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Unit-Area Loads of Suspended Sediment, Suspended Solids, and Total Phosphorus From Small Watersheds in Wisconsin

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Introduction

Watershed planners in the Wisconsin Department of Natural Resources (WDNR) and in Wisconsin county governments use estimates of loads of total solids and total phosphorus in streams for numerous management purposes. A few examples of these are to establish load reduction goals, to estimate the relative magnitude of nonpoint sources compared to point sources, and to estimate phosphorus loads to lakes. Solids and phosphorus are two of the most common nonpoint contaminants resulting from agricultural activity. Loads can be estimated either by monitoring the water quantity and water quality in a watershed or by modeling those same factors. Monitoring is the most accurate method for load estimation, but it is also time consuming and expensive. A simple method of estimating loads of chemical constituents or suspended solids in a watershed is to use unit-area loads that have been calculated from monitored data to estimate loads in watersheds where monitoring data are not available. A "unit-area load" is defined as the mass of a particular constituent transported by a stream, divided by the drainage area of the watershed.

The U.S. Geological Survey (USGS), in cooperation with the WDNR, is studying the factors that affect the loads of total solids and total phosphorus in Wisconsin watersheds. The objectives of that study are to:

- Tabulate unit-area loads and land-use characteristics for selected monitored watersheds in rural and urban areas of Wisconsin.
- Evaluate the effects of land-use characteristics, drainage area, and ecoregion on unit-area loads.
- Determine an appropriate grouping of unit-area loads for applications in different watersheds in Wisconsin.

This fact sheet summarizes unit-area loads of total suspended sediment or total suspended solids (a measure similar to total suspended sediment), and unit-area loads of total phosphorus from monitored watersheds in Wisconsin.

Watershed Characteristics

The USGS has monitored water quality in a number of watersheds in Wisconsin as part of studies conducted in cooperation with national, regional, state, and local agencies. All watersheds listed in this fact sheet are represented in USGS data bases for total suspended sediment, total suspended solids, and total phosphorus loads (fig. 1). The methods for analyzing total suspended sediment and total suspended solids are somewhat different. Thus, for water samples that contain large suspended particles (sand size or greater), the reported value of total suspended solids may be slightly less than the value reported for total suspended sediment analysis. For the purposes of this fact sheet, however, the two constituents are considered to be interchangeable.

The following criteria, which were met by 52 watersheds, were used to select the watersheds included in this summary:

- Data were collected from 1975 through 1996.
- Drainage areas are less than 200 square miles.
- One or more years of continuous data on sediment (or solids) and phosphorus loads are available.
- Point sources contribute less than 15 percent of the total monitored yearly load.

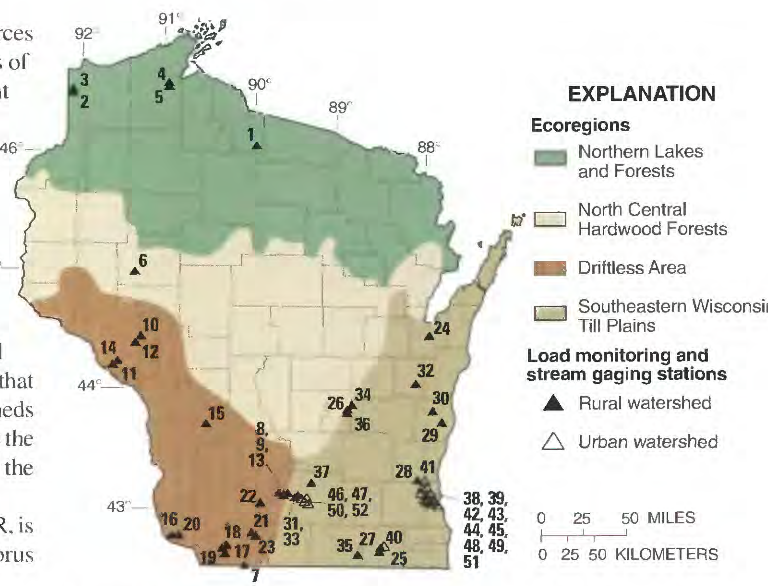

Figure 1. Location of watersheds and gaging stations.

