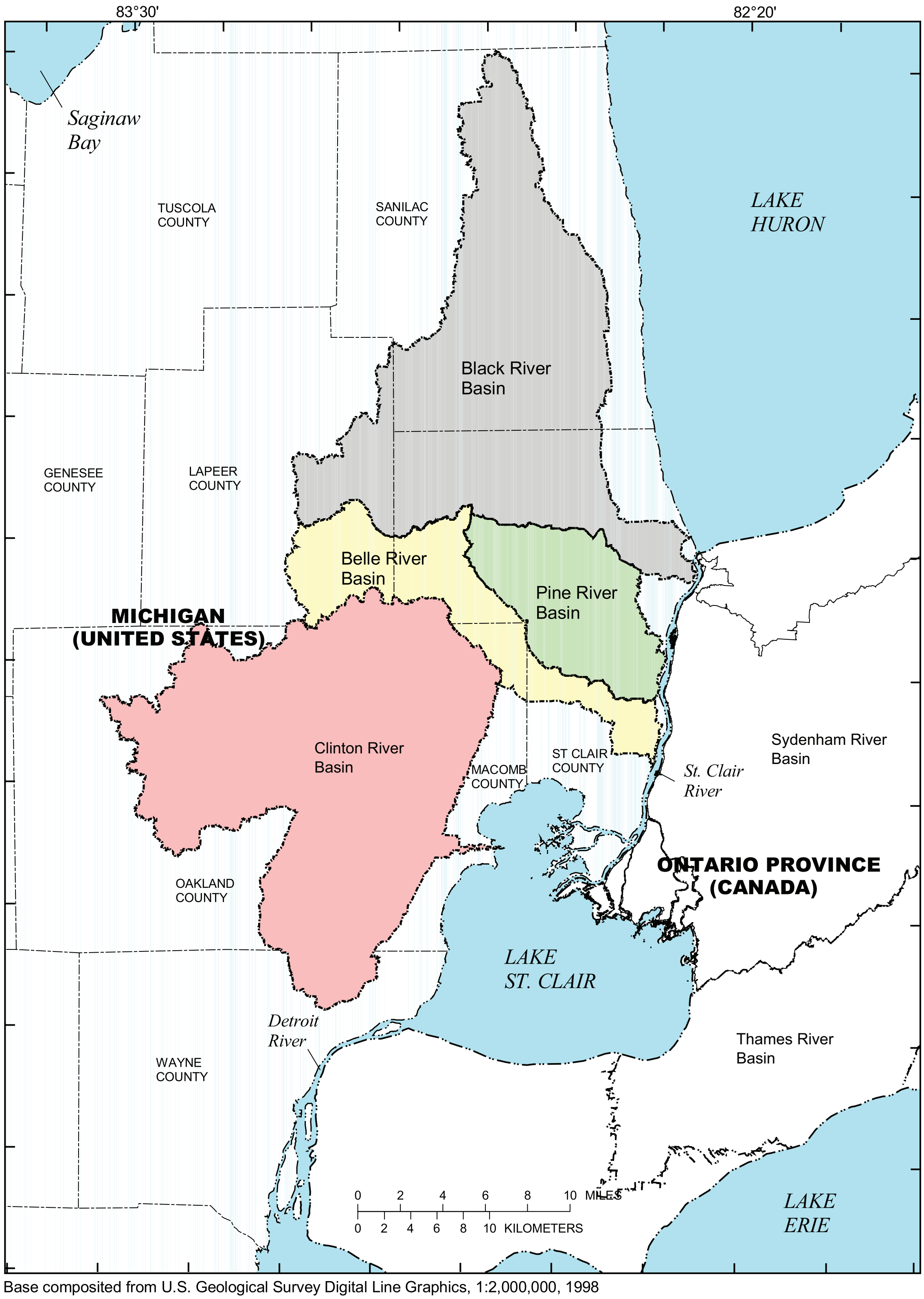


Figure 1. Location of St. Clair and Detroit River and study basins in Michigan.

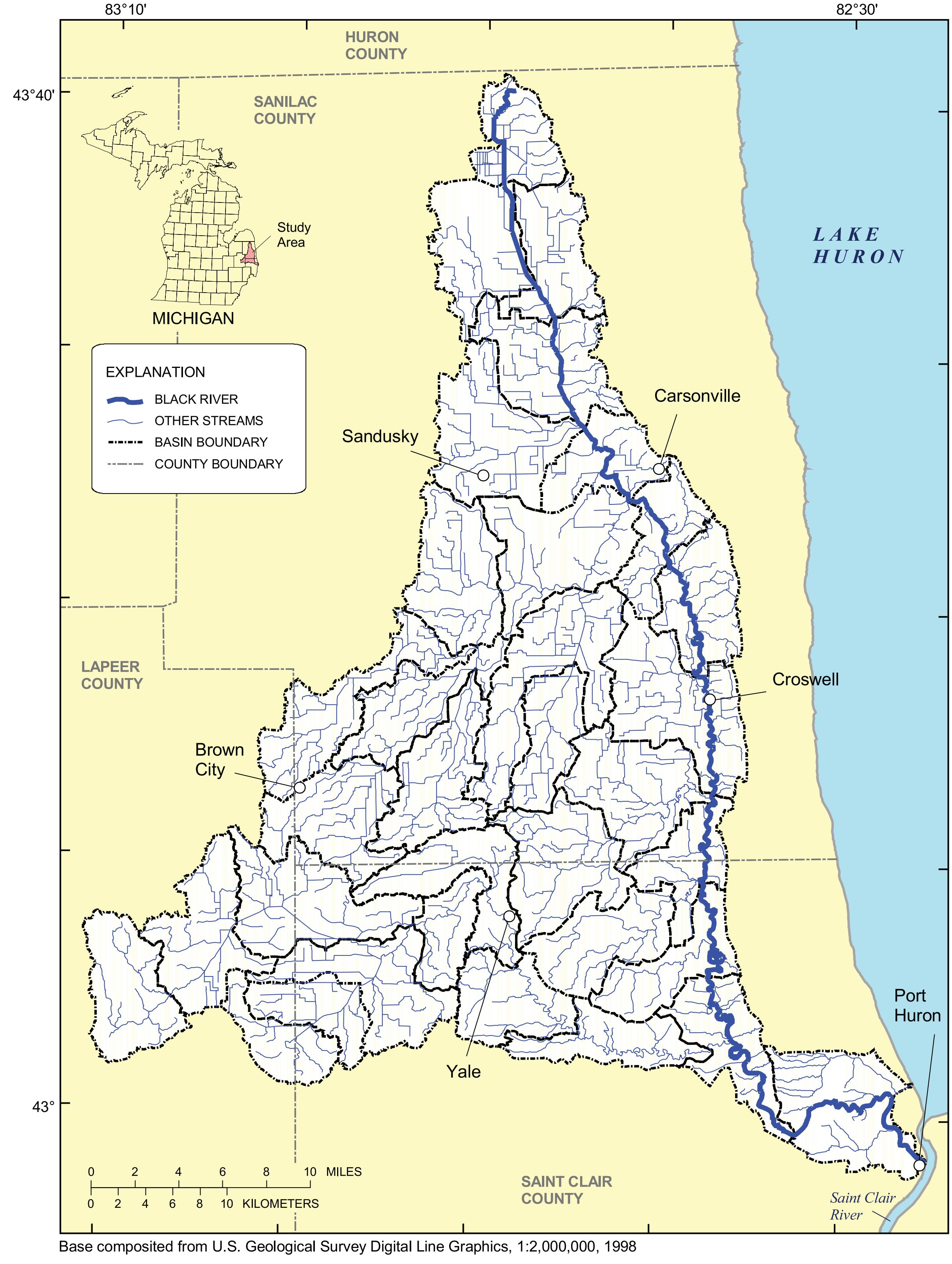


Figure 2. Black River basin.

Table 1. Land-use/land-cover percentages and areas in the Black River basin (Appendix 3, table 3-1; Michigan Center for Geographic Information, 2002; Michigan Department of Natural Resources, 2001).
[LUCODE, land-use code; mi^2, square miles]

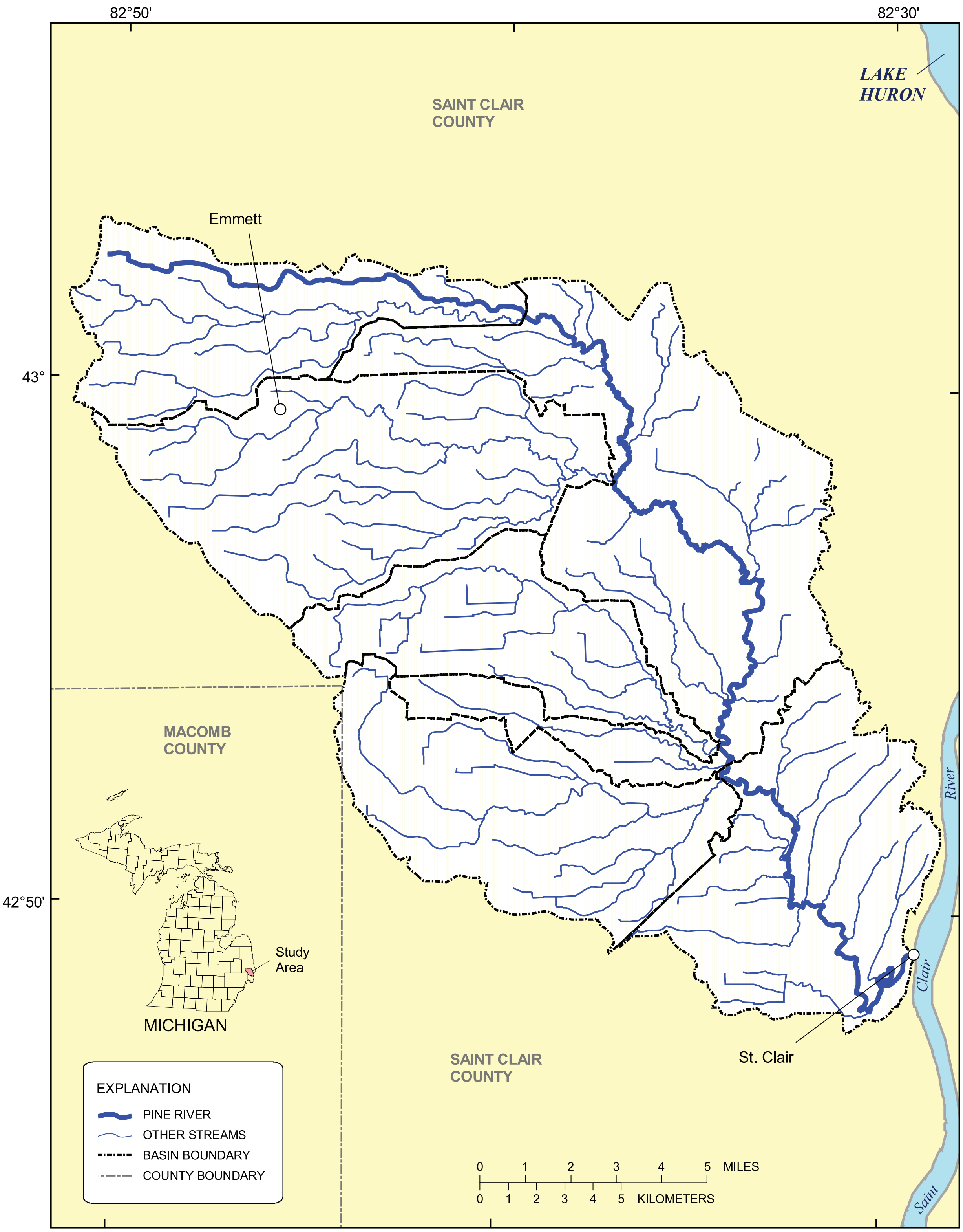
		1992 data set		2001 data set	
		Percentage of total land cover	Area (mi^2)	Percentage of total land cover	Area (mi^2)
11	Residential	1.44	10.24	1.44	10.22
12	Commercial/industrial/transportation	0.36	2.55	0.36	2.53
21	Cropland and pasture	78.77	559.54	78.77	559.20
22	Other agricultural land	0.00	0.00	0.00	0.00
23	Orchards/vineyards/other	0.00	0.00	0.00	0.00
24	Urban/recreational grasses	0.12	0.89	0.12	0.89
25	Shrub/low-density trees	0.00	0.00	0.00	0.00
31	Herbaceous open land/grasslands	0.00	0.00	0.00	0.00
41	Deciduous forest	11.19	79.51	11.20	79.52
42	Coniferous forest	1.04	7.40	1.04	7.40
43	Mixed forest	0.17	1.18	0.17	1.18
50	Water	0.46	3.26	0.46	3.25
61	Woody wetlands	6.23	44.22	6.23	44.20
62	Emergent herbaceous wetlands	0.15	1.08	0.15	1.08
75	Bare/sparsely vegetated	0.07	0.47	0.07	0.47

Table 2. Land-use/land-cover percentages and areas in the Belle River basin (Appendix 3, table 3-1; Michigan Center for Geographic Information, 2002; Michigan Department of Natural Resources, 2001).
[LUCODE, land-use code; mi^2, square miles]

		1992 data set		2001 data set	
LUCODE	Definition	Percentage of total land cover	Area (mi^2)	Percentage of total land cover	Area (mi^2)
11	Residential	1.38	3.13	1.38	3.13
12	Commercial/industrial/transportation	0.66	1.49	0.66	1.49
21	Cropland and pasture	70.89	161.06	70.90	161.00
22	Other agricultural land	0.00	0.00	0.00	0.00
23	Orchards/vineyards/other	0.00	0.00	0.00	0.00
24	Urban/recreational grasses	0.28	0.63	0.28	0.63
25	Shrub/low-density trees	0.00	0.00	0.00	0.00
31	Herbaceous open land/grasslands	0.00	0.00	0.00	0.00
41	Deciduous forest	18.60	42.27	18.59	42.21
42	Coniferous forest	0.92	2.10	0.92	2.10
43	Mixed forest	0.18	0.40	0.18	0.40
50	Water	0.81	1.84	0.81	1.84
61	Woody wetlands	5.90	13.41	5.90	13.39
62	Emergent herbaceous wetlands	0.24	0.53	0.24	0.53
75	Bare/sparsely vegetated	0.15	0.34	0.15	0.34

Base composited from U.S. Geological Survey Digital Line Graphics, 1:2,000,000, 1998

Figure 3. Belle River basin.



Base composited from U.S. Geological Survey Digital Line Graphics, 1:2,000,000, 1998

Figure 4. Pine River basin.

Table 3. Land-use/land-cover percentages and areas in the Pine River basin (Appendix 3, table 3-1; Michigan Center for Geographic Information, 2002; Michigan Department of Natural Resources, 2001).
[LUCODE, land-use code; mi^2, square miles]

		1992 data set		2001 data set	
LUCODE	Definition	Percentage of total land cover	Area (mi^2)	Percentage of total land cover	Area (mi^2)
11	Residential	0.99	1.94	1.01	1.96
12	Commercial/industrial/transportation	0.69	1.35	0.70	1.36
21	Cropland and pasture	59.57	115.93	59.54	115.84
22	Other agricultural land	0.00	0.00	0.00	0.00
23	Orchards/vineyards/other	0.00	0.00	0.00	0.00
24	Urban/recreational grasses	0.36	0.70	0.36	0.70
25	Shrub/low-density trees	0.00	0.00	0.00	0.00
31	Herbaceous open land/grasslands	0.00	0.00	0.00	0.00
41	Deciduous forest	26.88	52.31	26.89	52.31
42	Coniferous forest	1.45	2.82	1.45	2.82
43	Mixed forest	0.33	0.64	0.33	0.65
50	Water	0.50	0.97	0.50	0.97
61	Woody wetlands	9.00	17.51	9.00	17.52
62	Emergent herbaceous wetlands	0.02	0.05	0.02	0.05
75	Bare/sparsely vegetated	0.20	0.39	0.20	0.39

27 percent of the total land cover, respectively. The eastern part of the basin is mostly wooded wetlands, with a small section of low-intensity urban area in the southeast. The Pine River basin had approximately a 0.02-percent increase in residential and commercial land use and the same extent of reduction in deciduous forest, mixed forest, and woody wetlands between 1992 and 2001 (table 3).

