# Data-Driven Approaches to Measuring the Effects of Water Quality Policies

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# Outline

## Economic Studies

- **Distinguishing Features**
  - Few key parameters
  - Research designs control for processes
  - Point and nonpoint source behavior
  - Contrast with mechanistic models
- **General Approaches**
  - End of Pipe or Edge of Field
  - Ambient Measurements
  - Use and Damages

# End of Pipe

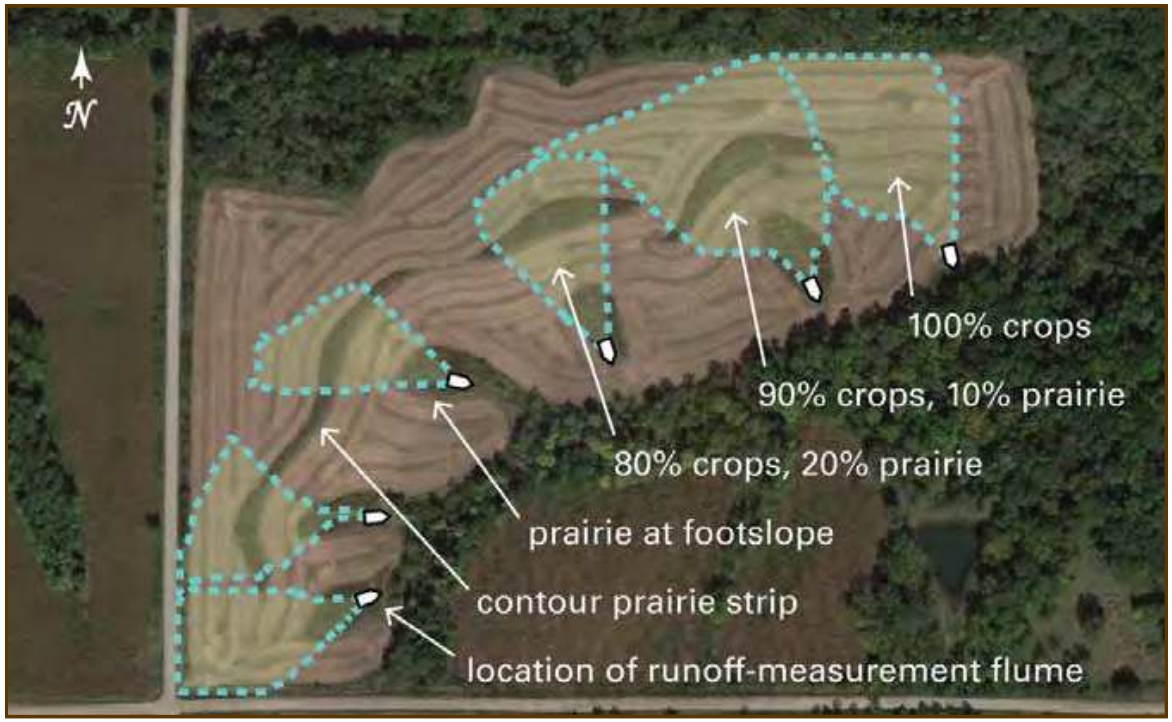
## Point Sources

- **Theory**
  - Municipal, Industrial Behavior
  - Government Interventions, Effluent Limits, Overlapping Regulations
- **Data**
  - Monthly plant-level discharge data from US EPA
- **Empirics**
  - Panel Data and Differences-in-Differences
- **Examples**
  - Earnhart (2004a, 2004b, 2007, 2014); Shimshack and Ward (2008); Cohen and Keiser (2015)

# Edge of Field

## Nonpoint Sources

- Land use and conservation practices
- Very little **data-driven** approaches in economics




