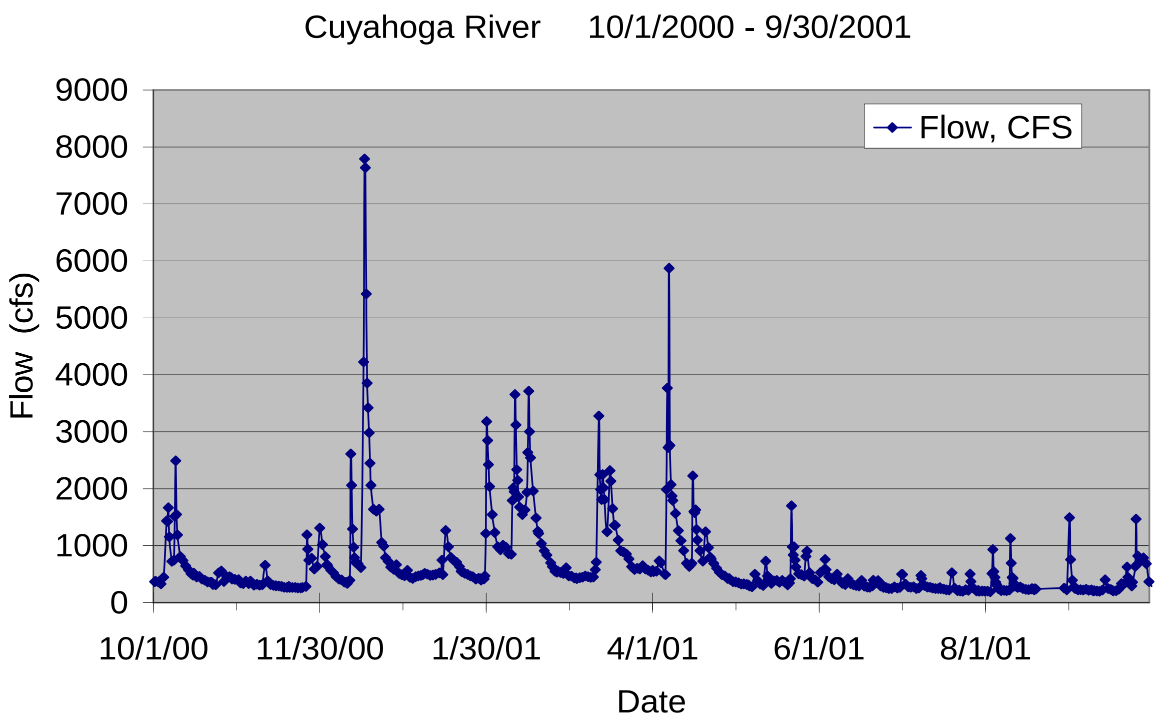
2.a. Hydrographs, Sedigraphs and Chemographs