METHODS FOR ESTIMATION OF NONPOINT-SOURCE NUTRIENT AND TOTAL-SUSPENDED-SOLIDS LOADS

The PLOAD model used for computation of nonpoint-source nutrient loads in this study is a GIS model that generates estimates of pollutant loads on an average annual basis for any user-specified constituent (CH2M HILL, 2001). PLOAD was designed to be generic so that it can be applied as a screening tool in a wide range of applications including NPDES stormwater permitting, watershed management, or reservoir-protection projects (CH2M HILL, 2001).

A brief description of the input data used to compute nutrient and total-suspended-solid loads in the Black, Belle, and Pine River basins is given in the sections that follows.

Basin Boundaries and Land-Use Data

Basin boundaries and land-use data are required input in the PLOAD model. The basin boundaries define the areas for which the pollutant loads are computed. The basin boundaries must have a code field containing unique identifiers for each basin. The code field for the subbasins within the Black, Belle, and Pine River basins were given unique numbers called Shed ID's (Appendix 1, tables 1-1, 1-2, and 1-3).

Besides basin boundaries, PLOAD requires a land-use file for computing pollutant loads. The land-use coverages also have a code field identifying the land-use types. The code field for the land-use coverages within the Black, Belle, and Pine River basins consisted of unique numbers called LUCODE (table 3). A total of 15 LUCODES were used for each study basin. Before computing the pollutant loads, PLOAD spatially overlaid the basin and land-use coverages in order to determine the areas of various land-use types for each basin or for each subbasin within a basin.

Load Computation Methods

Pollutant loading rates and an impervious-terrain factor must be compiled in tabular files for use in the PLOAD application. The pollutant-loading table consists of the event mean concentrations (EMC) and the export coefficients. Loads are estimated by use of USEPA's Simple Method, which requires

Table 4. Percent imperviousness associated with land-use code (adapted from CH2M HILL, 2001).

LUCODE	Definition	Percent impervious
11	Residential	25
12	Commercial/industrial/transportation	80
21	Cropland and pasture	2
22	Other agricultural land	2
23	Orchards/vineyards/other	25
24	Urban/recreational grasses	2
25	Shrub/low-density trees	2
31	Herbaceous open land/grasslands	2
41	Deciduous forest	2
42	Coniferous forest	2
43	Mixed forest	2
50	Water	100
61	Woody wetlands	2
62	Emergent herbaceous wetlands	2
75	Bare/sparsely vegetated	50

the EMC values as an input pollutant-loading rate. The impervious-terrain factor table identifies the percentage of imperviousness for each land-use type (table 4). A brief description of the Simple Method and the determination of EMC values are given below.

Simple Method

The Simple Method is used for the calculations of pollutant loads in the PLOAD model. The Simple Method is based on two equations to calculate the loads for each specific pollutant type. First, the runoff coefficient for each land-use type must be derived with the equation

$$R_{vu} = 0.05 + (0.009 * I_u) \qquad (1)$$

Where R_{vu} is the runoff coefficient for land-use type u, in inches of runoff per inch of rainfall and

I_u is percent imperviousness.

Percent imperviousness is extracted from the impervious-terrain factor table (table 4).

The pollutant loads are then calculated with the following equation (CH2M HILL, 2001):

$$L_p = \sum u(P * P_j * R_{vu} * C_u * A_u * 2.72/12) \qquad (2)$$

Where L_p is pollutant loads, in pounds,

P is the precipitation, in inches per year,

P_j is ratio of storms producing runoff,

R_{vu} is runoff coefficient for land-use type u,

C_u is Event Mean Concentration for land-use type u, in milligrams per liter, and

A_u is area of land-use type u, in acres.

Review and Determination of Event Mean Concentrations

Generally a water-quality model requires an input of pollutant loading rates, which in our study would be the event mean concentrations (EMCs). EMCs represent the concentrations of a specific pollutant contained in stormwater runoff coming from a particular land-use type within a basin; they are reported as mass of the pollutant per unit volume of water. The data necessary for computing site-specific EMCs were not collected during the Lake St. Clair Monitoring Project; therefore, EMCs for this study were chosen after careful evaluation of published-literature, EMCs from national studies (Smullen and others, 1999; Brezonik and Stadelmann, 2001; Line and others, 2002) and local EMCs from the Muskegon Project, which estimated EMCs from the Rouge River Project (Muskegon River Project, 2005). The EMCs used in the PLOAD model are listed in table 5.

Computation of Runoff by Alternate Method

Runoff ($P * P_j * R_{vu}$) is a required input variable for the Simple Method in the PLOAD model. While the model has a built in equation (Equation 1), it was decided for this study, to compute a more accurate ratio for the study area by the use of the Soil Conservation Service's method described as follows (McCuen, 1982). The SCS method assumes the following rainfall-runoff relation given in the equations below:

$$\frac{F}{S} = \frac{Q}{P - I_a} \qquad (4)$$

The volume of runoff (Q) depends on the volume of precipitation (P) and the volume of storage (S) that is available for retention. The actual retention (F) is the difference between the volume of precipitation and runoff. A certain volume of the precipitation at the beginning of the storm, which is called initial abstraction (I_a), will not appear as runoff. The actual retention, when the initial abstraction is considered, is

$$F = (P - I_a) - Q \qquad (5)$$

Substituting equation 5 into equation 4 yields the following:

Table 5. Event mean concentrations used in the PLOAD model to compute nutrient and total-suspended-solids loading rates in the Black, Belle, and Pine River basins.

		Event Mean Concentrations, in milligrams per liter		
LUCODE	Definition	Total N	Total P	Total-suspended-solids
11	Residential	2.25	0.5	25
12	Commercial/industrial/transportation	1.92	.34	35
21	Cropland and pasture	2.5	.4	27
22	Other agricultural land	2.31	.39	25
23	Orchards/vineyards/other	1.92	.37	17
24	Urban/recreational grasses	1.95	.37	20
25	Shrub/low-density trees	.94	.15	22
31	Herbaceous open land/grasslands	.94	.15	19
41	Deciduous forest	.94	.15	16
42	Coniferous forest	.94	.15	14
43	Mixed forest	.94	.15	15
50	Water	.65	.08	3
61	Woody wetlands	.75	.11	8
62	Emergent herbaceous wetlands	.75	.11	8
75	Bare/sparsely vegetated	.65	.08	30

$$\frac{(P-I_a)-Q}{S}=\frac{Q}{P-I_a} \tag{6}$$

Rearranging 6 to solve for Q yields

$$Q=\frac{(P-I_a)^2}{(P-I_a)+S} \tag{7}$$

The initial abstraction is a function of land use, treatment, and condition; interception; infiltration; depression storage; and antecedent soil moisture. An empirical analysis was done for the development of SCS rainfall-runoff relation, and the following formula was found to be best for estimating I_a

$$I_a=0.2S \tag{8}$$

Equation 8 implies that the factors affecting I_a would also affect S. Substituting equation 8 into equation 7 yields

$$Q=\frac{(P-0.2S)^2}{P+0.8S} \tag{9}$$

Empirical studies (McCuen, 1982) indicate that S can be estimated

$$S=\frac{1000}{CN}-10 \tag{10}$$

where CN is known as the curve number and is based on the classification of more than 4,000 soils into four hydrologic soils group (HSG) according to their minimum infiltration rate obtained for bare soil after prolonged wetting (U.S. Soil Conservation Service, 1985). The Natural Resources Conservation Service (NRSC) STATSGO soil coverage was used to derive an average CN for each study basin (Natural Resources Conservation Service, 2004). This land-use average CN was used with land-use percentages and average annual precipitation to derive an annual run-off for each subbasin. Equation 9 was solved by use of MathCAD to determine runoff in inches, from the Black, Belle, and Pine River basins, using average annual precipitation (University of Utah, Department of Meteorology, 2005) for the study area and weighted curve-number values based on the percent land-use data. The computed runoff values were compared to the average rainfall to determine a rainfall to runoff ratio for each study basin, which was then used as an input into the PLOAD model.

ESTIMATED LOADS IN THE BLACK, BELLE, AND PINE RIVER BASINS

PLOAD results in the Black, Belle, and Pine River basins are based on the 2001 land-use data. The model generates an output in the form of total load (pounds per year) and amount associated with runoff (milligrams per liter) for total nitrogen, total phosphorus, and total-suspended solids. These results do not represent the receiving-water concentrations, because the PLOAD model does not take into account the dynamic processes within the water bodies; instead, the model is based on an empirical relation between the EMCs, land-use coverage, and mean annual precipitation. Thus, the results produced are average annual load estimates. Description of the PLOAD results for each study basin is given below.

Black River Basin

The 34 subbasins in the Black River basin range from 11.3 mi^2 to 31.2 mi^2 in area. Loading rates based on 2001 land-use scenario for total nitrogen, total phosphorus, and total-suspended solids average 14,576 lb/yr, 2,376 lb/yr, and 165,097 lb/yr, respectively, at the subbasin level (figs. 5, 6, and 7). These loading rates translate into average concentrations of 2.09 mg/L, 0.34 mg/L, and 22.44 mg/L, respectively (Appendix 1, table 1-1). The total-nitrogen, total-phosphorus, and total-suspended-solids loads from the entire Black River basin for the 2001 land-use data are approximately 495,599 lb/yr, 80,777 lb/yr, and 5,613,282 lb/yr, respectively.

Subbasins in the Black River basin with comparatively high total-nitrogen, total-phosphorus, and total-suspended-solids loading rates include subbasins 6 4, 6 17, and 6 34 (figs. 8, 9, and 10).

Belle River Basin

The 12 subbasins in the Belle River range from 7.6 mi^2 to 23.1 mi^2 in area. Loading rates based on the 2001 land-use scenario for total nitrogen, total phosphorus, and total-suspended solids average 13,047 lb/yr, 2,124 lb/yr, and 152,587 lb/yr, respectively at the subbasin level (figs. 11, 12, and 13). These loading rates translate into average concentrations of 1.91 mg/L, 0.31 mg/L, and 22.43 mg/L, respectively (Appendix 1, table 1-2). The total-nitrogen, total-phosphorus, and total-suspended-solids load from the entire Belle River basin for the 2001 land-use data are approximately 156,561 lb/yr, 25,491 lb/yr, and 1,831,045 lb/yr, respectively.

The subbasins in the Belle River basin with comparatively high total-nitrogen, total-phosphorus, and total-suspended-solids loading rates include subbasins 3 8, 3 52, and 3 53 (figs. 14, 15, and 16).

Pine River Basin

The six subbasins in the Pine River basin range from 23.7 mi^2 to 53.4 mi^2 in area. Loading rates based on the 2001 land-use scenario for total nitrogen, total phosphorus, and total suspended solids average 20,202 lb/yr, 3,276 lb/yr, and 246,725 lb/yr, respectively, at the basin level (figs. 17, 18, and 19). These loading rates translate into average concentrations of 1.84 mg/L, 0.30 mg/L, and 22.15 mg/L, respectively (Appendix 1, table 1-3). The total-nitrogen, total-phosphorus, and total-suspended-solids loads from the entire Pine River basin for the 2001 land-use data are approximately 121,212 lb/yr, 19,655 lb/yr, and 1,480,352 lb/yr, respectively.

The subbasin in the Pine River basin with comparatively high total-nitrogen, total-phosphorus, and total-suspended-solids loading rates include the subbasin 2 74 (figs. 20, 21, and 22.)

RESULTS

The PLOAD model was designed to be a screening tool to estimate average annual nonpoint-source nutrient and total-suspended-solid loads based on available GIS land-use coverage. Figures 8-22 show the range of loads for total nitrogen, total phosphorus, and total-suspended solids in the Black, Belle, and Pine River subbasins.

Results from the PLOAD model can be very helpful in predicting average nutrient loads delivered to the St. Clair River from the Black, Belle, and Pine River basins. Based on 2001 land-use data, total-nitrogen loads from the Black, Belle, and Pine River basins are approximately 495,599 lb/yr, 156,561 lb/yr, and 121,212 lb/yr, respectively; the total-phosphorus loads are 80,777 lb/yr, 25,493 lb/yr, and 19,655 lb/yr, respectively; and the total-suspended-solids loads are 5,613,282 lb/yr, 1,831,045 lb/yr, and 1,480.352 lb/yr, respectively. However, figures 8-22 are not as helpful in pinpointing sources of those loads within the subbasins. Therefore, subbasin loads have been normalized to lb/yr/square mile in figures 23-31 to assist watershed managers in potential-source determinations.

Subbasins in the Black River basin with comparatively high total-nitrogen, total phosphorus, and total-suspended-solids loading rates per square mile include subbasins 6 34 near Port Huron, 6 4 near Sandusky, 6 6 near Brown City, and 6 17 near Croswell, (figs. 23, 24, and 25). Based on 2001 land-use data, the largest loading rates per square mile of total-nitrogen (1,298 lb/yr/mi2), total-phosphorus (245 lb/yr/mi2), and total-suspended-solids (17,139 lb/yr/mi2) came from subbasin 6 34 which includes the city of Port Huron.

Subbasins in the Belle River basin with comparatively high total-nitrogen, total phosphorus, and total-suspended-solids loading rates per square mile include subbasins 3 2 and 3 3 near Imlay City, 3 4 near Capac, 3 9 near Marine City, and 3 7 near Richmond (figs. 26, 27, and 28). Based on 2001 land-use data, the largest loading rates per square mile of total-nitrogen (1,067 lb/yr/mi2), total-phosphorus (186 lb/yr/mi2), and total-suspended-solids (13,669 lb/yr/mi2) came from subbasin 3 3 which includes the city of Imlay City.

Subbasins in the Pine River basin with comparatively high total-nitrogen, total phosphorus, and total-suspended-solids loading rates per square mile include subbasins 2 76 near the city of St. Clair and 2 72 near Emmett (figs. 29, 30, and 31). Based on 2001 land-use data, the largest loading rates per square mile of total-nitrogen (699 lb/yr/mi2) came from subbasin 2 72 which includes the city of Emmett; and the largest loading rates per square mile of total-phosphorus (116 lb/yr/mi2), and total-suspended-solids (9,202 lb/yr/mi2) came from subbasin 2 76 which includes the city of St. Clair.

From the above findings, it should be apparent that the largest predicted loading rates come from subbasins that contain comparatively high percentages of industrial, commercial, transportation, or residential land use. This is a direct result of the weighting factors assigned to land-use codes. Although residential, commercial/industrial/ transportation, and agricultural lands contribute similar event mean concentrations (see table 5), the weighting for impervious-terrain runoff (table 4) or the curve number runoff factor (used in the "runoff by alternate method" section) are significantly larger than they are for agricultural lands. This means that the PLOAD model will consistently predict larger loads from basins that contain urban centers verses basins without urban centers. It should be noted that if sufficient nutrient samples could be collected at stream outflow points for all subbasins, then the gross estimated subbasin loads, generated by the PLOAD model, could be verified or refuted.

SUMMARY AND CONCLUSIONS

The Lake St. Clair Regional Monitoring Project planned a 3-year water-quality assessment of the basins within the United States that drain to Lake St. Clair. The main objectives of the Regional Monitoring Project partners were to complete a comprehensive assessment of the hydrological, chemical, and physical state of the surface water in the study area. This included water-quality monitoring and analysis, collection of discrete (grab) and automatic water-quality samples, monitoring of bacteria, and the creation of a database to store all relevant data collected from the past and future field-data-collection programs.

In cooperation with the Lake St. Clair Monitoring Project, the U.S. Geological Survey (USGS) assessed nonpoint-source loads of nutrients and total-suspended solids in the Black, Belle, and Pine River basins. The timeframe for the comparison of load estimation was based on the availability and similarity of methods used in the processing of land-use data for 1992 and 2001 (see appendices table 3).

