Summary of Nitrogen, Phosphorus, and Suspended-Sediment Loads and Trends Measured at the Nine Chesapeake Bay River Input Monitoring Stations: Water Year 2024 Update

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Introduction

The Chesapeake Bay River Input Monitoring (RIM) network consists of nine stations located near the nontidal-tidal interface of the nine largest rivers in the Chesapeake Bay watershed (fig. 1). These rivers are the Susquehanna, Potomac, James, Rappahannock, Appomattox, Pamunkey, Mattaponi, Patuxent, and Choptank. Stations are located near U.S. Geological Survey (USGS) streamgages to permit estimates of nutrient and sediment loading and trends in the amount of constituents delivered downstream. The Chesapeake Bay partnership uses results from this monitoring network to determine the amounts of, and trends in, nitrogen, phosphorus, and suspended sediment delivered annually from the nontidal portion of the Chesapeake Bay watershed.

Trends in Load Delivered to Tidal Waters from the RIM Stations

Trends in total nitrogen, total phosphorus, and suspended-sediment flow-normalized (FN) load are shown for the nine RIM stations in table 1. Trends are shown for a long-term (water years 1985 through 2024) and short-term (water years 2015 through 2024) period. Green-shaded cells indicate "improving" trends, orange-shaded cells indicate "degrading" trends, and grey-shaded cells indicate "no trend." These trend-direction terms are based on Chesapeake Bay restoration goals for water-quality attainment (for example, a reduction of nutrients and sediment is an "improvement"). The "no trend" term indicates that an "improving/degrading" trend is about as likely to exist as it is not to exist, based on a middling probably score from the trend-estimation model.

Table 1. Total nitrogen, total phosphorus, and suspended-sediment trend direction and percent change of FN load for water years 1985 through 2024 (Long-term) and water years 2015 through 2024 (Short-term). "Improving" trend results are shaded green; "Degrading" trend results are shaded orange; "No Trend" results are shaded grey. Stations are ordered by decreasing watershed area.

RIVER INPUT MONITORING STATION	TREND DIRECTION AND PERCENT CHANGE IN FN LOAD					
	TOTAL NITROGEN		TOTAL PHOSPHORUS		SUSPENDED SEDMENT	
	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term
SUSQUEHANNA RIVER AT CONOWINGO, MD	*-31.2*	*-12.4*	*-4.55*	*-22.8*	*+21.5*	*-24.8*
POTOMAC RIVER AT CHAIN BRIDGE, MD	*-18.4*	*-7.58*	*-24.3*	*-1.02*	*-41.7*	*+13.1*
JAMES RIVER AT CARTERSVILLE, VA	*-8.03*	*+11.2*	*-22.1*	*+25.8*	*+40.3*	*+20.9*
RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA	*-15.6*	*+7.26*	*+31.2*	*+7.55*	*+50*	*+1.68*
APPOMATTOX RIVER AT MATOACA, VA	*+6.42*	*+5.41*	*+99.5*	*+23.4*	*+44.2*	*+38.9*
PAMUNKEY RIVER NEAR HANOVER, VA	*-1.33*	*-3.86*	*+59.2*	*+0.961*	*+36.3*	*-9.87*
MATTAPONI RIVER NEAR BEULAHVILLE, VA	*-6.43*	*+1.67*	*+6.37*	*+8.94*	*+8.59*	*+26.9*
PATUXENT RIVER AT BOWIE, MD	*-69.5*	*-20.9*	*-66.7*	*-5.21*	*-43.7*	*-4.07*
CHOPTANK RIVER NEAR GREENSBORO, MD	*-2.5*	*-4.52*	*+77.4*	*+20.2*	*-34.3*	*-7.5*

Long-term and short-term trends in total nitrogen load

- Long-term trends in total nitrogen FN load indicate improving conditions at six stations, including the four largest rivers (Susquehanna, Potomac, James, and Rappahannock) along with the Mattaponi and Patuxent. The Appomattox shows degrading conditions and the Pamunkey and Choptank indicate no long-term trend (meaning a trend was deemed as likely to exist as not) for this time period.
- Short-term trends in total nitrogen FN load indicate improving conditions at five stations (Susquehanna, Potomac, Pamunkey, Patuxent, and Choptank) and degrading conditions at three stations (James, Rappahannock, and Appomattox). The Mattaponi shows no short-term trend for this time period.

