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

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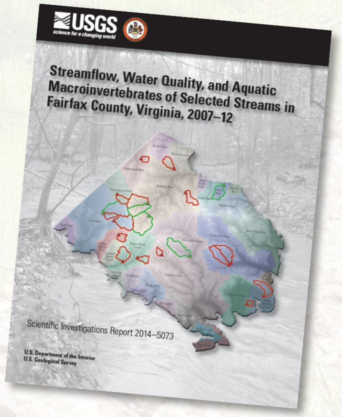
This presentation will describe how nutrients and sediment have changed over a recent ten-year period in Fairfax County streams in response to landscape and climatic conditions and management practice effects:

1. Study Design
2. Nutrient and Sediment Loads
3. Water-Quality Responses and Drivers

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**




**Jastram, 2014**


**Porter and others, 2020**


**Webber and others, 2023**

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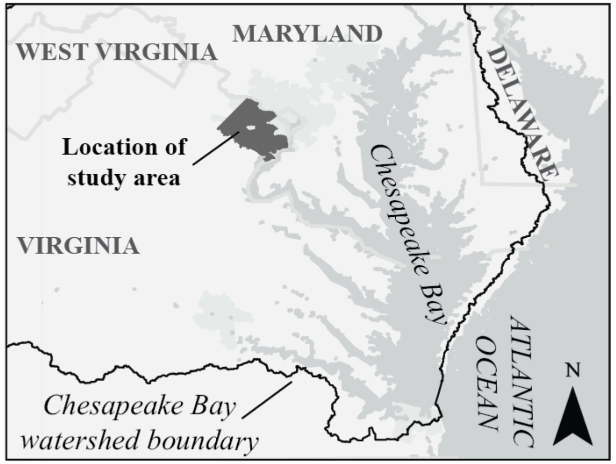
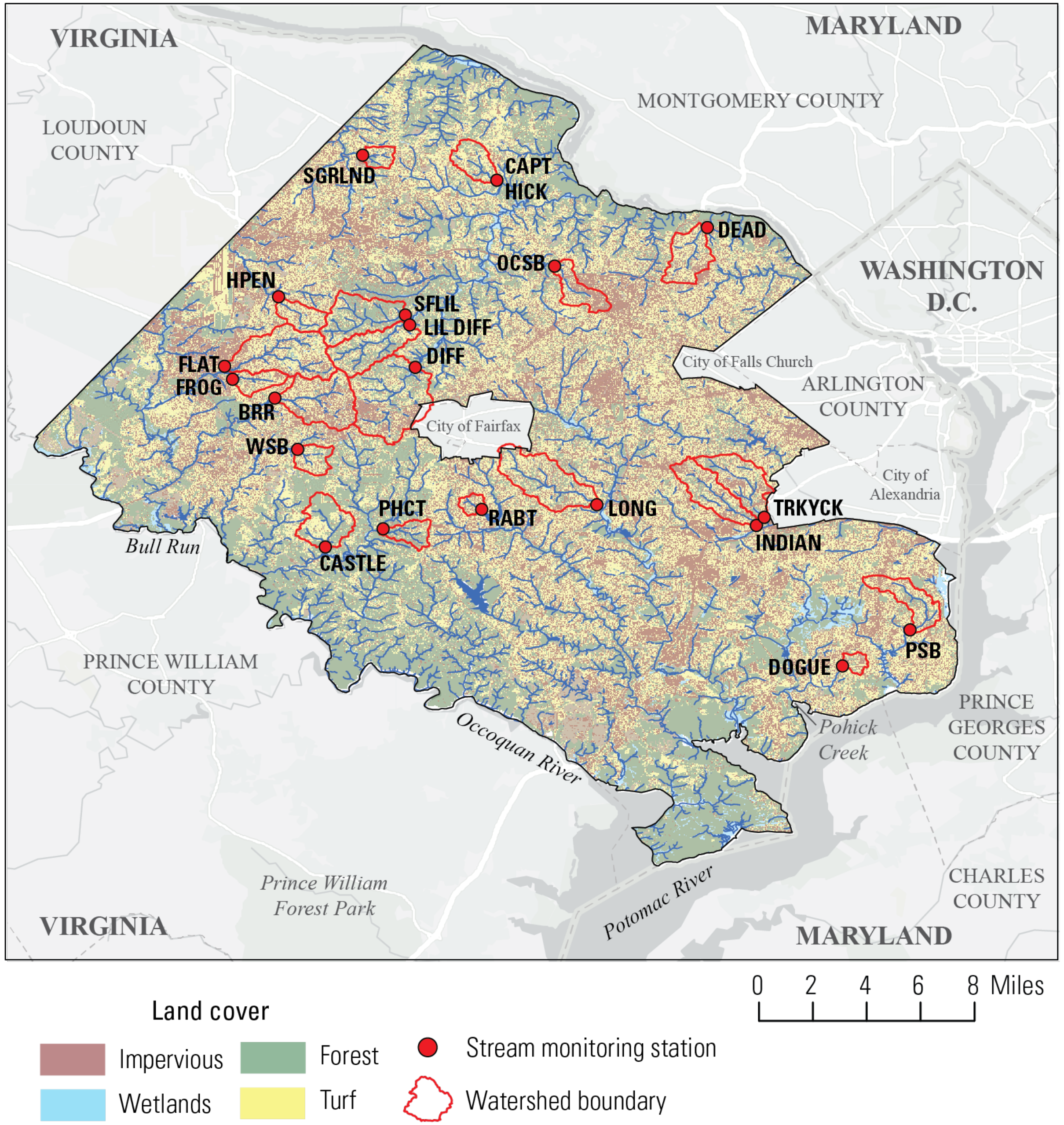
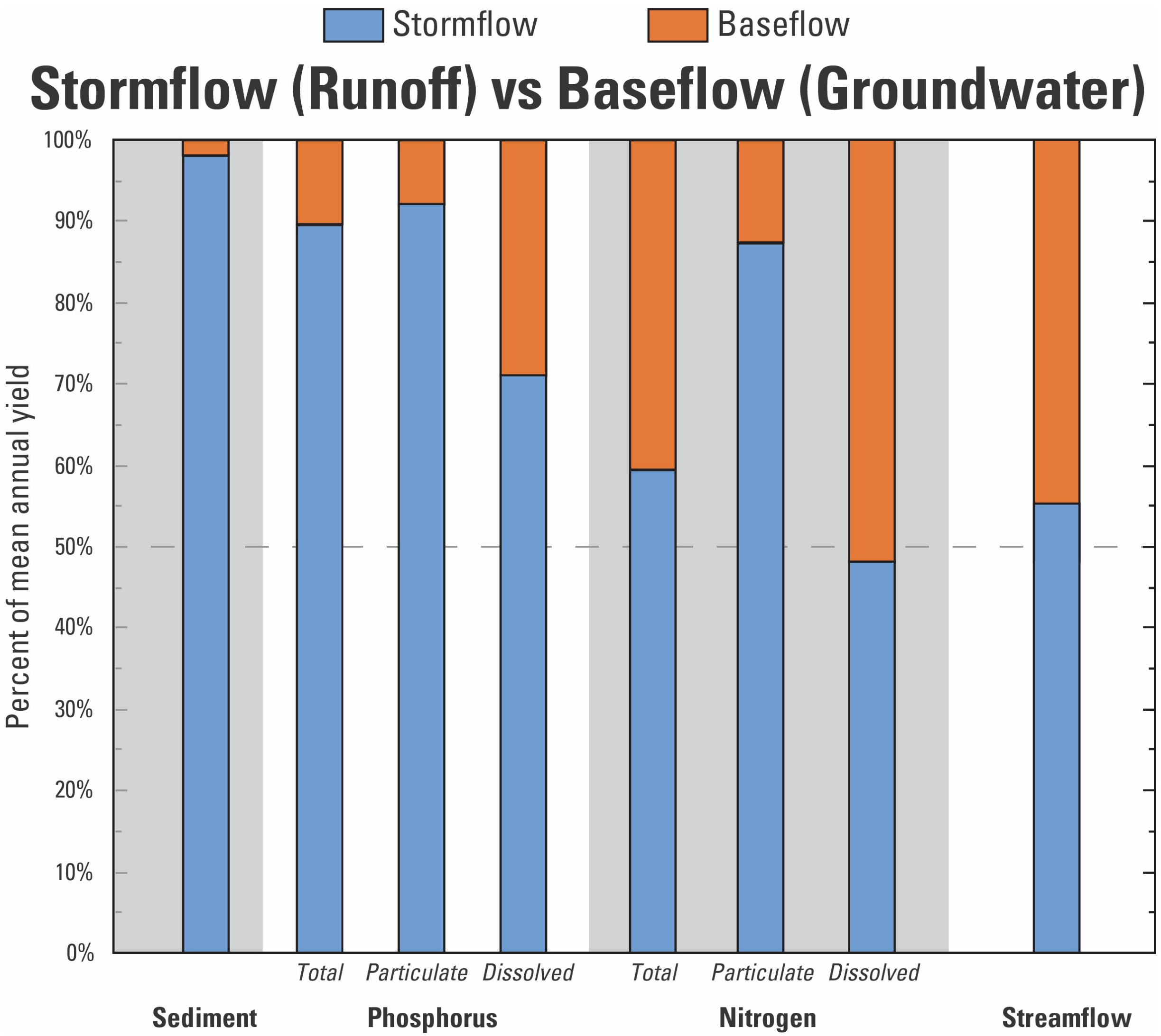
# The monitoring network is designed to assess Fairfax County stream conditions