Nonpoint-source loads of total nitrogen, total phosphorus, and total suspended solids were estimated on an average annual basis using the USEPA's PLOAD model. PLOAD is a GIS-based numerical program that generates gross estimates of pollutant loads based on an empirical approach involving a correlation between land-use type and pollutant loads. For this study, nutrients and total-suspended-solids loads were computed using a modified version of USEPA's Simple Method in the PLOAD model. Input data requirements for the Simple Method included the determination of event mean concentrations (EMCs). The necessary data required for the computation of site-specific EMCs were not collected during the Lake St. Clair Monitoring Project; instead the EMCs were chosen after careful evaluation of the published literature on EMC values from national and local studies.

The land-use data show a maximum of 0.02-percent change in any of the 15 landuse categories between the two timeframes. This small change in land use is reflected in the PLOAD results in the study area between the two time periods. Because the difference in load rates is so slight between the two time periods, only the model results for the current (2001) land-use data set are discussed in detail in this report.

PLOAD model results for the 2001 land-use data include the total-nitrogen loads in the Black, Belle, and Pine River basins of approximately 495,599 lb/yr, 156,561 lb/yr, and 121,212 lb/yr, respectively; the total-phosphorus loads of 80,777 lb/yr, 25,493 lb/yr, and 19,655 lb/yr, respectively; and the total-suspended-solids loads of 5,613,282 lb/yr, 1,831,045 lb/yr, and 1,480,352 lb/yr, respectively. The subbasins in the Black, Belle, and Pine River basins with comparatively high total-nitrogen, total-phosphorus, and total-suspended-solids loads per square mile are characterized by comparatively high percentages of industrial, commercial, transportation, or residential land use.

The results from the PLOAD model provide useful information about the approximate average annual loading rates from the three study basins. In particular, the results identify subbasins with comparatively high loading rates. This could aid water-resources managers and planners in evaluation of the effectiveness of public expenditures for water-quality improvements, assessment of progress towards achieving established water-quality goals, and planning of preventive actions.

ACKNOWLEDGMENTS

This study was conducted in cooperation with the Lake St. Clair Regional Monitoring Project partners. Technical reviews of this report were performed by Stephen Lipscomb (USGS Idaho Water Science Center) and Lori Fuller (USGS Michigan Water Science Center. Graphical and editorial assistance was provided by Sharon Baltusis and Michael Eberle.

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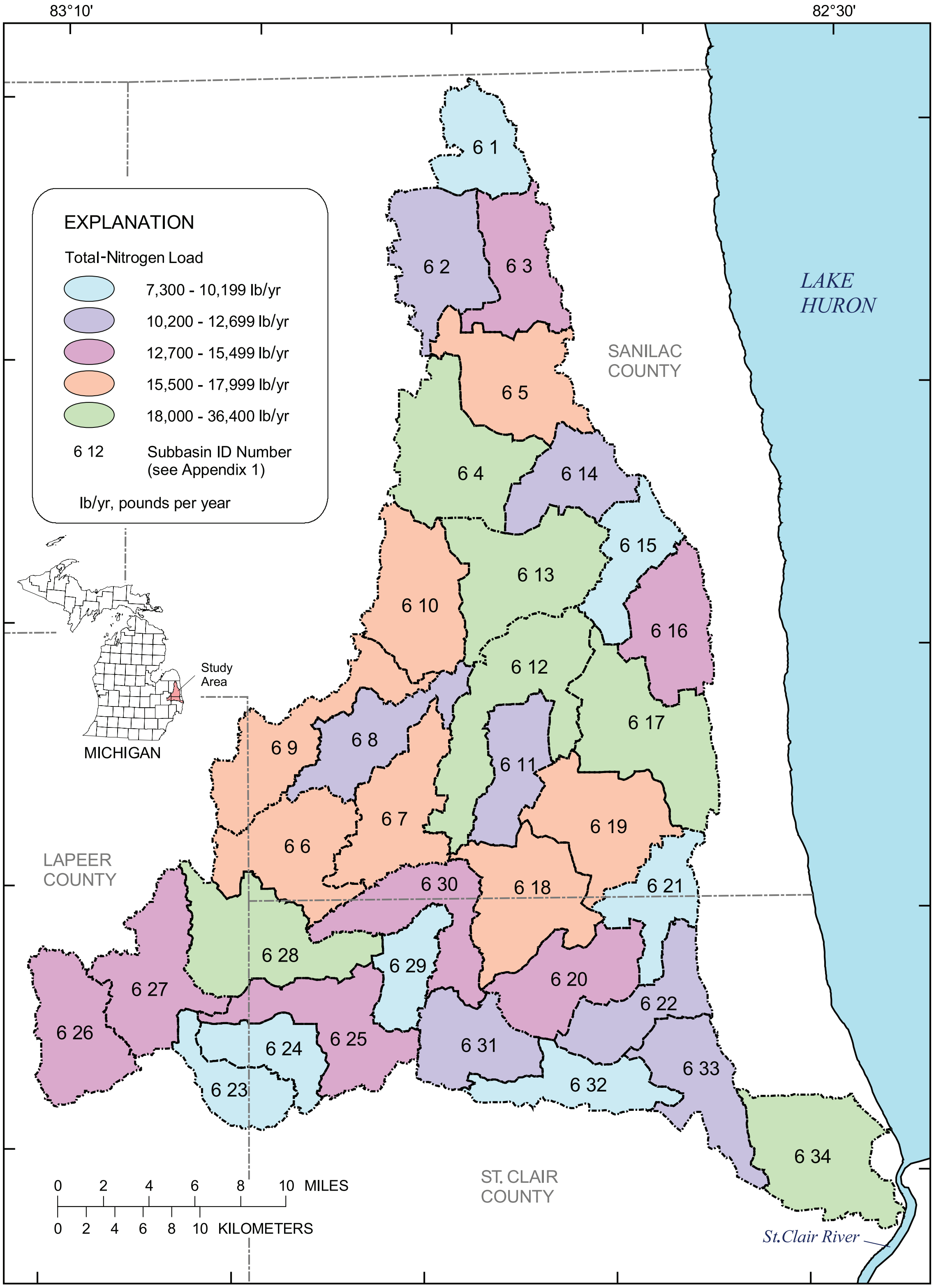

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Figure 5. Range of total-nitrogen loads in subbasins in the Black River basin (based on 2001 land-use data).

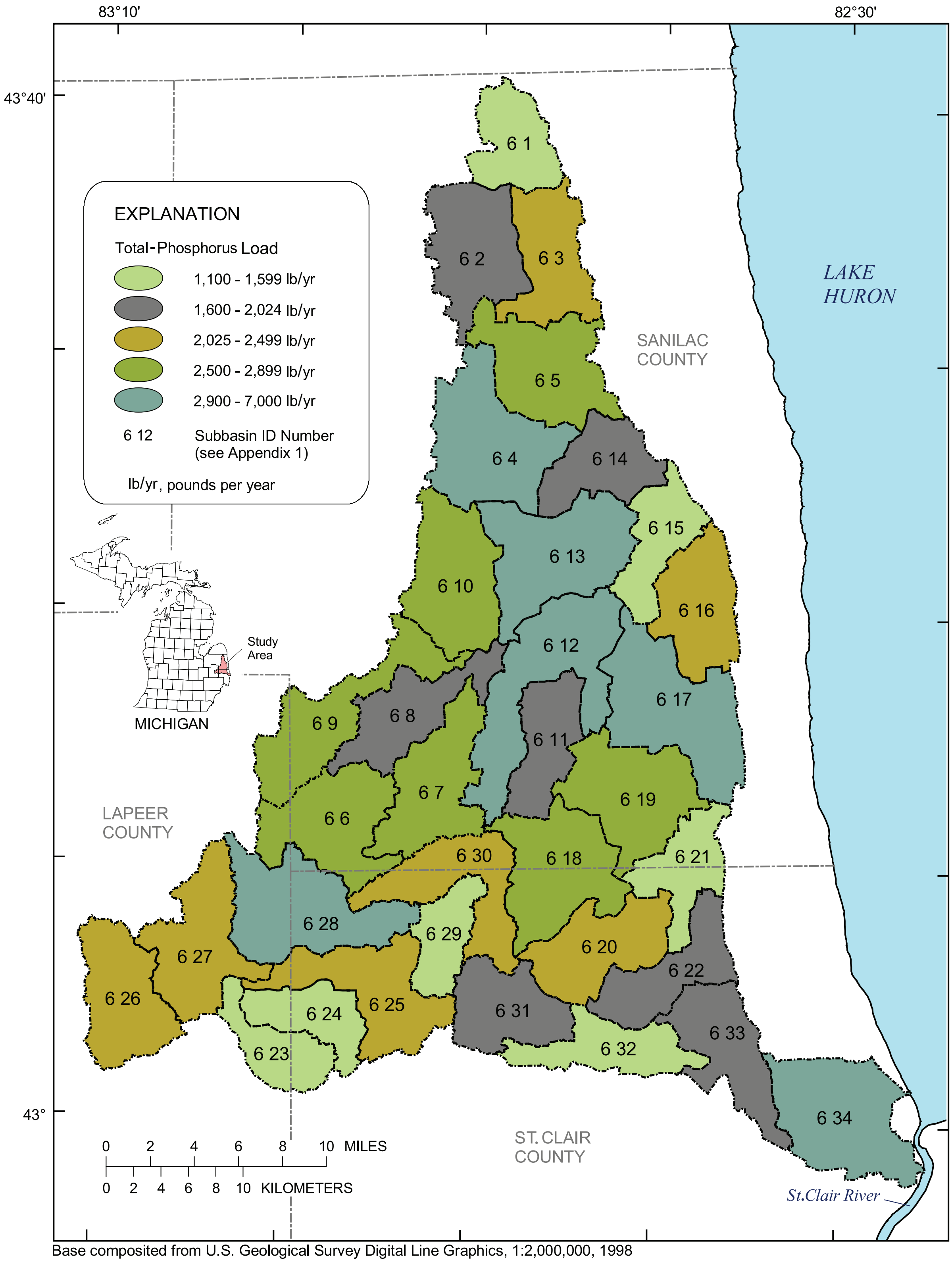

Figure 6. Range of total-phosphorus loads in subbasins in the Black River basin (based on 2001 land-use data).

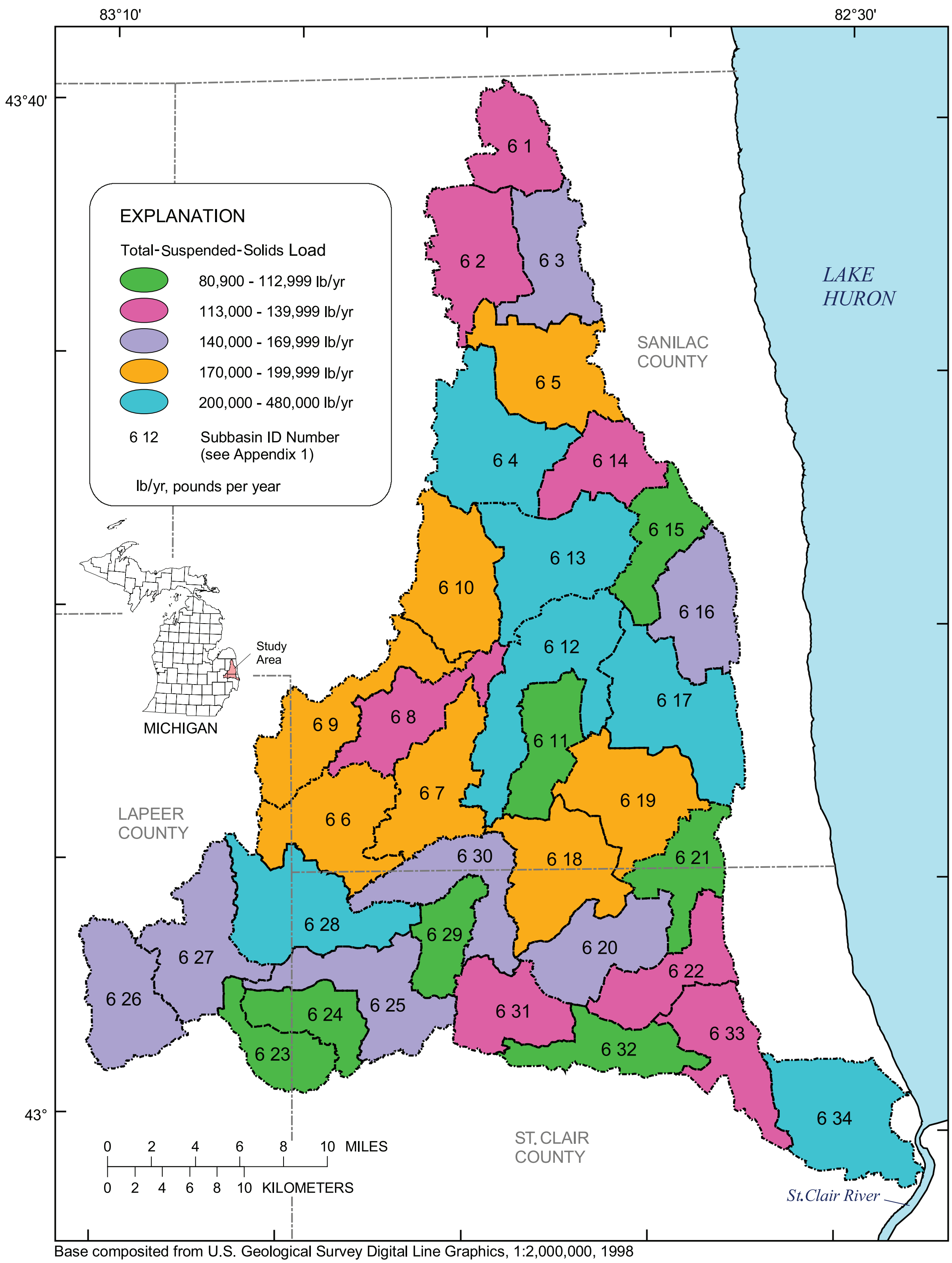

Figure 7. Range of total-suspended-solids loads in subbasins in the Black River basin (based on 2001 land-use data).

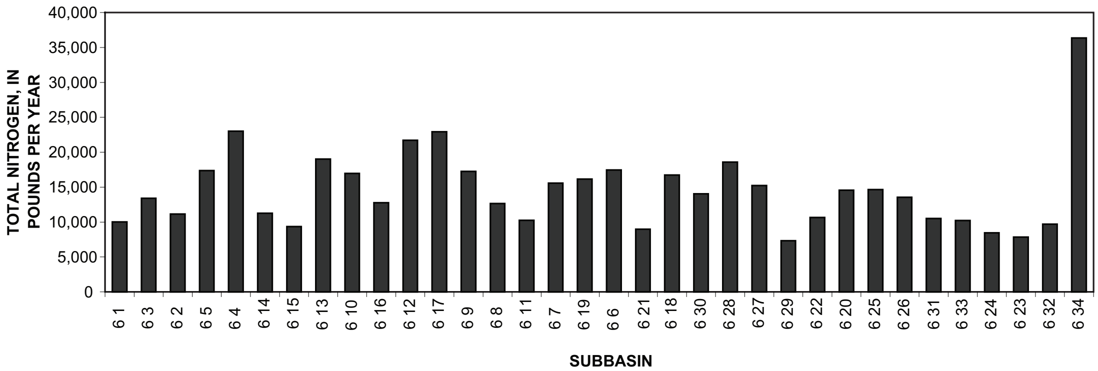

Figure 8. Distribution of total-nitrogen loads among Black River subbasins (based on 2001 land-use data).