Long-term and short-term trends in total phosphorus load

- Long-term trends in total phosphorus FN load indicate improving conditions at the Susquehanna, Potomac, James, and Patuxent and degrading conditions at the Rappahannock, Appomattox, Pamunkey, and Choptank. The Mattaponi shows no long-term trend.
- Short-term trends in total phosphorus FN load indicate improving conditions at the Susquehanna and degrading conditions at the James, Rappahannock, Appomattox, Mattaponi, and Choptank. No discernable trends were observed at the Potomac, Pamunkey or Patuxent.

Long-term and short-term trends in suspended-sediment load

- Long-term trends in suspended-sediment FN load indicate degrading conditions at six stations (Susquehanna, James, Rappahannock, Appomattox, Pamunkey, and Mattaponi), and improving conditions at the Potomac, Patuxent, and Choptank.
- Short-term trends in suspended-sediment FN load indicate improving conditions at two of the nine stations (Susquehanna and Choptank), degrading conditions at four stations (Potomac, James, Appomattox, and Mattaponi), and no discernable trend for conditions at the Rappahannock, Pamunkey, or Patuxent stations.

Trends in Relation to the Chesapeake Bay Total Maximum Daily Load (TMDL): 1995-2024

Trends from water years 1995 through 2024 were computed to align with the timeframe used by the 2010 Chesapeake Bay TMDL (table 2). The TMDL load allocations and planning targets represent modeled reductions from 1995 that would have met water-quality standards in the Chesapeake Bay (Linker and others, 2013; U.S. Environmental Protection Agency, 2010).

Meeting TMDL load reduction goals in the RIM watersheds likely requires an “improving” trend relative to conditions in 1995. Only three RIM stations had "improving" trends from water years 1995 through 2024, indicated by green-shaded cells in Table 2: FN loads at the Susquehanna, Potomac, and Patuxent for total nitrogen only. All other nutrient and sediment trends increased ("degrading" trends indicated by orange-shaded cells), except for total phosphorus at Patuxent and suspended sediment at Choptank that showed no discernable trend, indicated by grey-shaded cells.

Table 2. Total nitrogen, total phosphorus, and suspended-sediment trend direction and percent change of FN load from water years 1995 through 2024. “Improving” trend results are shaded green; “Degrading” trend results are shaded orange. “No Trend” results are shaded grey. Stations are ordered by decreasing watershed area.

RIVER INPUT MONITORING STATION	TREND DIRECTION AND PERCENT CHANGE IN FN LOAD: TMDL PERIOD 1995-2024		
	TOTAL NITROGEN	TOTAL PHOSPHORUS	SUSPENDED SEDIMENT
SUSQUEHANNA RIVER AT CONOWINGO, MD	*-14.3*	*+24.9*	*+15.6*
POTOMAC RIVER AT CHAIN BRIDGE, MD	*-18.6*	*+13.7*	*+49.4*
JAMES RIVER AT CARTERSVILLE, VA	*+14*	*+32.4*	*+26.8*
RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA	*+13.4*	*+52.4*	*+26.2*
APPOMATTOX RIVER AT MATOACA, VA	*+18.4*	*+30.5*	*+64.1*
PAMUNKEY RIVER NEAR HANOVER, VA	*+6.87*	*+27*	*+38.7*
MATTAPONI RIVER NEAR BEULAHVILLE, VA	*+12.9*	*+10*	*+39.2*
PATUXENT RIVER AT BOWIE, MD	*-41.9*	*-7.19*	*+16*
CHOPTANK RIVER NEAR GREENSBORO, MD	*+9.54*	*+96.1*	*-6.77*

Trends in Streamflow at the RIM Stations

Trends in mean-annual streamflow from water years 1985 through 2024 describe whether the average amount of streamflow at the RIM stations is increasing or decreasing over a long-term period. Only the Choptank showed a statistically significant change (1.3% increase) in mean-daily streamflow.

