SOURCE WATER QUALITY AND THE COST OF NITRATE TREATMENT IN THE MISSISSIPPI RIVER BASIN

Sridhar Vedachalam, Ankita Mandelia, and Eric Heath
Northeast-Midwest Institute

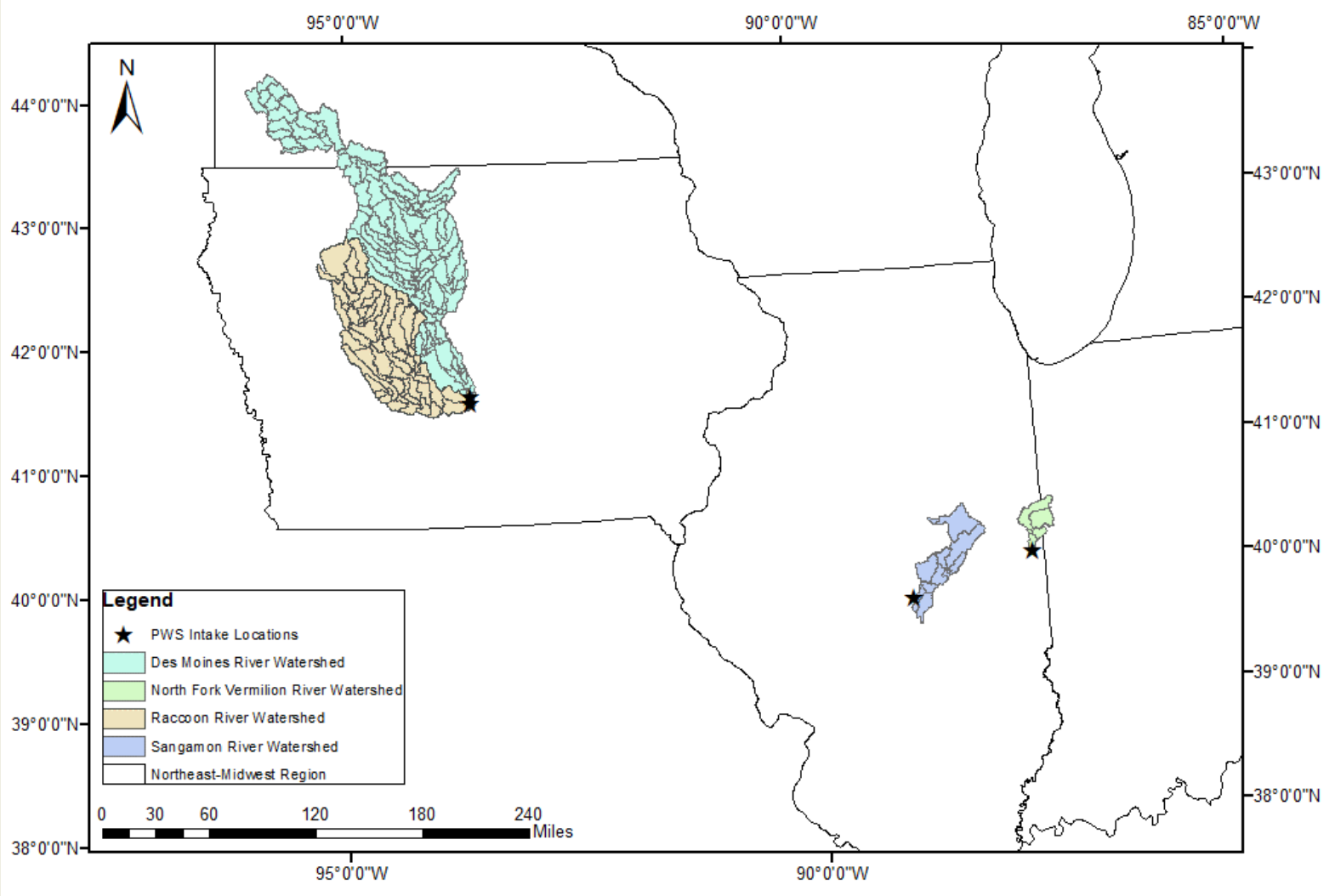
Congressional Briefing
May 23, 2018

Nutrients and Algal Blooms

Nutrients and Drinking Water

Photo credits: Des Moines Water Works

Study Locations