IA State STRIPS Project

# Surface Water Quality

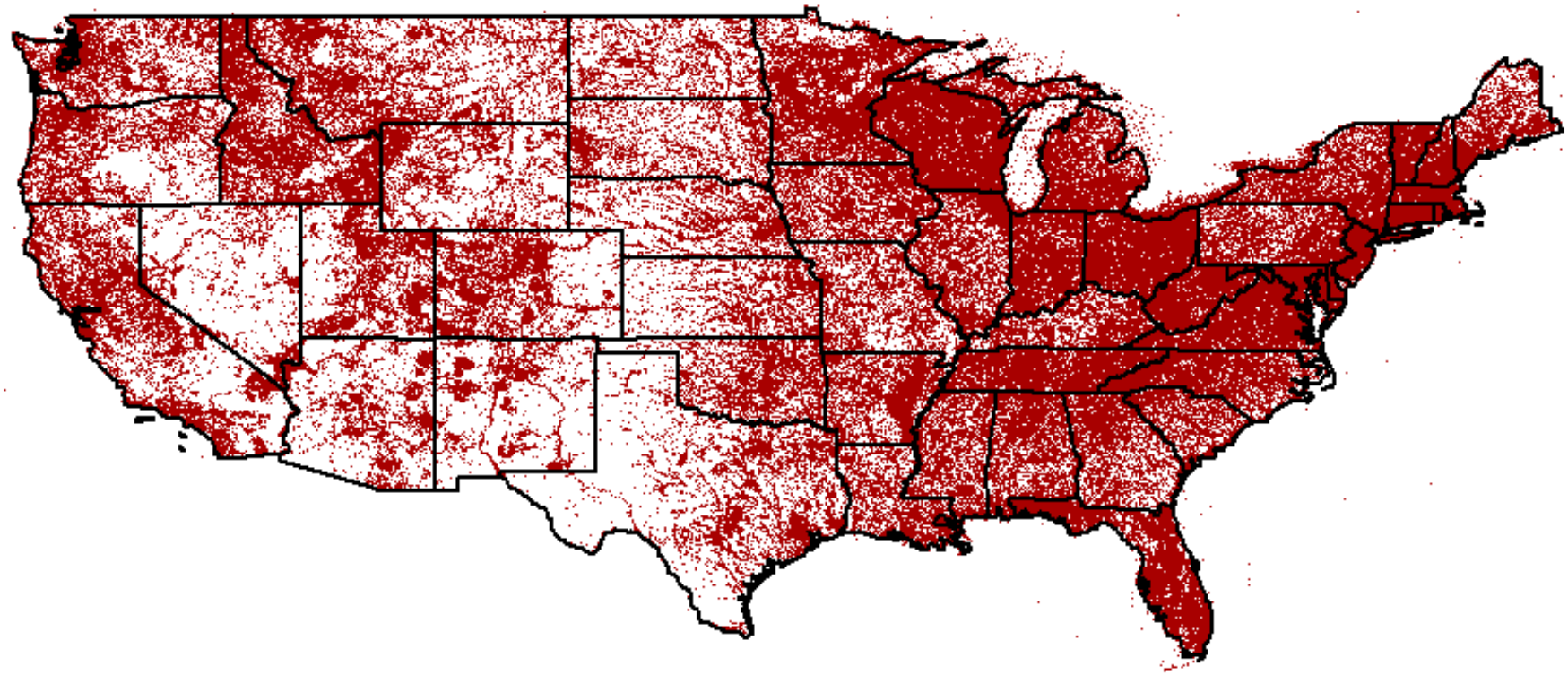
- **Limited Number of Economic Studies**
  - Conservation Reserve Program (Sprague and Gronberg 2012)
  - Environmental Regulations (Smith and Wolloh 2012; Greenstone and Hanna 2014; Keiser and Shapiro 2015)
  - Fracking (Olmstead et al. 2013)
  - Transboundary Pollution (Sigman 2002, 2005; Limpscomb and Mobarak 2014)
- **Common in Hydrology Literature**
  - Trend Studies
  - USGS SPARROW Models

# Key Components

- **Data and Routing**
  - US rivers, streams, lakes (US EPA, USGS)
  - Global rivers and streams (UN)
  - Focus on BOD, DO, Fecal Coliform, Nutrients
- **Research Designs**
  - OLS with many controls
  - Watershed or station fixed effects
  - Differences-in-Differences with upstream vs. downstream