- There are 20 stream monitoring stations in Fairfax County, VA ranging in size from 0.5 to 5.5 mi$^2$.
- 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.



# Delivery mechanism – how loads move from land to stream




*The stormflow portion represents constituent mobilized by overland runoff – transporting upland sources or eroding streambanks/beds*

*The baseflow portion represents constituent mobilized to the stream via groundwater discharges*

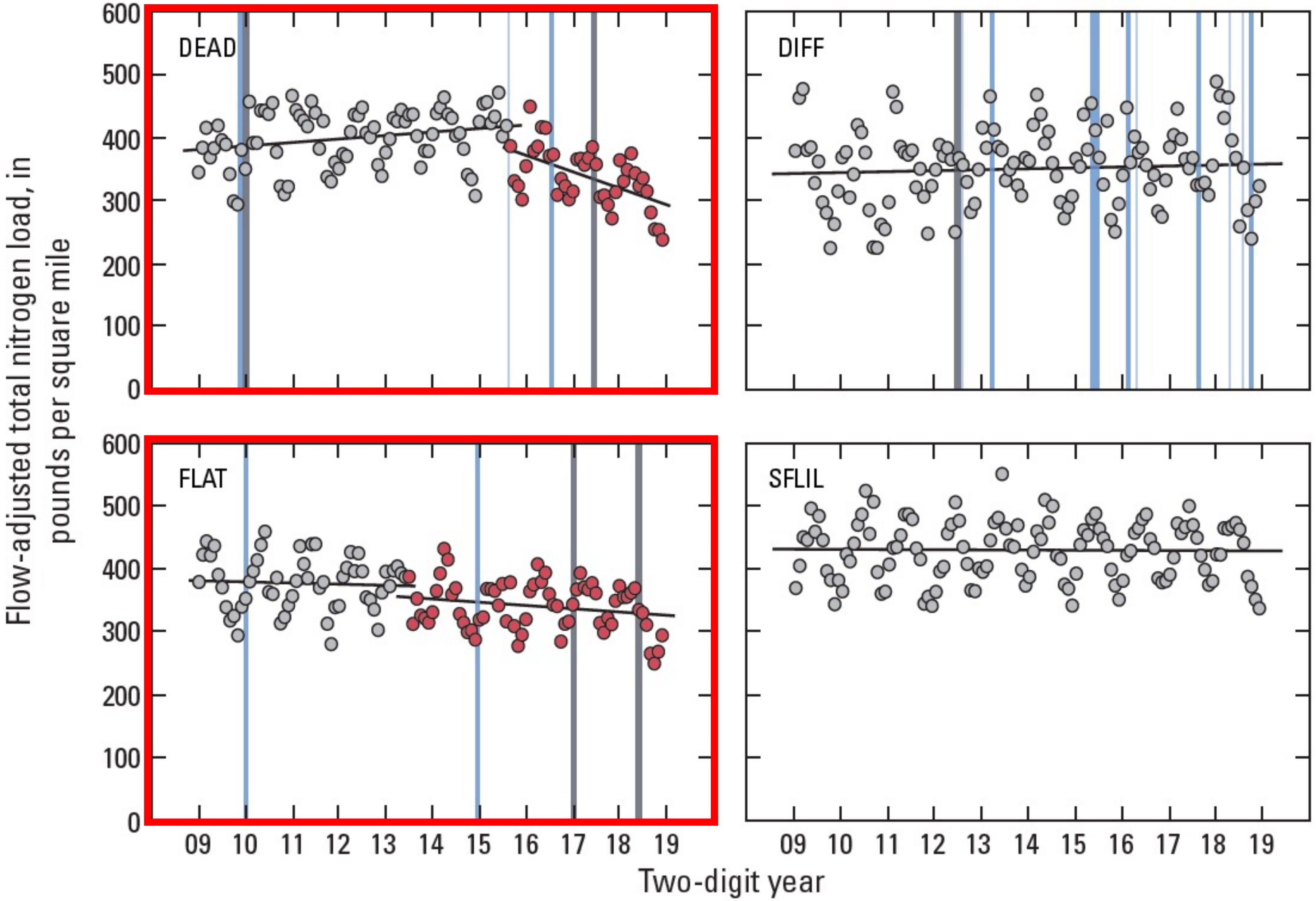
## Key Findings

- Sediment and Phosphorus (both particulate and dissolved) were primarily transported during periods of stormflow
- Nitrogen loads were variable – The particulate fraction was mobilized by stormflows, whereas the dissolved fraction was evenly split. Groundwater N plays a major role due to the solubility of $NO_3^-$ in soils
- These streams are only slightly stormflow dominant, but stormflows carry a disproportionate amount of load for most constituents

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

**EXPLANATION**
- Management implementations
- Monthly yield
- Change point in monthly yield
- Significant Trend

## Flow-adjusted Total Nitrogen Yields




Changes in calculated nutrient and sediment loads did not clearly align with the timing or expected magnitude of management-practice reductions.

