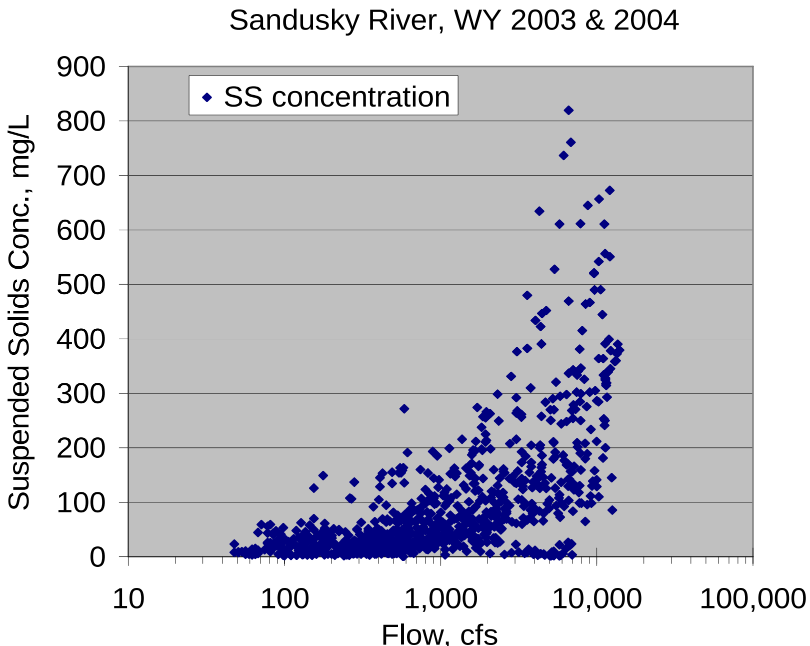
2.g. Relationships between Pollutant Loading and Stream Discharge

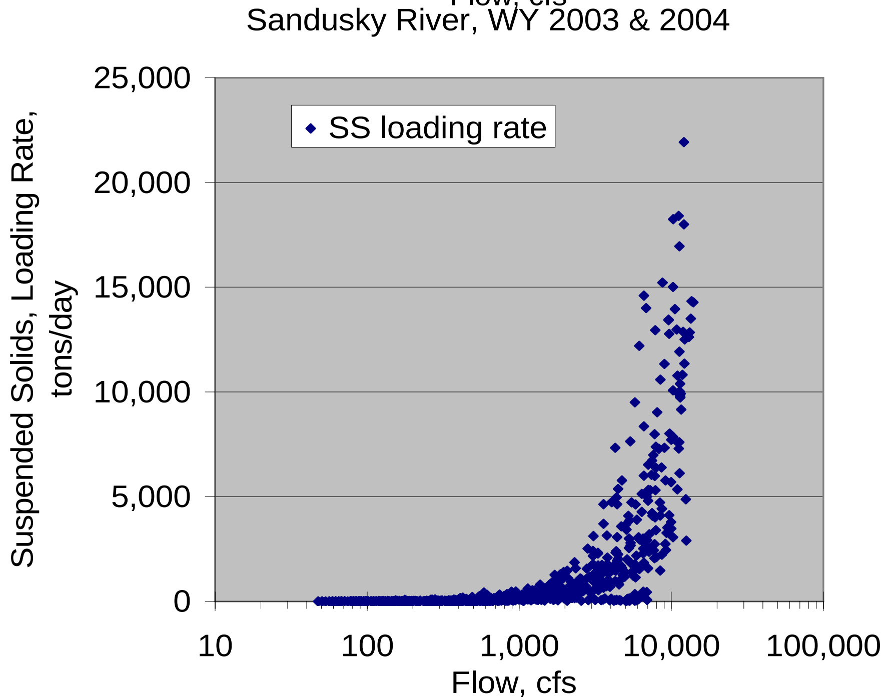
Introduction

Graphs of the relationship between the concentration of a pollutant and stream flow provide a useful qualitative picture of the impacts of point and nonpoint sources on pollutant concentrations. In many situations, pollutant concentrations are the focus of concern. In drinking water supplies, nitrate and pesticide concentrations are of interest. For aquatic life, pollutant concentrations in streams are important and may be the focus of control efforts.

