

# Evaluating Water-Quality Drivers in Streams of Fairfax County, Virginia

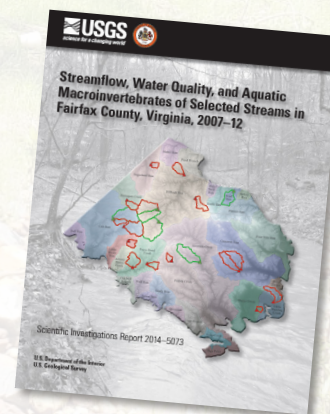
**Jimmy Webber**, Jeff Chanat, Aaron Porter, and John Jastram  
jwebber@usgs.gov

*U.S. Geological Survey, Virginia and West Virginia Water Science Center*

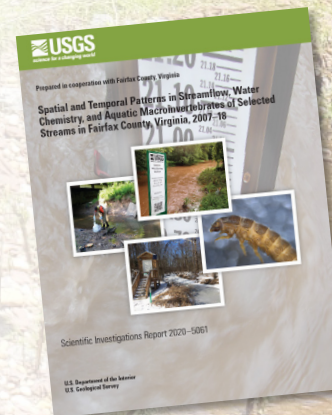
This presentation will describe how nutrient, sediment, and salinity conditions have changed over a recent ten-year period in Fairfax County streams in response to landscape and climatic conditions and management practice effects:

1. Study Design and Methods
2. Management Practices in Fairfax County
3. Water-Quality Responses and Drivers
4. Management Practice Effects

This work is part of an upcoming USGS report that builds on previous research efforts. Visit our project website to learn more about ongoing science in Fairfax County: [va.water.usgs.gov/fairfax](http://va.water.usgs.gov/fairfax)



**Jastram, 2014**



**Porter and others, 2020**

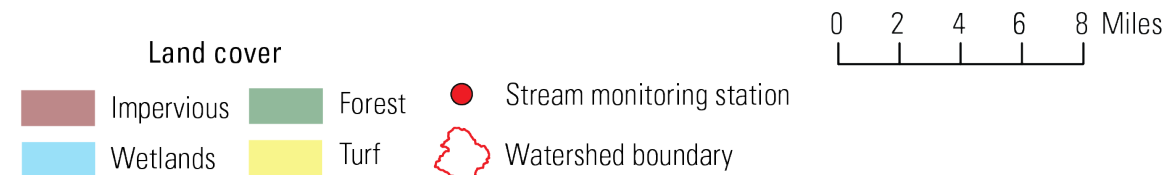
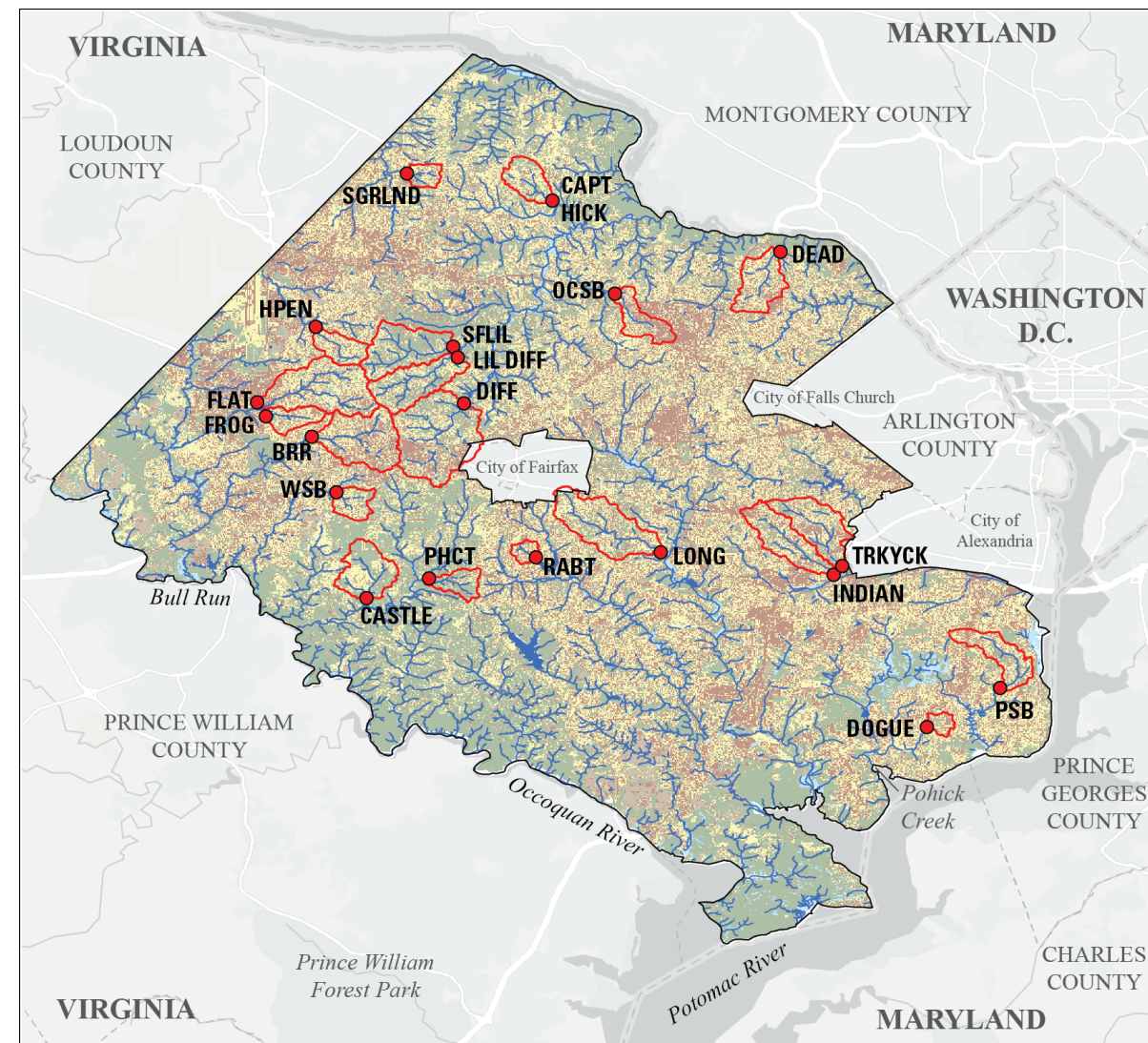
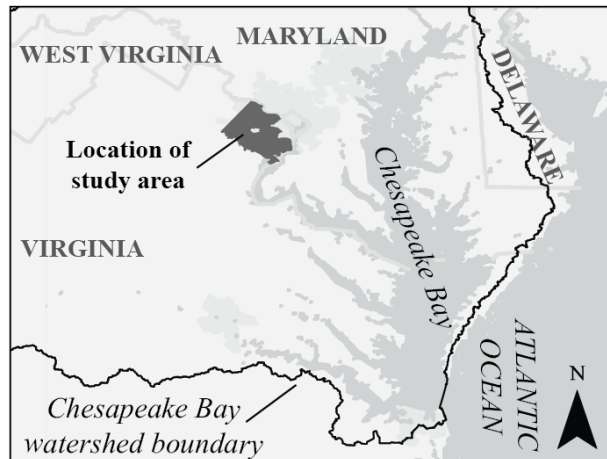
# Evaluating Water-Quality Drivers in Streams of Fairfax County, Virginia

