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

By Steven R. Corsi¹, David J. Graczyk¹, David W. Owens¹, and Roger T. Bannerman²

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.](image)

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 15 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
### Table 1: Land use, drainage area, and unit-area loads summary statistics for selected monitored watersheds in Wisconsin

<table>
<thead>
<tr>
<th>Watershed and monitoring station</th>
<th>U.S.G.S. Downstream order number</th>
<th>Drainage area (square miles)</th>
<th>Land use percentage</th>
<th>Unit-area loads of total suspended solids or sediment (ton per square mile)</th>
<th>Unit-area loads of total phosphorus (pound per square mile)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water</td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Southern Wisconsin Till Plains Ecoregion-Rural</td>
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<tr>
<td>Ripon in the Southeastern Wisconsin Till Plains and for Joos Valley Creek near Ripon in the Southeastern Wisconsin Till Plains ecoregion and the Driftless Area ecoregion</td>
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<tr>
<td>These composite samples resulted in an &quot;event mean concentration.&quot; Samples also were collected during low-flow periods. &quot;Event loads&quot; were computed by multiplying the event mean concentrations and the storm flow volumes. The low-flow rates were computed by use of the integrated method. Total annual loads were computed by summing the event and low-flow units. 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 Plympton and Silver Creek near Ripon in the Southeastern Wisconsin Till Plains and for Joes Creek near Pewaukee in the Southeastern Wisconsin Till Plains near Barneveld.</td>
<td>89.1</td>
<td>89.1</td>
<td>89.1</td>
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<tr>
<td>Southeastern Wisconsin Till Plains Ecoregion-Urban</td>
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</tbody>
</table>

### Notes
- [e, estimated — not available] — not used because point discharge greater than 15 percent of total load]
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.

**References Cited**


**Table 2.** Minimum, maximum, and median unit-area loads of total suspended sediment or solids and total phosphorus for ecoregions in Wisconsin

<table>
<thead>
<tr>
<th>Ecoregions</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>Number of Watersheds</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>Number of Watersheds</th>
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<td>650</td>
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<td>499</td>
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