In other cases, the concern is pollutant loading to downstream receiving waters such as Lake Erie or the Ohio River. To calculate the pollutant loading rate, pollutant concentrations are multiplied by the stream flow associated with that sample. Multiplication by an appropriate conversion factor then yields a pollutant loading rate in units such as kg/day, lbs/day or tons/day for each sample (see section on Loading Calculations, Annual Loads, and Unit Area Loads for calculation of conversion factors). These calculations provide an instantaneous loading rate at the time of sample collection.

The graph in the lower right shows the relationship between loading rates for suspended solids and stream flow for the Sandusky River. These are the same data as plotted in the upper right graph. It is evident that high sediment loading rates are even more focused on high flow periods than are high sediment concentrations. We have retained linear scales on the y-axis for both graphs to facilitate their visual comparison.





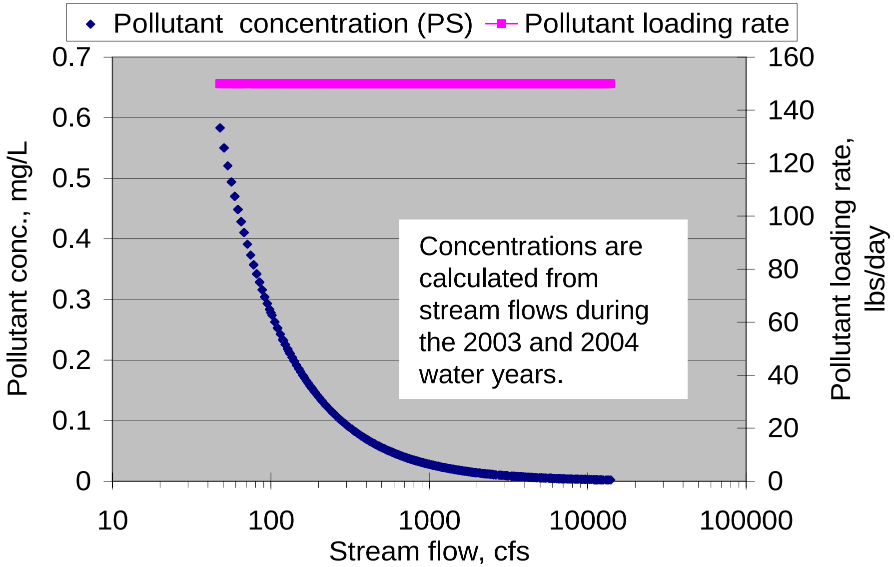
Concentrations versus loading rates in relation to stream flow

The adjacent graph shows that chloride concentrations decrease with increasing flow. While part of this pattern is likely due to increasing dilution of point source inputs as flow increases, much of the pattern is due to increasing dilution of nonpoint-derived sources of chloride by increasing amount of rainfall.

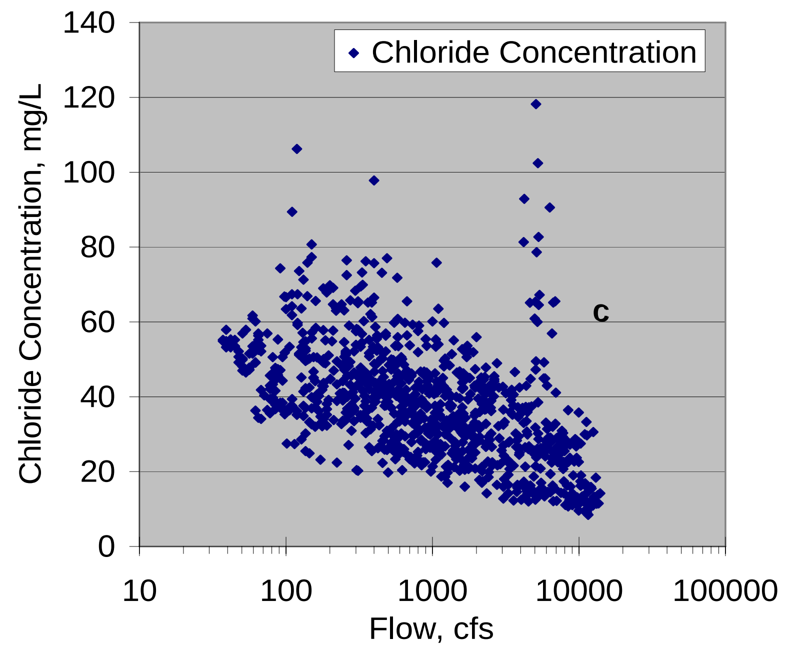
When the same data are plotted as instantaneous loading rates, it is evident that chloride loading rates increase with increasing stream flow (lower right graph). The data indicate that chloride concentrations decrease by a factor of about eight while stream flows increase by a factor of about 300-fold. Thus the product of concentration times flow increases with increasing flow. Thus much of the chloride is derived from nonpoint sources.