## Some important messages from this research:

1. Water-quality changes occurred from 2008 through 2018 in Fairfax County streams. In general: nitrogen concentrations declined, phosphorus concentrations and specific conductance increased, and suspended sediment concentrations were unchanged.
2. Differences in physical watershed characteristics, landscape activities, and year-to-year climatic patterns helped explain these water-quality changes.
3. Expected management-practice effects were not consistently observed in monitored responses.
4. Future investigations of management-practice effects in urban streams will need to control for influences from landscape and climatic conditions.

# The monitoring network is designed to assess Fairfax County stream conditions

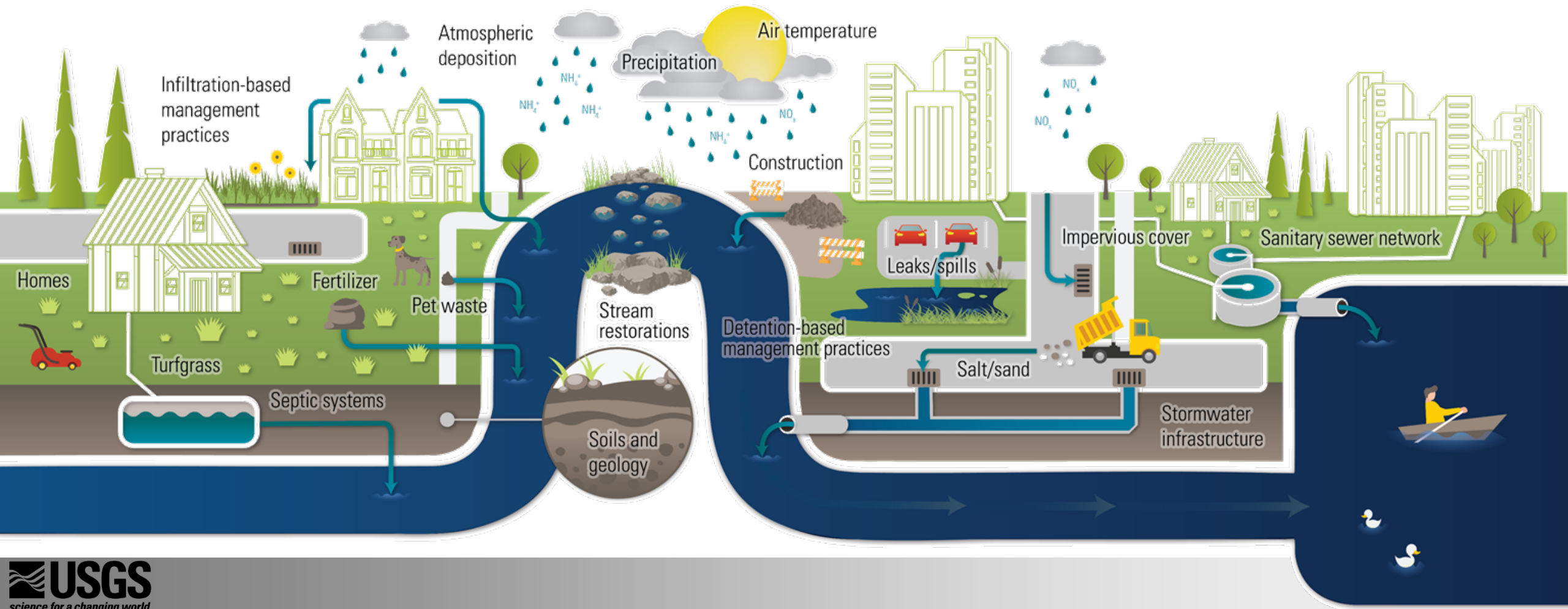
- There are 20 stream monitoring stations in Fairfax County, VA ranging in size from 0.5 to 5.5 mi<sup>2</sup>.
- 14 stations were established in 2007; 6 stations were added in 2012.
- Measures of hydrology, water-quality, and ecology are collected from the monitoring network.
  - Nitrogen, phosphorus, and suspended sediment concentrations are analyzed from monthly and/or storm targeted water-quality samples.