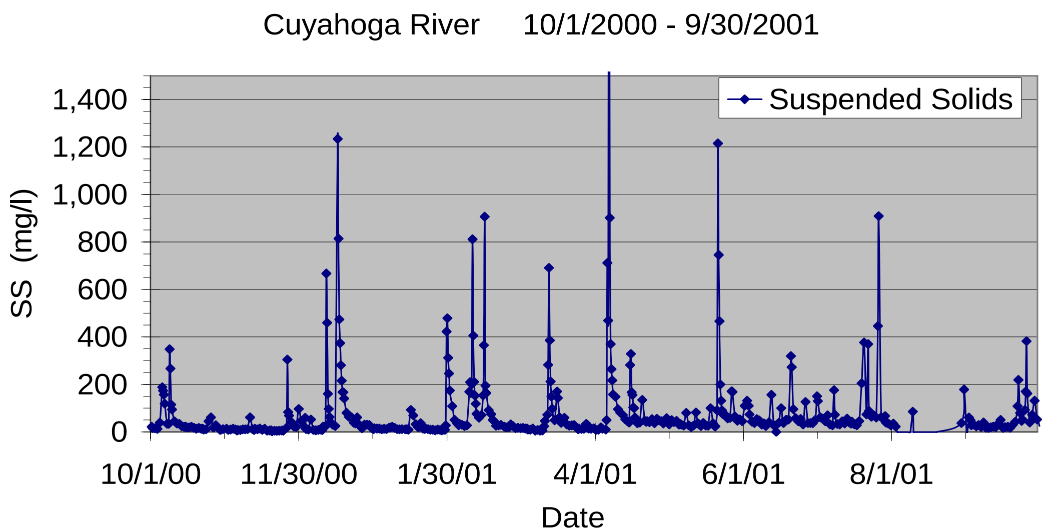
Description

One constant characteristic of streams and rivers is that they are constantly changing. Anyone living near a stream or river is familiar with the changes in flow that occur during floods. At locations where stream gauging stations are in operation, it is possible to quantify these changes and show how the stream flow or discharge changes with time. Plots of these changes are referred to as hydrographs. The graph below shows the changes in discharge for the Cuyahoga River for a one year period beginning 10/01/2000 and ending 9/30/2001 (i.e., the 2001 Water Year). This hydrograph is based on the streamflow occurring at the time of collection of samples analyzed as part of the tributary loading program and is plotted from the tributary loading data files. The spikes on the graph represent runoff events or floods of various sizes. After each runoff event, stream flow drops relatively rapidly at first, then more gradually until the next storm runoff event occurs.

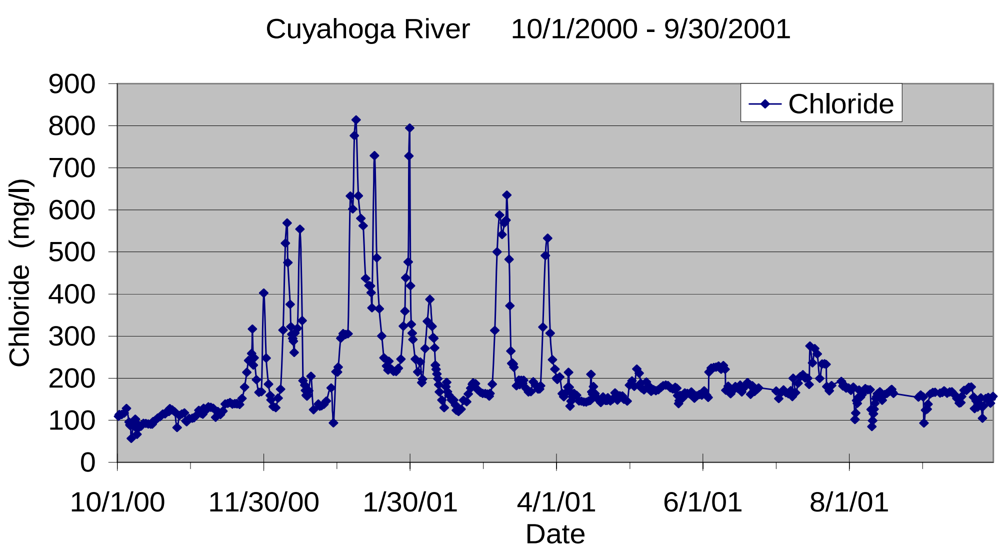


Description, continued

Streamflow is not the only characteristic of streams and rivers that is constantly changing. Concentrations of suspended sediment and various chemicals also change with time. Plots of changing sediment concentrations with time are called sedigraphs while plots of changing chemical concentrations with time are called chemographs. A sedigraph and a chloride chemograph for the Cuyahoga River, 2001 WY are shown below.



The peaks in sediment concentrations occur in connection with runoff events or floods.



The Cuyahoga River has very high chloride concentrations relative to other Ohio rivers. The high chloride concentrations during winter months are probably related to runoff from road salt applications.

Examples of Hydrographs, Sedigraphs, & Chemographs

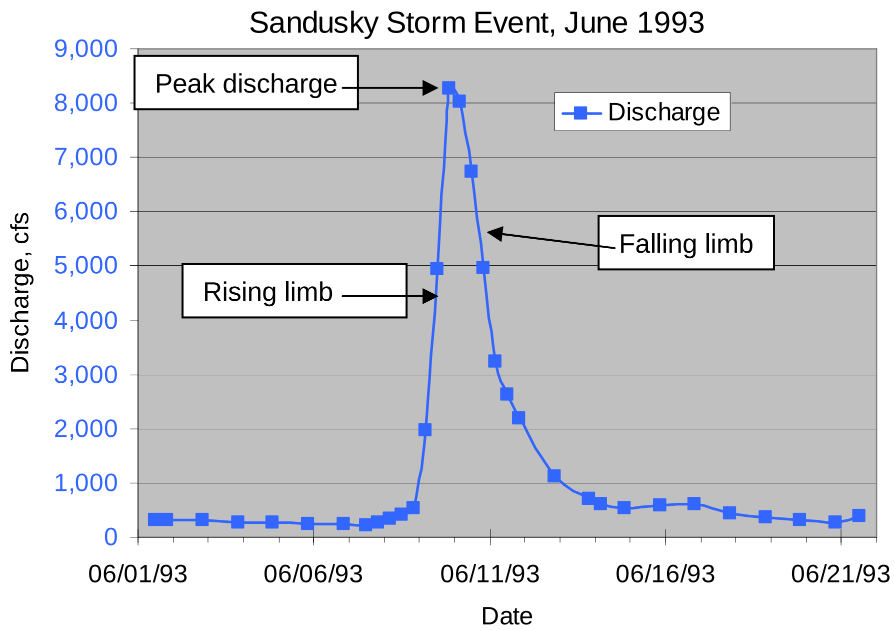
Concentration Changes During a Runoff Event