Land use, drainage area, ecoregion, and other watershed characteristics such as slope, soil type, and climate affect the magnitude and variability of unit-area loads. Land-use data for each of the watersheds (table 1) were compiled by the WDNR Research Center on the basis of aerial-photograph interpretation from photographs taken throughout the 1970's and 1980's (U.S. Geological Survey, 1990). Data follow the format of the Land Use and Land Cover classification system (Anderson and others, 1976). Of the 52 selected watersheds, 7 are rural with 50 percent or more land in forest, and 30 are rural with 50 percent or more land in agriculture; the remaining 15 watersheds are more than 20 percent urban. Watersheds are grouped in table 1 by ecoregions (Omernick and Gallant, 1988) in areas of similar climate, landforms, soil, natural vegetation, hydrology, or other ecologically relevant variables. All but six watersheds monitored were in either the Driftless Area or the Southeastern Wisconsin Till Plains. All watersheds shown as having 20 percent or greater urban land use are in the Southeastern Wisconsin Till Plains in the Milwaukee and Madison areas; the data from these watersheds are summarized separately from those for rural watersheds. Previous studies indicate that the quality of biota and habitat of Wisconsin streams draining watersheds with greater than 10 to 20 percent urban land use is not as good as the quality of biota and habitat of more rural streams (Wang and others, 1997).

Calculated Unit-Area Loads

Loads of total suspended sediment (or solids) and phosphorus from the selected watersheds were computed using one of two methods, depending on the sampling protocol for each individual sampling site. For most sites, multiple samples were collected during periods of storm runoff, and additional samples were collected during low-flow periods. For these sites, the integrator method (Porterfield, 1972) was used to compute total annual loads. For the remainder of the sites, multiple samples were collected during each storm runoff period and composited into a single sample; analyses of

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Table 1. Land use, drainage area, and unit-area loads summary statistics for selected monitored watersheds in Wisconsin