Patterns in Annual Freshwater Flow and Loads Delivered from the Total RIM Watershed Area to Tidal Waters

Load results were summed from the nine RIM stations to quantify the total nitrogen, phosphorus, and suspended-sediment loads delivered from the RIM watershed area to tidal waters. Together, the nine RIM stations represent loads and streamflow delivered from 78 percent of the 64,000-square-mile Chesapeake Bay watershed (fig. 1). The Chesapeake Bay Program uses these RIM loads, and estimated loads from the remaining unmonitored areas, to compute a total nutrient and sediment load to the Bay.

- Estimated annual-mean streamflow entering the Chesapeake Bay in water year 2024 was 84,000 cubic feet per second (cfs), about 6 percent (4,700 cfs) above the long-term (1937-2024) annual-mean streamflow of 79,300 cfs (fig. 2), which indicates a below average total streamflow amount for the year. How did this mean annual streamflow rank? Water year 2024 had the 30th highest streamflow since 1937 (88 years).
- In water year 2024, the summed load from the nine RIM stations were as follows:

- Total nitrogen: 187 million pounds (Mlb), 13 Mlb less than the long-term average of 200 Mlb for 1985-2024 (fig. 3).
- Total phosphorus: 12 Mlb, 0.2 Mlb more than the long-term average of 11.8 Mlb for 1985- 2024 (fig. 4).
- Suspended sediment: 3.4 million tons (Mton), 0.5 Mton less than the long-term average of 3.9 (Mtons) for 1985-2024 (fig. 5).

Methods

Loads, and changes in loads, of nitrogen, phosphorus, and suspended-sediment in rivers across the Chesapeake Bay watershed are calculated using monitoring data from the RIM stations for water years 1985 to 2024 (Mason and Soroka, 2025). Additional information for each monitoring station is available through the USGS "Chesapeake Bay Water Quality Loads and Trends" site (usgs.gov/CB-wq-loads-trends). This website provides State, Federal, and local partners, as well as the general public, ready access to a wide range of data for nutrient and sediment conditions across the Chesapeake Bay watershed.

Loads are computed using Weighted Regression on Time, Discharge and Season (WRTDS) bootstrap models (Chanat and others, 2015), which are then flow-normalized (FN) to produce the published trend estimates. These models are calibrated using sampling data collected monthly and during eight additional storm-events each year to obtain a minimum of 20 samples per year, representing a range of streamflow and constituent-loading conditions. The WRTDS serial error from each daily load model is then leveraged using a dynamic auto-correlation Kalman-filter adjustment to produce the published loads (Zhang and Hirsch, 2019). Ultimately, trends in loads at the RIM stations go through the FN process to remove the year-to-year variability in river flow; by doing so, changes in nitrogen, phosphorus, and suspended-sediment loads resulting from changing sources, delays associated with storage and transport of historical inputs, and (or) implemented management actions are better identified.

In this summary, results are reported from three water-year periods: (1) long-term trends from 1985 through 2024, (2) short-term trends from 2015 through 2024, and (3) trends from 1995 through 2024. The RIM stations where FN loads are lower in the end year than in the start year are classified as having improving conditions, whereas stations where the FN loads are higher in the end year than in the start year are classified as having degrading conditions (improving/degrading conditions are based on a likelihood estimate probability score of greater than or equal to 67 percent). A station is classified as having no trend if there is no discernable difference between the FN loads in the start year and those in the end year (based on a probability score greater than 33 and less than 67 percent).

Trends in annual-mean streamflow were computed using a Mann-Kendall test. The annual rate of change was determined from the slope of a Thiel-Sen line. An alpha value of 0.05 was used to interpret the significance of streamflow trends.

References Cited

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Zhang, Q. and Hirsch, R. M., 2019, River water-quality concentration and flux estimation can be improved by accounting for serial correlation through an autoregressive model: Water Resources Research, 55, 9705–9723 p., accessed May 6, 2024 at doi.org/10.1029/2019WR025338.