# Many factors can influence water-quality conditions in Fairfax County streams

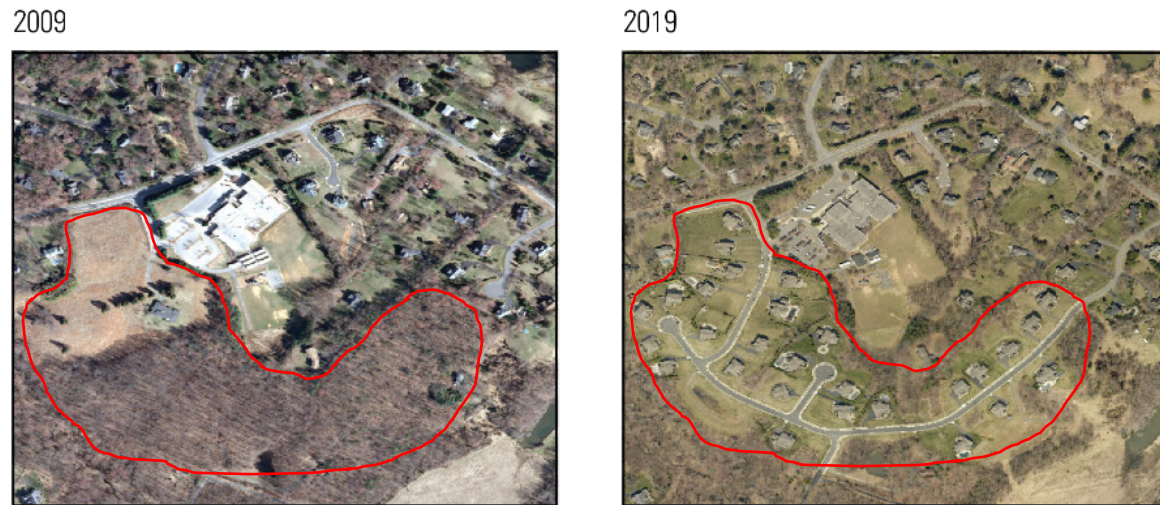
Datasets were built that represent hypothetical drivers of water quality in Fairfax County streams.

About 100 variables were included, with values representing annual conditions from 2009 through 2018 in 14 study watersheds.



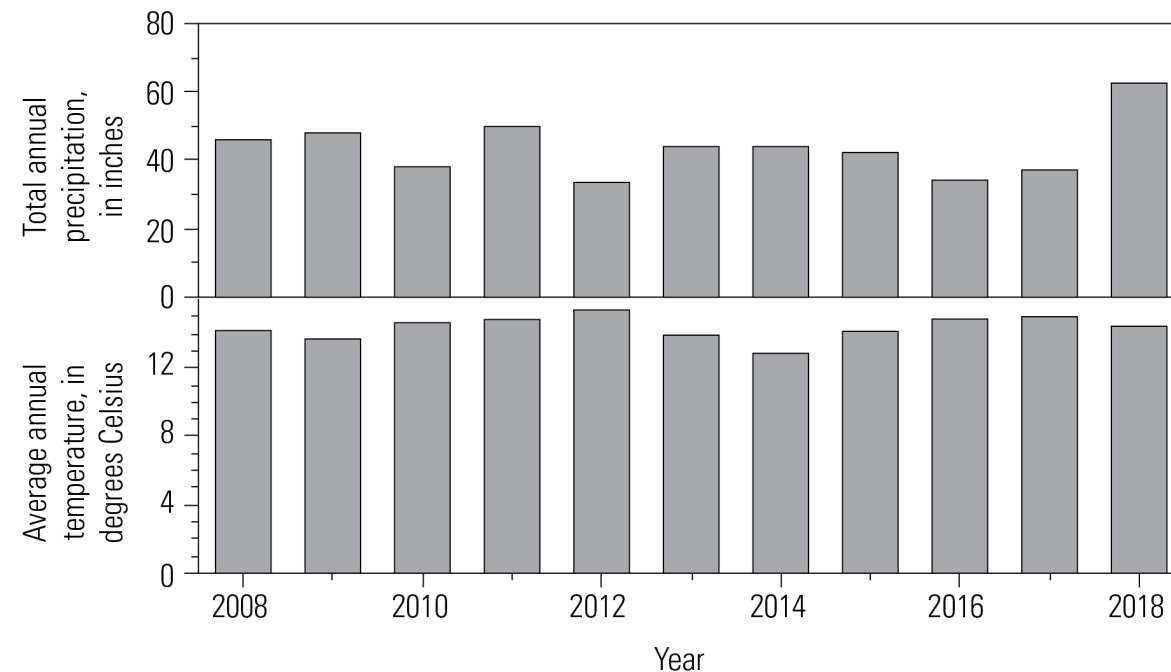
# The study period captured a general expansion of the built environment and variable climatic conditions

- Fairfax County's population increased by about 10%, or 100,000 people during the study period, requiring new homes, roads, and infrastructure to manage additional stormwater and wastewater.
- These measures of urbanization generally increased in all study watersheds.
- The increases in urbanization observed throughout Fairfax County during the study period were generally smaller than changes that occurred in previous decades.



Aerial photography within one study watershed in 2009 and 2019, with changes in development between these years highlighted in a red outline.

- Total annual precipitation ranged from 33.6 inches in 2012 to 62.6 inches in 2018.
- Average-annual air temperature ranged from 12.9 °C in 2014 to 15.4 °C in 2012



Bar graphs showing total annual precipitation and average-annual air temperature in Fairfax County from 2008 through 2018.

# This study considered the effect of management practices that were implemented to reduce nitrogen, phosphorus, and sediment loads

**Stormwater Retrofits:** practices capture stormwater runoff in temporary storage areas and reduce loads through physical or biochemical processes.



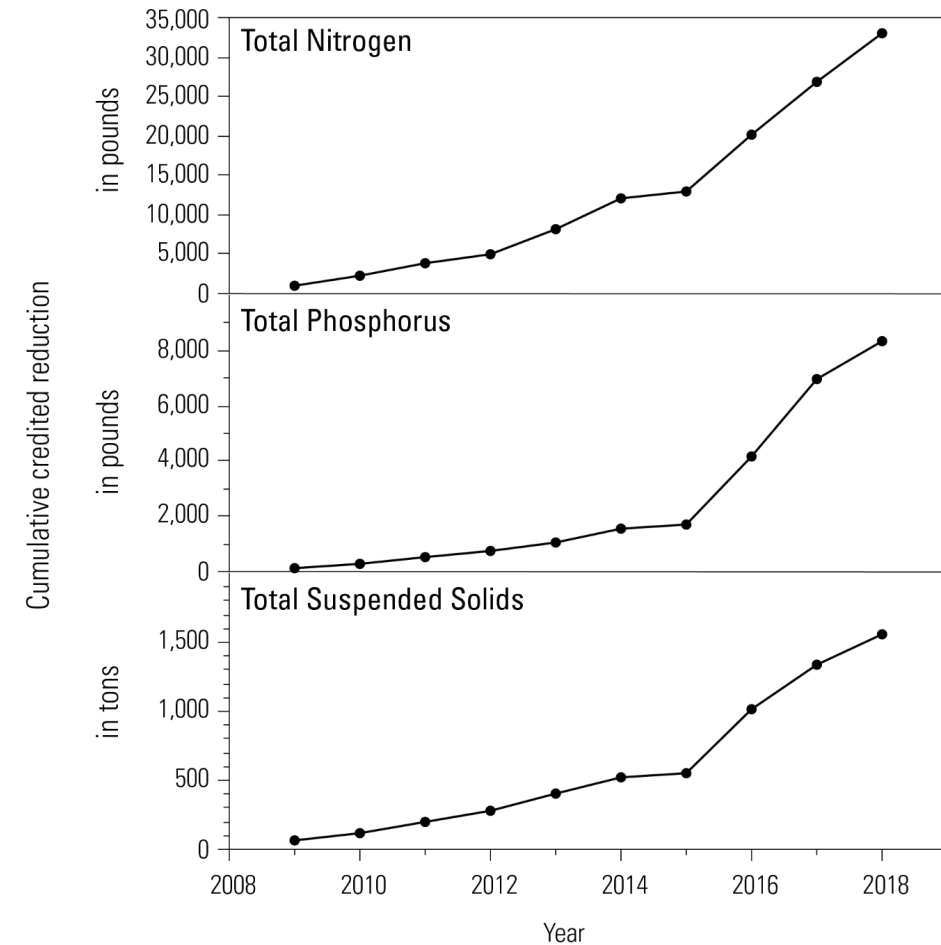
Photo, courtesy of Fairfax County, of a stormwater retrofit management practice.