# Data

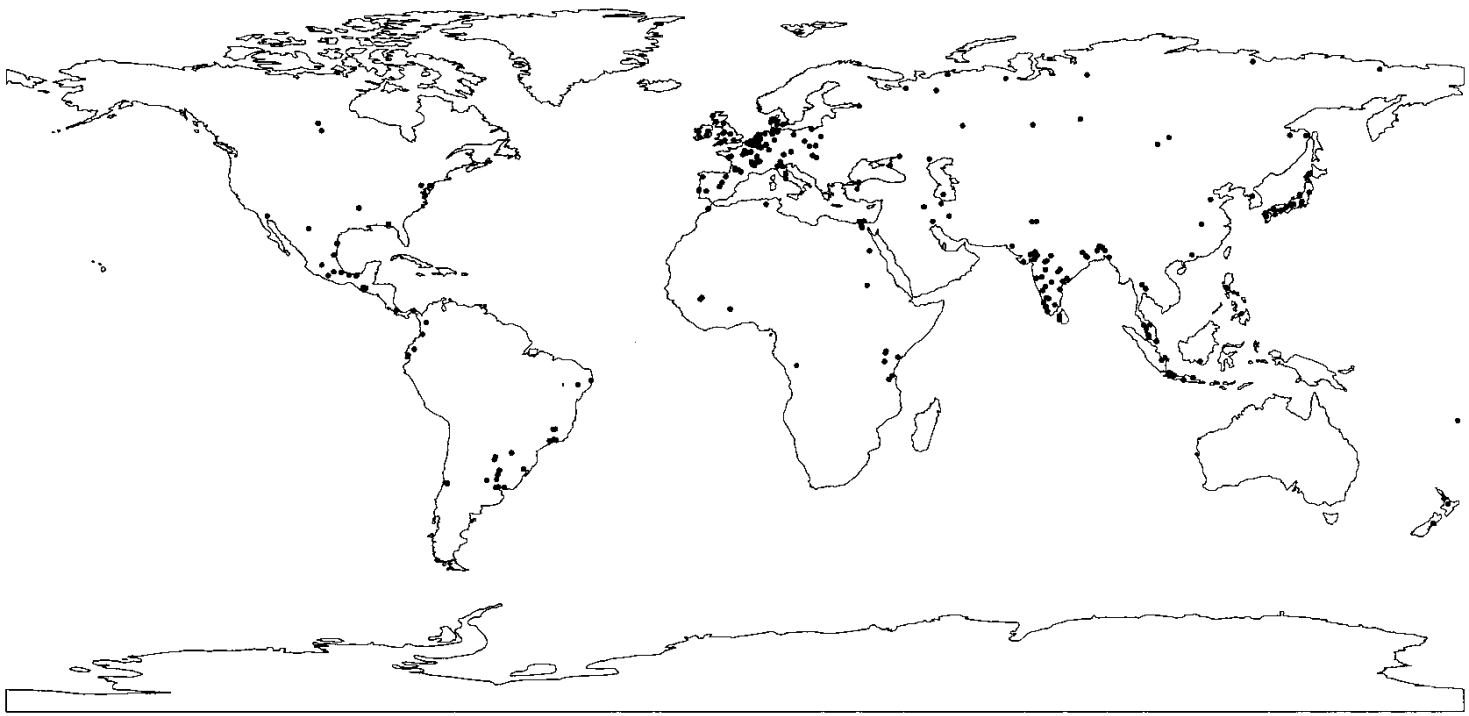
## US EPA (STORET) and USGS (NWIS)



Keiser and Shapiro (2015)

# Data

## UN Global Environment Monitoring System



Sigman (2002)