Additional Information and USGS Contacts

For more information on this topic, visit the “Water-Quality Loads and Trends at Nontidal Monitoring Stations in the Chesapeake Bay Watershed” website at usgs.gov/CB-wq-loads-trends, or contact:

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For more information on USGS Chesapeake Bay studies, visit chesapeake.usgs.gov, or contact Ken Hyer, **kenhyer@usgs.gov**.

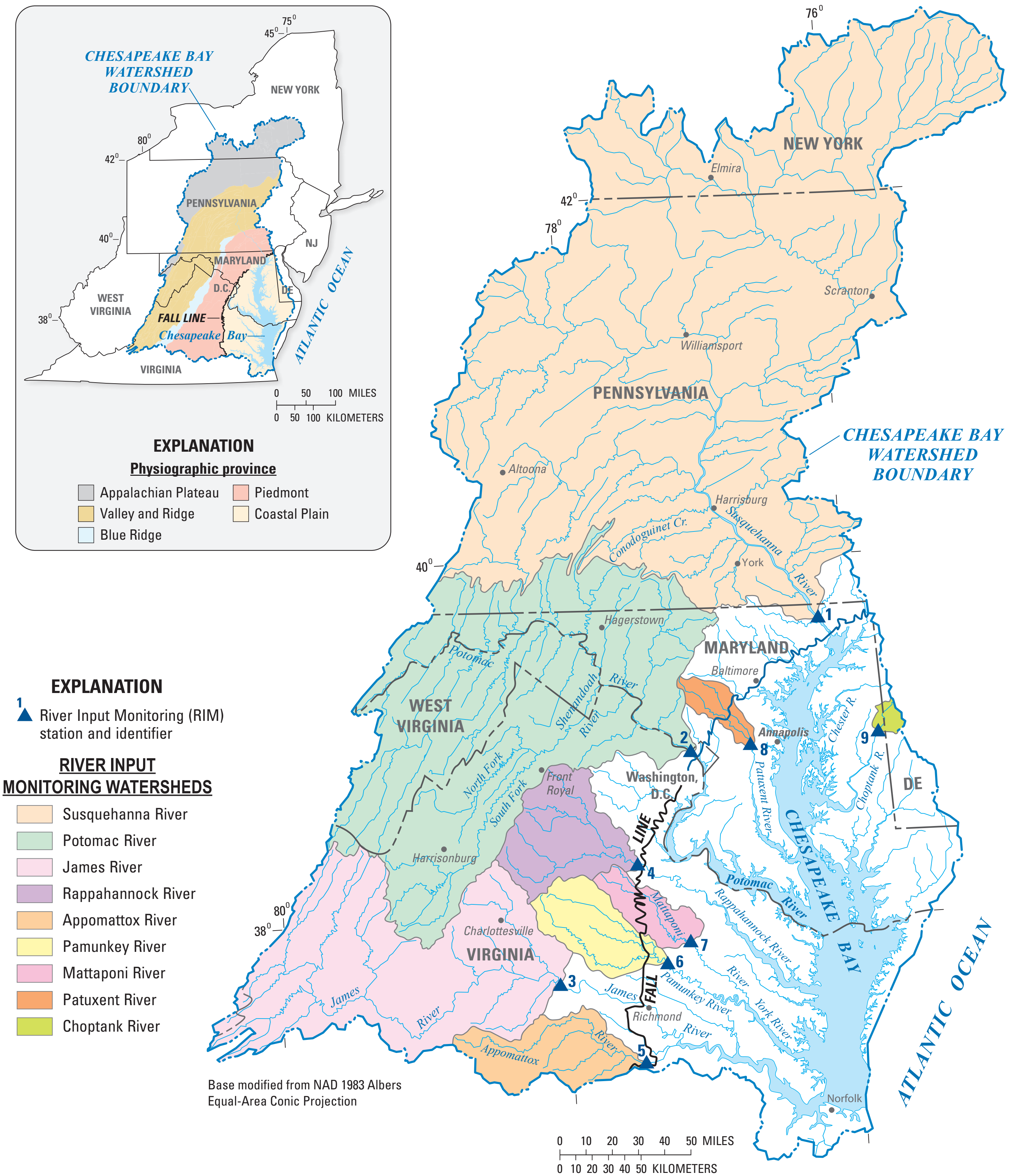

Figure 1. Location of the nine River Input Monitoring (RIM) stations in the Chesapeake Bay watershed. Station names are provided in Table 1.