**Channel Restorations:** practices that target the restoration of stormwater outfalls or stream segments.



Photo, courtesy of Fairfax County, of a restored stream reach.

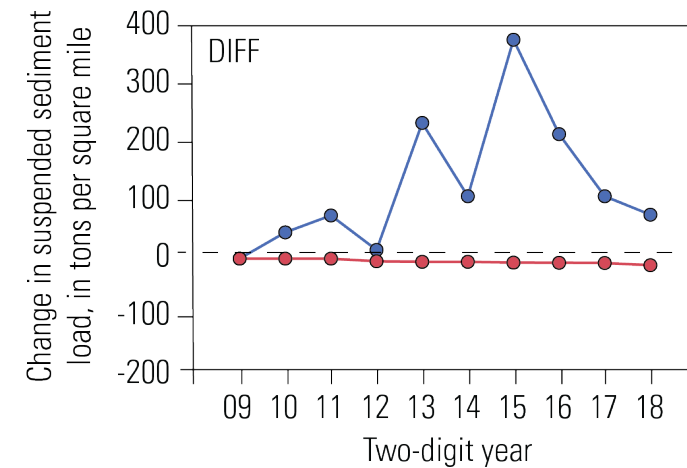
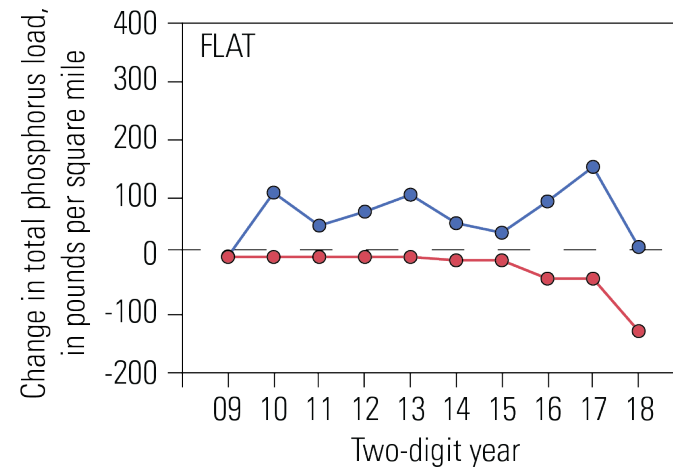
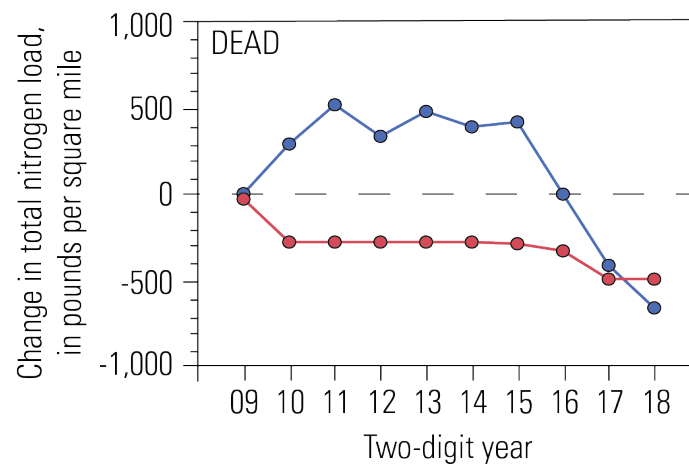
These practices are expected to reduce thousands of pounds of nitrogen, phosphorus, and sediment in Fairfax County streams.



Graph showing the cumulative credited reduction of total nitrogen, total phosphorus, and total suspended solids for Fairfax County management practices completed from 2009 through 2018.

# Expected management-practice effects were not consistently observed in monitored responses

1. Management-practice effects did not help explain the variability of median-annual water-quality responses in models that accounted for landscape and climatic effects.
2. Changes in hydrology during storm events were not consistent with management-practice effects.
3. Changes in calculated nutrient and sediment loads did not clearly align with the timing or expected magnitude of management-practice reductions.