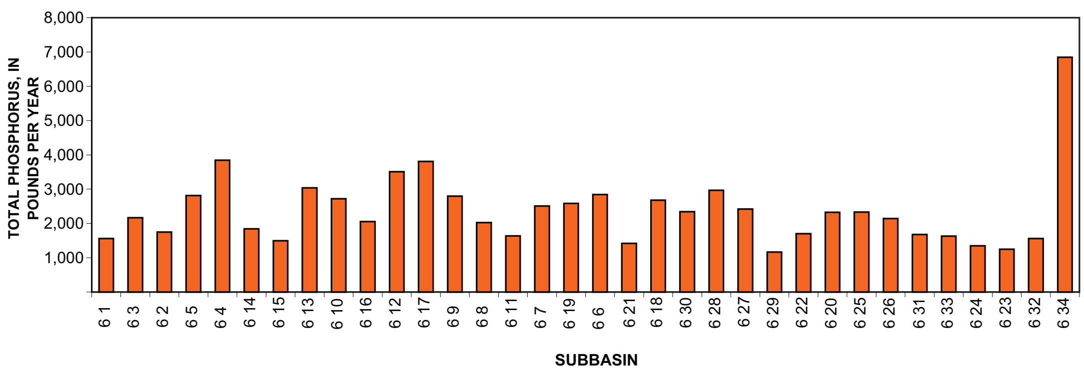

Figure 9. Distribution of total-phosphorus loads among Black River subbasins (based on 2001 land-use data).

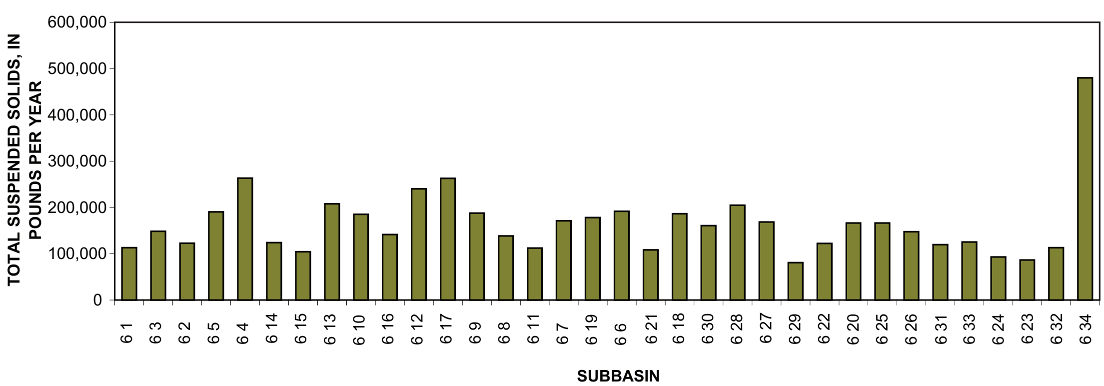

Figure 10. Distribution of total-suspended-solids loads among Black River subbasins (based on 2001 land-use data).

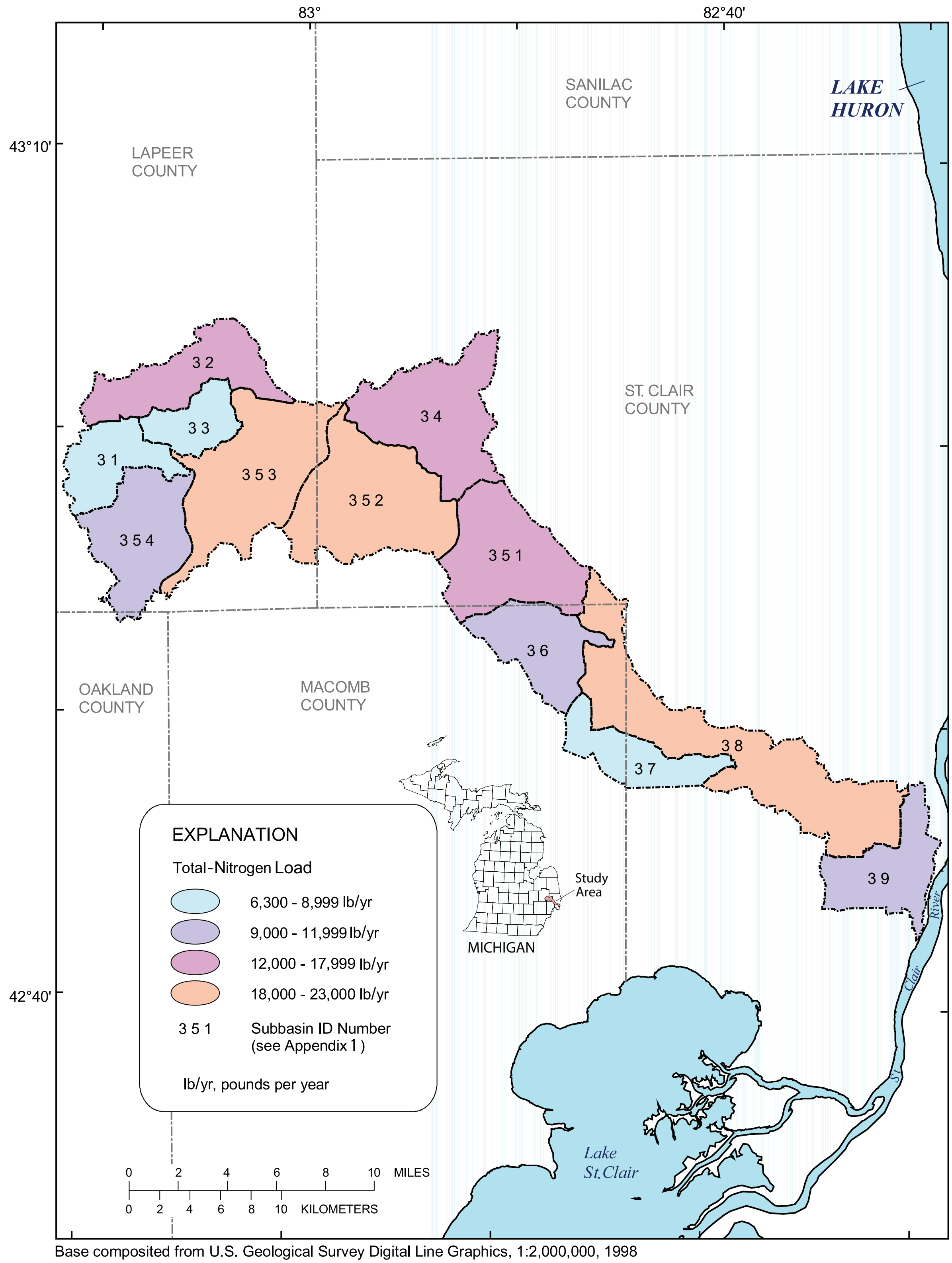

Figure 11. Range of total-nitrogen loads in subbasins in the Belle River basin (based on 2001 land-use data).

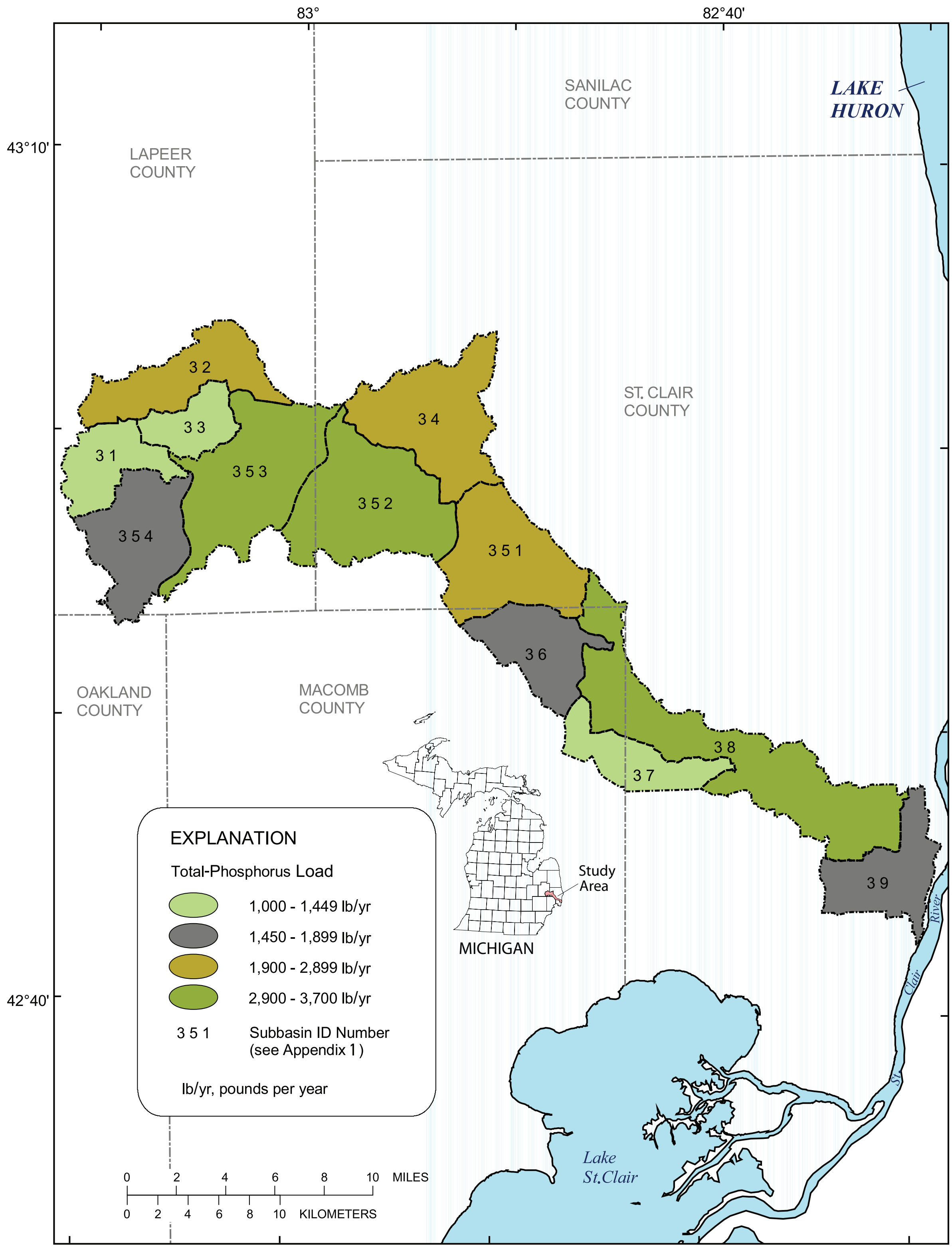

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Figure 12. Range of total-phosphorus loads in subbasins in the Belle River basin (based on 2001 land-use data).

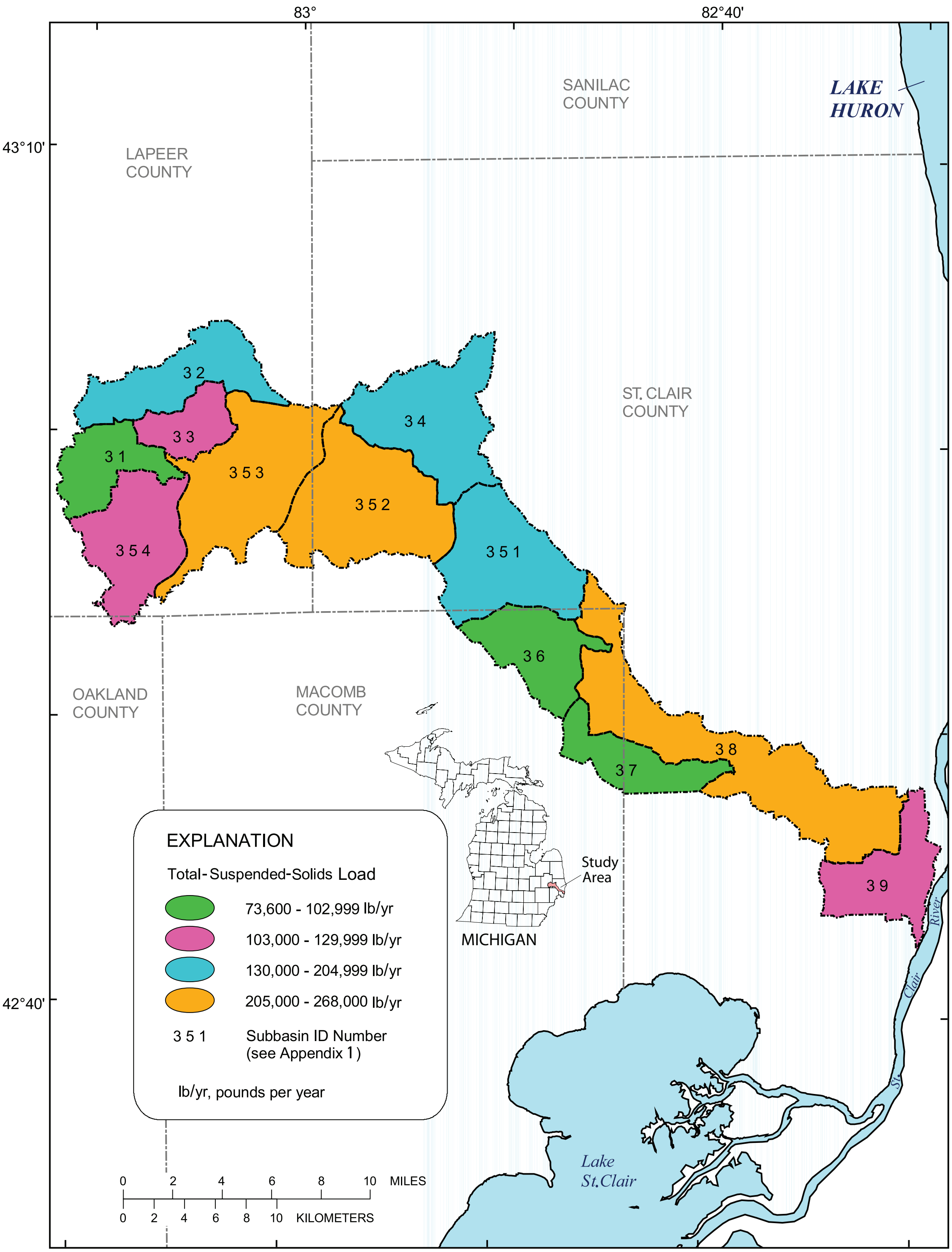

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Figure 13. Range of total-suspended-solids loads in subbasins in the Belle River basin (based on 2001 land-use data).

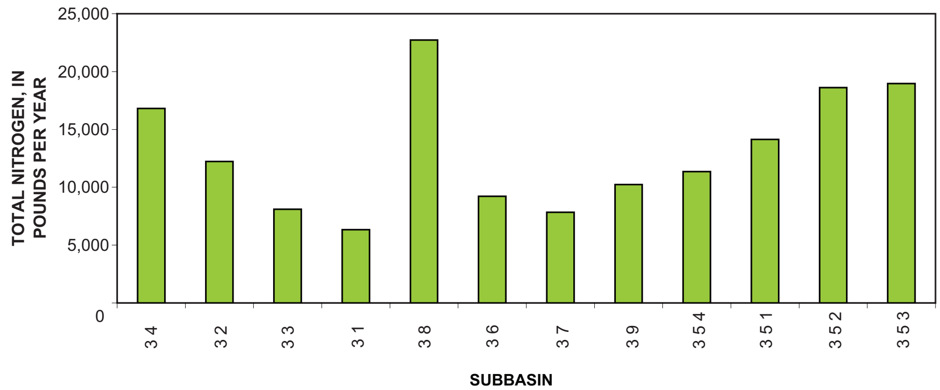

Figure 14. Distribution of total-nitrogen loads among Belle River subbasins (based on 2001 land-use data).

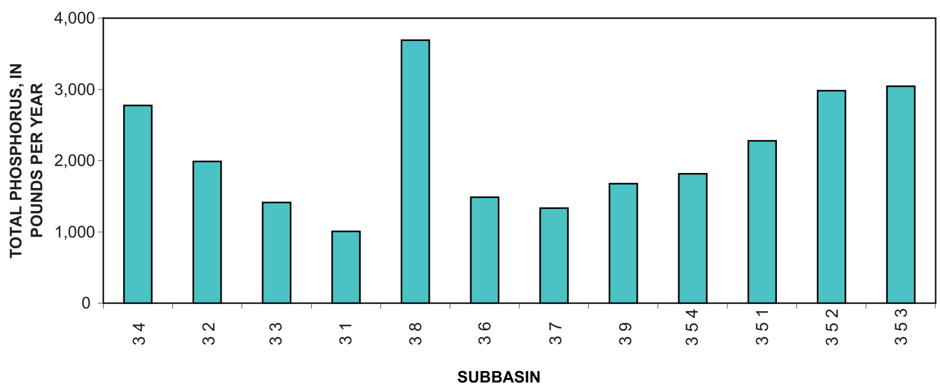

Figure 15. Distribution of total-phosphorus loads among Belle River subbasins (based on 2001 land-use data).