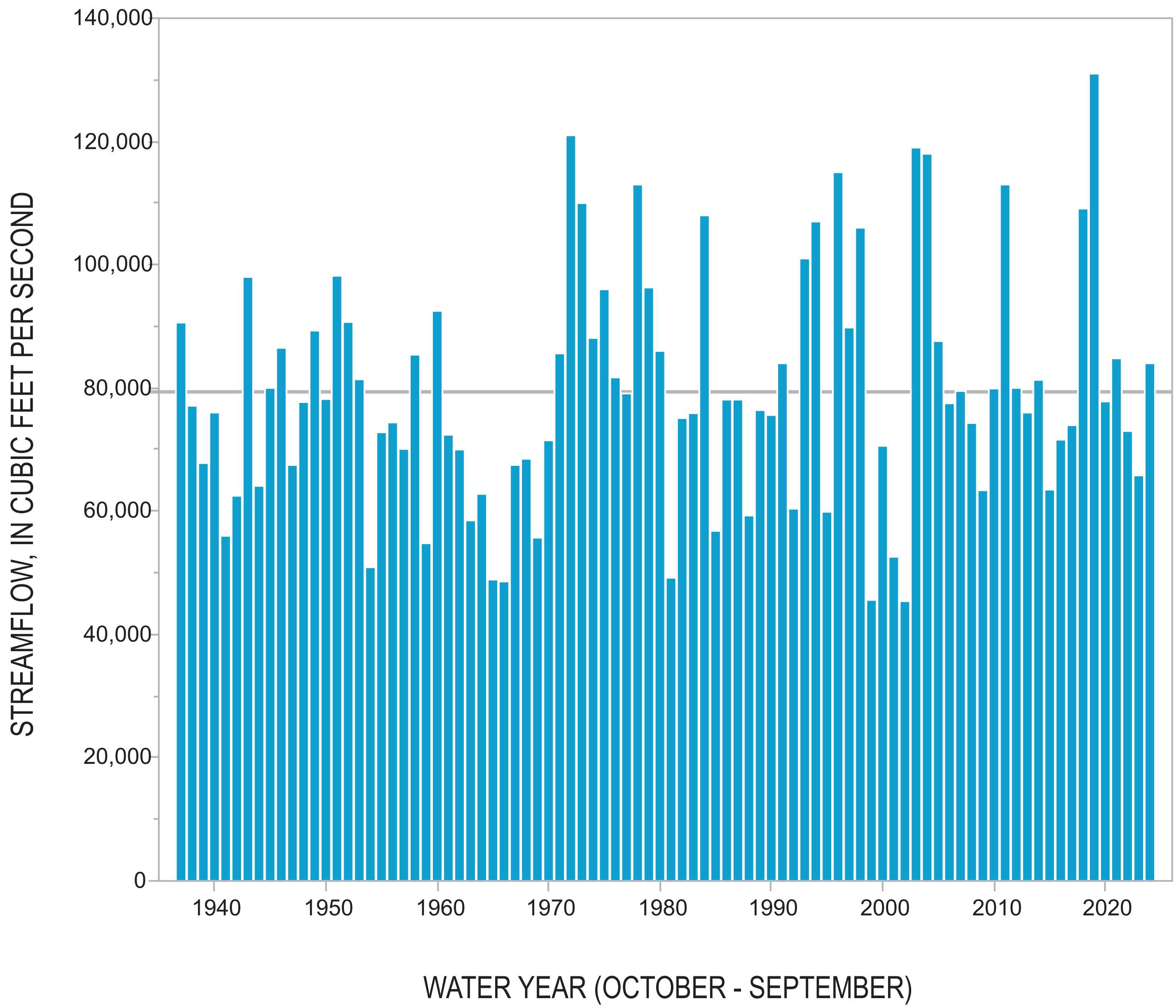

Figure 2. Estimated annual-mean streamflow entering the Chesapeake Bay. Gray line represents the average annual-mean streamflow of 79,300 cubic feet per second.