Study Locations

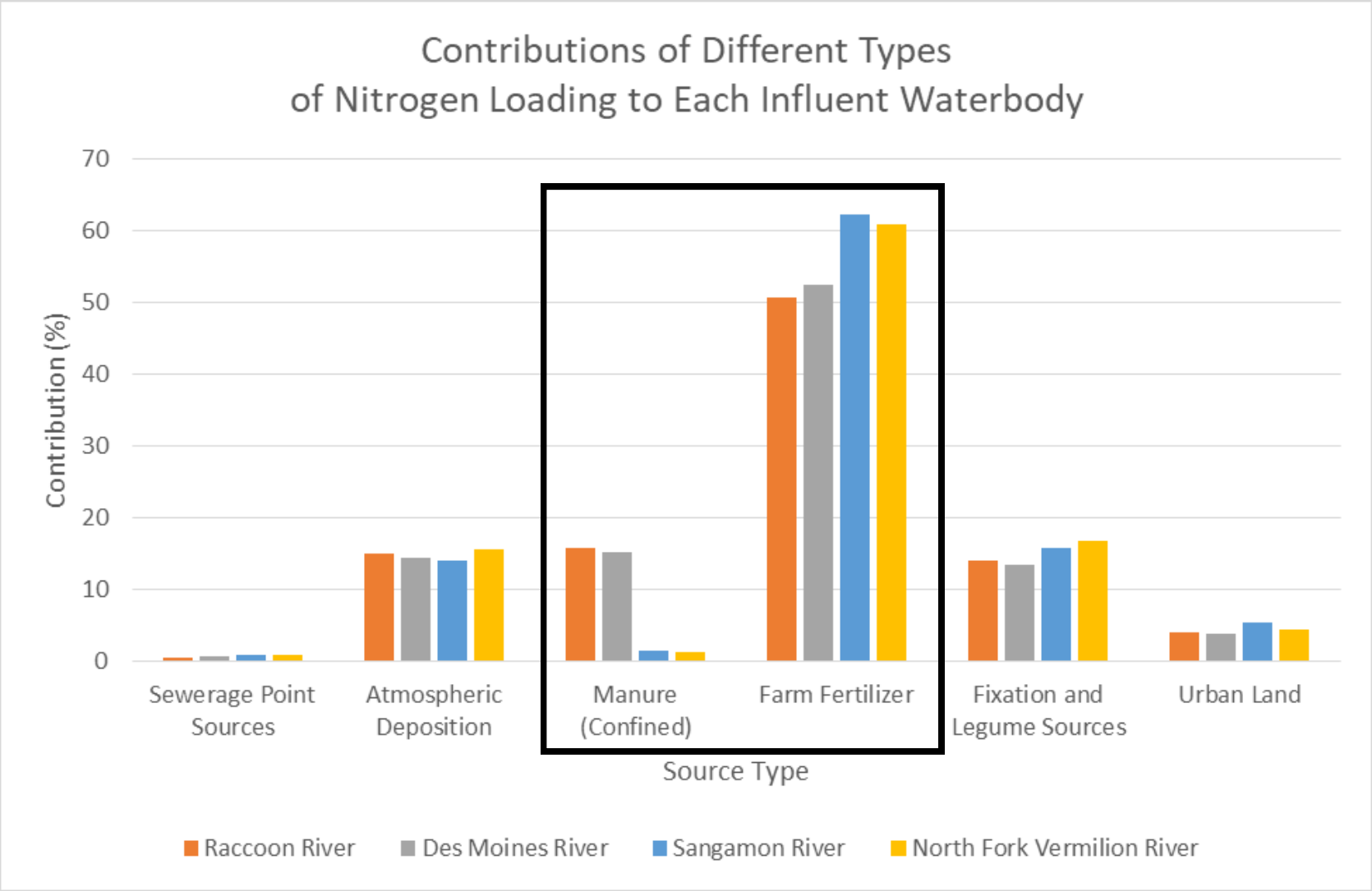
Utility	State	Intake Source	Source Watershed	Watershed size (square miles)
Des Moines Water Works	IA	Raccoon River	Raccoon River	12,884
		Des Moines River	Des Moines River	3,625
City of Decatur	IL	Lake Decatur	Sangamon River	925
Aqua Illinois Vermilion County	IL	Lake Vermilion	North Fork Vermilion River	293