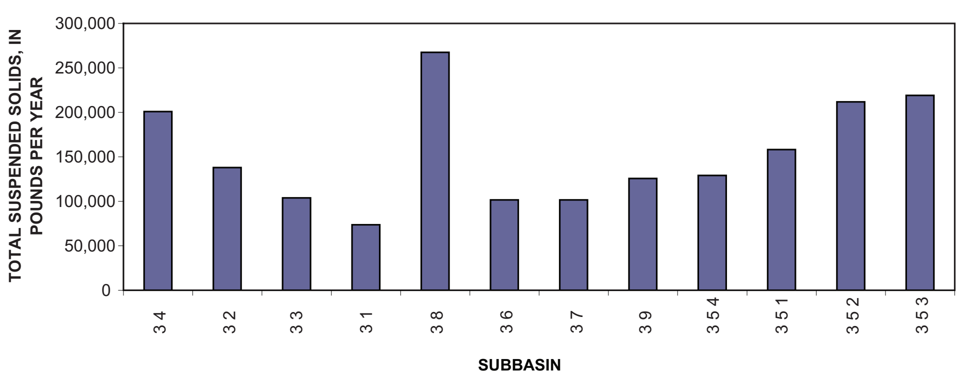

Figure 16. Distribution of total-suspended-solids loads among Belle River subbasins (based on 2001 land-use data).

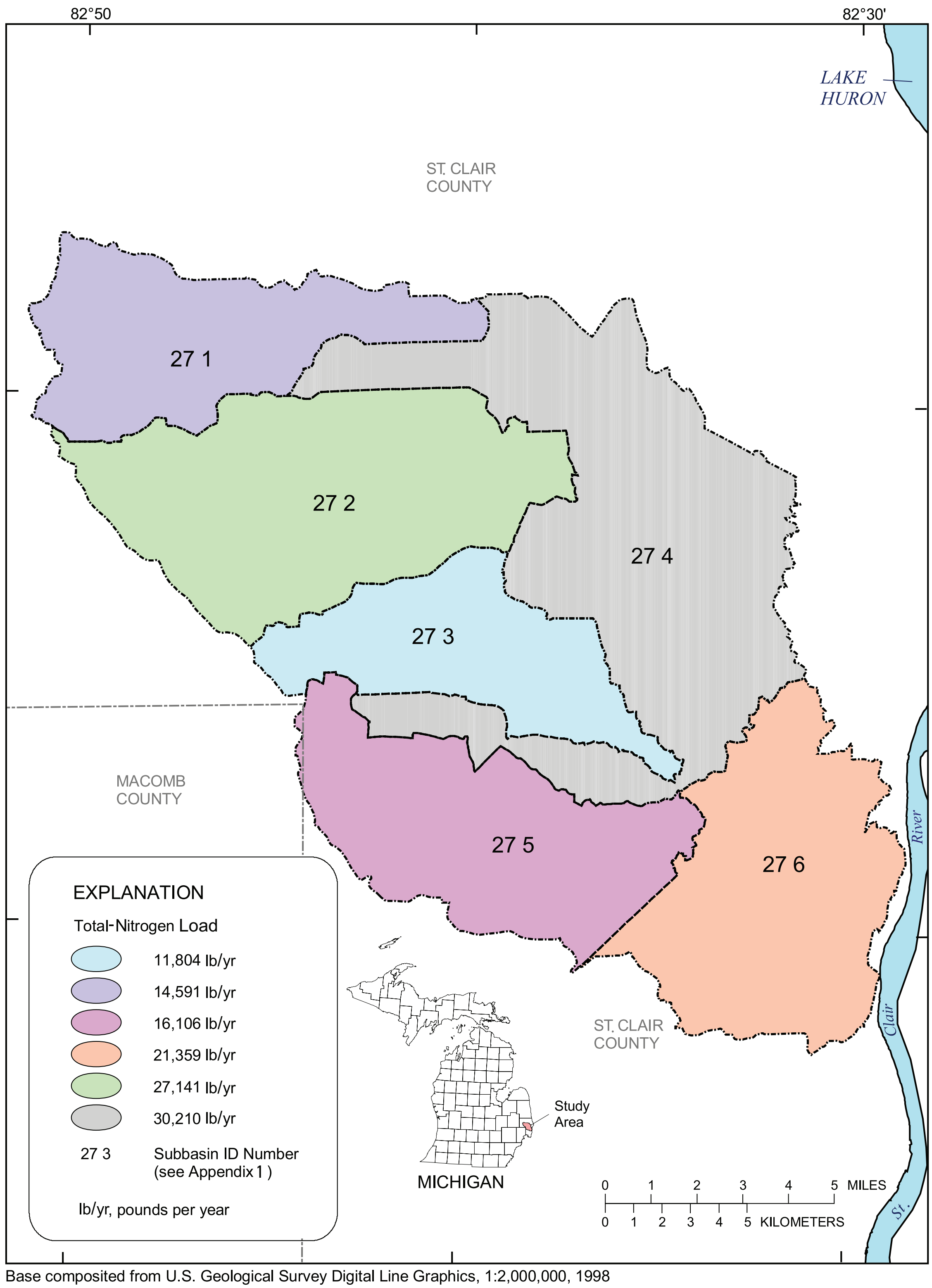

Figure 17. Range of total-nitrogen loads in subbasins in the Pine River basin (based on 2001 land-use data).

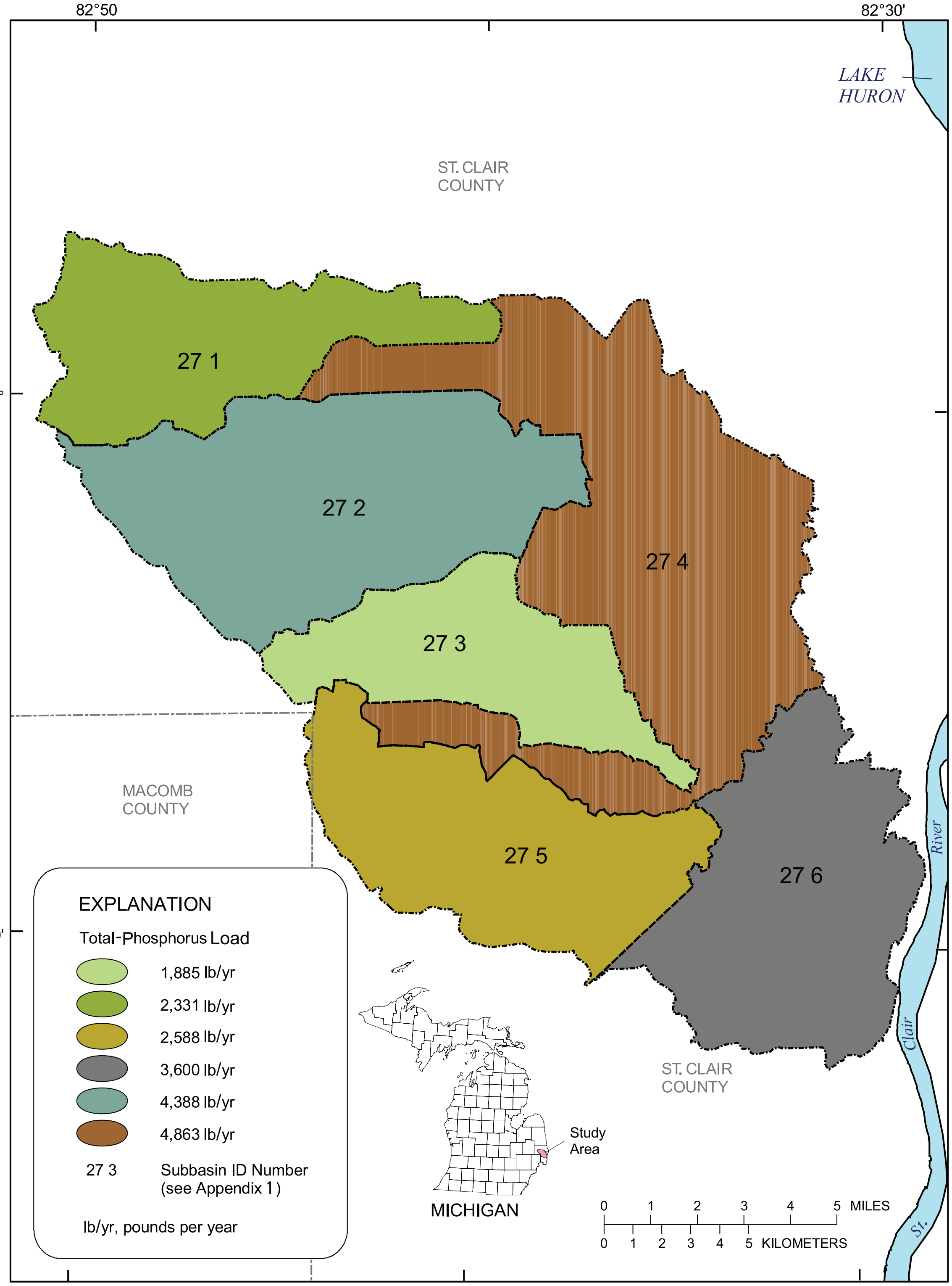

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Figure 18. Range of total-phosphorus loads in subbasins in the Pine River basin (based on 2001 land-use data).

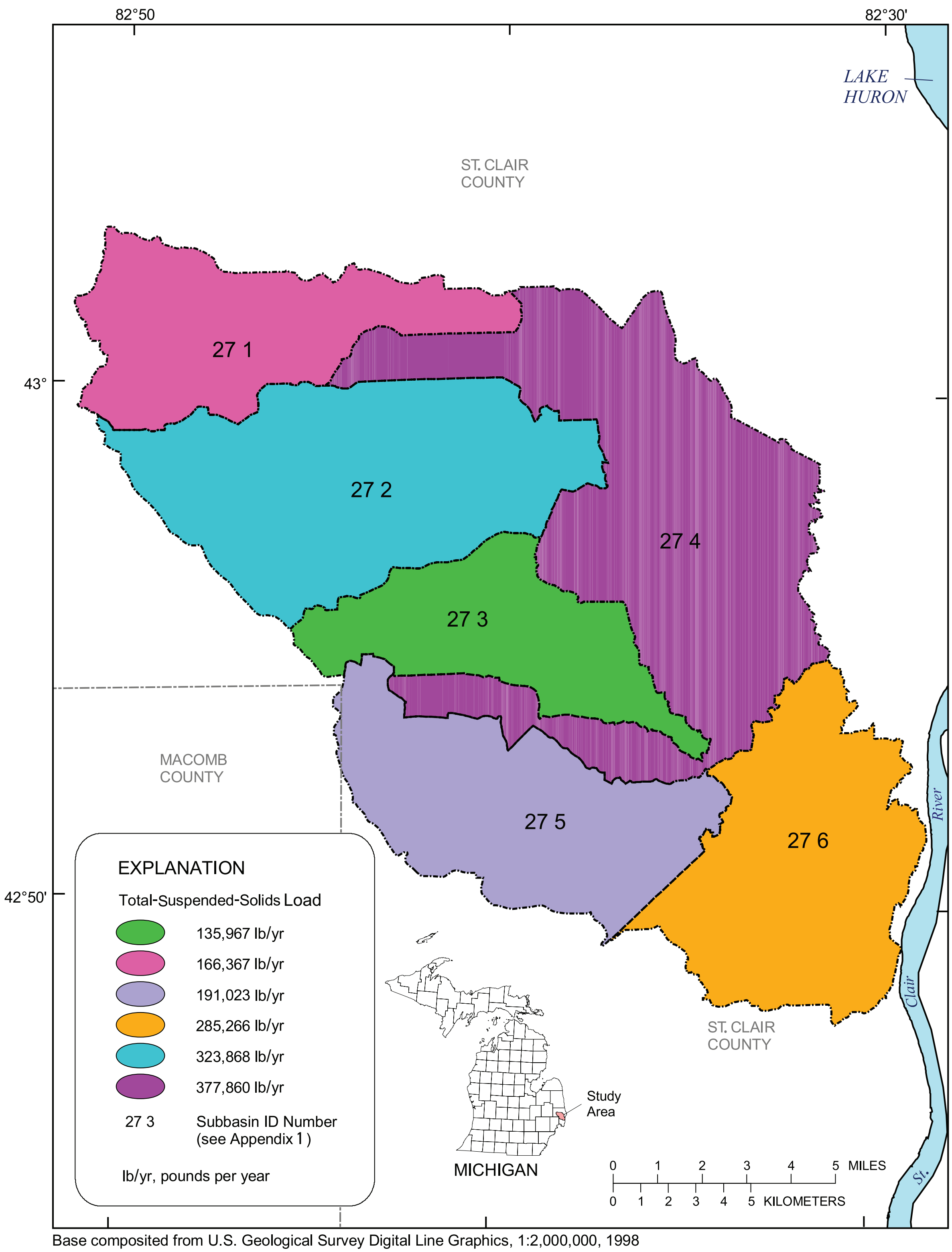

Figure 19. Range of total-suspended-solids loads in subbasins in the Pine River basin (based on 2001 land-use data).

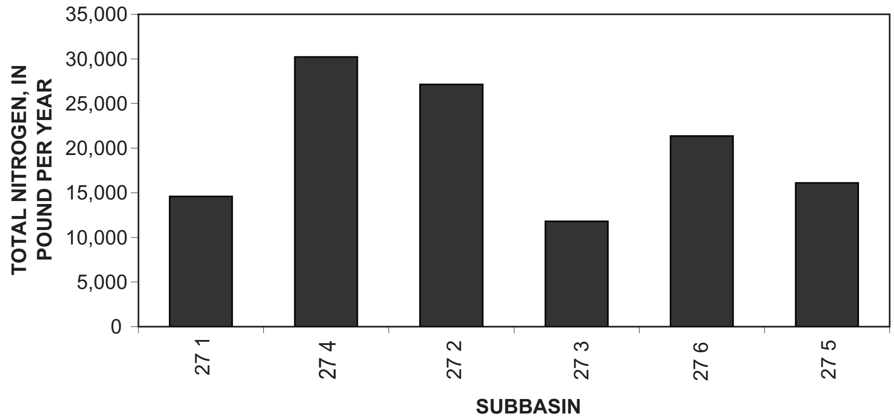

Figure 20. Distribution of total-nitrogen loads among Pine River subbasins (based on 2001 land-use data).

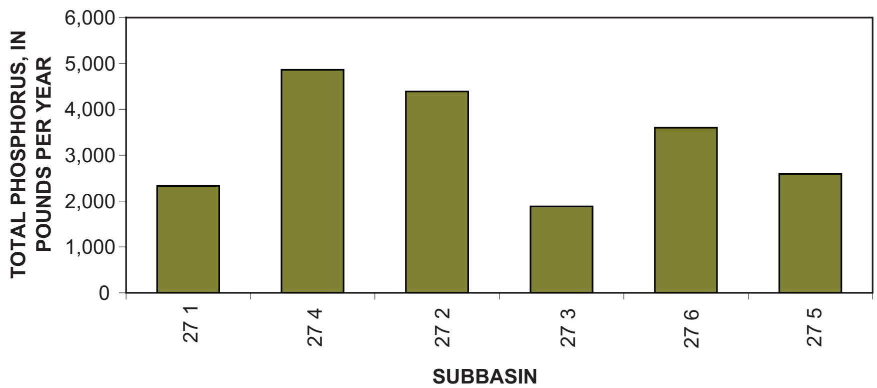

Figure 21. Distribution of total-phosphorus loads among Pine River subbasins (based on 2001 land-use data).