[SOURCE: usgs.gov/centers/cba/science/freshwater-flow-chesapeake-bay?qt-science_center_objects=0#qt-science_center_objects]

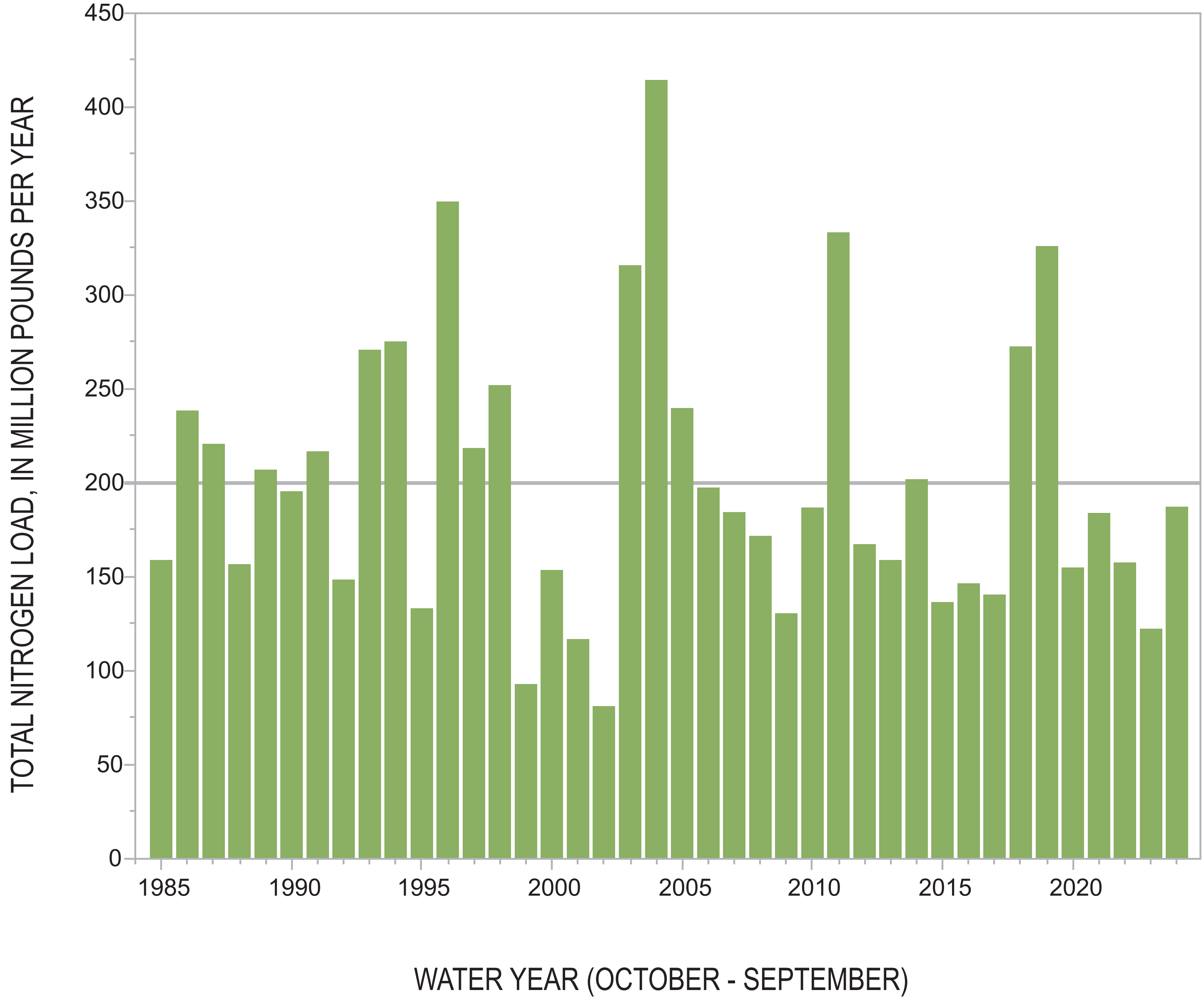

Figure 3. Combined annual total nitrogen delivered from the nine River Input Monitoring stations to the Chesapeake Bay. Gray line represents the mean annual combined load of 200 million pounds per year.