	Watershed and monitoring station	USGS Downstream order number	Drainage Area (square miles)	Land-use percentage						Unit-area loads of total suspended solids or sediment (tons per square mile)				Unit-area loads of total phosphorus (pounds per square mile)			
				Urban	Agriculture	Forest	Water	Wetland	Other	Minimum	Maximum	Median	Years of Record	Minimum	Maximum	Median	Years of Record
	**Northern Lakes and Forests Ecoregion**																
1	Bear River near Manitowish Waters	05357335	81.3	0.9	0.1	60.0	22.3	16.4	0.3	2	3	3	3	23	26	24	3
2	Little Balsam Creek near Patzau	04024315	5.2	0.0	6.0	81.2	0.6	12.1	0.0	29	116	73	2	—	—	372	e
3	Little Balsam Creek Tributary near Patzau	04024318	0.5	0.0	49.9	50.1	0.0	0.0	0.0	31	133	82	2	—	—	320	e
4	Pine Creek Tributary near Moquah	04026348	0.6	0.0	15.9	84.1	0.0	0.0	0.0	5	27	16	2	—	—	106	e
5	Pine Creek near Moquah	04026349	21.5	0.0	27.7	72.3	0.0	0.0	0.0	113	348	231	2	—	—	943	e
	**North Central Hardwood Forests Ecoregion**																
6	Duncan Creek Tributary near Tilden	05364850	4.2	0.0	91.9	8.1	0.0	0.0	0.0	17	275	146	2	387	1600	992	2
	**Driftless Area Ecoregion**																
7	Apple River near Shullsburg	05418731	9.3	0.0	99.2	0.8	0.0	0.0	0.0	137	282	209	2	461	1400	929	2
8	Black Earth Creek at Cty P	05406460	14.6	2.6	68.1	27.9	0.3	0.0	1.1	31	70	50	2	106	312	209	2
9	Brewery Creek at Cross Plains	05406470	10.5	0.9	81.9	16.7	0.5	0.0	0.0	4	251	63	8	67	1020	346	8
10	Bruce Valley Creek near Pleasantville	05379288	10.1	0.0	66.4	33.6	0.0	0.0	0.0	—	—	215	1	—	—	1600	1
11	Eagle Creek near Fountain City	05378185	14.3	0.0	37.1	62.9	0.0	0.0	0.0	274	557	429	4	623	1250	813	4
12	Elk Creek near Independence	05379305	99.7	0.1	66.6	33.3	0.0	0.0	0.0	—	—	200	1	—	—	1460	1
13	Garfoot Creek at Cross Plains	05406491	5.4	0.0	56.0	43.8	0.0	0.0	0.2	37	216	63	7	324	1310	528	7
14	Joos Valley Creek near Fountain City	05378183	5.9	0.0	36.7	63.3	0.0	0.0	0.0	237	493	304	4	537	109	752	4
15	Kickapoo River at Ontario	05407500	151	0.4	62.4	37.2	0.0	0.0	0.0	78	191	135	4	—	—	803	e
16	Kuenster Creek near North Andover	054134435	9.6	0.0	100.0	0.0	0.0	0.0	0.0	36	1010	332	3	240	3960	957	3
17	Madden Branch near Meekers Grove	05414920	15	0.0	100.0	0.0	0.0	0.0	0.0	239	684	462	2	749	2290	1520	2
18	Madden Branch Tributary near Belmont	05414915	2.8	0.0	100.0	0.0	0.0	0.0	0.0	229	740	485	2	543	207	1310	2
19	Pats Creek near Belmont	05414894	5.4	0.0	100.0	0.0	0.0	0.0	0.0	200	309	254	2	681	1750	1210	2
20	Rattlesnake Creek near North Andover	05413449	42.4	0.0	99.2	0.8	0.0	0.0	0.0	139	837	200	3	722	3670	821	3
21	Steiner Branch near Waldwick	05433510	5.9	0.0	71.0	29.0	0.0	0.0	0.0	85	369	227	2	231	708	469	2
22	Trout Creek Site A near Barneveld	05406573	8.4	0.6	56.3	43.1	0.0	0.0	0.0	45	266	175	4	—	—	709	e
23	Yellowstone River near Blanchardville	05433500	28.5	0.0	99.0	1.0	0.0	0.0	0.0	54	220	137	2	—	—	683	e
	**Southeastern Wisconsin Till Plains Ecoregion–Rural**																
24	Bower Creek near DePere	04085119	14.8	0.0	99.4	0.6	0.0	0.0	0.0	49	751	131	4	618	1800	685	4
25	Delevan Lake Tributary at Delevan	05431018	10	1.0	94.7	2.2	0.4	1.7	0.0	4	12	8	2	41	59	50	2
26	Green Lake Inlet near Green Lake	04073468	53.5	5.6	85.1	1.9	0.6	6.3	0.5	7	67	15	9	—	—	*	e
27	Jackson Creek near Elkhorn	05431016	16.8	13.2	86.3	0.0	0.5	0.0	0.1	15	103	17	3	141	438	194	3
28	Little Menomonee River near Friestadt	04087050	8	10.4	84.5	3.6	0.0	0.0	1.6	15	62	39	2	201	455	328	2
29	Onion River near Sheboygan Falls	04085845	91.8	1.1	92.8	4.1	0.3	1.5	0.2	78	90	84	2	—	—	*	e
30	Otter Creek near Plymouth	040857005	9.5	5.7	85.9	6.1	1.4	0.6	0.2	9	91	26	6	85	588	246	6
31	Pheasant Branch at Middleton	05427948	18.3	8.4	90.3	0.1	0.0	0.0	1.1	14	350	81	14	183	1440	650	3
32	South Branch Manitowoc River at Hayton	04085395	109	2.6	87.2	5.8	0.1	4.2	0.1	5	6	5	2	—	—	84	e
33	South Fork Pheasant Branch at Hwy 14	05427945	5.7	15.1	84.3	0.0	0.0	0.0	0.5	61	97	63	3	—	—	340	e
34	Silver Creek near Ripon	040734644	36.2	7.9	85.2	0.8	0.2	5.8	0.2	11	48	19	9	176	666	283	9
35	Turtle Creek near Clinton	05431486	199	5.0	88.5	3.6	1.9	0.8	0.3	45	177	111	2	—	—	722	e
36	White Creek near Green Lake	04073462	3.1	0.3	92.7	7.1	0.0	0.0	0.0	24	1710	338	7	85	1400	458	7
37	Yahara River at Windsor	05427718	73.6	2.7	96.0	0.7	0.2	0.2	0.2	8	116	22	6	86	526	154	6
	**Southeastern Wisconsin Till Plains Ecoregion–Urban**																
38	Hawley Road Storm Sewer at Wauwatosa	04087130	1.8	100.0	0.0	0.0	0.0	0.0	0.0	—	—	17	1	—	—	127	e
39	Honey Creek at Wauwatosa	04087119	10.3	94.0	5.6	0.0	0.0	0.0	0.4	163	169	166	2	—	—	698	e
40	Jackson Creek Tributary near Elkhorn	054310157	4.3	39.0	59.3	0.0	1.2	0.0	0.5	27	184	52	13	133	1210	291	13
41	Jefferson Park Drainage at Germantown	04087019	1.8	19.6	80.4	0.0	0.0	0.0	0.0	—	—	451	1	—	—	1150	e
42	Kinnickinnic River at Milwaukee	04087159	20.2	95.7	4.3	0.0	0.0	0.0	0.0	264	329	297	2	—	—	1110	e
43	Lincoln Creek at Milwaukee	40869415	9.6	100.0	0.0	0.0	0.0	0.0	0.0	—	—	100	1	—	—	328	1
44	Little Menomonee River at Milwaukee	04087070	19.7	26.5	68.9	3.3	0.0	0.0	1.3	75	140	107	2	—	—	555	e
45	Menomonee River at Wauwatosa	04087120	123	49.8	45.7	3.0	0.0	0.7	0.8	21	85	74	5	—	—	524	e
46	Monroe St. detention pond inlet at Madison	430309089260701	0.4	100.0	0.0	0.0	0.0	0.0	0.0	77	205	141	2	171	446	308	2
47	Nine Springs Creek tributary storm sewer at Madison	05429268	0.2	100.0	0.0	0.0	0.0	0.0	0.0	177	303	240	2	585	1000	794	2
48	Noyes Creek at Milwaukee	04087060	1.9	79.5	19.0	0.0	0.0	0.0	1.4	165	230	197	2	—	—	662	e
49	Schoonmaker Creek at Wauwatosa	04087125	1.9	100.0	0.0	0.0	0.0	0.0	0.0	54	63	59	2	—	—	291	e
50	Spring Harbor at Madison	05427965	3.3	57.5	36.9	0.0	0.0	0.0	5.6	61	163	130	5	—	—	526	e
51	Underwood Creek at Wauwatosa	04087088	18.2	82.4	10.3	4.3	0.3	2.2	0.6	45	57	51	2	—	—	332	e
52	Willow Creek at Madison	05427970	3.2	95.6	4.3	0.1	0.0	0.0	0.0	80	293	143	6	—	—	558	e

