U.S. Geological Survey (USGS) Science Summary— Spatial and temporal variation of stream chemistry associated with contrasting geology and land-use patterns in the Chesapeake Bay watershed— Summary of results from Smith Creek, Virginia; Upper Chester River, Maryland; Conewago Creek, Pennsylvania; and Difficult Run, Virginia, 2010–2013

(Released November 2016)

Introduction and Issue

Across the Bay watershed, improvements in nitrogen and phosphorus have been seen at over half the nontidal monitoring stations during the past decade; however, more progress needs to be made to reduce nutrients and sediment to improve water-quality conditions in the Bay. Therefore, in 2010, the U.S. Geological Survey partnered with the U.S. Environmental Protection Agency and the U.S. Department of Agriculture to initiate water-quality monitoring in four selected small watersheds that were targeted for increased implementation of management practices. The objective of this study was to investigate spatial and temporal variations in water chemistry and suspended sediment in these four relatively small watersheds that represent a range of land-use patterns and underlying geology to (1) characterize current water-quality conditions in these watersheds, and (2) identify the dominant sources, sinks, and transport processes in each watershed. The USGS has released initial results of the study, which included four watersheds:

- **The Smith Creek watershed (105-mi^2) –**
  44 percent agricultural land use that includes extensive pastureland devoted to beef and dairy cattle production, poultry production, and, to a lesser extent, row cropping.
- **The Upper Chester River watershed (36-mi^2) –**
  64 percent agricultural land use with predominantly row-crop agriculture.
- **The Conewago Creek watershed (52-mi^2) –**
  37 percent agricultural land use with predominantly cattle production and row cropping activities.
- **The Difficult Run watershed (58-mi^2) –**
  57 percent residential land use.

Innovative Monitoring and Analysis

The study applied several innovative monitoring and analysis techniques in these watersheds that included:

- Continuous water-quality monitoring of nitrate, turbidity, specific conductance, dissolved oxygen, and pH, which provided an improved understanding of nutrient and sediment transport patterns and loads.
- Analysis of nitrate isotopes in water samples to better understand potential nitrogen sources.
- Extensive spatial monitoring to develop a detailed understanding of how stream chemistry varies throughout the watersheds.

For more information about this science summary contact Ken Hyer (kenhyer@usgs.gov) or Jimmy Webber (jwebber@usgs.gov).
For additional information about nontidal water-quality trends across the watershed visit http://cbrim.er.usgs.gov/.
For additional information about USGS Chesapeake Bay studies visit http://chesapeake.usgs.gov/.

Key Results: Smith Creek

- The primary source of the nitrogen is likely agricultural manure, followed by commercial fertilizer.
- The dominant geographic source of nitrate discharged to Smith Creek appears to be headwater springs, which provided the bulk of the water in Smith Creek during the driest, lowest flow conditions.
- During 1985–2014, nitrate concentrations in Smith Creek increased at a rate of approximately 0.01 mg/L per year, while flow-normalized nitrate fluxes (loads) have decreased by approximately 0.1% per year. Increasing nitrate concentrations during low-flow conditions suggest that concentrations of nitrate in the groundwater discharged to Smith Creek are increasing over time.
- Management activities that reduce the amount of nitrogen transported to groundwater are important because subsequent groundwater discharge to the stream, particularly in the upper part of the watershed, appears to be driving the increasing concentrations of nitrate observed in Smith Creek.

Key Results: Upper Chester

- The predominant sources of nitrogen and phosphorus are inorganic fertilizers and nitrogen fixation by legume crops.
- Nitrate concentrations have increased in Chesterville Branch since the early 1990s. The water-quality changes are related to nitrogen use in the watershed, with higher concentrations of nitrate delivered through groundwater to streams. The median age of groundwater discharging to Chesterville Branch is about 25 years, so nitrate concentrations reflect historical land use. The effects of conservation practices implemented in the last 10 years to more effectively utilize nitrogen applied to cropland, which should reduce nitrate leaching to groundwater, are not yet great enough or of long enough duration to be evident in stream water quality.
- Managing nitrogen in surface water will require a decrease in the amount of nitrate reaching groundwater. Ways to accomplish this reduction include reduced application of nitrogen fertilizer on crop land and expanded use of cover crops that retain nitrogen in the soil zone for use by the next crop.

Key Results: Conewago Creek

- Manure sources of nitrogen dominate the input of nitrogen to the watershed.
- Mean concentrations of nearly every measured constituent increased from upstream to downstream, indicative of the changing land uses.
- The development of nutrient management plans that address especially the application of manures, as well as commercial fertilizer could be important for reducing the overall nitrogen loading to the basin. These management activities will likely be most effective in the middle part of the watershed in areas that tend to have the greater amount of agricultural land.
- Managing these manure and fertilizer inputs should have a corollary benefit of reducing phosphorus inputs because nonpoint-source phosphorus inputs seem to dominate the phosphorus transport.

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Key Results: Difficult Run

- Analyses suggest that a mixture of sources, including septic system leachate, atmospheric deposition, and commercial fertilizer application, may be significant sources of nitrogen within the basin.
- A majority of the total flow in Difficult Run occurs as stormflow. The prominence of high-flow events is likely influenced by the degree of imperviousness of the watershed, which magnifies the effect of overland runoff on water quality.
- The Captain Hickory Run subwatershed had high nitrate and TN concentrations during all sampling events. These concentrations are likely affected by elevated density of septic systems contributing to groundwater discharge of nitrate, though other nitrogen sources also may contribute.
- Management activities for nitrogen would likely be most effective by the ongoing maintenance of septic systems, the management of fertilizer applications, and the possible expansion of the sanitary-sewer infrastructure. For the management of sediment and phosphorus, most loading occurs during the few relatively large storm events that occur each year; management strategies that target these few large events are critical.