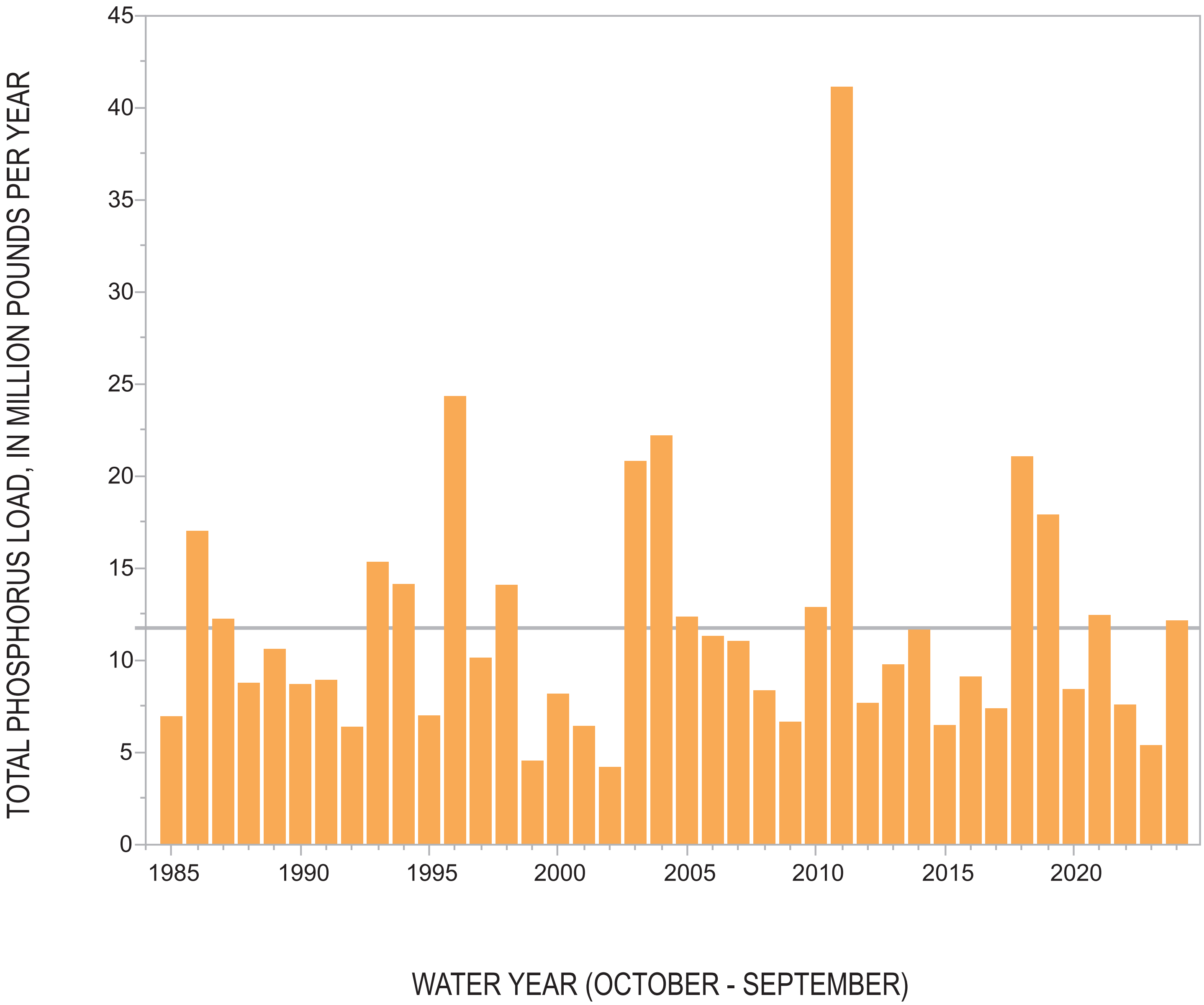

Figure 4. Combined annual total phosphorus delivered from the nine River Input Monitoring stations to the Chesapeake Bay. Gray line represents the mean annual combined load of 11.8 million pounds per year.