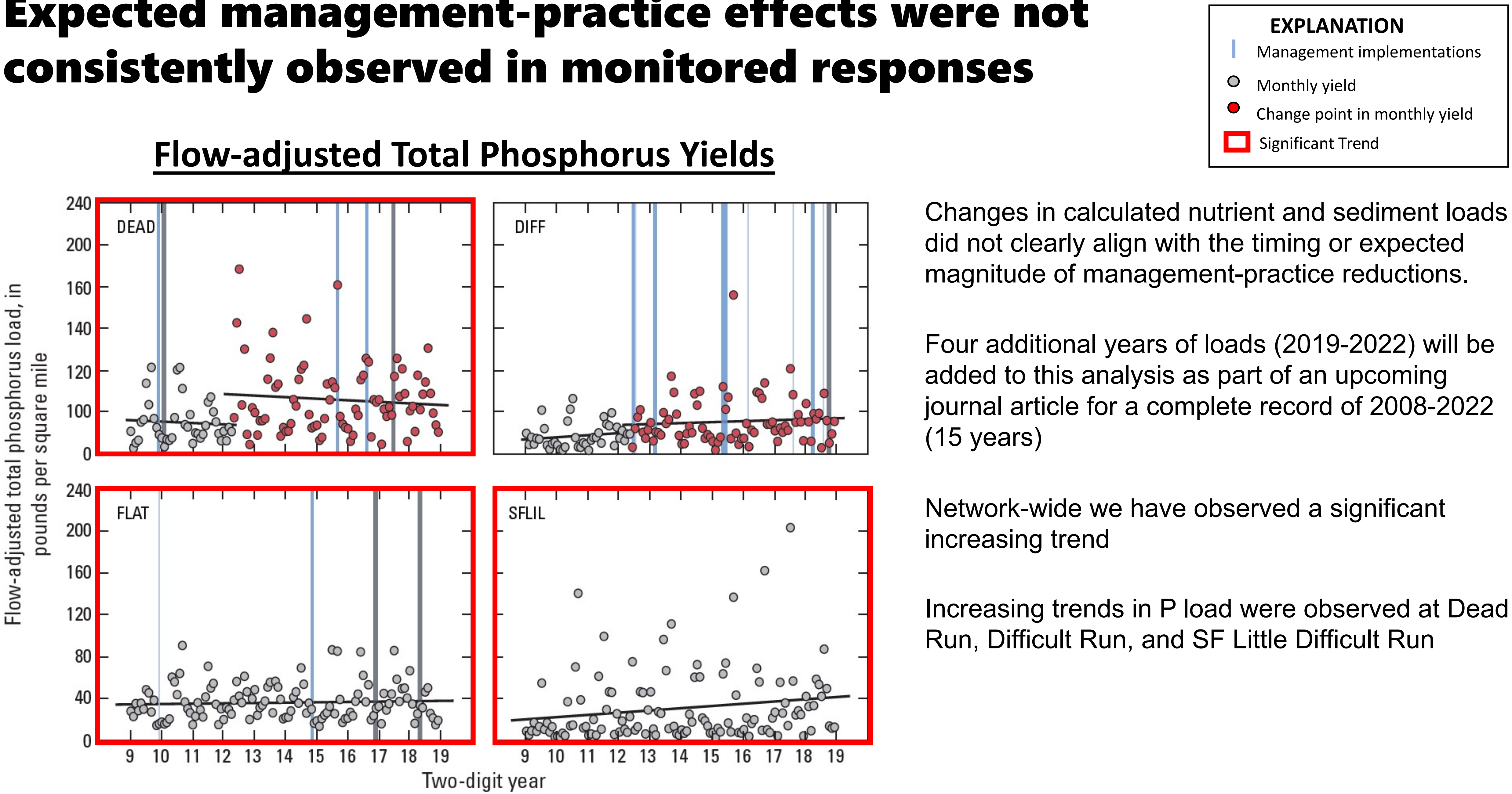
Four additional years of loads (2019-2022) will be added to this analysis as part of an upcoming journal article for a complete record of 2008-2022 (15 years)

Network-wide we have observed a significant decreasing trend

Decreasing trends in N were observed at Dead Run and Flatlick Branch. Stream restorations occurred in both watersheds, but the timing of those projects do not align with the calculated change points.

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

## Flow-adjusted Total Phosphorus Yields

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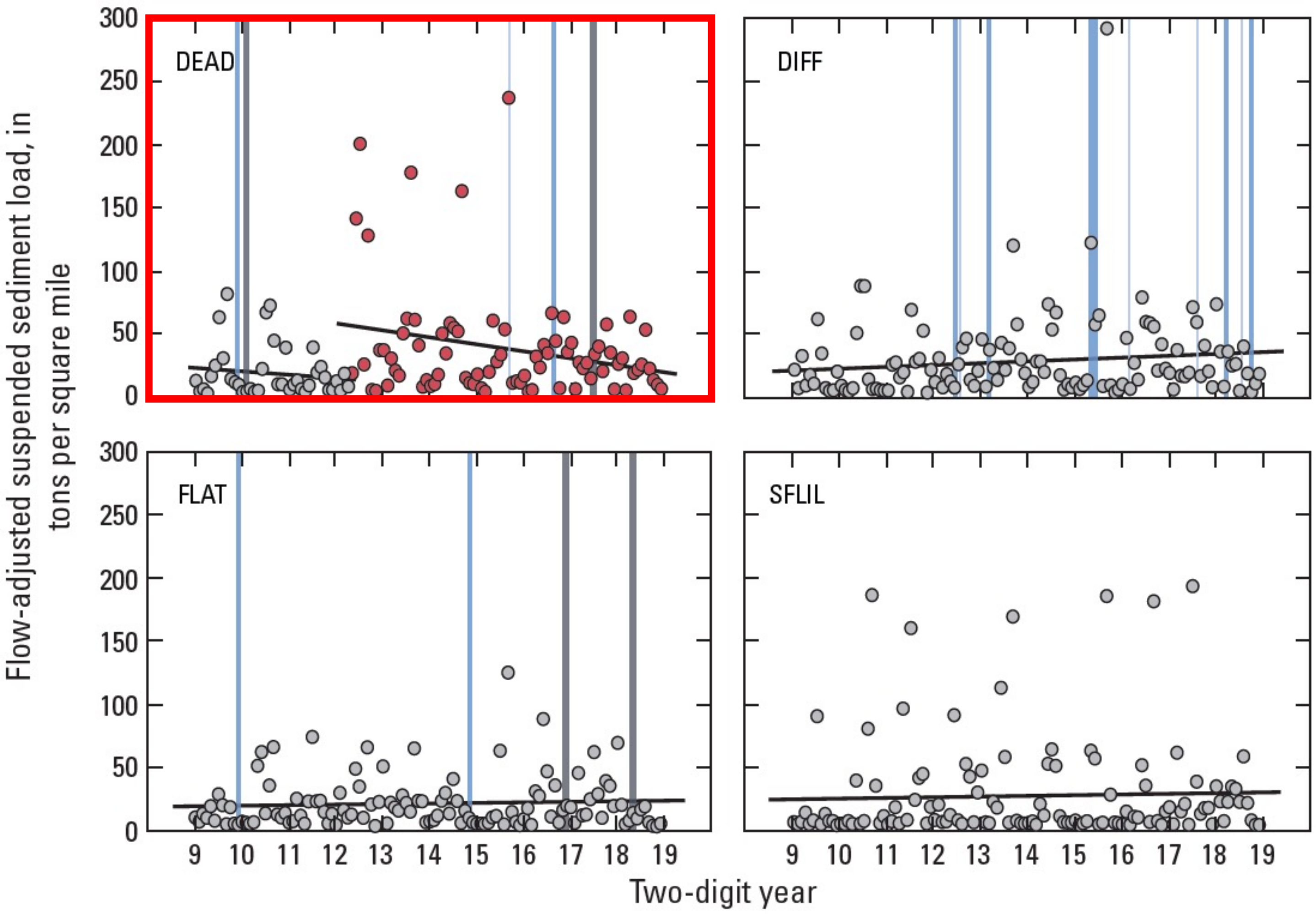
Network-wide we have observed a significant increasing trend