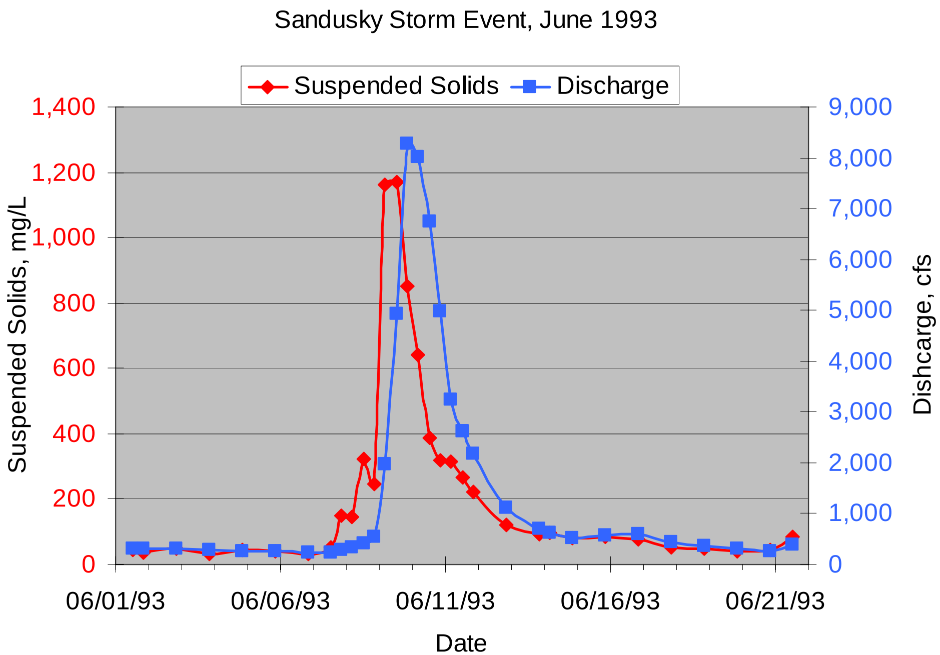
Rainfall measurements on the mornings of June 8 and 9, 1993 reported 1.15 and 2.38 inches of rainfall at the NOAA weather station in Tiffin, OH, which is upstream from the stream gauging station at Fremont on the Sandusky River. This rainfall broke a relatively long dry period extending through most of May. These rain storms were followed by 11 days without significant rainfall except for 0.37 inches on June 15. The resulting runoff event on the Sandusky River presents an opportunity to examine the concentration changes during a runoff event uncomplicated by other runoff events. Land use in the Sandusky watershed is dominated by row crop agriculture on soils having extensive tile drainage.

Runoff hydrographs, as illustrated in the upper right graph, can be divided into a rising limb, leading to a peak discharge, followed by a falling limb. The points on the hydrograph occur at 8-hour intervals during the runoff event and at 24 hour intervals during most of the base flow conditions preceding and following the runoff event. In this, as well as most hydrographs, the rising limb is steeper than the falling limb. In other words, streams rise during a runoff event more quickly than they fall. Subsequent graphs show sediment and chemical concentration changes in relation to the runoff hydrograph.

The individual points on the hydrograph plot correspond to flows at the time samples were collected and analyzed for the tributary loading studies. As evident in the adjacent graph, the suspended sediment concentrations peaked in samples collected on the rising limb of the hydrograph and had already begun to decline by the time the peak discharge had been reached. Such advanced peaks of sediment concentrations during runoff events are typical of many rivers and for many storm runoff events.