If a pollutant were derived strictly from point sources, those sources had a constant loading rate, and the pollutant behaved conservatively (i.e. no in-stream processing), then the graph of concentration vs flow and instantaneous loading versus flow would take the form shown below. Increasing loading rates with increasing flow implies nonpoint source contributions.

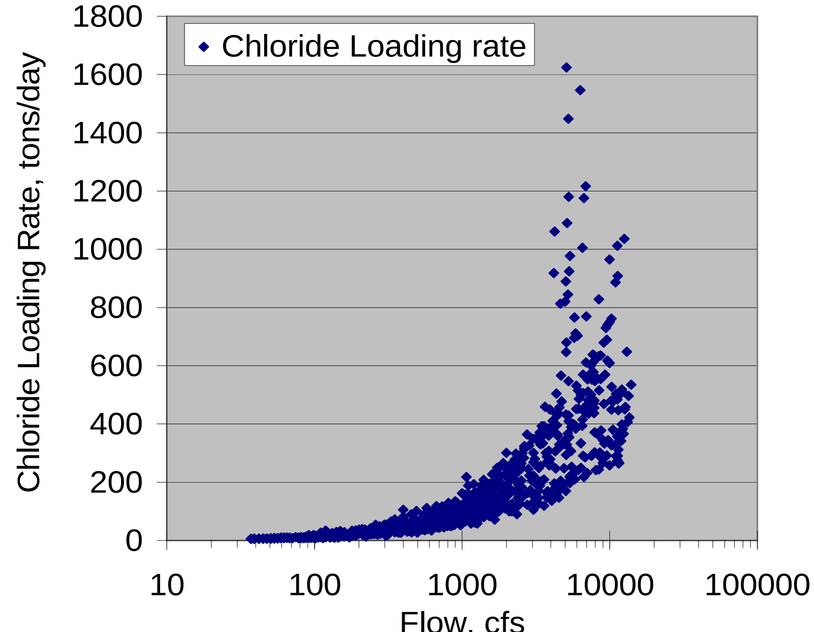
Sandusky River, hypothetical point source only pollutant with input rate of 150 lbs per day.