Increasing trends in P load were observed at Dead Run, Difficult Run, and SF Little Difficult Run

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

**EXPLANATION**
- Management implementations
- Monthly yield
- Change point in monthly yield
- Significant Trend

## Flow-adjusted Suspended Sediment Yields

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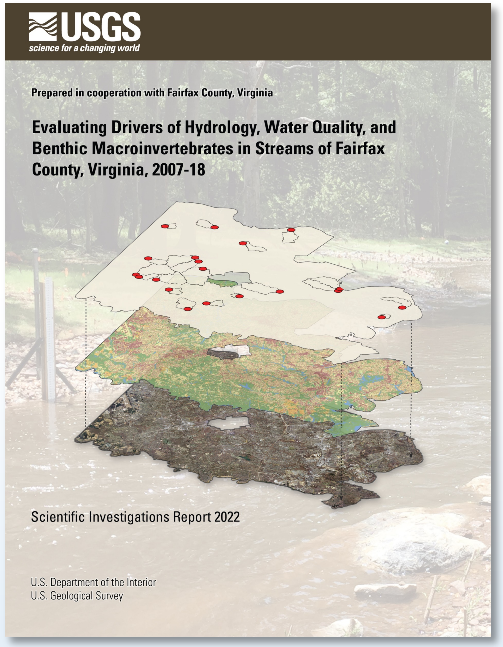
Network-wide we have observed a significant increasing trend

An increasing trend in sediment load was observed at Dead Run

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




**Webber and others, 2023**

## Some important messages from this research:

1. Water-quality changes occurred from 2008 through 2018 in Fairfax County streams. 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.

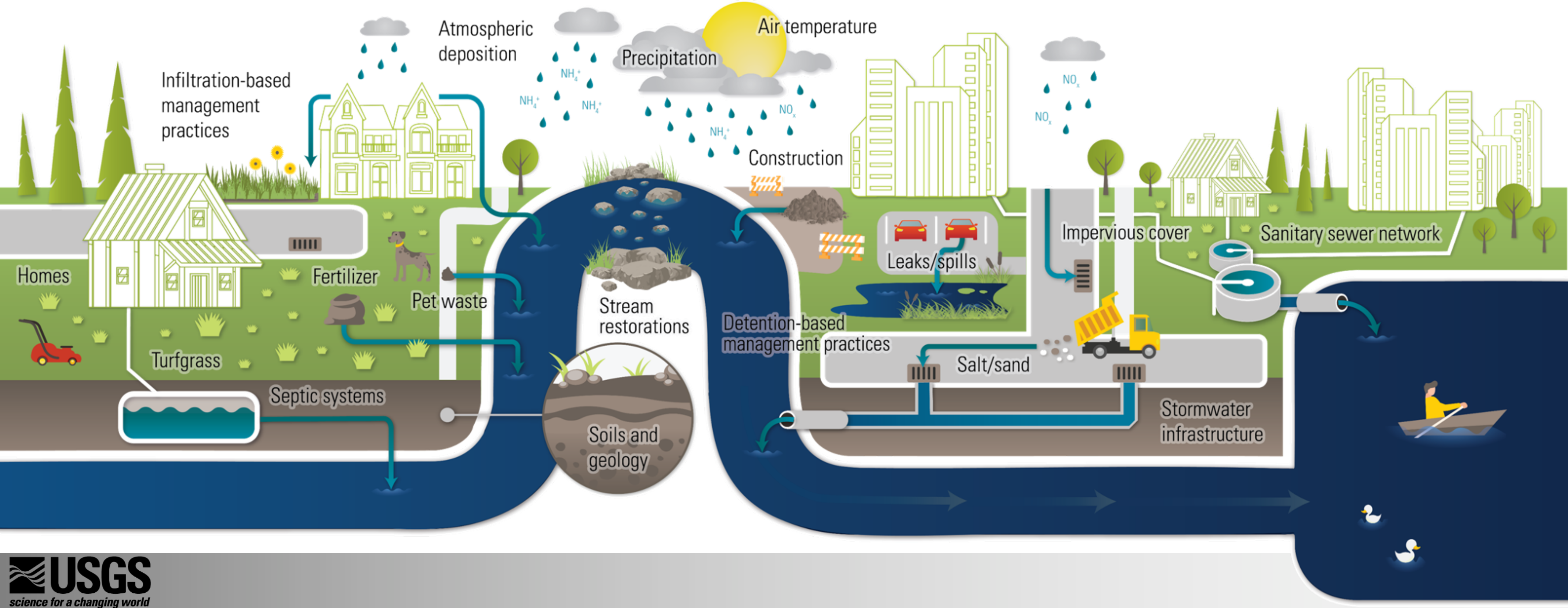
3. Expected management-practice effects were not consistently observed in monitored responses.

4. Future investigations of management-practice effects in urban streams will need to control for influences from landscape and climatic conditions.

# 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.



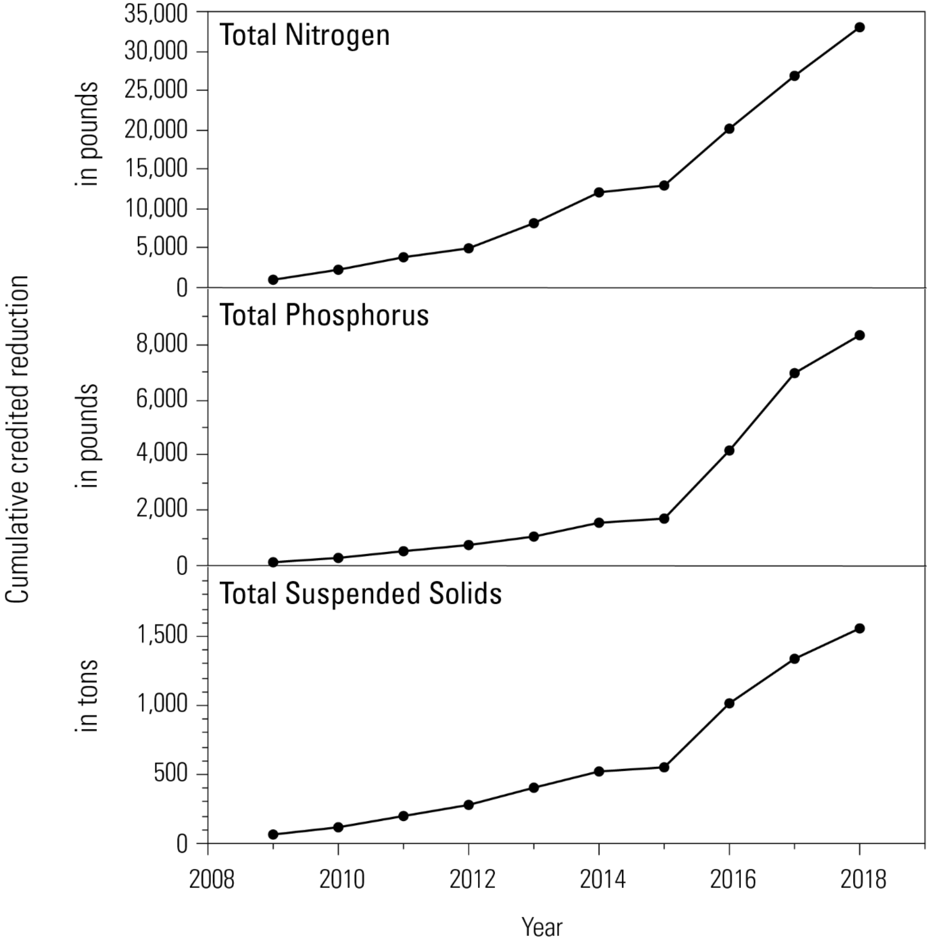
# This study considered the effect of management practices that were implemented to reduce nitrogen, phosphorus, and sediment loads