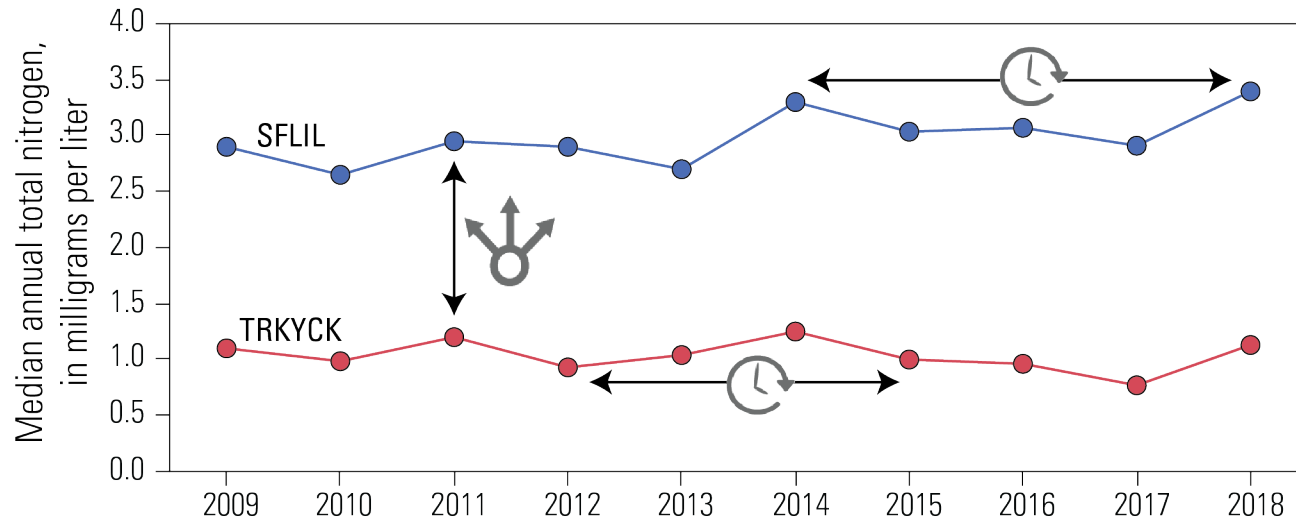
## EXPLANATION

— Change in flow-adjusted load relative to 2009    — Change in credited management-practice load reduction relative to 2009

Graphs of expected management-practice effects and calculated nutrient and sediment loads at selected study watersheds from 2009 through 2018.

# A variety of factors explained spatial and temporal water-quality differences

Water-quality variability included differences between study watersheds ( ↷ ) and changes over time ( ⌚ ).



Graph showing spatial and temporal variability of median annual total nitrogen concentrations at two study watersheds: SFLIL and TRKYCK

## Responses

	Total nitrogen	Total phosphorus	Suspended sediment	Specific conductance
Air temperature			⌚	⌚
Precipitation	⌚	⌚		
Developed land				↷
Turfgrass cover		↷		
Septic systems	⌚ ↷			
Dissolved oxygen		↷		
Soil depth		⌚ ↷		↷
Stream density			↷	

**Factors**

### Type of factor

- Climatic condition
- Wastewater infrastructure
- Physical watershed characteristic
- Land use and land cover
- Water quality

Linear mixed-effect models were used to evaluate how landscape, stream, and climatic conditions explained the variability of median-annual water-quality responses in 14 study watersheds over 10 years.



# Total nitrogen (TN) concentrations were related to septic system density and annual differences in rainfall

## Observed Responses

TN concentrations (on average, 0.5 – 3.0 mg/L) declined in 5 (▼) and increased in 1 (▲) study watershed between 2008 and 2018.

Other stations had no trend (○).

## Explanation of Variability

### Septic Systems



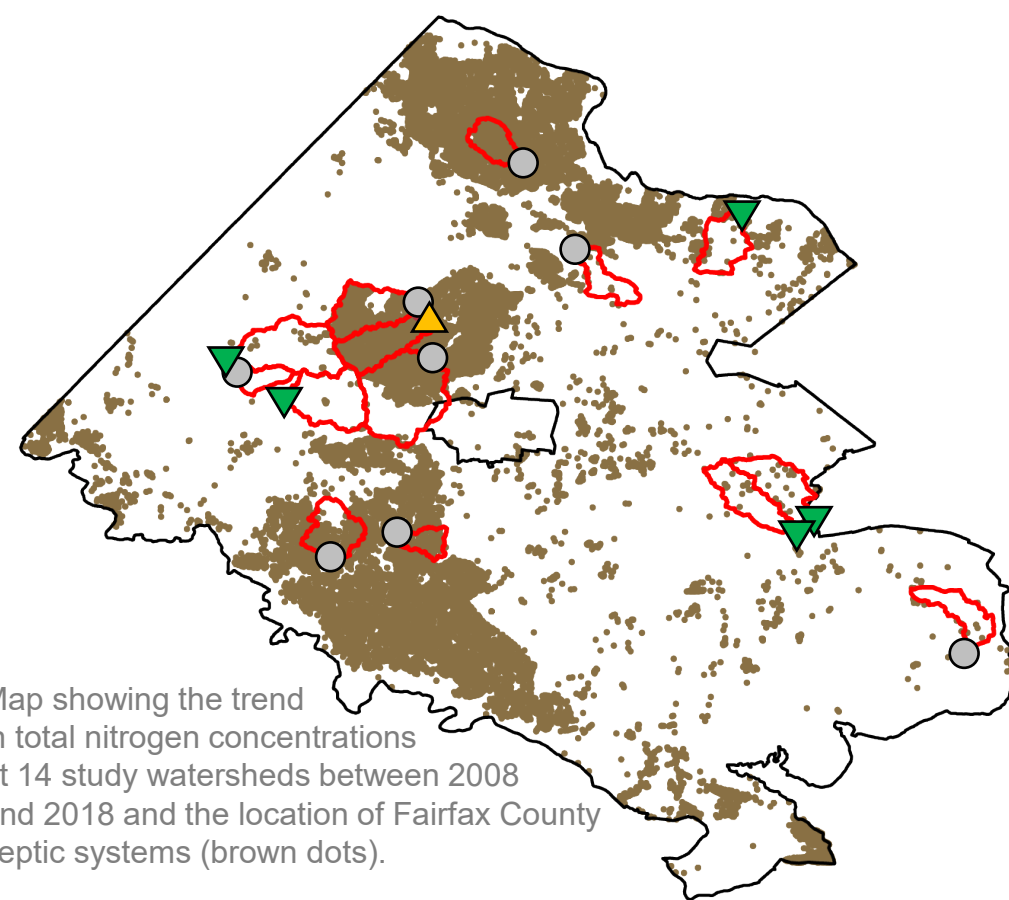
In watersheds with above average septic-system densities:

1. TN concentrations were higher than average and
2. TN concentration increases over time were more positive.

### Rainfall



TN concentrations were higher in years with more heavy rainfall days<sup>1</sup>.