Future Directions

- Continue water-quality monitoring so the influence of more recent management practices can be detected.
- Use the trends and understanding of watershed processes to explain water-quality changes and response to management actions in these watersheds.

Source of information

The findings in this Science Summary are reported in the article below, which should be used as the reference for this information:

Hyer, K.E., Denver, J.M., Langland, M.J., Webber, J.S., Böhlke, J.K., Hively, W.D., and Clune, J.W., 2016, Spatial and temporal variation of stream chemistry associated with contrasting geology and land-use patterns in the Chesapeake Bay watershed—Summary of results from Smith Creek, Virginia; Upper Chester River, Maryland; Conewago Creek, Pennsylvania; and Difficult Run, Virginia, 2010–2013: U.S. Geological Survey Scientific Investigations Report 2016–5093, 211 p., http://dx.doi.org/10.3133/sir20165093.

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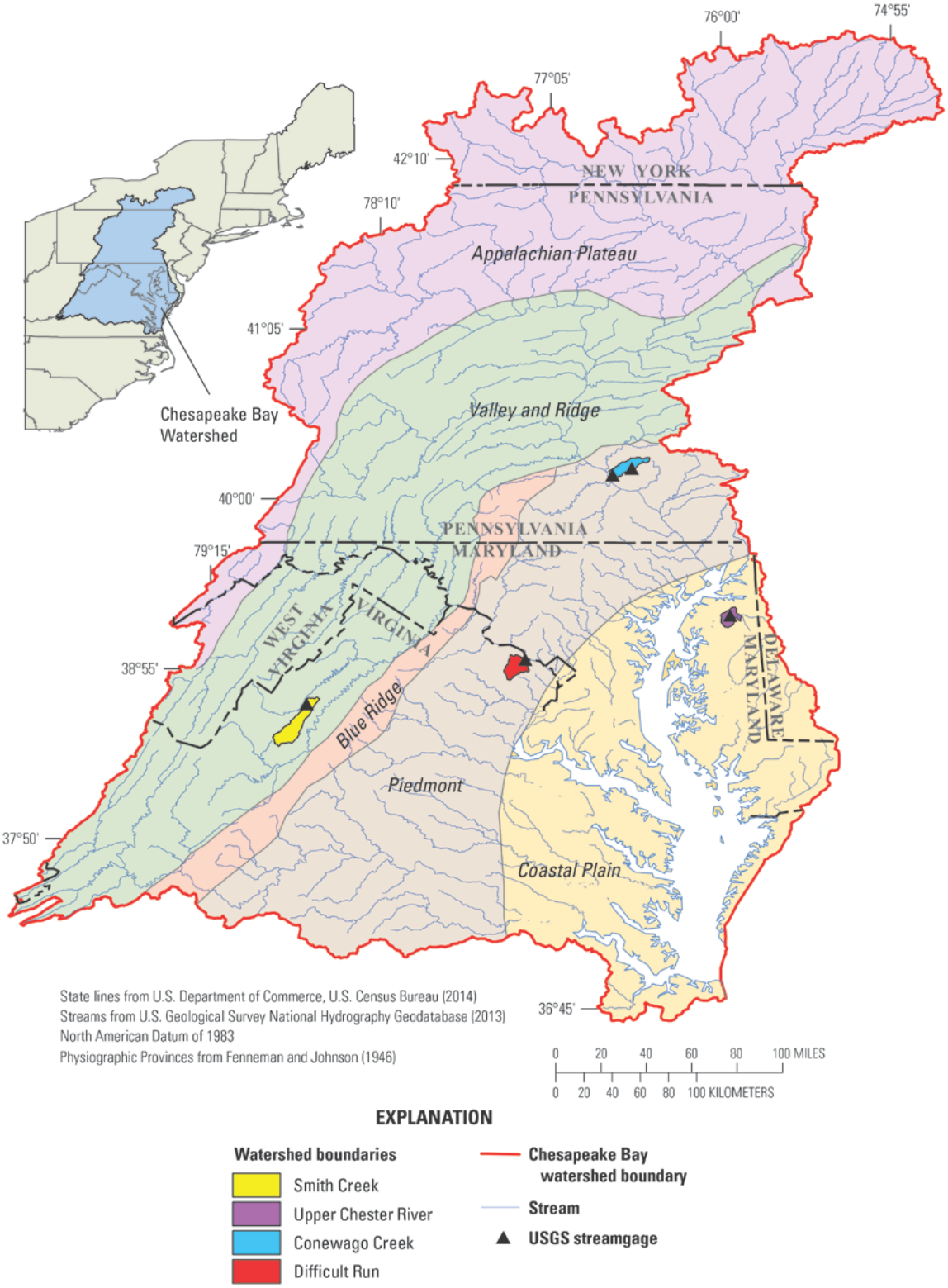

Figure 1. Map showing physiographic provinces and the location of the four study watersheds within the Chesapeake Bay watershed.

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