[e, estimated; —, not available; *, not used because point discharge greater than 15 percent of total load]

these composite samples resulted in an "event mean concentration." Samples also were collected during low-flow periods. "Event loads" were computed by multiplying the event mean concentrations and the stormflow volumes. The low-flow loads were computed by use of the integrator method. Total annual loads were computed by summing the event and low-flow loads. Unit-area loads were then computed for all watersheds by dividing total annual load by the watershed drainage area.

All of the unit-area loads presented in this fact sheet represent the sum of loads from low-flow periods and storm-runoff periods. Because many best-management practices are designed specifically for controlling nonpoint pollution during storm-runoff periods, it would be useful to have an estimate of what fraction of the total load originates from storm runoff. Storm-runoff loads were separated from total loads for Otter Creek near Plymouth and Silver Creek near Ripon in the Southeastern Wisconsin Till Plains and for Joos Valley Creek near Fountain City and Rattlesnake Creek near North Andover in the Driftless Area to give an indication of the magnitude of low-flow load and storm-runoff load as a percentage of total load. Median annual storm-runoff loads as a percentage of annual total suspended-sediment or suspended-solids loads are, for Otter Creek, 66%; Silver Creek, 59%; Joos Valley Creek, 93%; and Rattlesnake Creek, 95%. Median annual storm-runoff loads as a percentage of annual total phosphorus loads are, for Otter Creek, 56%; Silver Creek, 36%; Joos Valley Creek, 87%; and Rattlesnake Creek, 82%. Storm-runoff percentages for the two watersheds in the Driftless Area are notably higher than those for the two sites in the Southeastern Wisconsin Till Plains.