Map showing the trend in total nitrogen concentrations at 14 study watersheds between 2008 and 2018 and the location of Fairfax County septic systems (brown dots).

# Total phosphorus (TP) concentrations were likely related to phosphorus soil storage and landscape inputs

## Observed Responses

TP concentrations (on average, 0.01 to 0.10 mg/L) declined in 1 (▼) and increased in 4 (▲) study watershed between 2008 and 2018.

Other stations had no trend (○).

## Explanation of Variability

### Soil Depth



In watersheds with deeper soils:

1. TP concentrations were lower than average and
2. TP concentration increases over time were more positive.

### Turfgrass



TP concentrations were higher in watersheds with more turfgrass.

### Dissolved Oxygen

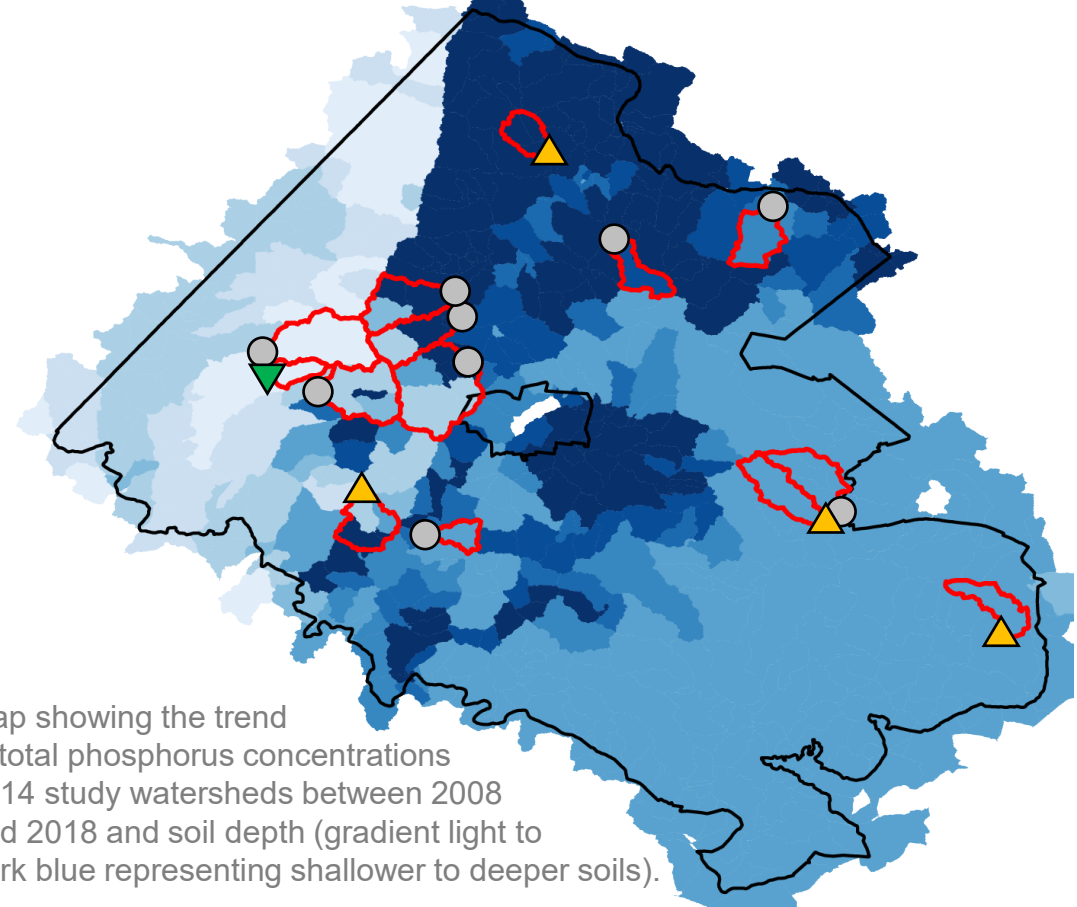


TP concentrations were higher in watersheds with lower stream dissolved oxygen concentrations.

### Rainfall



TP concentrations were lower in years with more rainfall.



Map showing the trend in total phosphorus concentrations at 14 study watersheds between 2008 and 2018 and soil depth (gradient light to dark blue representing shallower to deeper soils).

# Suspended sediment (SS) concentrations were likely related to factors affecting streambank erosion

## Observed Responses

SS concentrations (on average, 1 – 15 mg/L) declined in 1 (▼) and increased in 2 (▲) study watershed between 2008 and 2018.

Other stations had no trend (○).