# Data

## India (National Water Monitoring Programme)

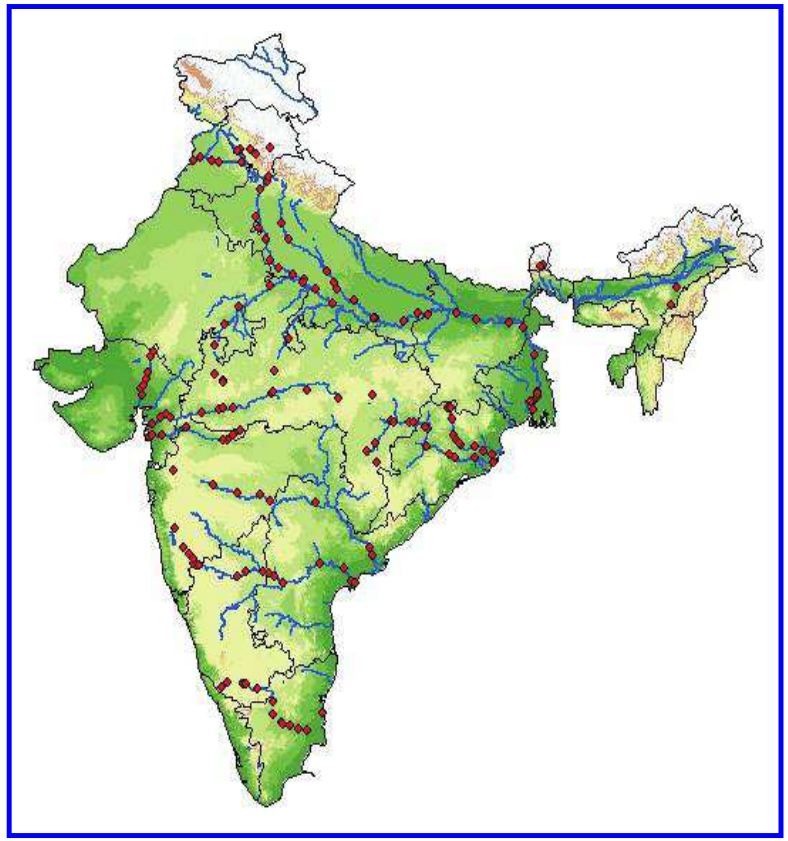


Figure 3. Water Quality Monitors on India's Major Rivers

*Notes:* Dots denote cities with monitoring stations under India's National Water Monitoring Programme (NWMP). Only cities with monitors on major rivers are included, as geospacial data for smaller rivers is unavailable. Geographical data are drawn from MIT's Geodata Repository. Monitoring locations are determined from CPCB and SPCB online sources and Google Maps.

Greenstone and Hanna (2014)

# Research Designs

## Cross-sectional Variation (OLS)

$$Y_i = \beta X_i + \alpha Z_i + \varepsilon_i$$

- Water quality ($Y_i$)
- Policy or action ($X_i$)
- Other factors ($Z_i$)