The advanced peak of suspended sediment concentration is caused, at least in part, by the sequence of surface runoff processes on contributing cropland. The first runoff water from the fields carries away the bulk of the "readily erodable sediment" from the field, with subsequent surface runoff water having lower sediment concentrations. This is equivalent to the "first flush" effects seen in urban runoff studies. For further discussion of advanced sediment peaks see Appendix 1.





Concentration Changes During a Runoff Event, cont.

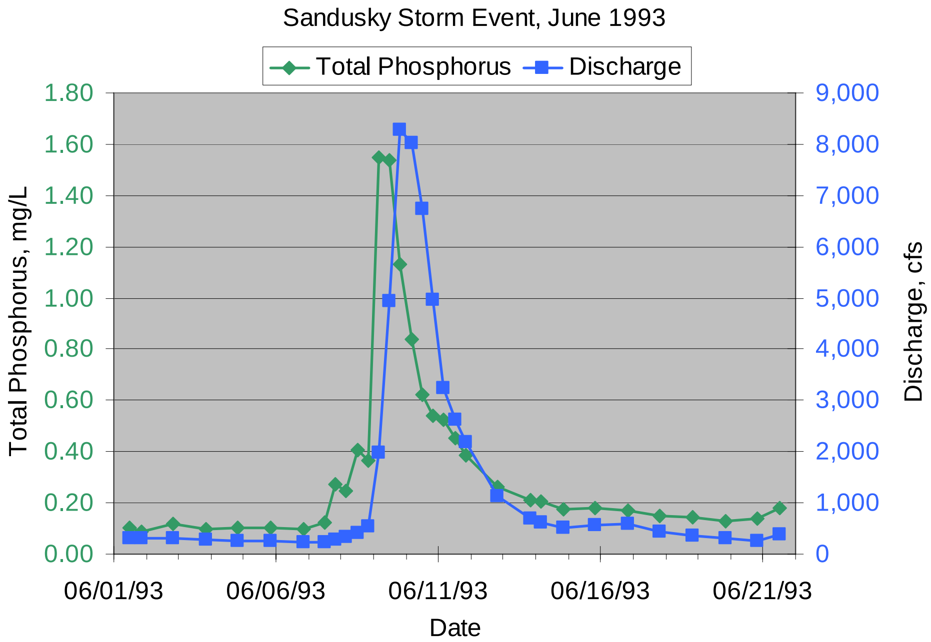
The total phosphorus chemograph on the right closely mimics the suspended solids sedigraph shown in the previous graph. It, too, has an advanced peak relative to the hydrograph. Most of the total phosphorus is particulate phosphorus and is attached to the sediment particles. The analytical procedure for total phosphorus involves a digestion procedure which removes the phosphorus from the sediment prior to phosphorus analysis.

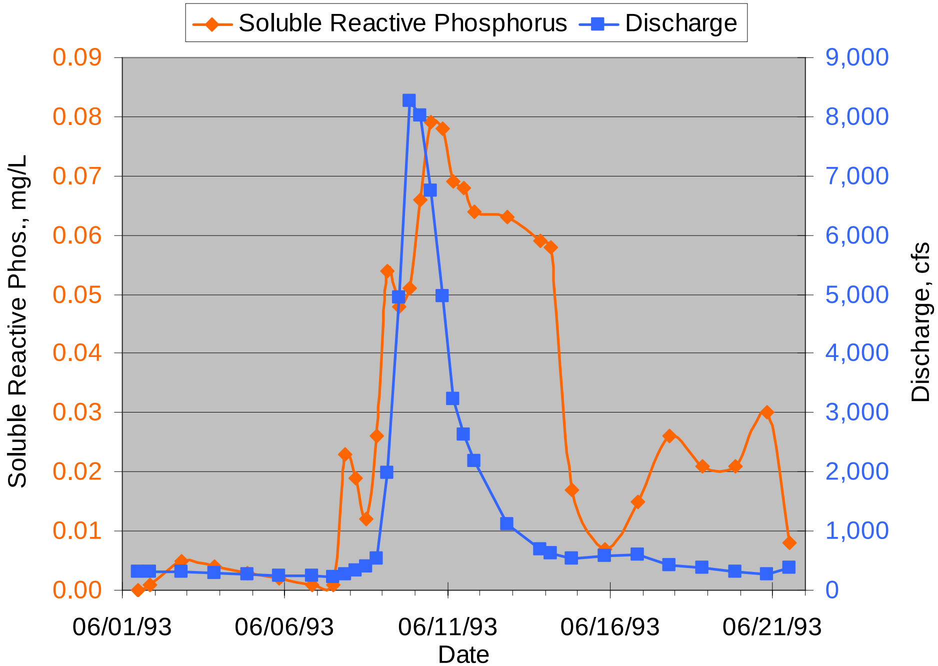
The soluble reactive phosphorus (SRP) concentrations also increase in association with the runoff event. However the timing of the increase in SRP is different from the timing for increases in suspended sediment and total phosphorus concentrations. The peaks in soluble reactive phosphorus concentrations occur after the peak discharge. Also SRP concentrations do not decrease as rapidly after their peak concentrations as do total phosphorus and suspended solids concentrations.