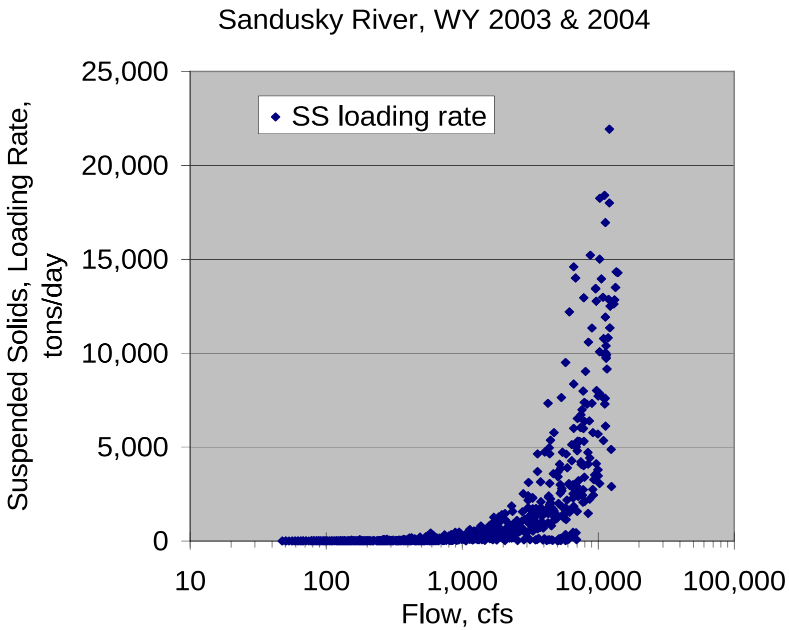


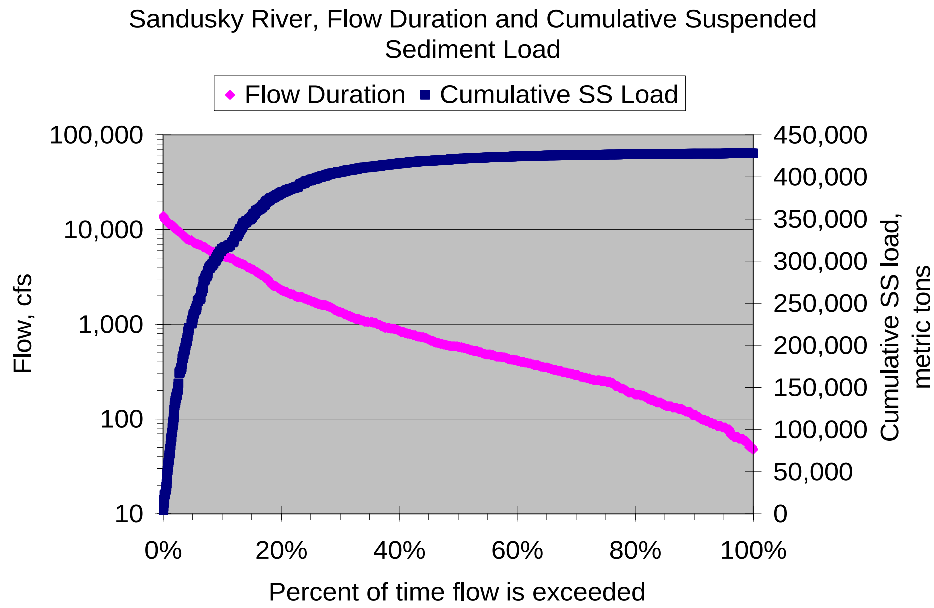
Sandusky River, WY 2003 & 2004



Sandusky River, WY 2003& 2004



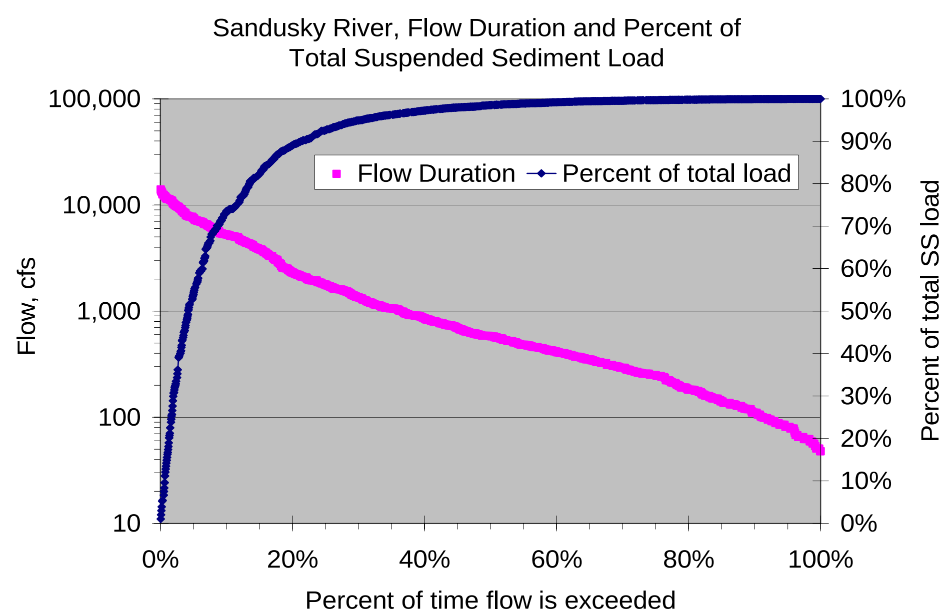




Flow Duration Curves, Cumulative Load Curves and Percent of Total Load Curves.