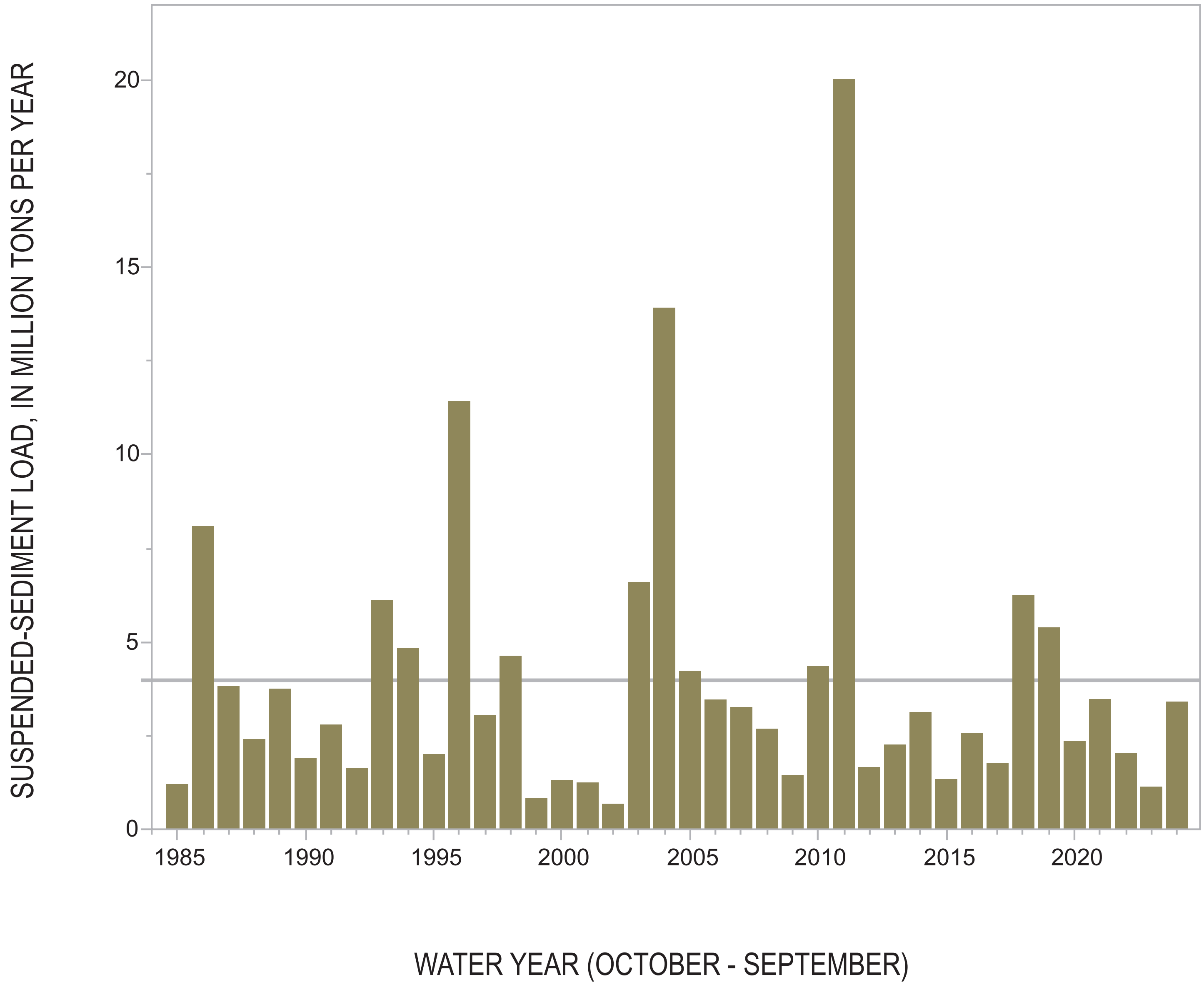

Figure 5. Combined annual suspended-sediment load delivered from the nine River Input Monitoring stations to the Chesapeake Bay. Gray line represents the mean annual combined load of 3.9 million tons per year.