Analyses for SRP are done on samples that have been filtered to remove the suspended sediment. Furthermore, the filtered samples are not digested prior to analysis for phosphorus. Comparison of the scales for the two forms of phosphorus shows that, for this storm event on the Sandusky River, the total phosphorus concentrations are much higher than the SRP concentrations. SRP is included in the analysis of total phosphorus. However it makes up only 5-10% of the total phosphorus during runoff events.

SRP apparently enters streams as part of the surface runoff from fields. Unlike suspended solids and total phosphorus, which are apparently focused in the initial surface runoff from fields, the SRP is present in relatively high concentrations throughout the entire period of surface runoff from the fields. In this sense, it is similar in behavior to atrazine, a relatively soluble herbicide that also enters streams primarily as part of the surface runoff pathway from fields.

Some SRP may enter streams through tile drainage, especially on fields with very high soil test levels for phosphorus. In general phosphorus is tied up on soil particles and, in contrast with nitrate, is not very mobile in the soil column.



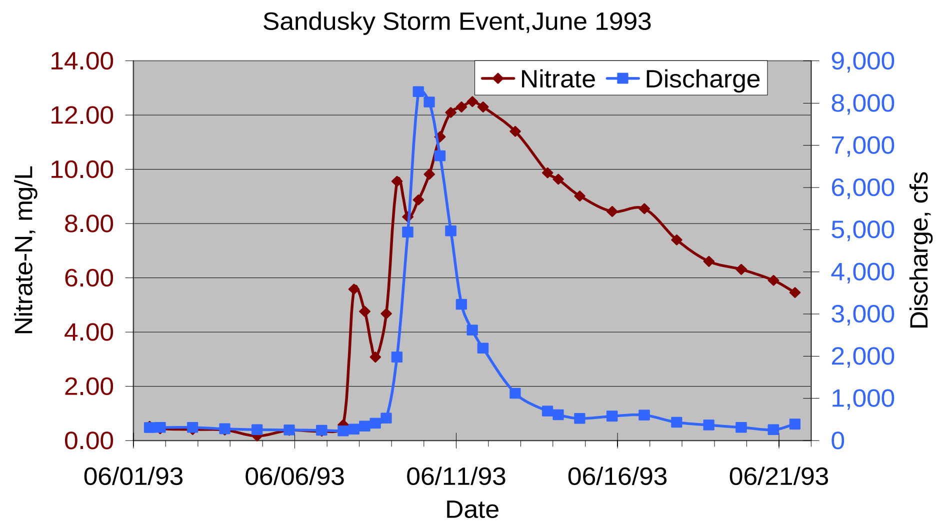


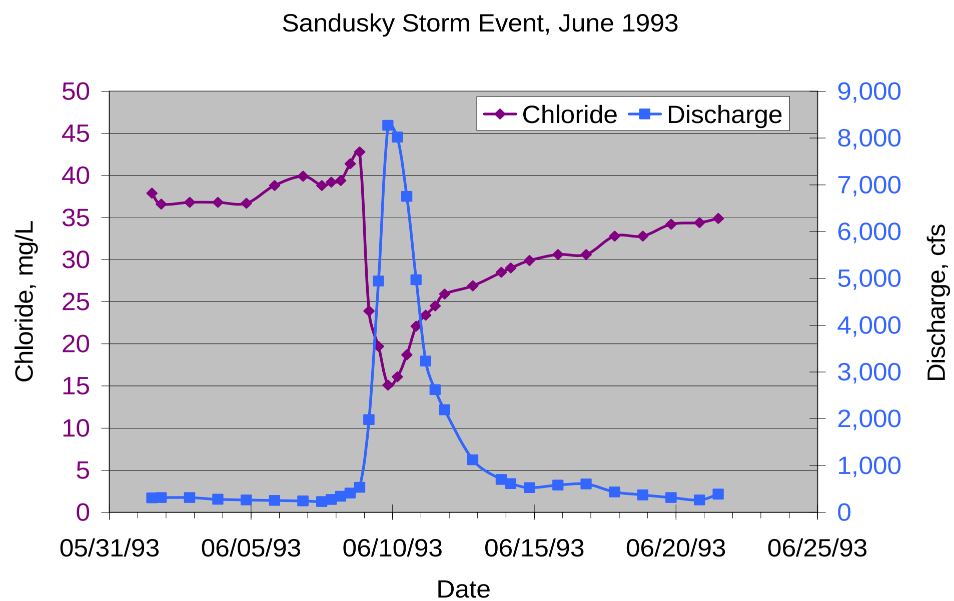
Concentration Changes During a Runoff Event, cont.