# Research Designs

$$Y_i = \beta X_i + \alpha Z_i + \varepsilon_i$$

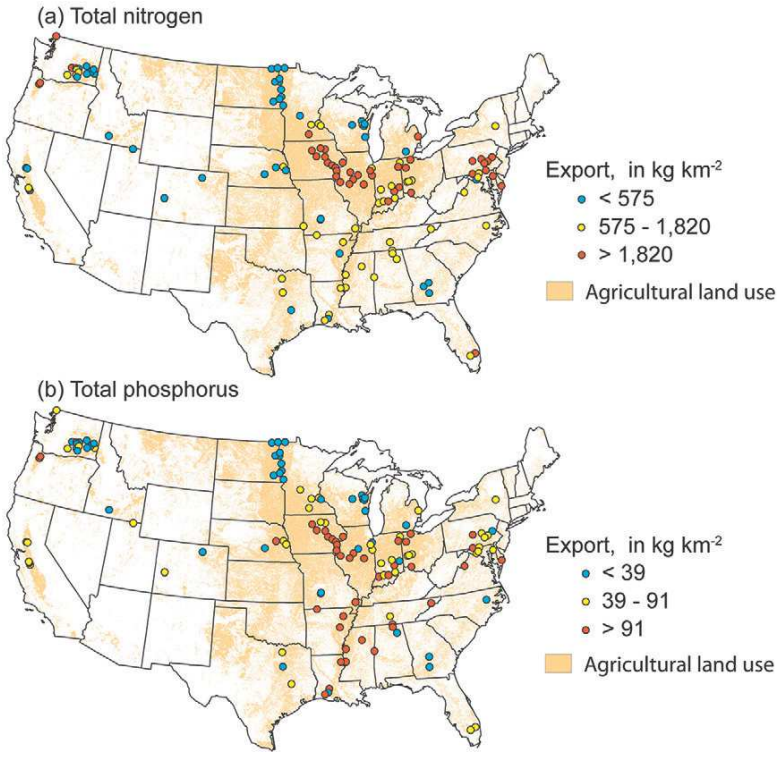



Fig. 1. Export (normalized to site drainage area) of (a) total nitrogen (N) and (b) total phosphorus (P) from agricultural watersheds in the United States.

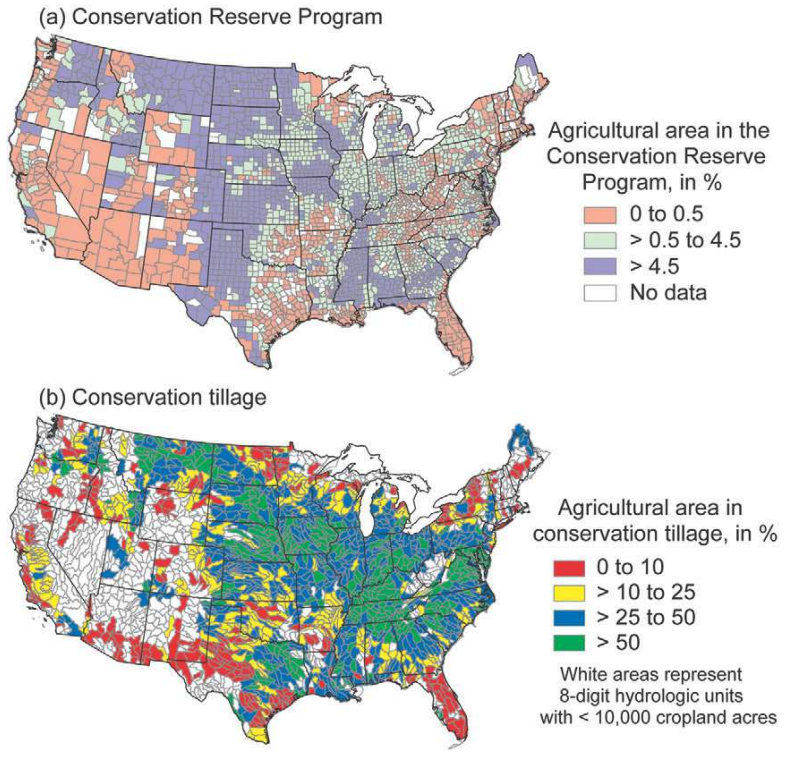



Fig. 2. Percentage of agricultural area in (a) the Conservation Reserve Program and (b) conservation tillage in the United States in 2002.

Sprague and Gronberg (2012)

# Research Designs

## Variation over Time and Space (Panel Data Methods)

$$Y_{it} = \beta X_{it} + \alpha Z_{it} + \delta_i + \delta_t + \varepsilon_{it}$$

- Water quality ($Y_{it}$)
- Policy or action ($X_{it}$)
- Other factors ($Z_{it}$)
- **County, watershed, or monitor fixed-effect ($\delta_i$)**
- **Year fixed-effect ($\delta_t$)**

# Research Designs

$$Y_{it} = \beta X_{it} + \alpha Z_{it} + \delta_i + \delta_t + \varepsilon_{it}$$