The above loading rate versus flow graph is useful, but it does not provide a quantitative picture of the actual relationship between flows and loading. It does not contain information relative to the frequency of occurrence of various flows nor does it indicate the duration of time the individual samples characterized the loading rate. Some points on the graph characterize loading rates for one third of a day while other points apply for two or more days.

Quantitative information regarding the relationship between stream flow and loading is provided by graphs that present the flow data in the form of flow duration curves and the loading data in the form of cumulative loads (upper right graph) or percent of total loads (lower right graph) in relation to flow duration percentages. In these graphs, the high flow conditions and high loading rate conditions appear on the left side of the graph while the low flow conditions are on the right side. This is the reverse of the loading rate versus flow graph as shown above. The x-axis shows the percent of time flows are exceeded, and high flows are exceeded a small percentage of the time.

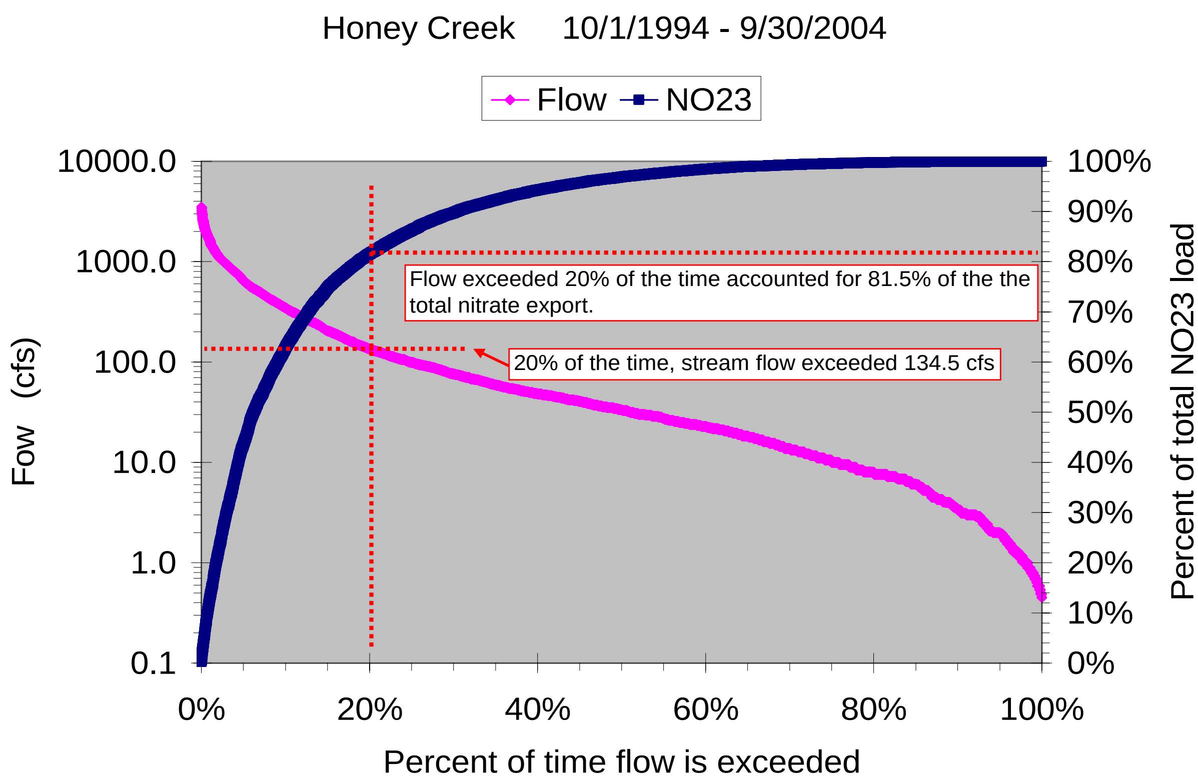


More on the interpretation of flow duration and percent of total load curves.