Nitrate is also carried into the Sandusky River in response to rainfall events. However, the pathway of the water that carries nitrate into streams is quite different from the pathway by which water carries suspended sediment into streams. Nitrate is carried into streams by water that percolates into the soil and then moves into tile systems that carry the water directly to streams. This pathway takes longer than the surface runoff pathway and persists for a longer period of time than surface runoff. Consequently, the nitrate chemograph peaks on the falling limb of the hydrograph and is much broader than the sedigraph or the total phosphorus chemograph. The peak nitrate concentrations also trail the peak SRP chemograph.

Nitrate provides an excellent tracer for the tile component of the storm hydrograph. The adjacent graph shows that nitrate concentrations do increase during the rising stage of the hydrograph. This indicates that tile flow does contribute to the peak discharge that occurs during storm events. In fact, the peak loading rates of nitrate coincide closely with the peak discharge (see Relationships between Pollutant Loading and Stream Discharge) Studies of tile flow from individual fields confirms that tiles comprise the major pathway by which nitrate enters streams.

During storm runoff conditions in the Sandusky River, chloride concentrations decrease. Thus the storm runoff water contains lower chloride concentrations than the baseflow water in the stream. The chloride that is present under baseflow conditions reflects some combination of chloride in the groundwater comprising the baseflow of the stream and point source inputs. In winter months, chloride can enter streams as part of surface runoff from road salt applications. This is evident from the annual chloride chemograph of the Cuyahoga River (see preceding section). The Cuyahoga River drains a heavily urbanized watershed.