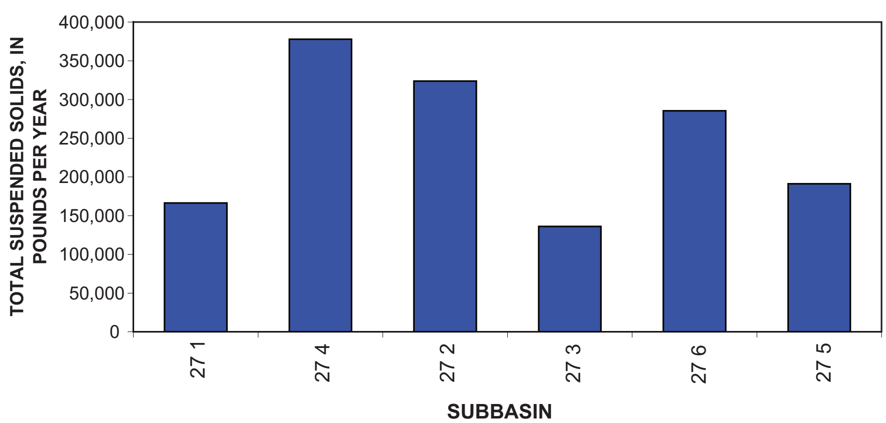

Figure 22. Distribution of total-suspended-solids loads among Pine River subbasins (based on 2001 land-use data).

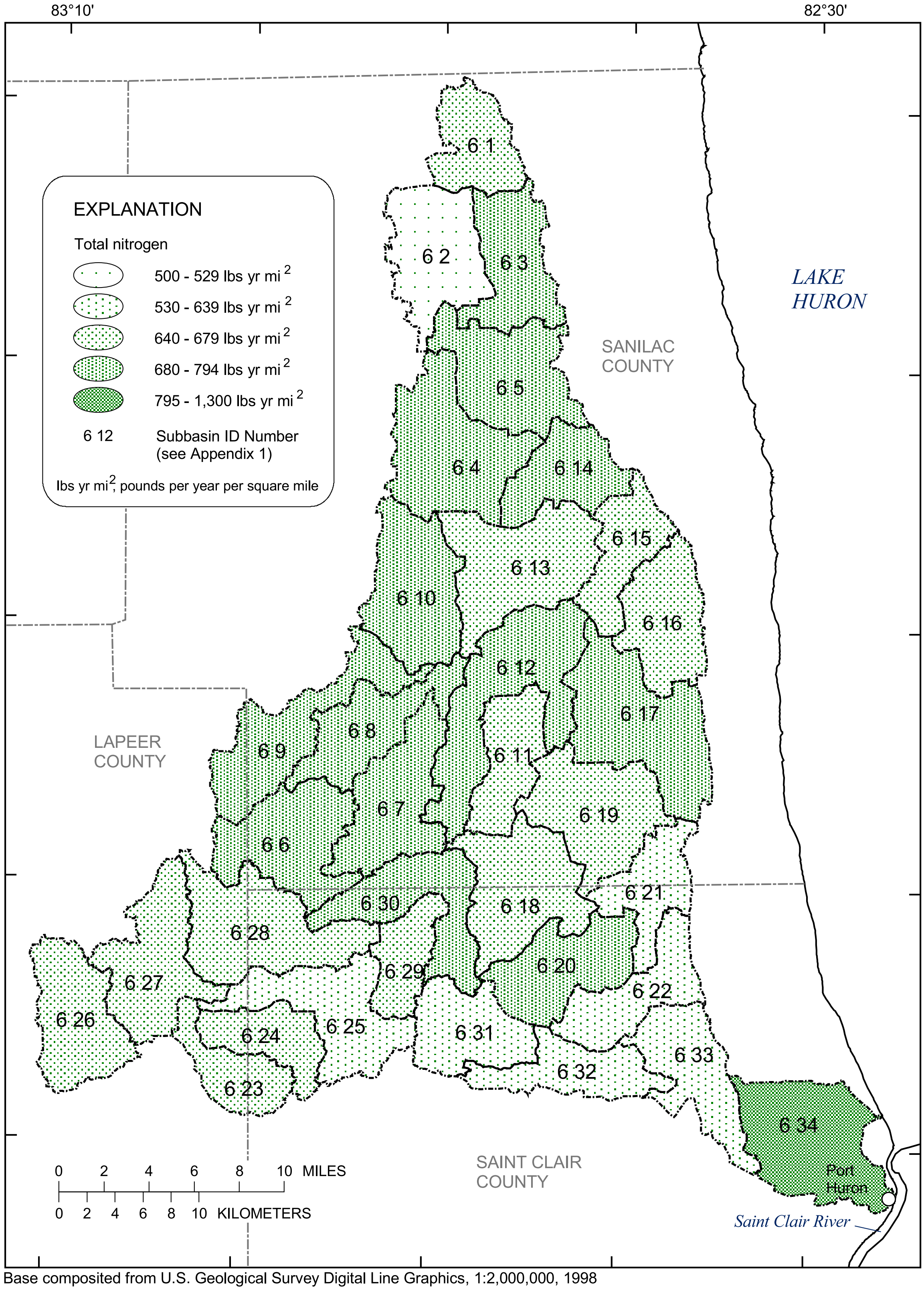

Figure 23. Range of normalized total-nitrogen loads in subbasins in the Black River basin (based on 2001 land-use data).

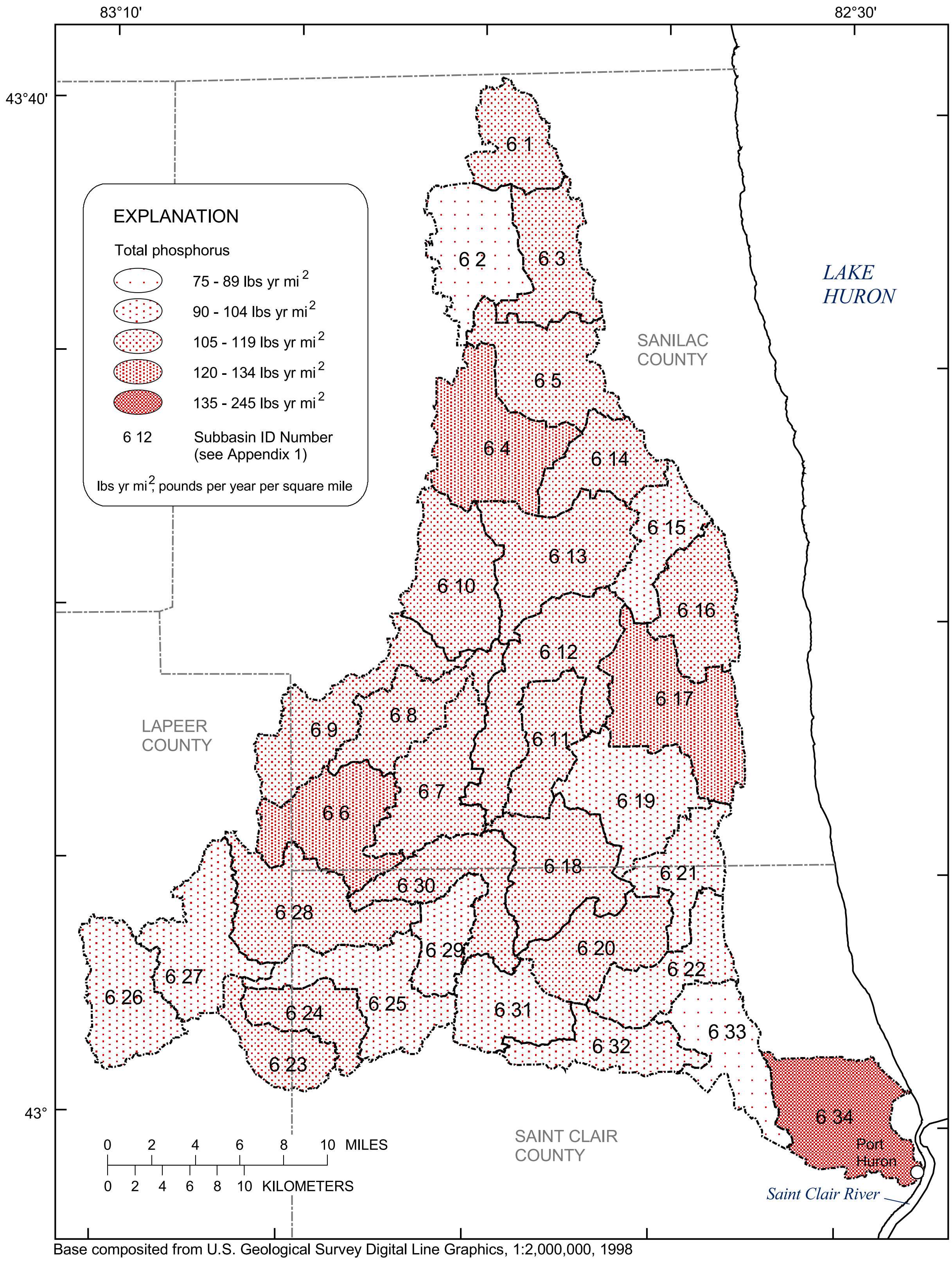

Figure 24. Range of normalized total-phosphorus loads in subbasins in the Black River basin (based on 2001 land-use data).

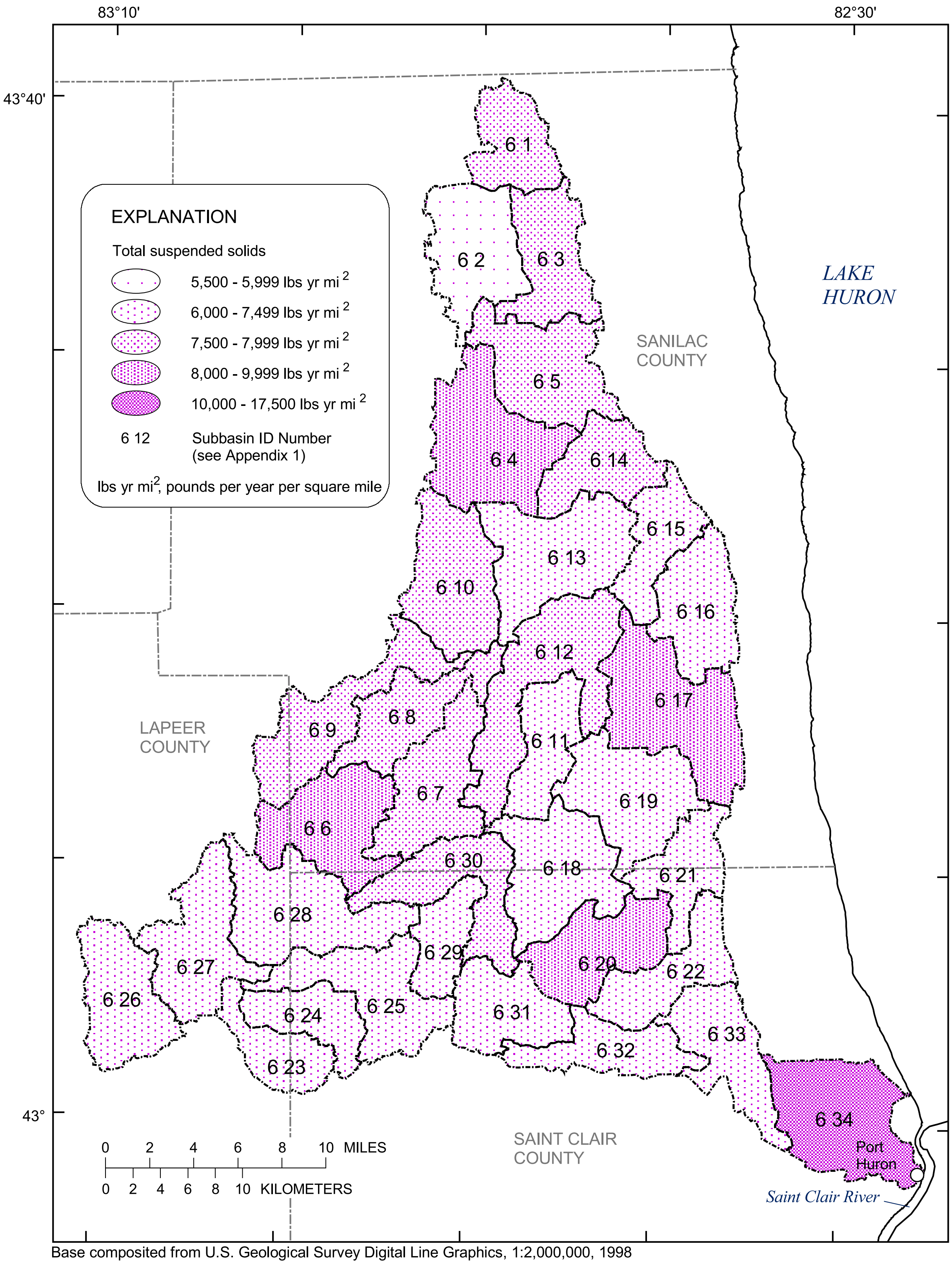

Figure 25. Range of normalized total-suspended solids loads in subbasins in the Black River basin (based on 2001 land-use data).

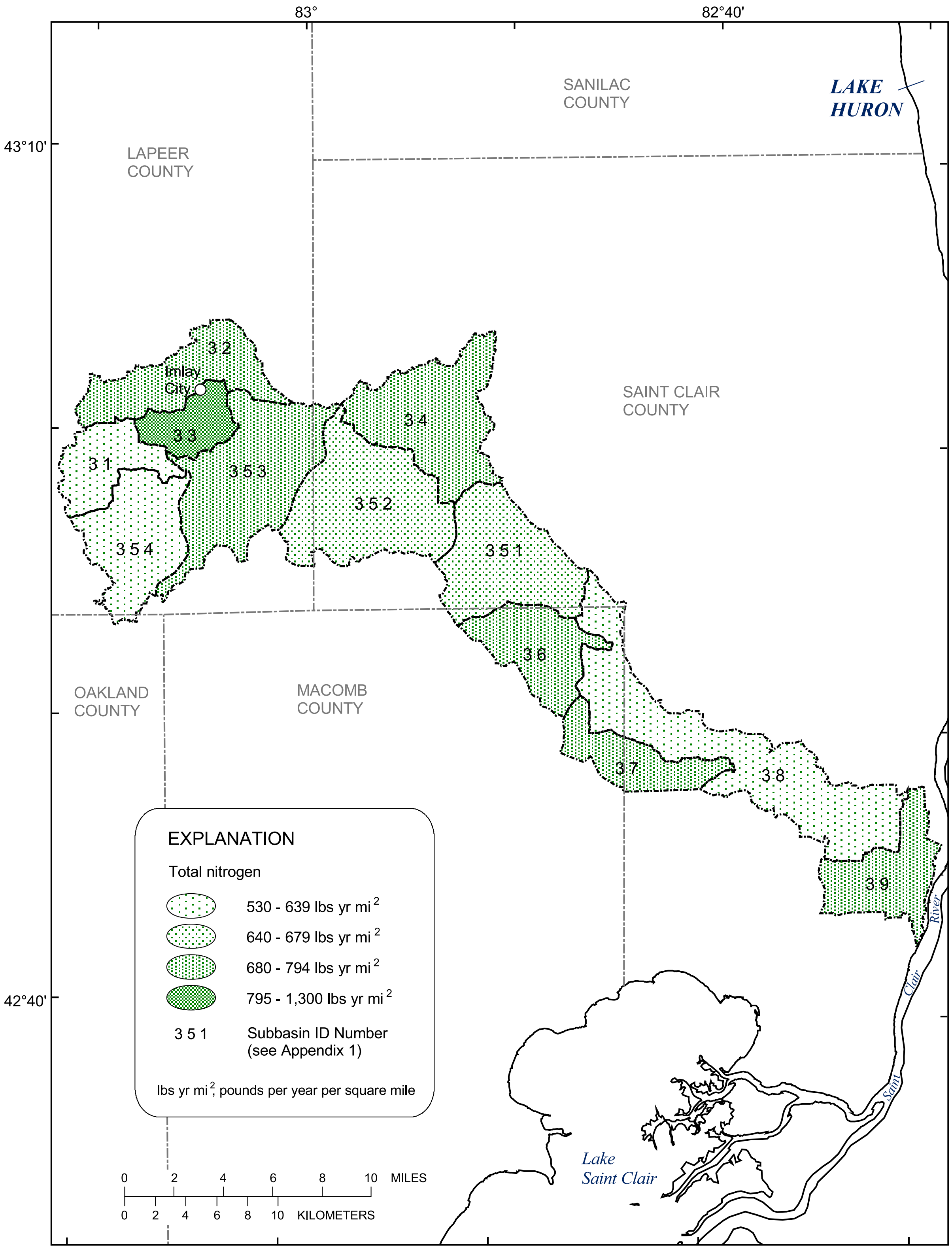

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Figure 26. Range of normalized total-nitrogen loads in subbasins in the Belle River basin (based on 2001 land-use data).