**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.

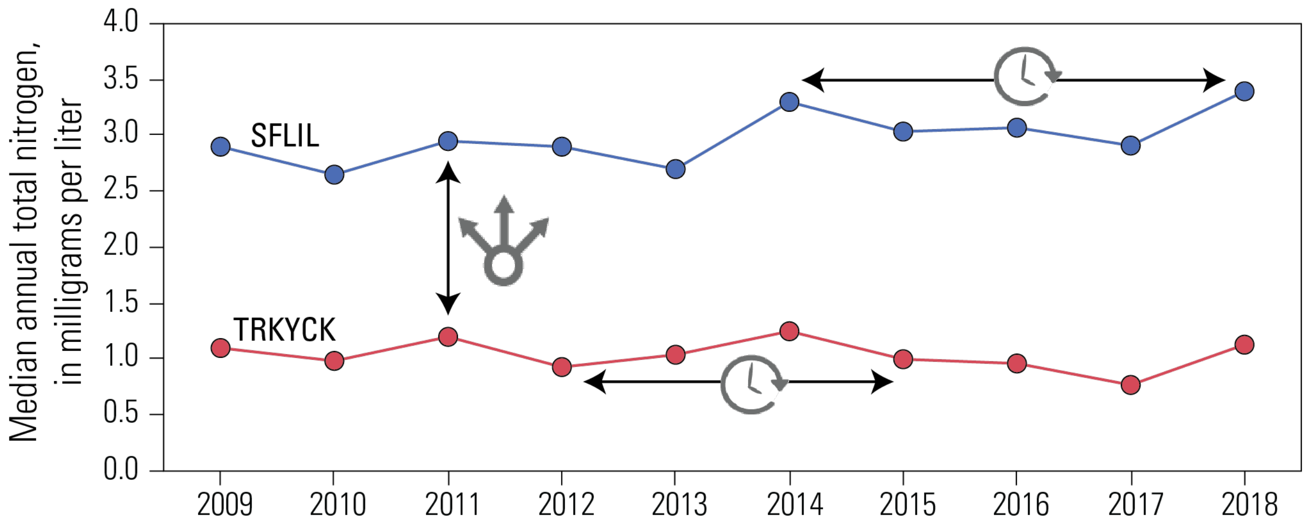



Graph showing the cumulative credited reduction of total nitrogen, total phosphorus, and total suspended solids for Fairfax County management practices completed from 2009 through 2018.

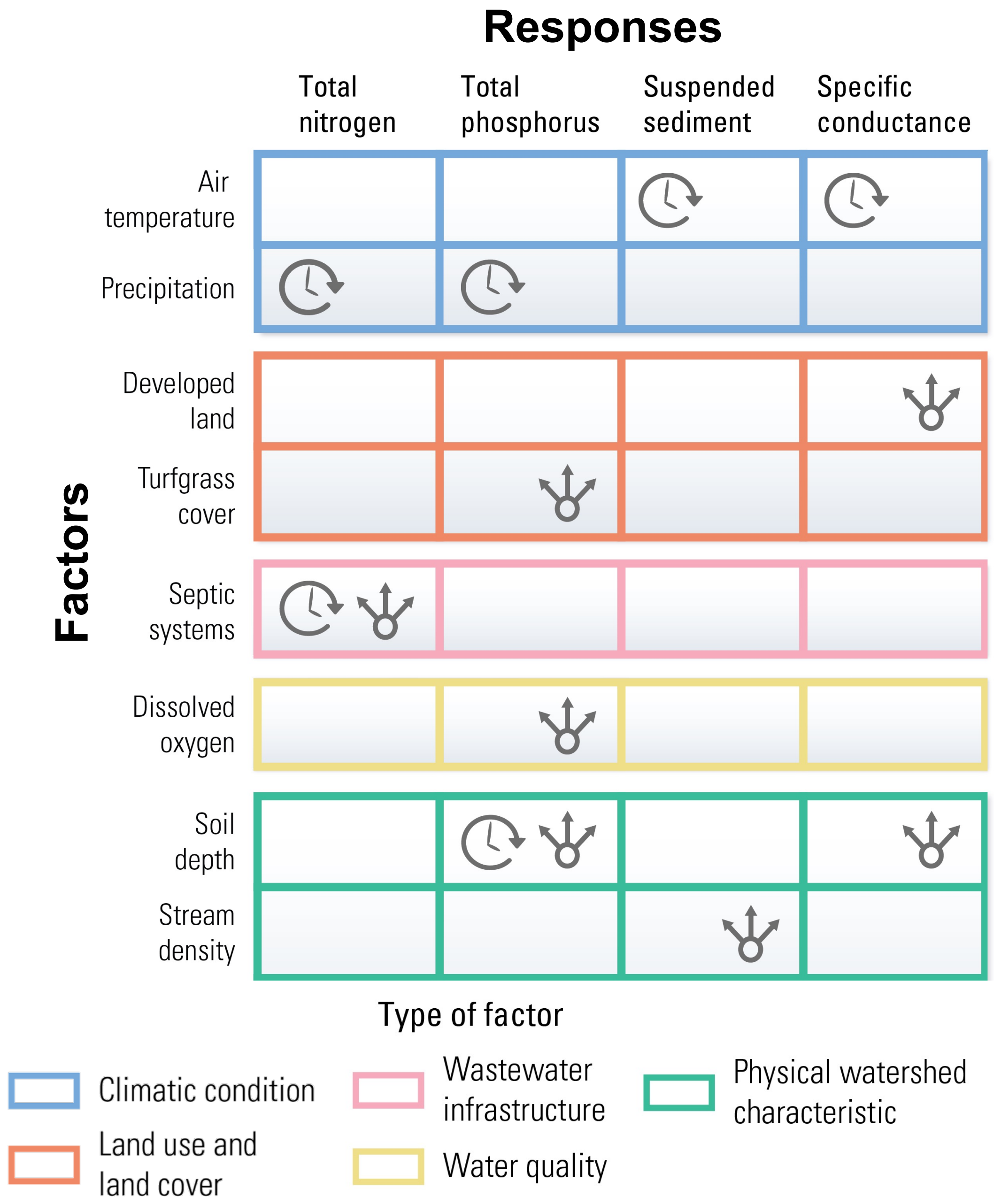
These practices are expected to reduce thousands of pounds of nitrogen, phosphorus, and sediment in Fairfax County streams.