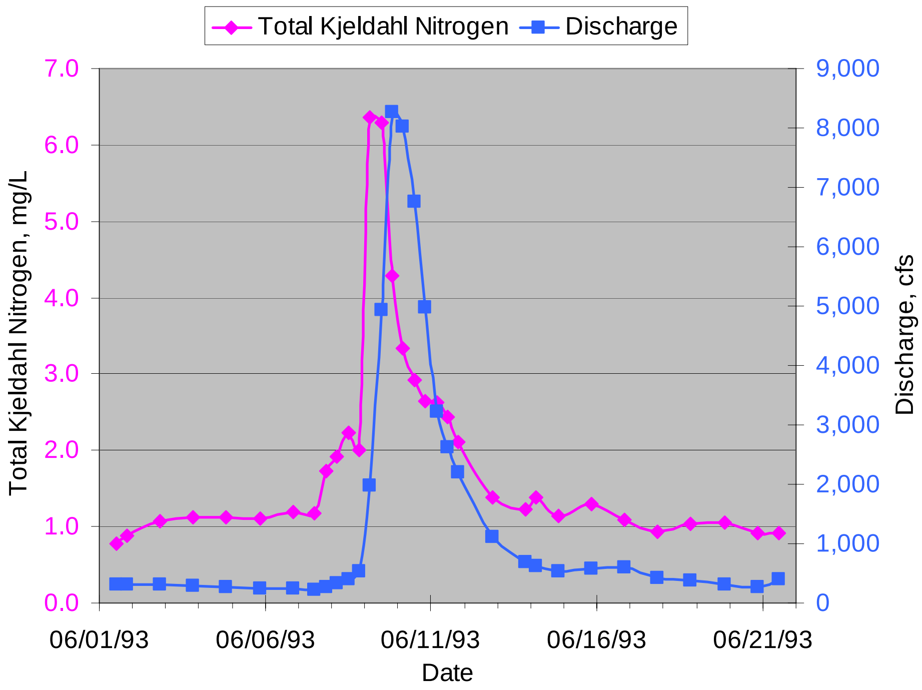


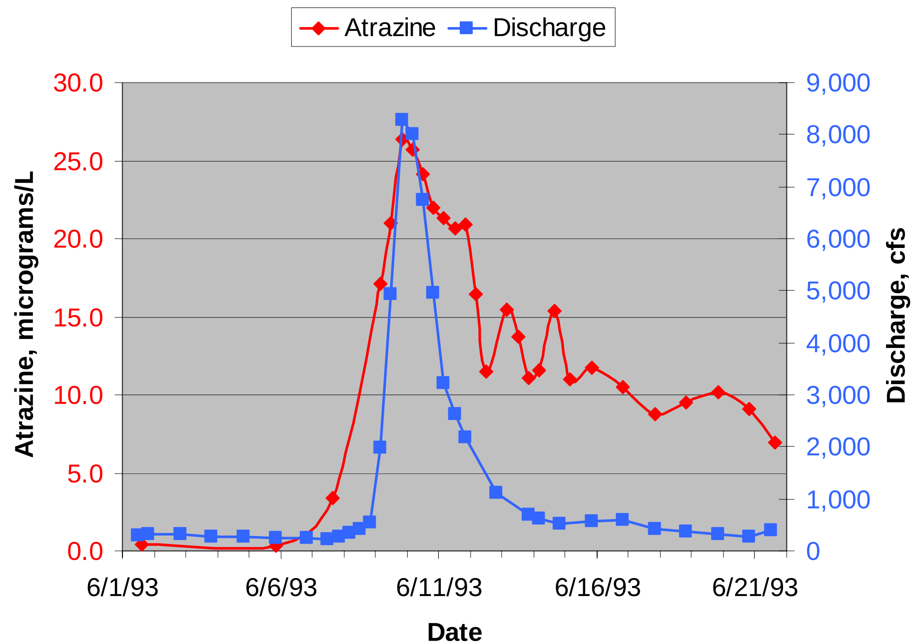
Concentration Changes During a Runoff Event, cont.

Total Kjeldahl Nitrogen (TKN), which includes organic nitrogen and ammonia, has a chemograph pattern that closely resembles that of suspended solids. During storm events, most of the TKN is associated with suspended sediments. The increase in TKN concentrations between storm flow and base flow is not as dramatic as that for total phosphorus. TKN increased by a factor of about 6-fold during this storm while total phosphorus increased by about 16-fold.

It is also noteworthy that the nitrate-N concentrations during runoff events in the Sandusky River are much higher than the TKN concentrations. In general, nitrate concentrations are much more variable among rivers than are TKN concentrations.

Atrazine and other surface-applied herbicides have chemographs that differ from both the suspended solids and nitrate chemographs. As illustrated for atrazine, their chemographs peak at the same time as the hydrograph peak, following the peak suspended solids concentration but preceding the peak nitrate concentration. These peaks are similar to that for SRP. We interpret this type of chemograph as reflecting surface runoff pathways from fields. They however lack the "first flush" effect that is evident for suspended solids and those nutrients attached to suspended solids particles, such as particulate phosphorus and particulate TKN.





Sources of Variability in Hydrographs, Sedigraphs and Chemographs: An Introduction

The preceding example of a storm hydrograph, sedigraph and various chemographs for the Sandusky River represented, in part, a “perfect storm,” in the sense that it was a large storm preceded and followed by an extended period of baseflow. A much more frequent situation is the occurrence of multiple storms in a watershed that result in much more complex hydrograph, sedigraph and chemograph patterns. There is extensive variability in hydrograph, sedigraph and chemograph patterns at a single sampling station. In addition, there are systematic variations in these graphs among differing stations.