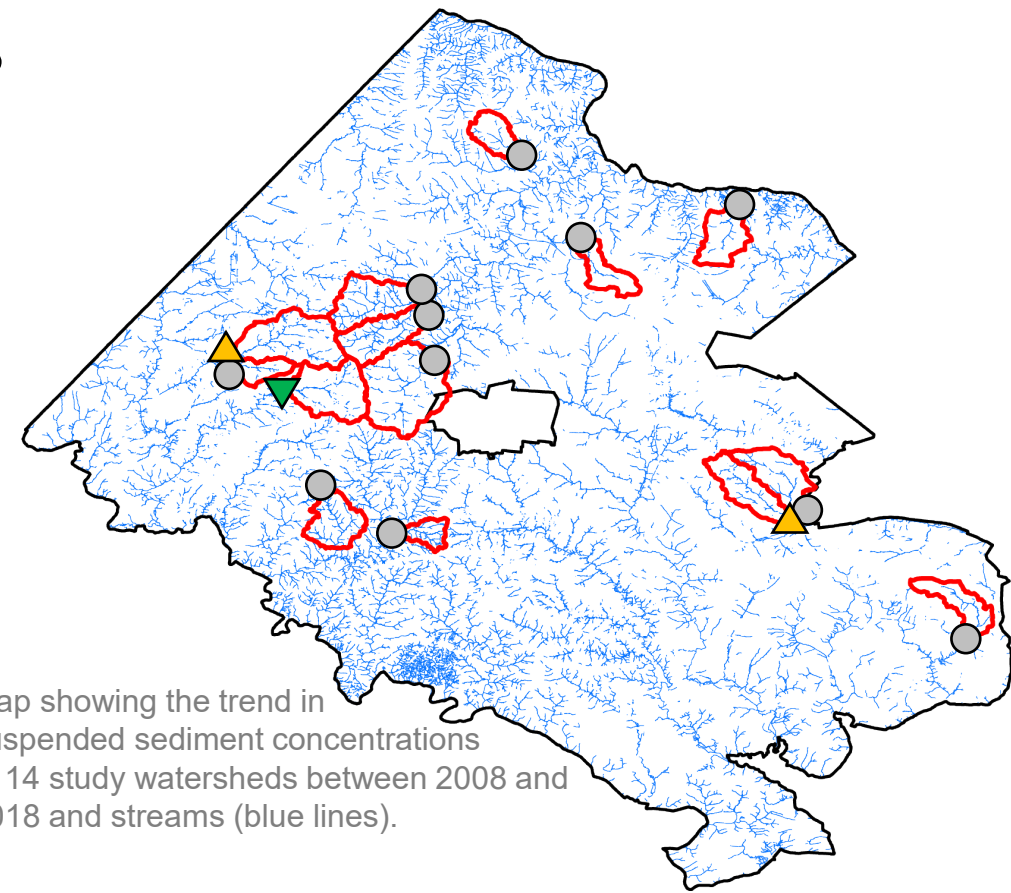
## Explanation of Variability

### Stream Density

SS concentrations were higher in watersheds with greater stream densities.



Photo of an exposed stream bank at one Fairfax County monitoring station.



Map showing the trend in suspended sediment concentrations at 14 study watersheds between 2008 and 2018 and streams (blue lines).

### Air Temperature

SS concentrations were higher in years with colder minimum air temperatures.

# Specific conductance (SC) was likely related to the applied amount and storage of salt on the landscape

## Observed Responses

SC values (on average, 150 – 500 uS/cm) declined in 0 (▼) and increased in 10 (▲) study watersheds between 2008 and 2018.

Other stations had no trend (○).

## Explanation of Variability

Developed Land



SC values were higher in watersheds with more developed land uses.

Soil Depth

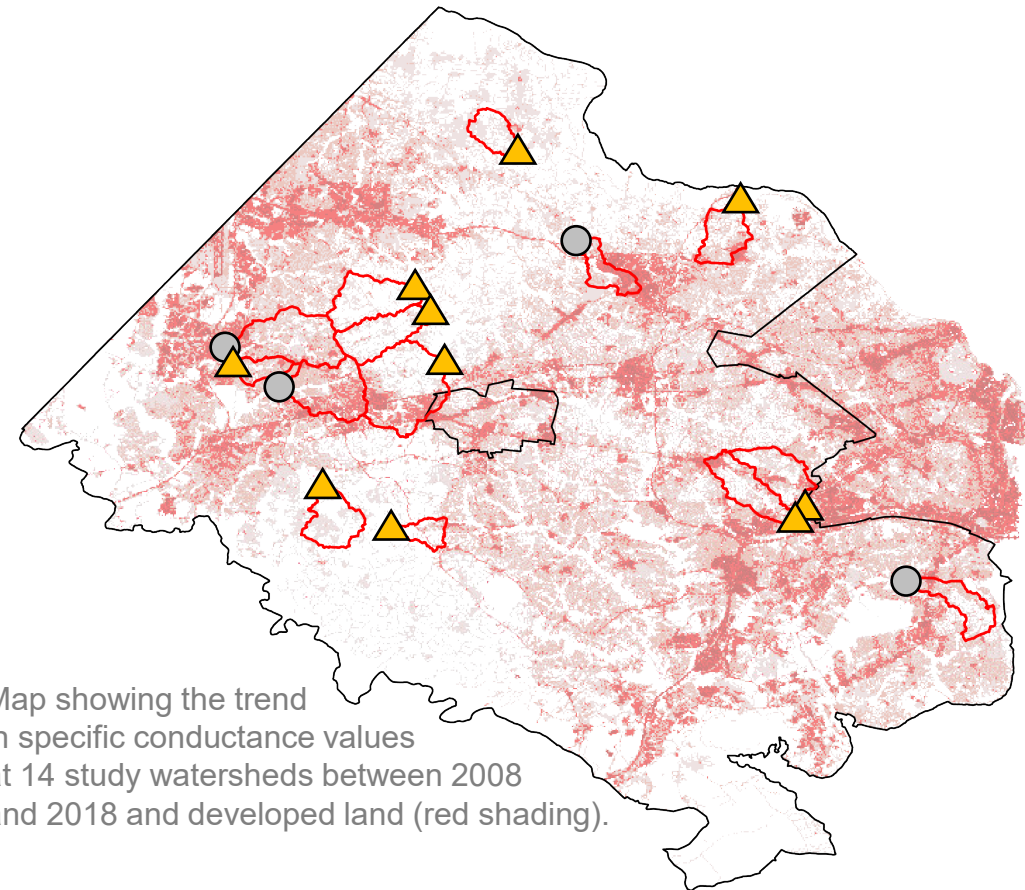


SC values were higher in watersheds with more shallow soils.

Air Temperature



SC values were higher in years with colder minimum air temperatures.