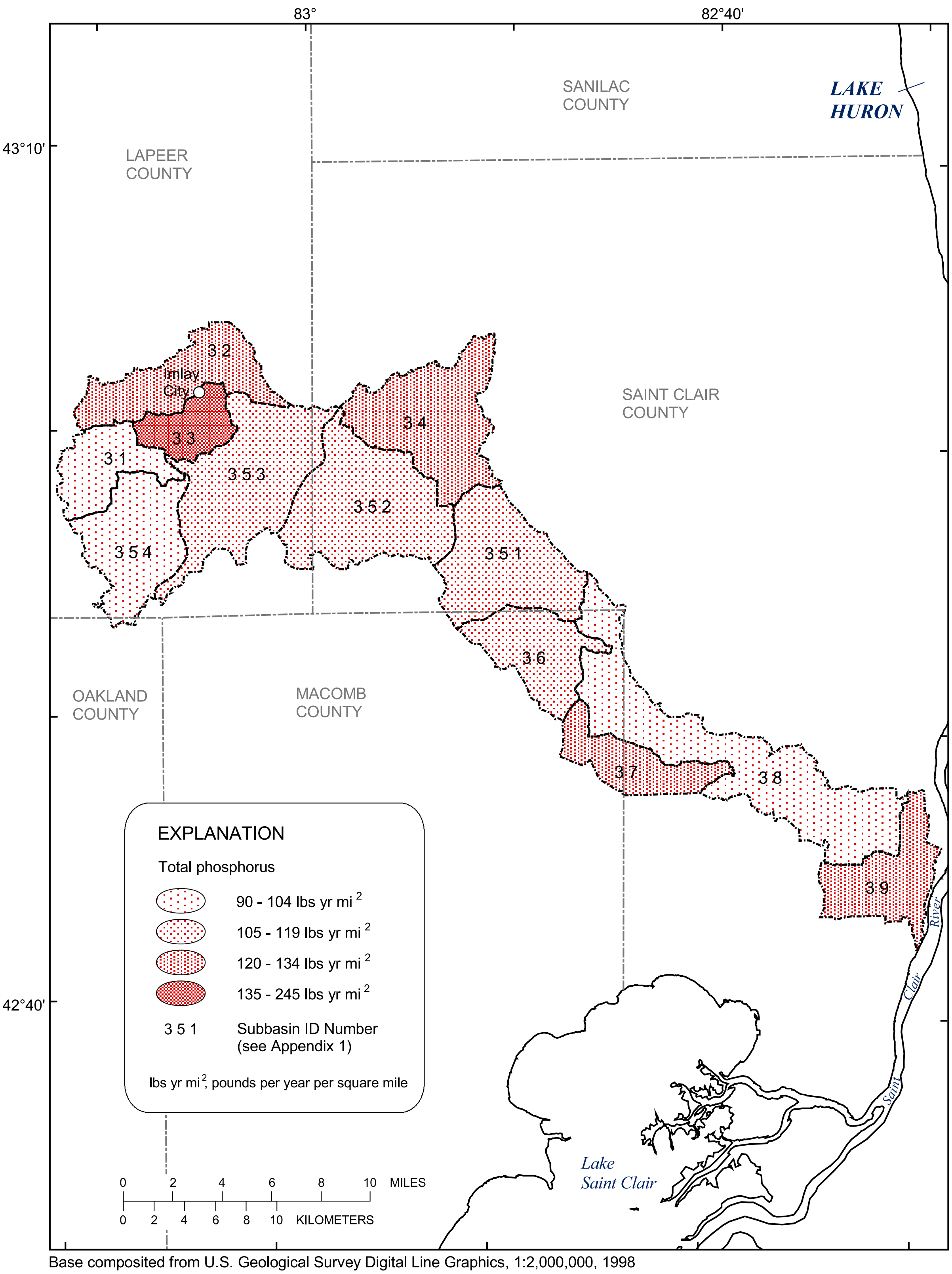

Figure 27. Range of normalized total-phosphorus loads in subbasins in the Belle River basin (based on 2001 land-use data).

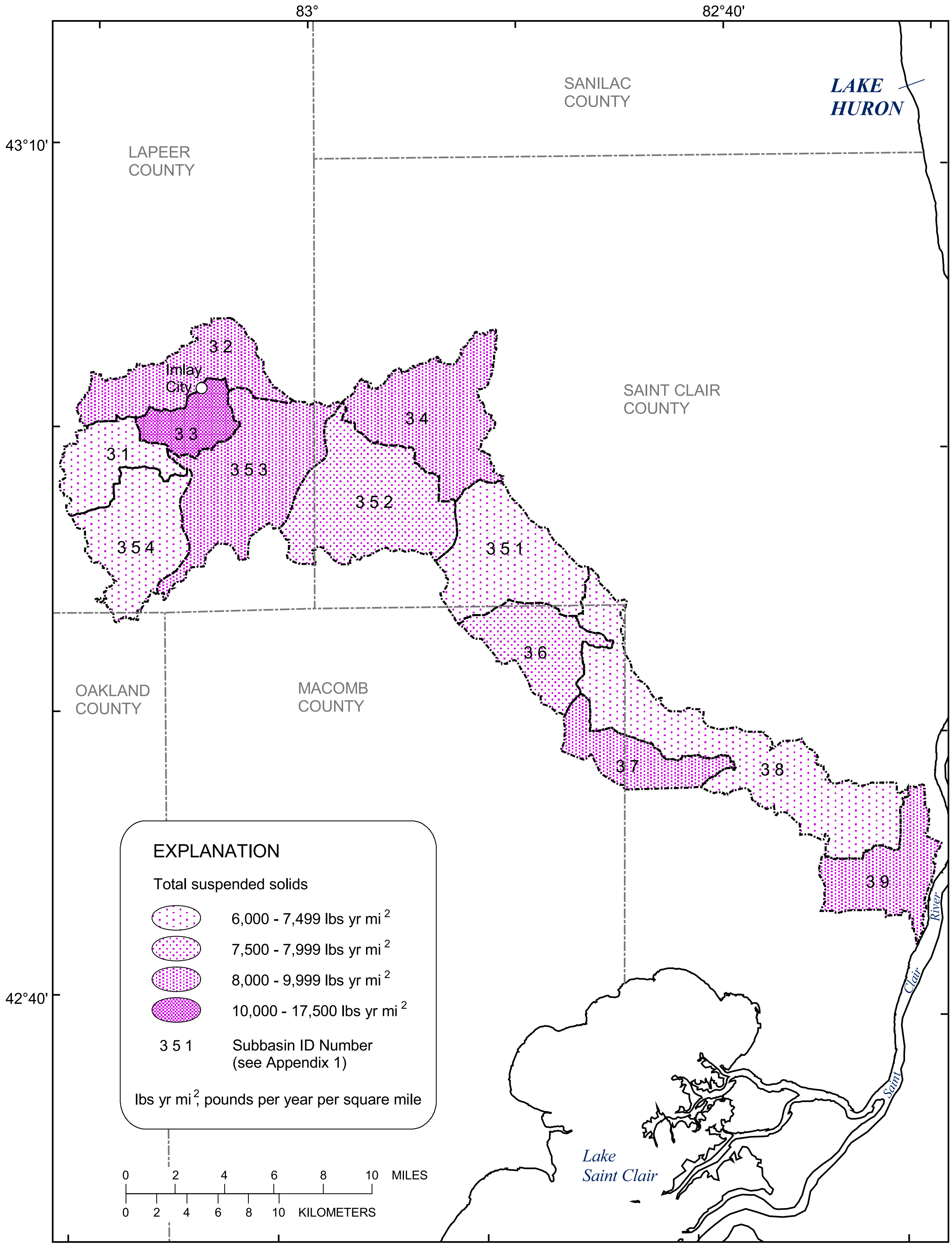

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Figure 28. Range of normalized total-suspended solids loads in subbasins in the Belle River basin (based on 2001 land-use data).

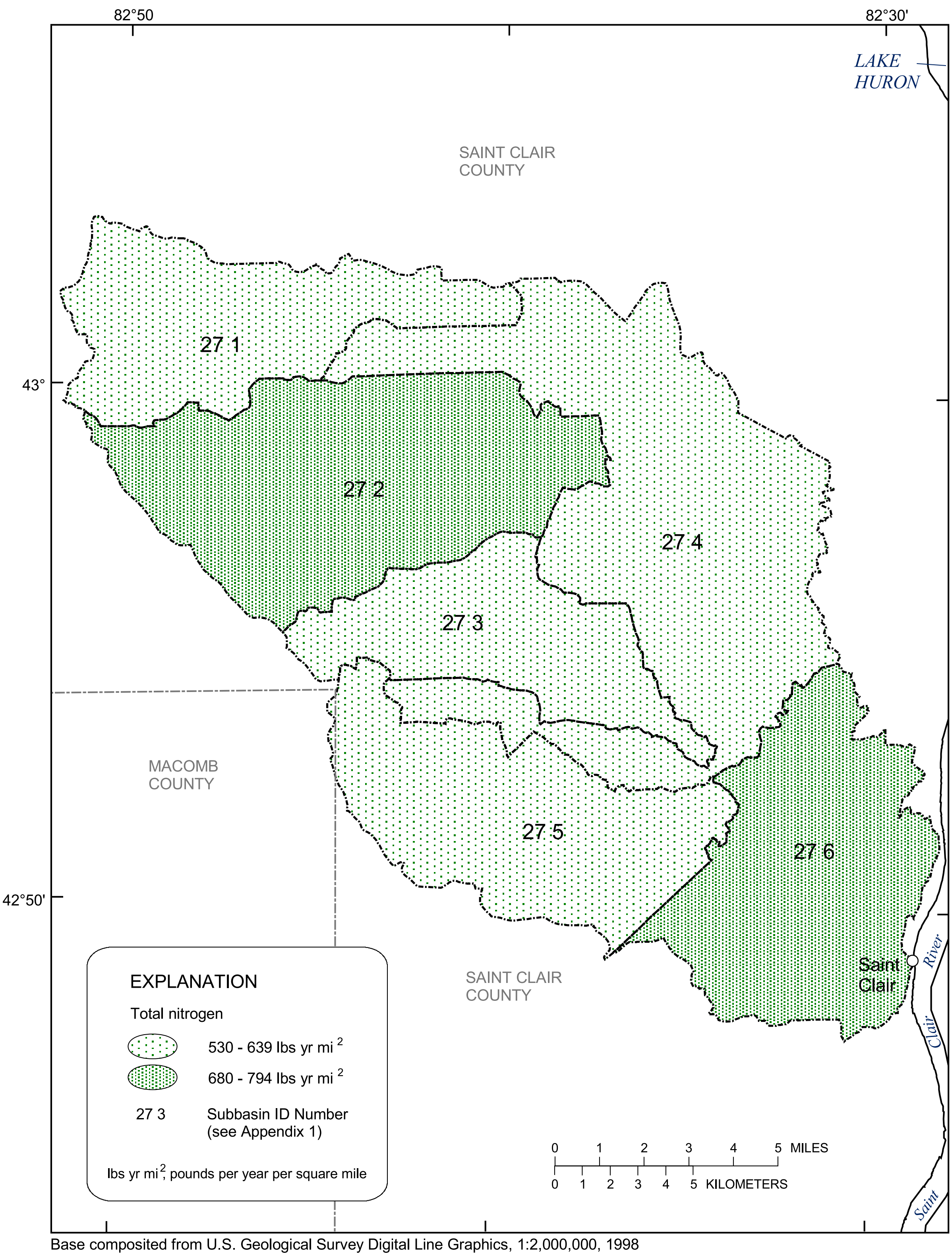

Figure 29. Range of normalized total-nitrogen loads in subbasins in the Pine River basin (based on 2001 land-use data).

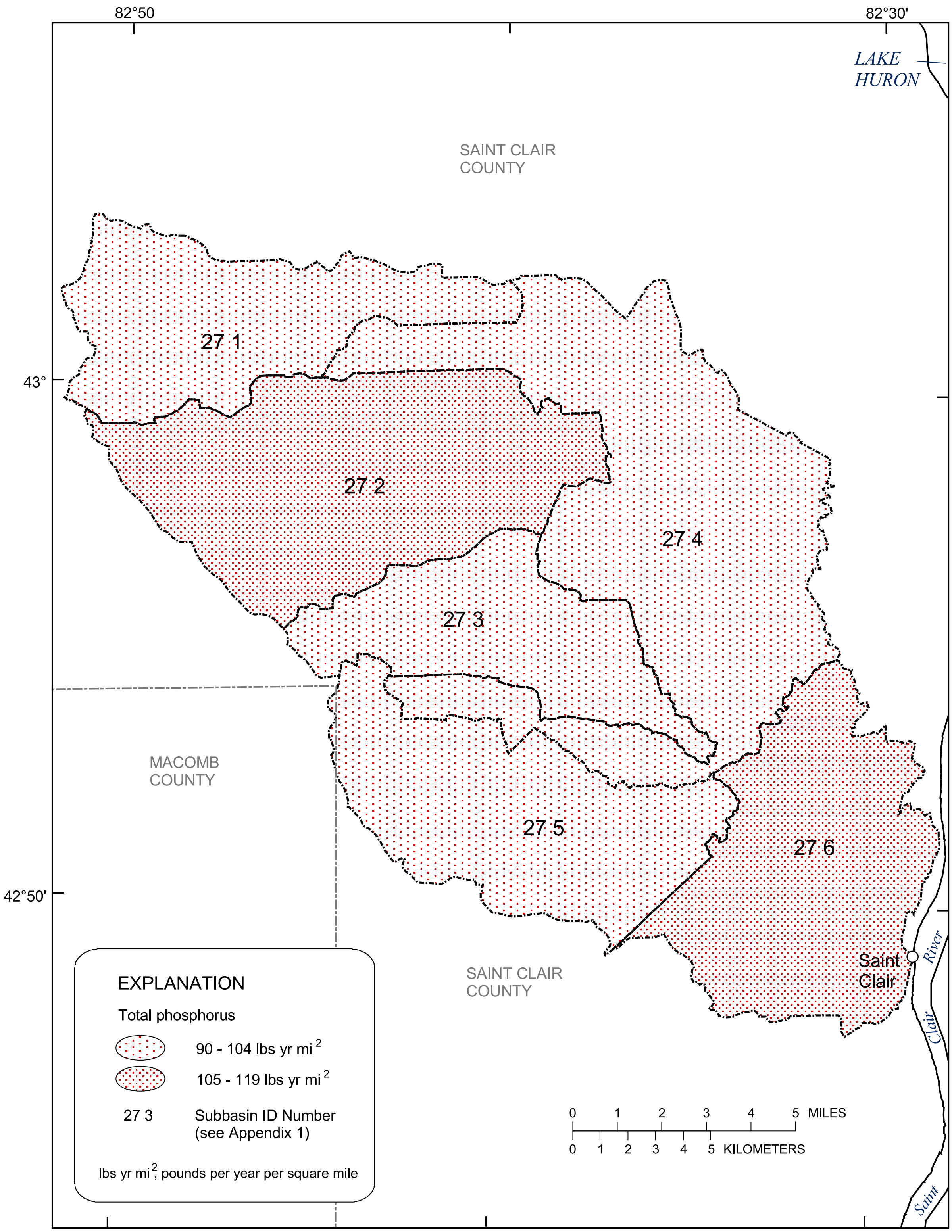

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Figure 30. Range of normalized total-phosphorus loads in subbasins in the Pine River basin (based on 2001 land-use data).