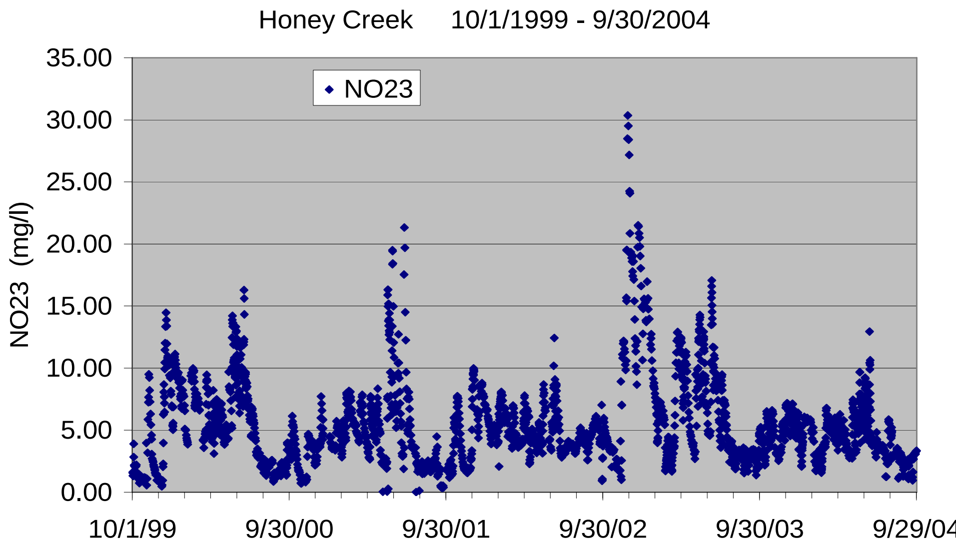
Sources of these single station and inter-station variations are illustrated in “Sources of Variability in Hydrographs, Sedigraphs and Chemographs” (in preparation). Sources of variability discussed under that section include:

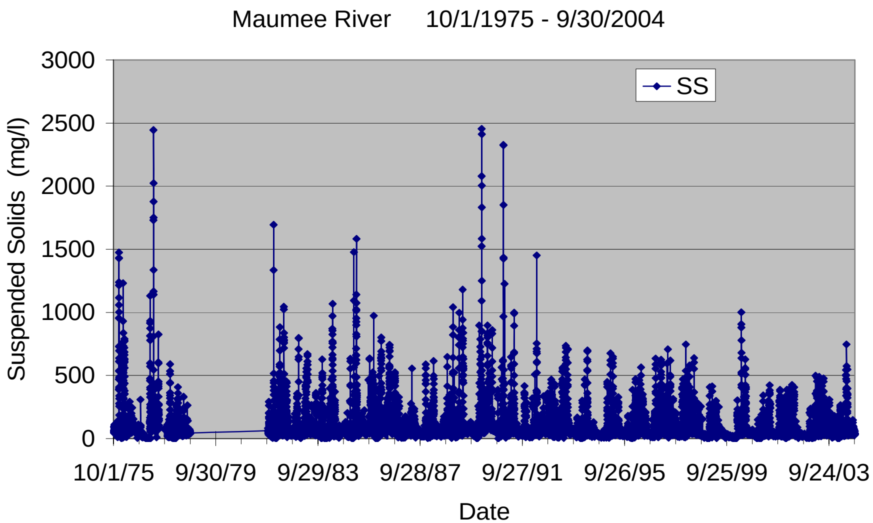
1. Annual variations in rainfall amounts, durations and intensity.
2. Seasonal variations.
3. Watershed scale effects (Watershed size).
4. Watershed land use.
5. Watershed soils and geology.

Longer Term Hydrographs and Chemographs

The hydrographs, sedigraphs, and chemographs shown previously covered either annual periods or single storms. There are occasions for which longer term graphs are useful. The upper right graph illustrates nitrate concentrations in Honey Creek over a five year period. It is clear from the graph that nitrate exceeded its drinking water standard (10 mg/L) in each of the past five years.

In some cases, long-term hydrographs can reveal trends in at least the peak runoff concentrations. In the Maumee River, peak sediment concentrations have decreased since 1975. We believe that erosion control programs in the Maumee Watershed have been effective in reducing peak sediment concentrations.





Plotting Issues and Directions

The procedures for plotting hydrographs, sedigraphs and chemographs are very straightforward. You may plot these graphs using the Chart Wizard of Excel or you may use the AnalysesTemplatev3 Excel file that is available for downloading from this Web site.

If you are going to plot the graphs yourself, brief instructions follow. However, these procedures assume that you are familiar with Excel plotting procedures.

1. Use the Excel Chart Wizard to make the graphs. See Excel instruction manuals or help files for aid in the use of the Chart Wizard. Within the Chart Wizard the X-Y scatter plots are used for making these graphs.
2. The data required from the RiverData files include the Datetime and flow and/or parameter concentrations for the date range of interest. These may be used directly from within the RiverData workbook or copied to a new Excel workbook.
3. Plot the Datetime on the x-axis.
4. Plot the flow or concentration on the y-axis.
5. If you are plotting two parameters on the graph, choose the second variable and plot it on the second y-axis.
6. Complete the graph using the Chart Options, Chart Location and other chart modification procedures, such as scale formatting.