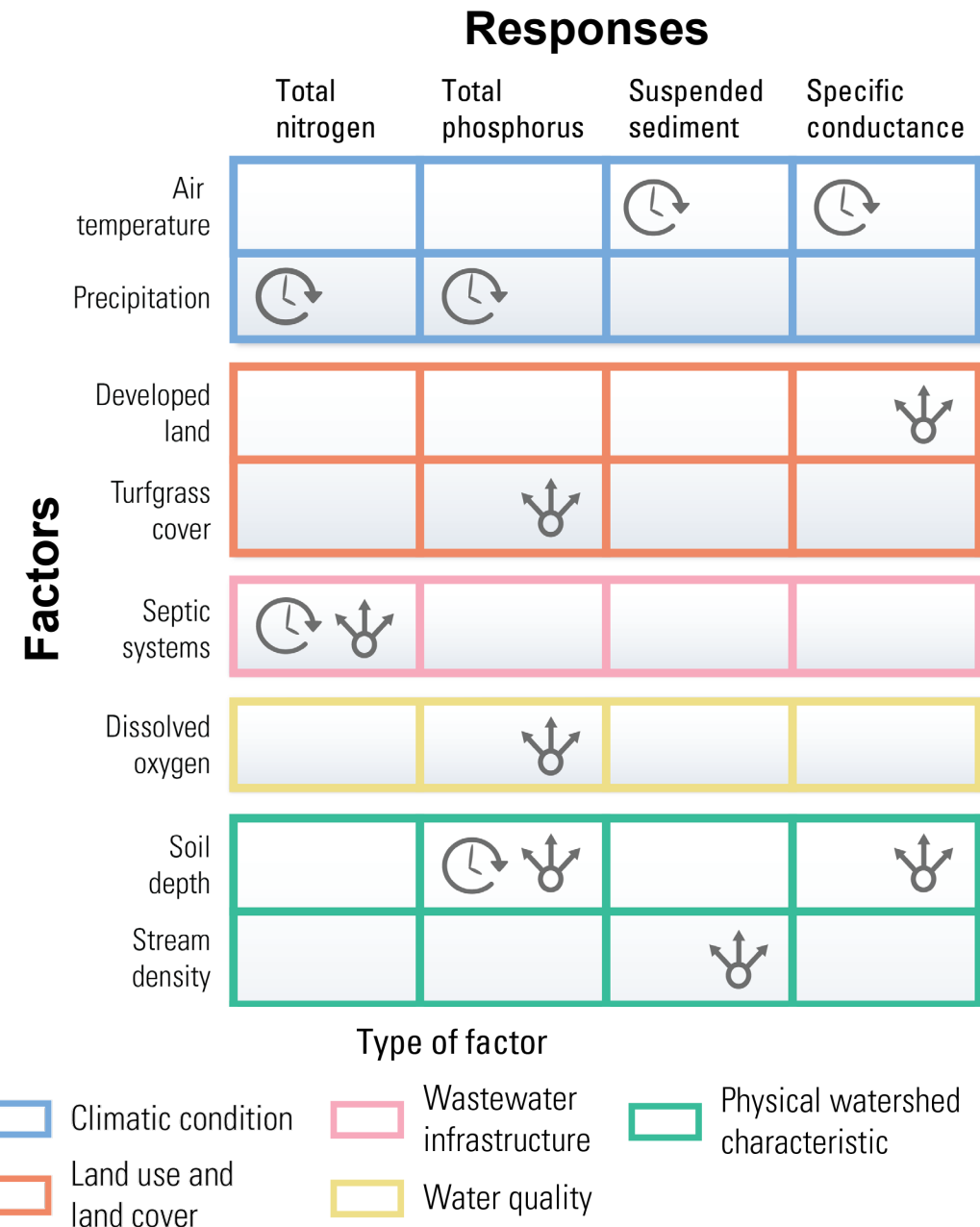
Map showing the trend in specific conductance values at 14 study watersheds between 2008 and 2018 and developed land (red shading).

# Expected management-practice effects were not consistently observed in monitored responses

1. Management-practice effects did not help explain the variability of median-annual water-quality responses in models that accounted for landscape and climatic effects.

Predictor	Fixed effects	
	Standardized Estimate	Standardized 95% CI
Intercept	0.00	0.00 – 0.00
Year ( $b_3$ )	-0.07	-0.23 – 0.09
R10D ( $b_3$ )	0.47	0.34 – 0.61
SEPTIC DEN ( $b_1$ )	0.67	0.31 – 1.03
SEPTIC DEN ( $b_2$ )	0.61	0.33 – 0.89
<b>TN TOT BMP (<math>b_3</math>)</b>	<b>-0.05</b>	<b>-0.19 – 0.10</b>
Marginal R <sup>2</sup>	0.58	
Conditional R <sup>2</sup>	0.98	
AIC	-47.25*	

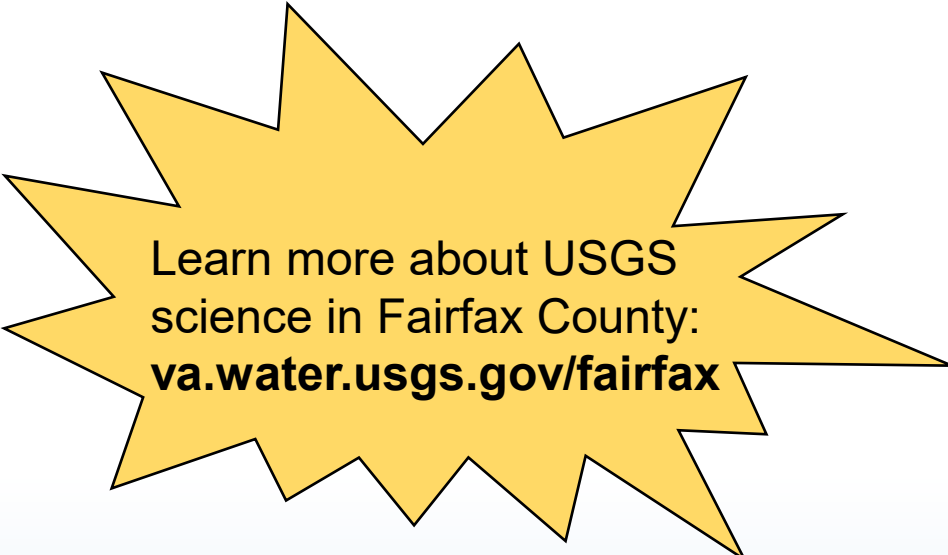
\*AIC of model without BMPs = -48.89



# Evaluating Water-Quality Drivers in Streams of Fairfax County, Virginia

Jimmy Webber, Jeff Chanat, Aaron Porter, and John Jastram  
jwebber@usgs.gov

*U.S. Geological Survey, Virginia and West Virginia Water Science Center*



Learn more about USGS science in Fairfax County:  
[va.water.usgs.gov/fairfax](https://va.water.usgs.gov/fairfax)

## Some important messages from this research:

1. Water-quality changes occurred from 2008 through 2018 in Fairfax County streams. In general: nitrogen concentrations declined, phosphorus concentrations and specific conductance increased, and suspended sediment concentrations were unchanged.
2. Differences in physical watershed characteristics, landscape activities, and year-to-year climatic patterns helped explain these water-quality changes.
3. Expected management-practice effects were not consistently observed in monitored responses.
4. Future investigations of management-practice effects in urban streams will need to control for influences from landscape and climatic conditions.