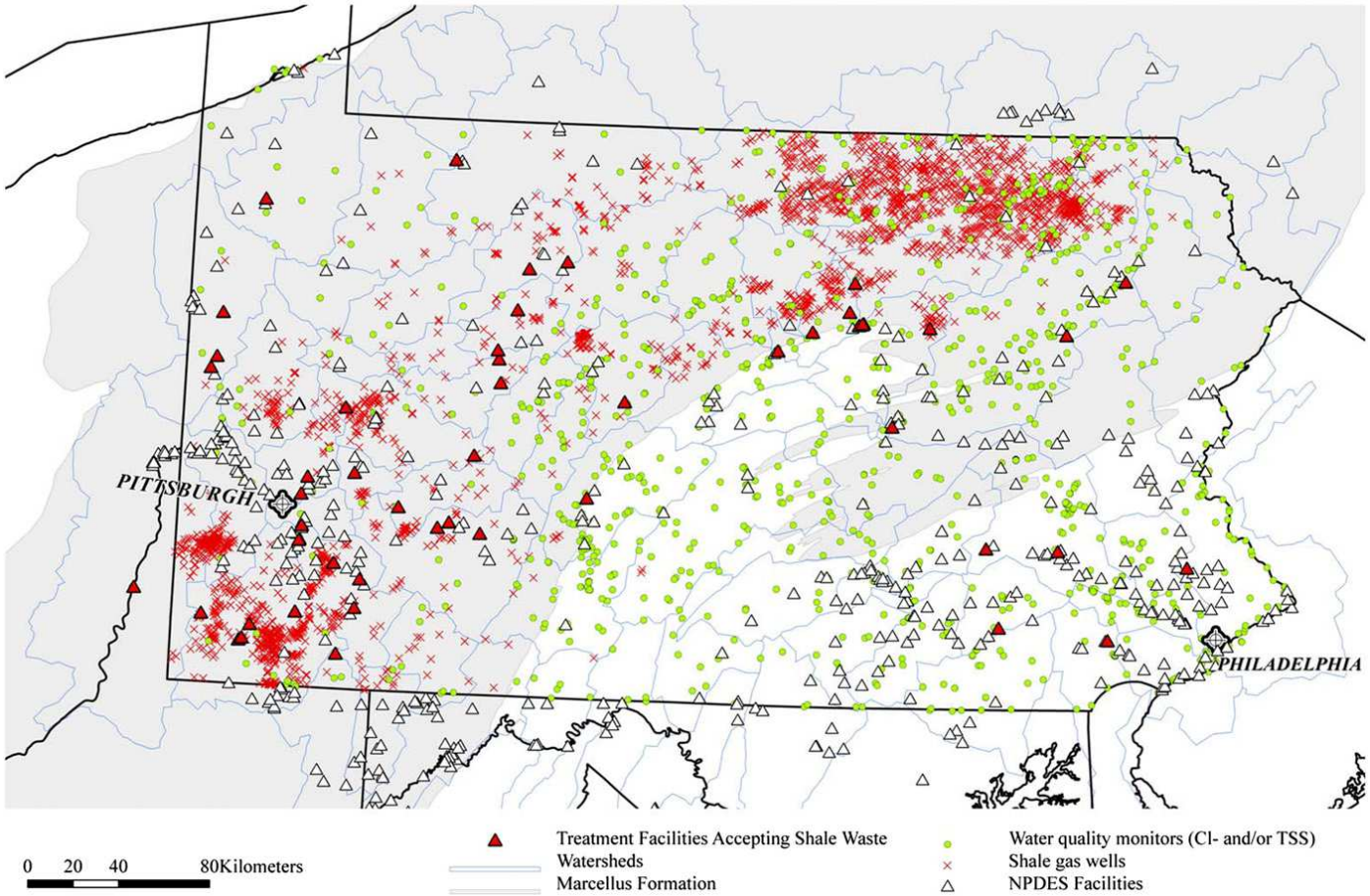



Fig. 1. Surface water quality monitors, shale gas wells, and wastewater treatment facilities in Pennsylvania watersheds (2000–2011).