Minimum, maximum, and median unit-area loads for each watershed listed in this fact sheet are presented in table 1. Several rural watersheds were not monitored for total phosphorus. For these watersheds, a regression analysis of monitored data was used to relate median unit-area loads of total suspended solids or sediment to median unit-area loads of total phosphorus and was further used to estimate unit-area loads of total phosphorus for rural watersheds without total phosphorus data. Not enough data on total phosphorus were available to do a similar regression for urban watersheds.

Unit-area loads of total suspended sediment (or solids) and total phosphorus within watersheds can vary greatly from year to year depending mainly on climatic conditions. Unit-area loads for several watersheds change by more than an order of magnitude from the year with minimum loads to the year with maximum loads (table 1). The statistics for watersheds with a long period of record are more representative of the variability of data from that particular watershed than those for watersheds with shorter periods of record. Data for watersheds with only a few years of record give some information about general loads, but variability is not well characterized.

Unit-area loads of total suspended sediment (or solids) and total phosphorus between watersheds also can vary greatly. This variability probably is due to a combination of many different watershed characteristics and climatic factors. For the watersheds listed in this fact sheet, no relation was apparent between unit-area loads and percent agriculture, percent forest, or drainage area. There were, however, differences between the unit-area loads of rural watersheds in the Southeastern Wisconsin Till Plains ecoregion and the Driftless Area ecoregion (fig. 2). Unit-area loads in the Driftless Area are typically greater than unit-area loads from rural watersheds in the Southeastern Wisconsin Till Plains. Watersheds in the Driftless Area tend to be steeper; consequently, runoff and stream velocities and thus erosion potential are higher, resulting in larger sediment and phosphorus loads. Total suspended sediment or solids for the Southeastern Wisconsin Till Plains indicate that median loads are slightly higher for urban watersheds than for rural watersheds in the same ecoregion, but that overall variability in urban unit-area loads is less.

Estimating loads

Minimum, maximum, and median unit-area loads of total suspended sediment (or solids) and total phosphorus for each ecoregion are presented in table 2. The minimum and maximum values represent extremes of all annual unit-area loads shown in table 1, whereas the median values are computed from the values in the median columns in table 1. The median unit-area loads for monitored watersheds can be used to estimate loads for watersheds where monitoring data are not available. From the variability in median unit-area loads shown in table 2, it is apparent that this method produces only a gross estimate of loads that should be used with caution.