A plot of the data from the preceding page is shown to the right. It shows that 20% of the time, stream flow in Honey Creek exceeded 134.5 cfs during the ten year period. It also shows that flows exceeded 20% of the time accounted for 81.5% of the nitrate export. Some other points on the curves, as taken from the plot files, are shown below.

Percent of time flow is exceeded	Flow cfs	Percent of the total nitrate export
1%	1,620	12.9%
5%	647	43.6%
10%	347	62.8%
20%	134	81.5%
50%	33	96.9%

The quantitative relationships between stream flow and pollutant export shift in systematic fashion with stream size. As watershed size becomes smaller, the percent of the total export accounted for by flows of a given exceedency increases. For example in the Maumee River (6330 sq. mi.) the 10% of the time with the highest flows accounted for 51.9% of the nitrate export. For the Sandusky (1253 sq. mi.) this same percent of time accounted for 59.2% of the nitrate export. For Honey Creek (149 sq. mi.) and Rock Creek (34.6 sq. mi.) the corresponding percentages were 62.8% and 75.6%.



The quantitative relationship between stream flow and chemical export also differs among parameters. For example, in Honey Creek, the 10% of the time with the highest flows during the 10/01/94 to 09/30/04 time period accounted for percentages of pollutant export shown to the right.

Suspended Solids	86.4%
Total Phosphorus	82.4%
Total Kjeldahl Nitrogen	76.0%
Soluble Reactive P.	74.8%
Nitrate	62.8%
Chloride	51.0%

Construction of flow duration curves and cumulative loading/percent of total load curves.

1	Total time	3502.762153				Total Load	6984269		
2									
3	Datetime	Time Window	Flow	NO23	Cum time	% Time	Load (kg)	cum Load	% Total Load
4	06/02/1997 04:00	0.33	3485.600	6.17	0.33	0.01%	17528.37	17528.37	0.25%
5	06/01/1997 20:00	0.33	3427.200	6.62	0.67	0.02%	18491.68	36020.05	0.52%
6	01/08/1998 20:00	0.33	3427.200	2.45	1.00	0.03%	6843.597	42863.65	0.61%
7	01/08/1998 12:00	0.33	3389.200	2.25	1.33	0.04%	6215.251	49078.9	0.70%
8	06/01/1997 12:00	0.33	3231.400	5.87	1.67	0.05%	15459.94	64538.84	0.92%
9	01/19/1996 04:00	0.33	3113.5	7.62	2.00	0.06%	19336.72	83875.56	1.20%
10	05/26/1997 04:00	0.33	3041.000	6.43	2.33	0.07%	15936.99	99812.55	1.43%
Rows 11- 4859 are omitted									
4860	09/14/2002 12:00	1.00	0.487	6.12	3498.76	99.89%	7.281548	6984248	100.00%
4861	09/18/2002 12:00	1.00	0.487	5.56	3499.76	99.91%	6.615262	6984255	100.00%
4862	09/19/2002 12:00	1.00	0.487	5.51	3500.76	99.94%	6.555773	6984261	100.00%
4863	10/17/2002 12:00	2.00	0.450	3.28	3502.76	100.00%	7.217994	6984269	100.00%

Shown above is a copy of an Excel file that illustrates the construction of flow duration curves and cumulative loading/percent total loading curves.

This is an example from Honey Creek showing the flow duration curve and nitrate export information for the 10-year period from 10/01/94 to 09/30/2004.

1. From the river data files, copy the Datetime, Time Window, Flow, and parameter concentration for the period of interest.
2. Sort the data by decreasing flow.
3. Calculate the parameter load for each sample (Time Window x Flow x Concentration x Conversion Factor (2.4468 in the above example) to give loads in kg).
4. Calculate the cumulative time and the cumulative load.
5. Calculate the cumulative time as a percent of the total time and the cumulative load as a percent of the total load.
6. Using the Excel Chart Wizard, plot the % time (flow was exceeded) on the x-axis, the flow (log scale) on the y1 axis, and the cumulative load or cumulative load as a percent of the total load on the Y2 axis.

Note: The above type of graph with the cumulative load as a percent of the total load is plotted automatically using the AnalysisTemplatev3 Excel file.