# 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




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

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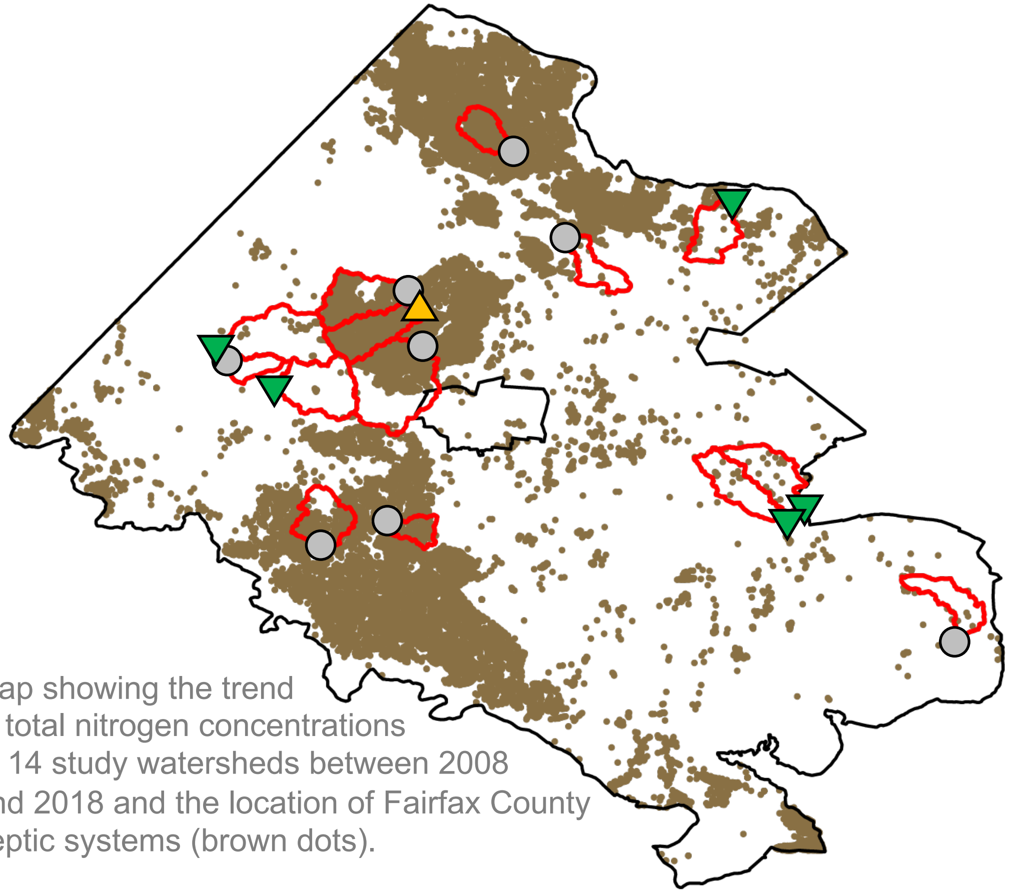
*Linear mixed-effect models were used to evaluate how landscape, stream, and climatic conditions explained the variability of median-annual water-quality responses in 14 study watersheds over 10 years.

# 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 (●).



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).

## Explanation of Variability

**Septic Systems**

In watersheds with above average septic-system densities:

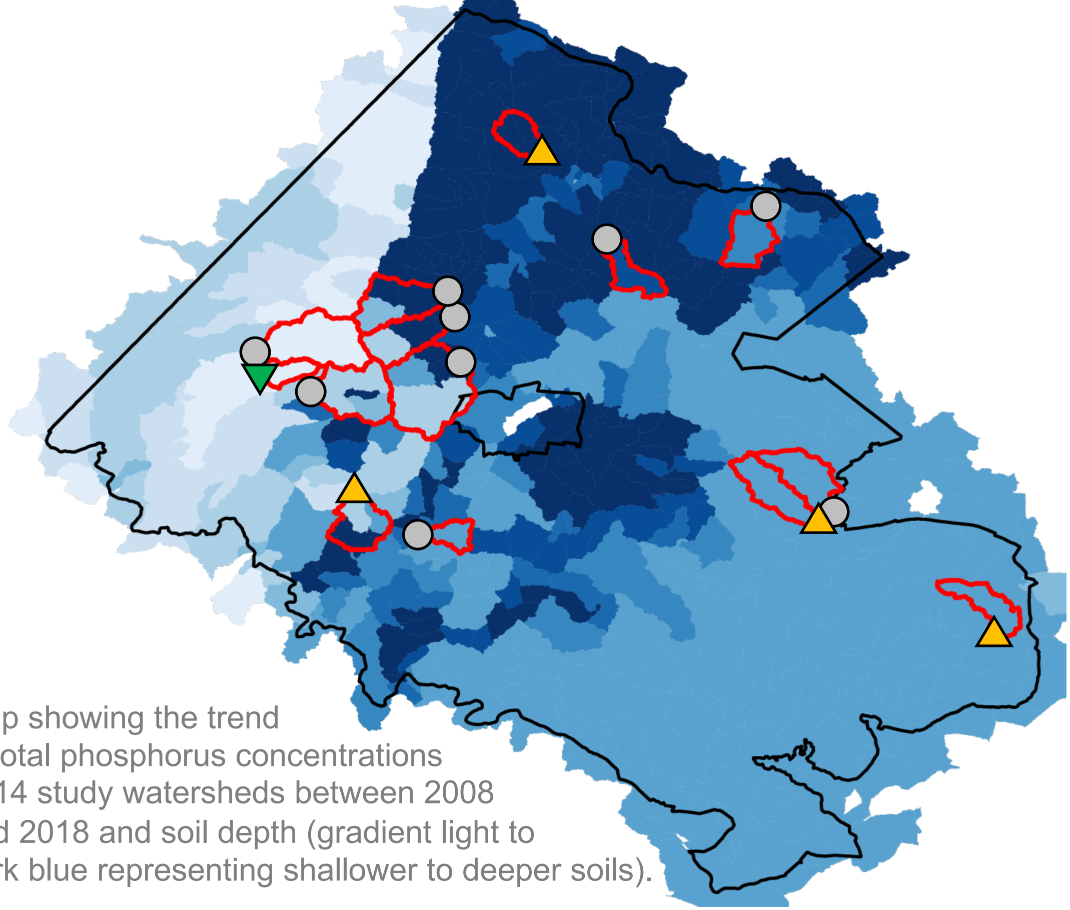
1. TN concentrations were higher than average and
2. TN concentration increases over time were more positive.

**Rainfall**

TN concentrations were higher in years with more heavy rainfall days[1].

[1]Defined as the number of days in a year that receive greater than or equal to about 0.4 inches of precipitation.

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



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).