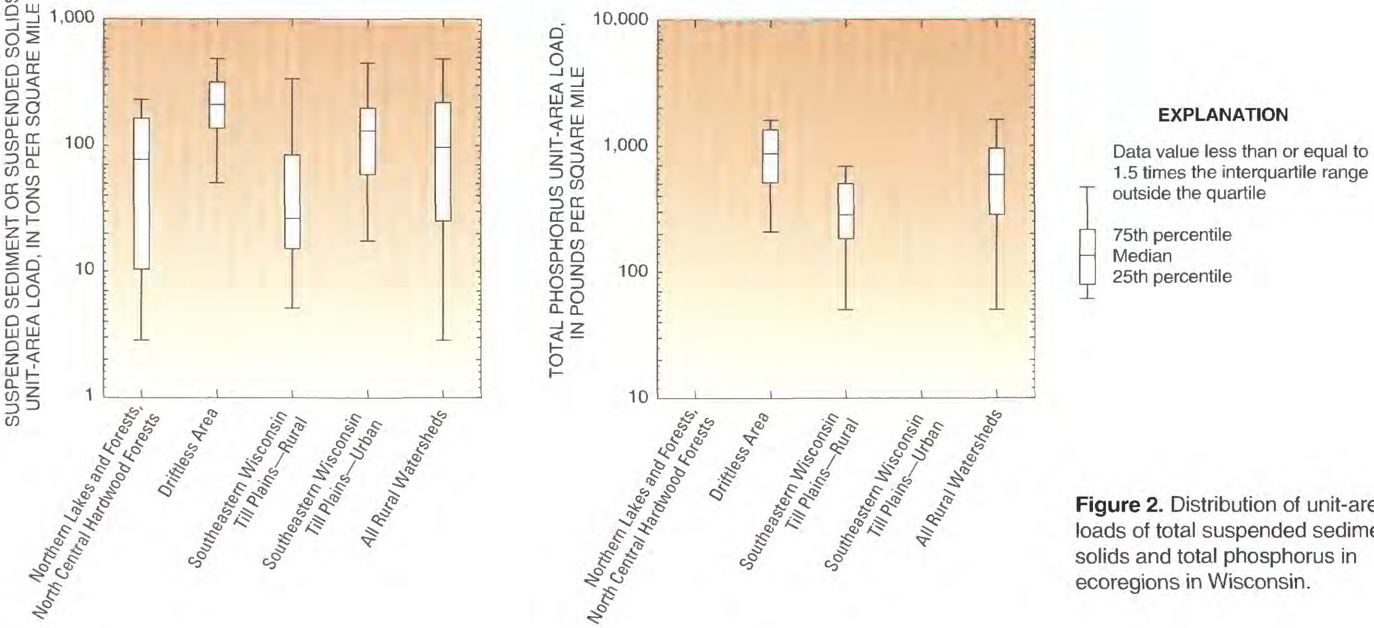

Figure 2. Distribution of unit-area loads of total suspended sediment/solids and total phosphorus in ecoregions in Wisconsin.

Estimates of loads of total suspended sediment (or solids) and total phosphorus can be made by using the following method:

From figure 1, identify the ecoregion of the watershed of interest. Then, find the median unit-area load for that ecoregion in table 2 and multiply it by the drainage area of the watershed of interest.

As an example, consider Pheasant Branch at Middleton, whose drainage area is 18.3 square miles. Suspended sediment loads at Pheasant Branch were monitored for 14 years, and total phosphorus loads were monitored for 3 years. During these periods, the median annual total suspended solids load was 1480 tons, and the median annual total phosphorus load was 11,900 pounds. To estimate the loads using the method described above, one would find that Pheasant Branch is in the Southeastern Till Plains ecoregion (fig. 1) and that the median unit-area loads for the Southeastern Till Plains are 32.4 tons per square mile for total suspended sediment and solids and 283 pounds per square mile for total phosphorus (table 2). Multiplying the unit-area loads by the drainage area results in total annual load estimates of 593 tons for total suspended sediment or solids and 5,180 pounds for total phosphorus. This example demonstrates that loads determined by this method are gross approximations—total suspended sediment and total phosphorus are underestimated by 60 percent and 57 percent, respectively.

In order to estimate loads more accurately, a more elaborate watershed model involving several additional variables could be used. Most existing watershed models of this type, however, are time consuming and expensive to use. Another way to improve the estimates would be to increase monitoring of loads of total suspended sediment (or solids) and total phosphorus in watersheds with more diverse land uses and watershed characteristics.

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Table 2. Minimum, maximum, and median unit-area loads of total suspended sediment or solids and total phosphorus for ecoregions in Wisconsin [—, insufficient data; to convert tons per square mile to pounds per acre, multiply by 3.12; to convert tons per square mile to kilograms per hectare, multiply by 3.50; to convert pounds per square mile to pounds per acre, divide by 640; to convert pounds per square mile to kilograms per hectare, multiply by 0.00175]

	Unit-area loads of total suspended solids or sediment (tons per square mile)				Unit-area loads of total phosphorus (pounds per square mile)			
Ecoregions	Minimum	Maximum	Median	Number of Watersheds	Minimum	Maximum	Median	Number of Watersheds
Northern Lakes and Forests Ecoregion	2.00	348	73	5	—	—	—	—
Driftless Area Ecoregion	4.29	1010	209	17	66.7	3960	875	14
Southeastern Wisconsin Till Plains Ecoregion—Rural	4.40	1710	32.4	14	40.7	1800	283	9
Southeastern Wisconsin Till Plains Ecoregion—Urban	17.0	451	130	15	133	1210	318	4
State Summary—Rural	2.32	1710	111	36	23.1	3960	650	24
State Summary	2.32	1710	120	52	23.1	3960	499	28

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