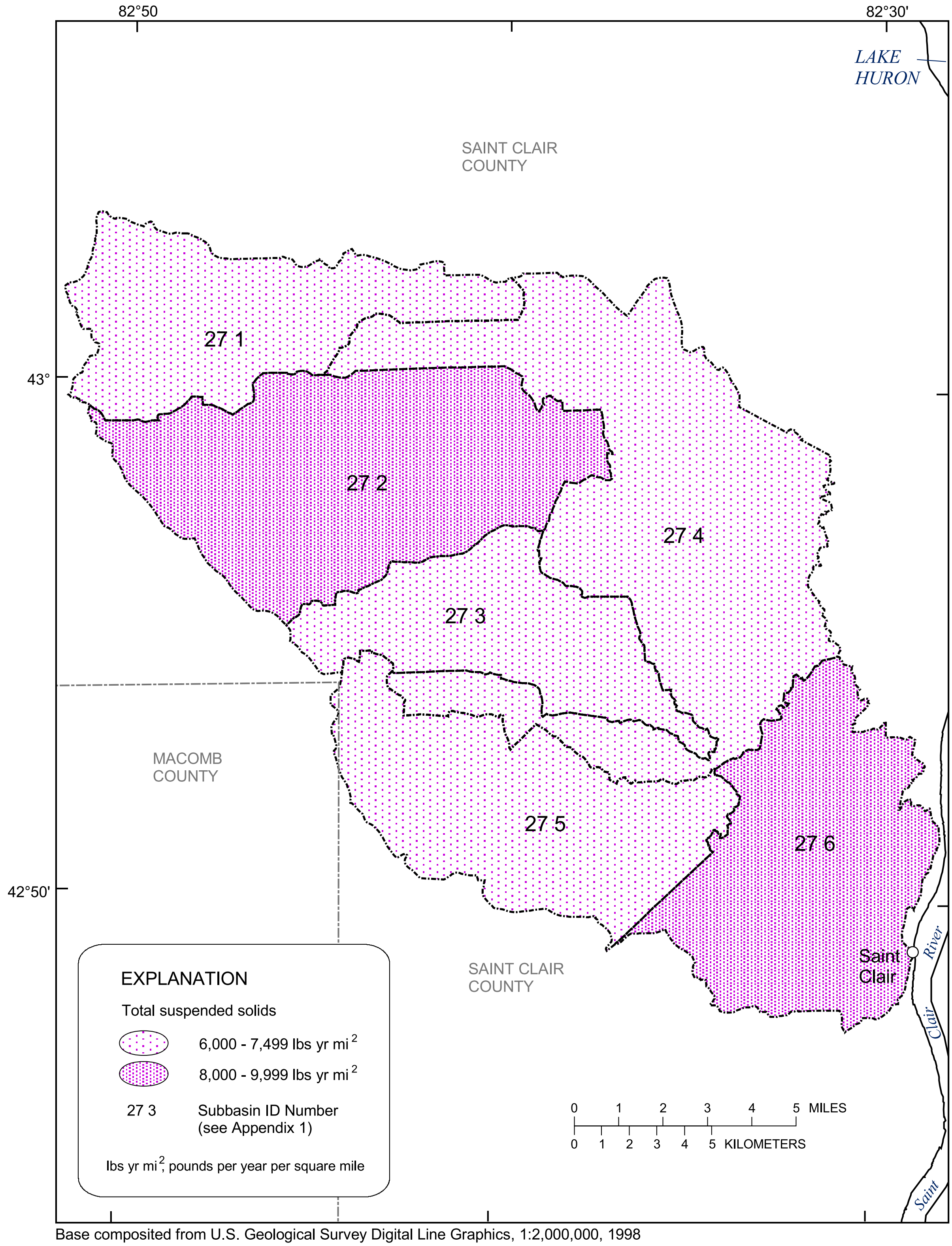

Figure 31. Range of normalized total-suspended solids loads in subbasins in the Pine River basin (based on 2001 land-use data).

Appendix 1

PLOAD Results for the Black, Belle, and Pine River Basins Based on the 2001 Land-Use-Data

Table 1- 1. PLOAD results for the Black River basin based on the 2001 land-use data.
[mi^2, square miles; lb/yr, pounds per year; mg/L, milligrams per liter; TSS, total suspended solids]

Subbasin identifier	Area (mi^2)	Total nitrogen (lb/yr)	Total phosphorous (lb/yr)	TSS (lb/yr)	Total nitrogen (mg/L)	Total phosphorous (mg/L)	TSS (mg/L)
6 1	14.9	10023	1563	113302	1.71	0.27	19.35
6 3	19	13404	2165	148501	2.28	0.37	25.28
6 2	22.2	11157	1747	122903	1.57	0.25	17.24
6 5	24.2	17355	2813	190402	2.33	0.38	25.61
6 4	29	23016	3841	263143	2.27	0.38	25.95
6 14	15.9	11266	1841	124093	2.24	0.37	24.64
6 15	14.6	9363	1495	104414	2.14	0.34	23.91
6 13	28.5	19012	3036	207651	2.23	0.36	24.39
6 10	24.2	16962	2717	185025	2.39	0.38	26.06
6 16	19.5	12765	2053	141567	2.12	0.34	23.50
6 12	31.2	21708	3508	240064	2.29	0.37	25.37
6 17	31.1	22928	3808	262738	2.09	0.35	24.00
6 9	23.6	17249	2796	187936	2.33	0.38	25.34
6 8	18.2	12644	2023	138288	2.40	0.38	26.21
6 11	15.1	10250	1639	112402	2.33	0.37	25.57
6 7	22.5	15576	2505	170998	2.36	0.38	25.91
6 19	24.9	16157	2582	178178	2.22	0.35	24.47
6 6	23.5	17444	2842	191772	2.38	0.39	26.15
6 21	14.5	8968	1419	108160	1.81	0.29	21.82
6 18	25.6	16725	2679	186368	2.16	0.35	24.03
6 30	20.3	14029	2341	160718	2.12	0.35	24.29
6 28	27.9	18575	2969	204841	2.28	0.36	25.12
6 27	23.2	15211	2418	168708	2.03	0.32	22.48
6 29	11.3	7310	1164	80985	2.13	0.34	23.63
6 22	16.9	10663	1700	122126	1.78	0.28	20.37
6 20	20.3	14555	2328	166497	2.05	0.33	23.40
6 25	23.2	14644	2331	166426	2.08	0.33	23.65
6 26	20.6	13557	2143	147636	1.56	0.25	16.98
6 31	17.3	10511	1678	119624	2.04	0.33	23.17
6 33	19.2	10211	1628	125378	1.33	0.21	16.39
6 24	12.8	8449	1350	93027	2.23	0.36	24.50
6 23	11.9	7850	1249	86603	2.11	0.34	23.33
6 32	15.3	9705	1558	112925	1.87	0.30	21.80
6 34	28	36355	6848	479882	1.75	0.33	23.10
Average		14,576	2,376	165,097			
Total or Sum		495,599	80,777	5,613,282			

Table 1- 2. PLOAD results for the Belle River basin based on the 2001 land-use data.
[mi^2, square miles; lb/yr, pounds per year; mg/L, milligrams per liter; TSS, total suspended solids]

Subbasin identifier	Area (mi^2)	Total nitrogen (lb/yr)	Total phosphorous (lb/yr)	TSS (lb/yr)	Total nitrogen (mg/L)	Total phosphorous (mg/L)	TSS (mg/L)
3 4	23.1	16817	2774	200964	1.98	0.33	23.66
3 2	16.1	12225	1988	137903	1.63	0.27	18.41
3 3	7.6	8107	1414	103883	1.93	0.34	24.71
3 1	10.5	6341	1007	73613	1.73	0.27	20.11
3 8	38	22729	3691	267505	1.82	0.29	21.37
3 6	13.5	9213	1487	101625	2.30	0.37	25.42
3 7	10.6	7836	1334	101670	1.85	0.32	24.05
3 9	13.8	10235	1677	125679	1.55	0.25	19.06
3 5 4	17.8	11345	1817	129075	1.78	0.28	20.20
3 5 1	21.7	14144	2278	158216	2.17	0.35	24.24
3 5 2	27.5	18611	2982	211718	2.15	0.34	24.41
3 5 3	27	18957	3044	219194	2.04	0.33	23.57
Average		13047	2124	152587			
Total or Sum		156561	25493	183045			

Table 1- 3. PLOAD results for the Pine River basin based on the 2001 land-use data.
[mi^2, square miles; lb/yr, pounds per year; mg/L, milligrams per liter; TSS, total suspended solids]

Subbasin identifier	Area (mi^2)	Total nitrogen (lb/yr)	Total phosphorous (lb/yr)	TSS (lb/yr)	Total nitrogen (mg/L)	Total phosphorous (mg/L)	TSS (mg/L)
27 1	23.7	14591	2331	166367	2.05	0.33	23.40
27 4	53.4	30210	4863	377860	1.49	0.24	18.67
27 2	38.8	27141	4388	323868	2.02	0.33	24.13
27 3	19.8	11804	1885	135967	1.99	0.32	22.88
27 6	31	21359	3600	285266	1.67	0.28	22.35
27 5	28.1	16106	2588	191023	1.81	0.29	21.48
Average		20202	3276	246725			
Total or Sum		121212	19655	1480352			

Appendix 2

PLOAD Results for the Black, Belle, and Pine River Basins Based on the 1992 Land-Use Data

Table 2- 1. PLOAD results for the Black River basin based on the 1992 land-use data.
[mi^2, square miles; lb/yr, pounds per year; mg/L, milligrams per liter; TSS, total suspended solids]

Subbasin identifier	Area (mi^2)	Total nitrogen (lb/yr)	Total phosphorous (lb/yr)	TSS (lb/yr)	Total nitrogen (mg/L)	Total phosphorous (mg/L)	TSS (mg/L)
6 1	14.9	10031	1564	113438	1.71	0.27	19.35
6 3	19	13432	2170	148842	2.28	0.37	25.28
6 2	22.2	11176	1750	123122	1.57	0.25	17.26
6 5	24.2	17351	2812	190316	2.34	0.38	25.61
6 4	29	23081	3852	263850	2.27	0.38	25.95
6 14	15.9	11269	1842	124124	2.24	0.37	24.63
6 15	14.6	9365	1496	104432	2.14	0.34	23.90
6 13	28.5	19011	3035	207639	2.23	0.36	24.40
6 10	24.2	16973	2719	185141	2.39	0.38	26.06
6 16	19.5	12778	2055	141721	2.12	0.34	23.50
6 12	31.2	21707	3508	240058	2.29	0.37	25.37
6 17	31.1	22940	3810	262863	2.09	0.35	24.00
6 9	23.6	17278	2800	188252	2.33	0.38	25.34
6 8	18.2	12643	2023	138285	2.40	0.38	26.20
6 11	15.1	10252	1640	112418	2.33	0.37	25.58
6 7	22.5	15578	2506	171015	2.36	0.38	25.91
6 19	24.9	16157	2582	178187	2.22	0.35	24.47
6 6	23.5	17444	2842	191767	2.38	0.39	26.15
6 21	14.5	8979	1420	108372	1.81	0.29	21.83
6 18	25.6	16711	2677	186106	2.16	0.35	24.06
6 30	20.3	14136	2358	161856	2.12	0.35	24.31
6 28	27.9	18581	2969	204899	2.28	0.36	25.12
6 27	23.2	15224	2421	168871	2.03	0.32	22.48
6 29	11.3	7309	1164	80968	2.13	0.34	23.63
6 22	16.9	10710	1707	122889	1.77	0.28	20.33
6 20	20.3	14542	2326	166271	2.05	0.33	23.43
6 25	23.2	14646	2332	166439	2.08	0.33	23.65
6 26	20.6	13585	2148	147920	1.56	0.25	17.00
6 31	17.3	10512	1678	119630	2.04	0.33	23.17
6 33	19.2	10209	1627	125382	1.33	0.21	16.38
6 24	12.8	8446	1350	93001	2.22	0.36	24.49
6 23	11.9	7854	1249	86625	2.11	0.34	23.30
6 32	15.3	9706	1558	112929	1.87	0.30	21.81
6 34	28	33789	6392	432851	1.73	0.33	22.21

Table 2- 2. PLOAD results for the Belle River basin based on the 1992 land-use data.
[mi^2, square miles; lb/yr, pounds per year; mg/L, milligrams per liter; TSS, total suspended solids]

Subbasin identifier	Area (mi^2)	Total nitrogen (lb/yr)	Total phosphorous (lb/yr)	TSS (lb/yr)	Total nitrogen (mg/L)	Total phosphorous (mg/L)	TSS (mg/L)
3 4	23.1	17004	2805	203174	1.98	0.33	23.66
3 2	16.1	12384	2014	139807	1.63	0.27	18.42
3 3	7.6	8186	1427	104873	1.93	0.34	24.69
3 1	10.5	6454	1024	74881	1.73	0.28	20.13
3 8	38	22998	3736	270639	1.82	0.30	21.37
3 6	13.5	9315	1503	102732	2.31	0.37	25.42
3 7	10.6	7985	1360	103971	1.85	0.32	24.13
3 9	13.8	10381	1701	127451	1.55	0.25	19.08
3 5 4	17.8	11474	1837	130601	1.77	0.28	20.19
3 5 1	21.7	14302	2303	159978	2.17	0.35	24.24
3 5 2	27.5	18833	3017	214235	2.15	0.34	24.41
3 5 3	27	19186	3081	221816	2.04	0.33	23.57

Table 2- 3. PLOAD results for the Pine River basin based on the 1992 land-use data.
[mi^2, square miles; lb/yr, pounds per year; mg/L, milligrams per liter; TSS, total suspended solids]

Subbasin identifier	Area (mi^2)	Total nitrogen (lb/yr)	Total phosphorous (lb/yr)	TSS (lb/yr)	Total nitrogen (mg/L)	Total phosphorous (mg/L)	TSS (mg/L)
27 1	23.7	14559	2326	165852	2.06	0.33	23.43
27 4	53.4	30311	4879	379529	1.49	0.24	18.66
27 2	38.8	27073	4378	323135	2.02	0.33	24.13
27 3	19.8	11870	1896	136590	1.99	0.32	22.90
27 6	31	20301	3476	274017	1.64	0.28	22.19
27 5	28.1	15836	2544	186377	1.84	0.30	21.62

Appendix 3

Land-Use Data-Source Information

Table 3- 1. Land-use data-source information.

1992 – Michigan 1992 NLCD GRID file by County

These 1992 land-cover data were published in 2002 by the Michigan Center for Geographic Information. The time period of the data used to generate this land cover is 1992. Derived from LandSat Thematic Mapper (TM) satellite data, the National Land Cover Data (NLCD) is a 21-class land-cover classification scheme. The spatial resolution of the data is 30 meters. The Michigan data set was cut out from larger regional data sets that are mosaics of LandSat TM scenes. The TM multiband mosaics were processed using an unsupervised clustering algorithm. Both leaves-off and leaves-on data sets were analyzed. The resulting clusters were then labeled using aerial photography and ground observations. Clusters that represented more than one land-cover category were also identified and, using various ancillary data sets, models developed to split the confused clusters into the correct land-cover categories.

2001 – IFMAP/GAP Lower Peninsula Land Cover

These 2001 land-cover data were published in 2003 by the Michigan Department of Natural Resources, Forest, Mineral and Fire Management Division. The time period of the data used to generate this land covers ranges from 1997 to 2001. The spatial resolution of the data is 30 meters. This land-cover data set was derived from LandSat TM imagery of three seasons: spring (leaf-off), summer, and fall (senescence). This data was filtered using a 3x3 majority kernel filter in each of the following land-cover classes: Upland Forest, Lowland Forest, Upland Openland, and Open Wetland.

Atiq U. Syed and Richard S. Jodoin—**Estimation of Nonpoint-Source Loads of Total Nitrogen, Total Phosphorous, and Total Suspended Solids in the Black, Belle, and Pine River Basins, Michigan, by Use of the PLOAD Model**—Scientific Investigations Report 2006-5071

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