## 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.

# 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.

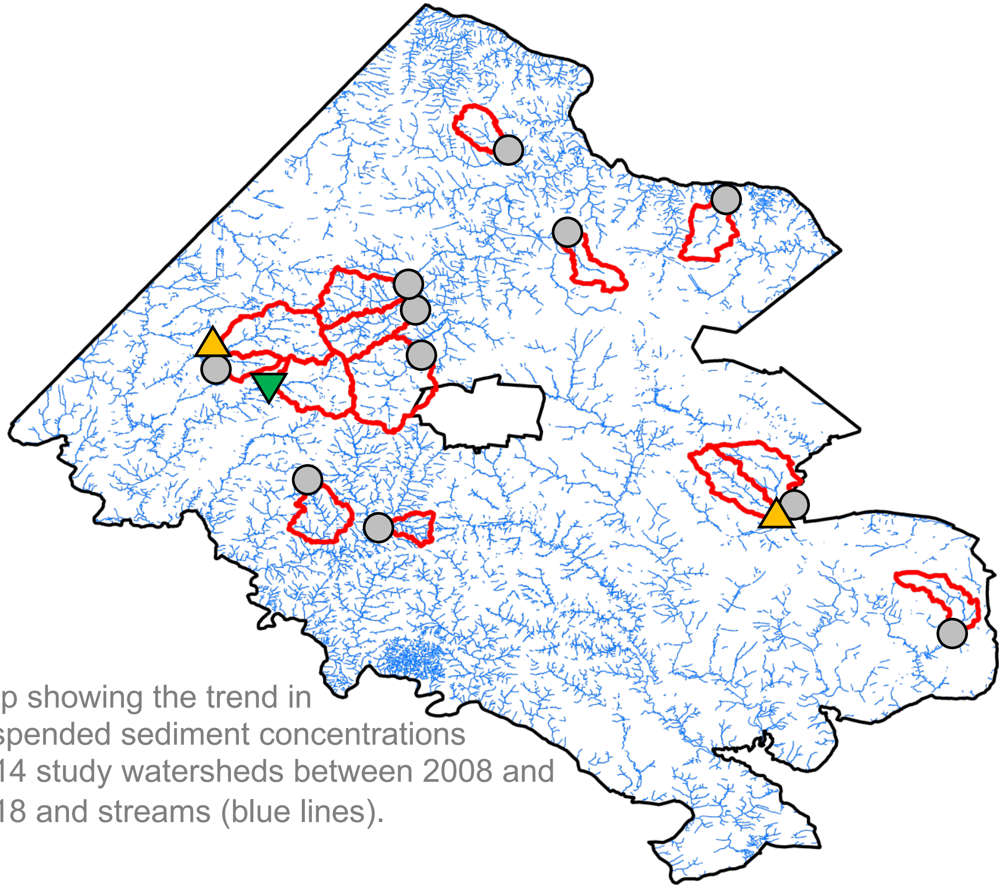
Other stations had no trend (●).

## 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.

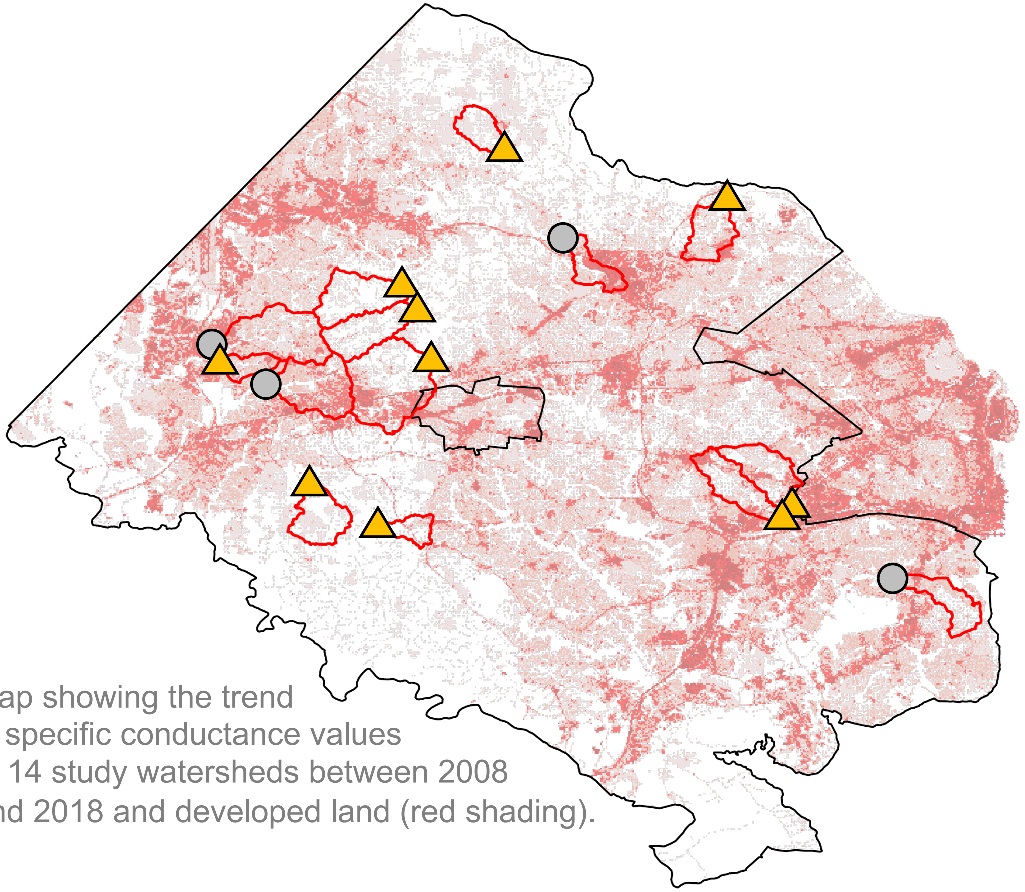


Map showing the trend in suspended sediment concentrations at 14 study watersheds between 2008 and 2018 and streams (blue lines).

**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



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

## Observed Responses

SC values (on average, 150 – 500 uS/cm) declined in 0 (▼) and increased in 10 (△) study watershed 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.

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**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.

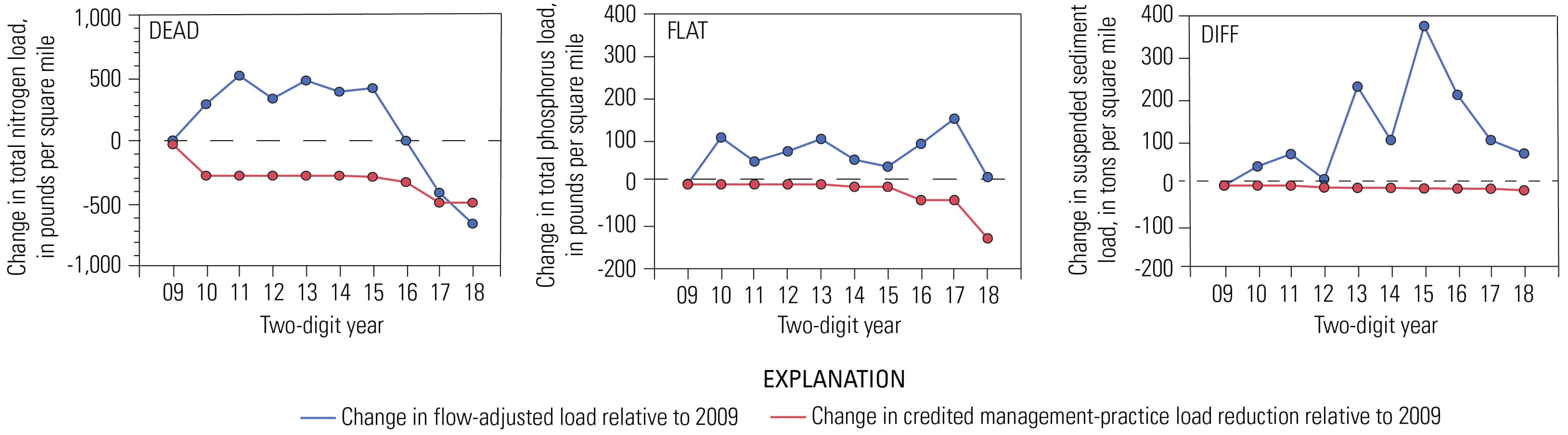
4. Future investigations of management-practice effects in urban streams will need to control for influences from landscape and climatic conditions.