Olmstead et al. (2013)

# Research Designs

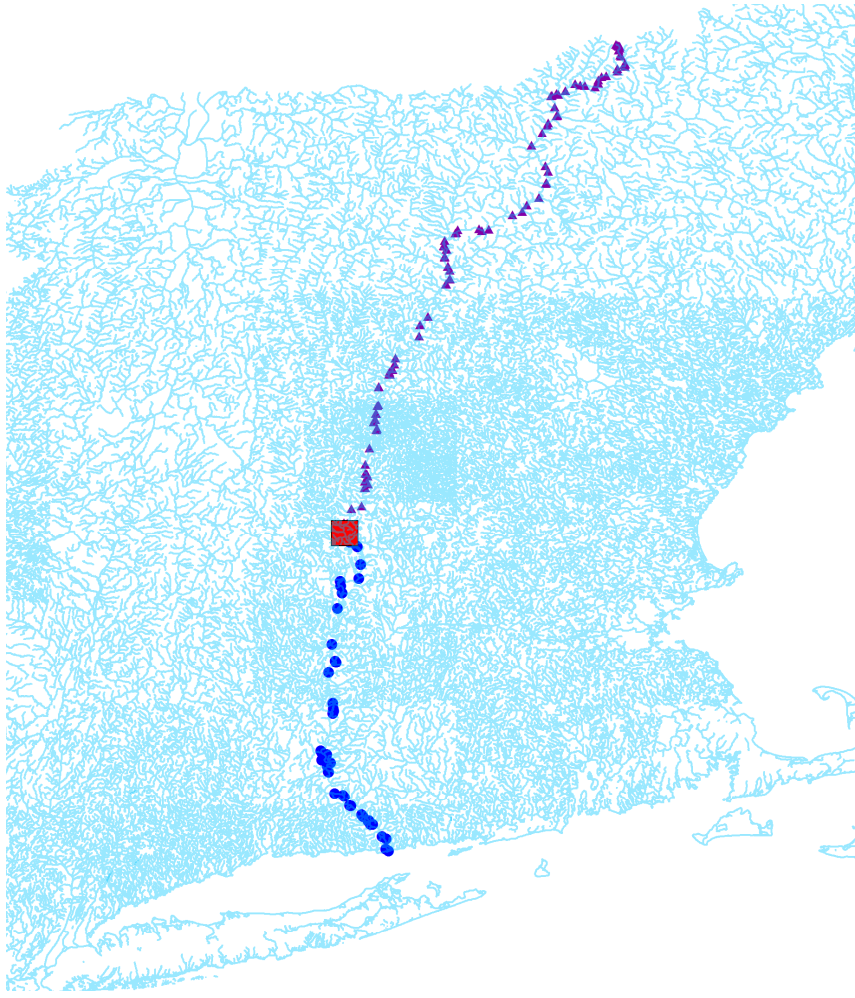
## Differences-in-Differences

$$Y_{idt} = \beta X_{it} \cdot d + \alpha Z_{idt} + \delta_{id} + \delta_{it} + \varepsilon_{idt}$$

- Water quality up or downstream of location i ($Y_{idt}$)
- Policy or action at location i and time t ($X_{it}$)
- **Downstream indicator ($d$)**
- Other factors ($Z_{idt}$)
- **Location-downstream fixed-effect ($\delta_{id}$)**
- **Location-year fixed-effect ($\delta_{it}$)**

# Research Designs

$$Y_{idt} = \beta X_{it} \cdot d + \alpha Z_{idt} + \delta_{id} + \delta_{it} + \varepsilon_{idt}$$



Keiser and Shapiro (2015)

# Research Needs for FEW

## Where do we go from here?

- **Focus**
  - Food and energy sectors
- **Data Needs**
  - Influent and effluent at point sources
  - Long-term ambient monitoring (US and global)
  - Upstream/downstream routing capabilities
- **Linking with Mechanistic Approaches**
  - Effluent processes
  - Removal processes
  - Dynamics and feedbacks