# 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.

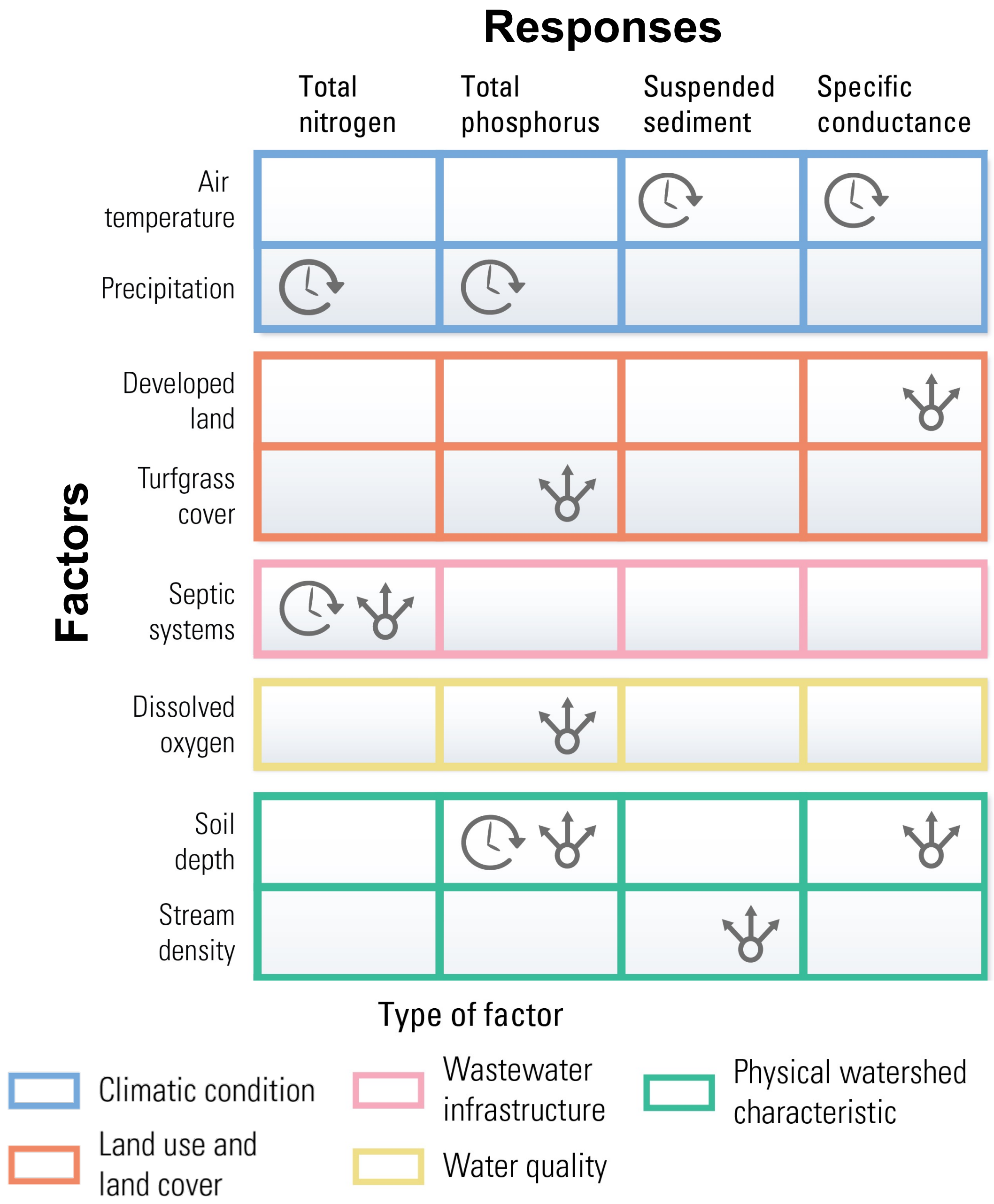



Graphs of expected management-practice effects and calculated nutrient and sediment loads at selected study watersheds from 2009 through 2018.

# 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.

| Fixed effects | | |
|---|---|---|
| **Predictor** | **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 |
| TN TOT BMP ($b_3$) | -0.05 | -0.19 – 0.10 |
| Marginal $R^2$ | 0.58 | |
| Conditional $R^2$ | 0.98 | |
| AIC | -47.25* | |
| *AIC of model without BMPs = -48.89 | | |

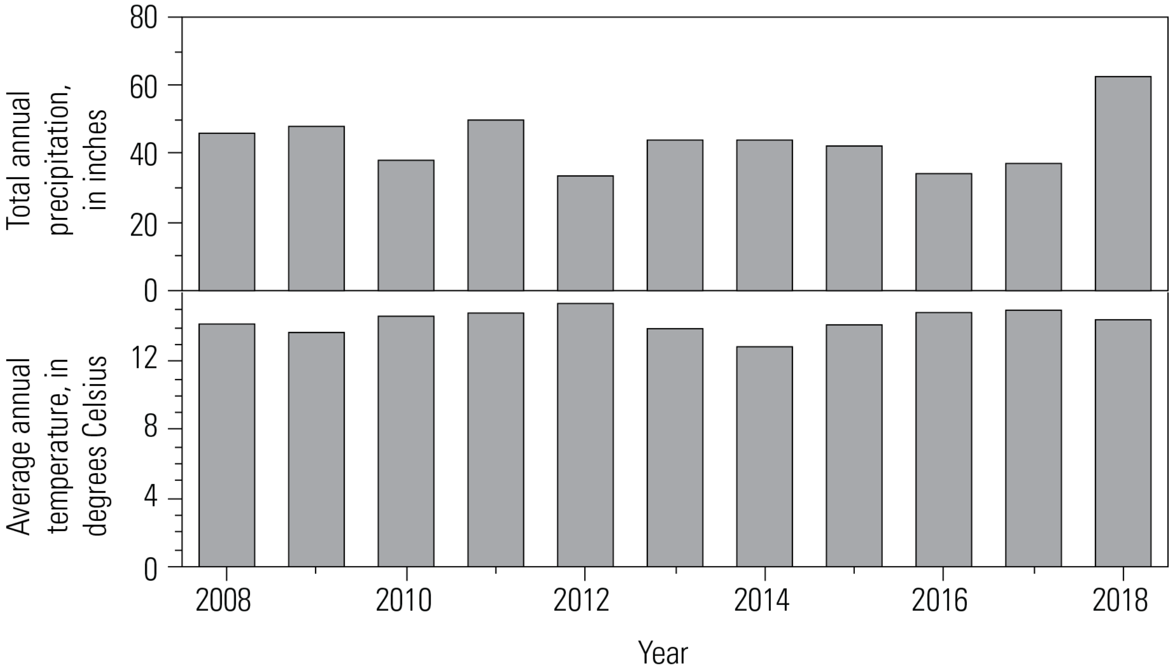


# The study period captured a general expansion of the built environment and variable climatic conditions

- 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.

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

2. Changes in hydrology during storm events were not consistent with management-practice effects.