Utility	State	Population Served	Capacity (MGD)	Average Production (MGD)
Des Moines Water Works	IA	233,020	100	47
City of Decatur	IL	76,122	36	20
Aqua Illinois Vermilion County	IL	46,560	14	8

Watershed Activities

Watershed	SPARROW-Modeled Flow-Weighted Mean concentration (mg/L)	10-Year Measured Mean Concentration (mg/L)	Total Nitrogen Load Delivered to River Outlet (kg)
Raccoon River (Des Moines, IA)	11.55	6.67	22,486,340
Des Moines River (Des Moines, IA)	9.12	6.02	30,237,999
Sangamon River (Decatur, IL)	6.47	4.52	3,832,495
North Fork Vermilion River (Vermilion County, IL)	6.44	4.37	1,833,558

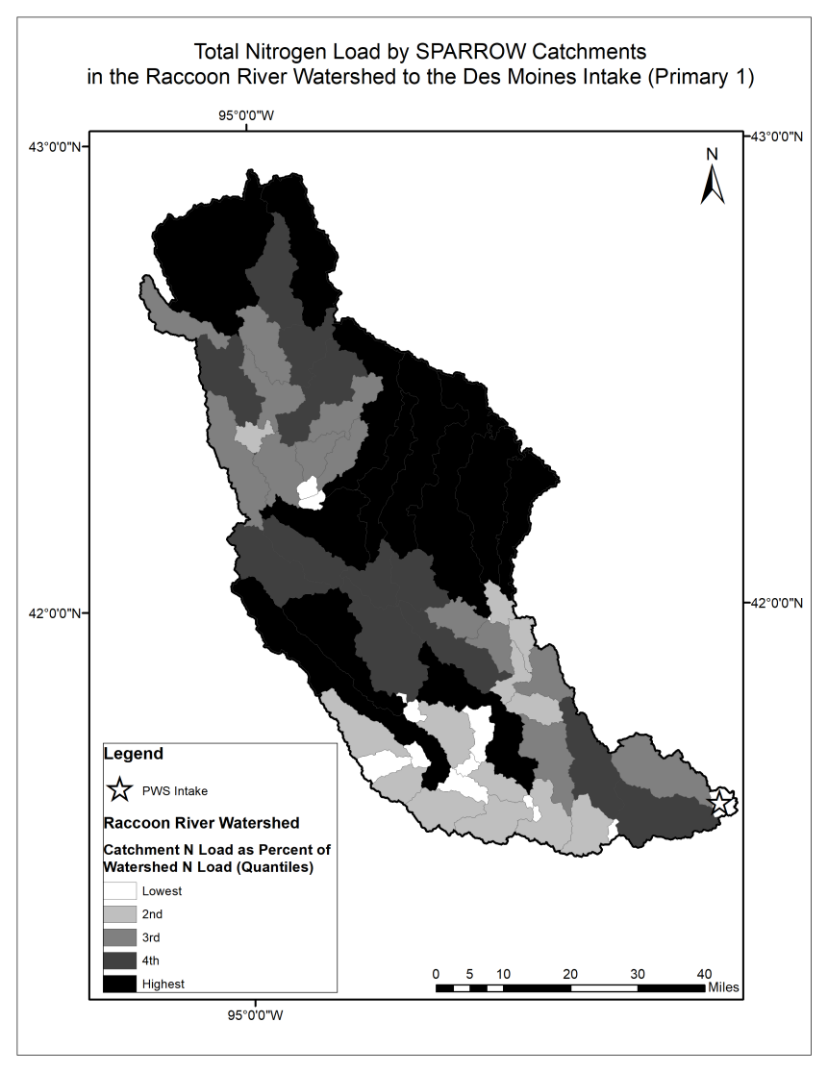
Watershed Activities

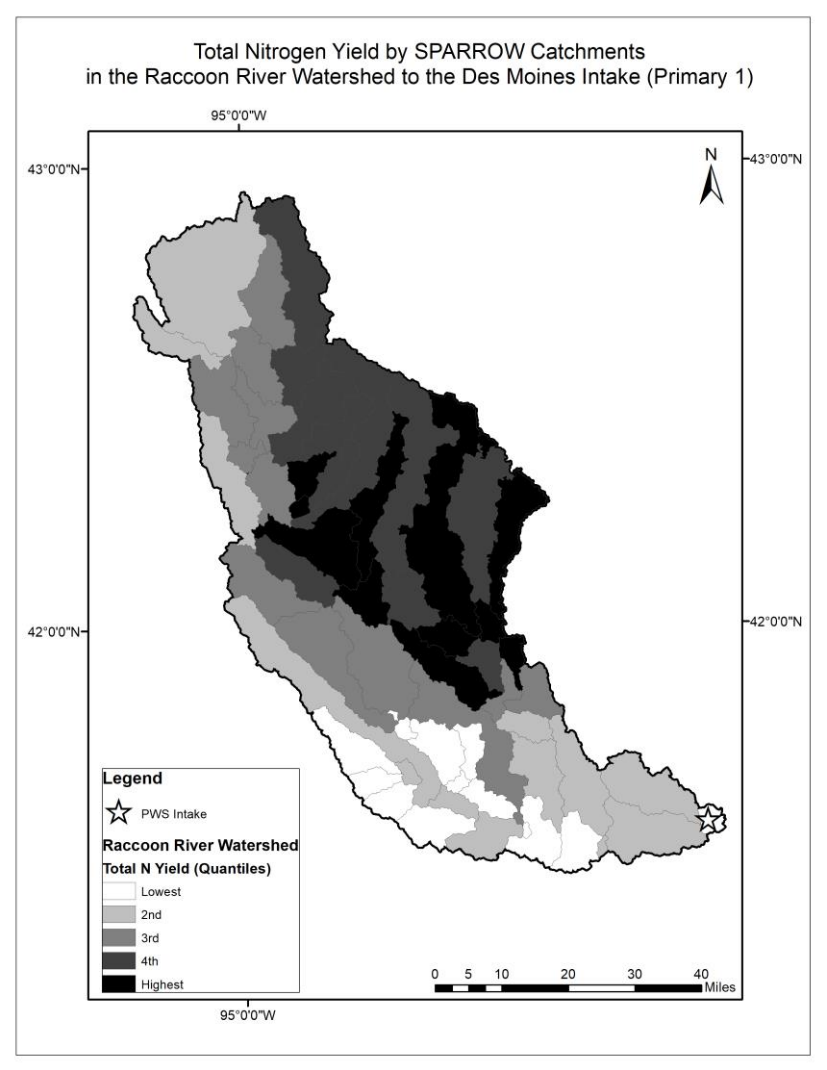


Watershed Activities – Raccoon River

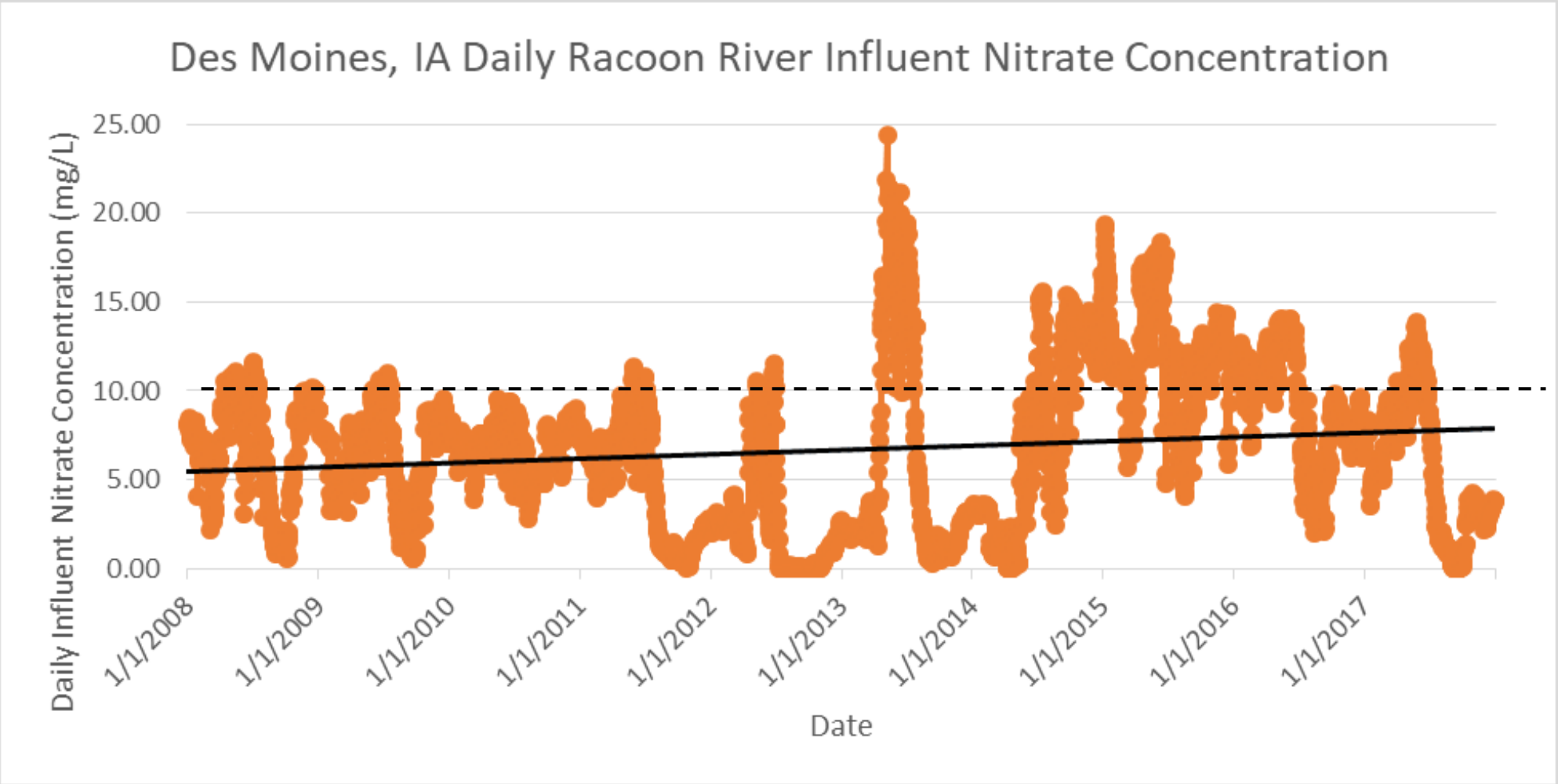
Raccoon River		Percent of Original Sum Load	
		Nutrient Reduction Scenarios	
Source Reduction Percentage	***On/Off (100%)***	***20%***	***45%***
Individual Sources			
Sewerage Point Sources	99	100	100
Atmospheric Deposition	85	97	93
Confined Manure	84	97	93
Farm Fertilizer	49	90	77
Fixation and Legume Sources	86	97	94
Urban Land Runoff	96	99	98
Source Combinations			
Point Sources	84	97	93
Runoff Loads	45	89	75
Urban Sources	96	99	98
Farm Field Loads	35	87	71
Background Sources	71	94	87
Farm Fertilizer + Background Sources	20	84	64
Red-Yellow-Green Color Scale	Cells colored in shades of red indicate lower rates of nitrogen loading reduction, with the darkest cell representing the lowest reduction; cells colored in shades of green indicate a greater nitrogen loading reduction, with the darkest cell representing the greatest reduction; and cells colored in shades of yellow indicate intermediate reductions.		

Watershed Activities – Raccoon River

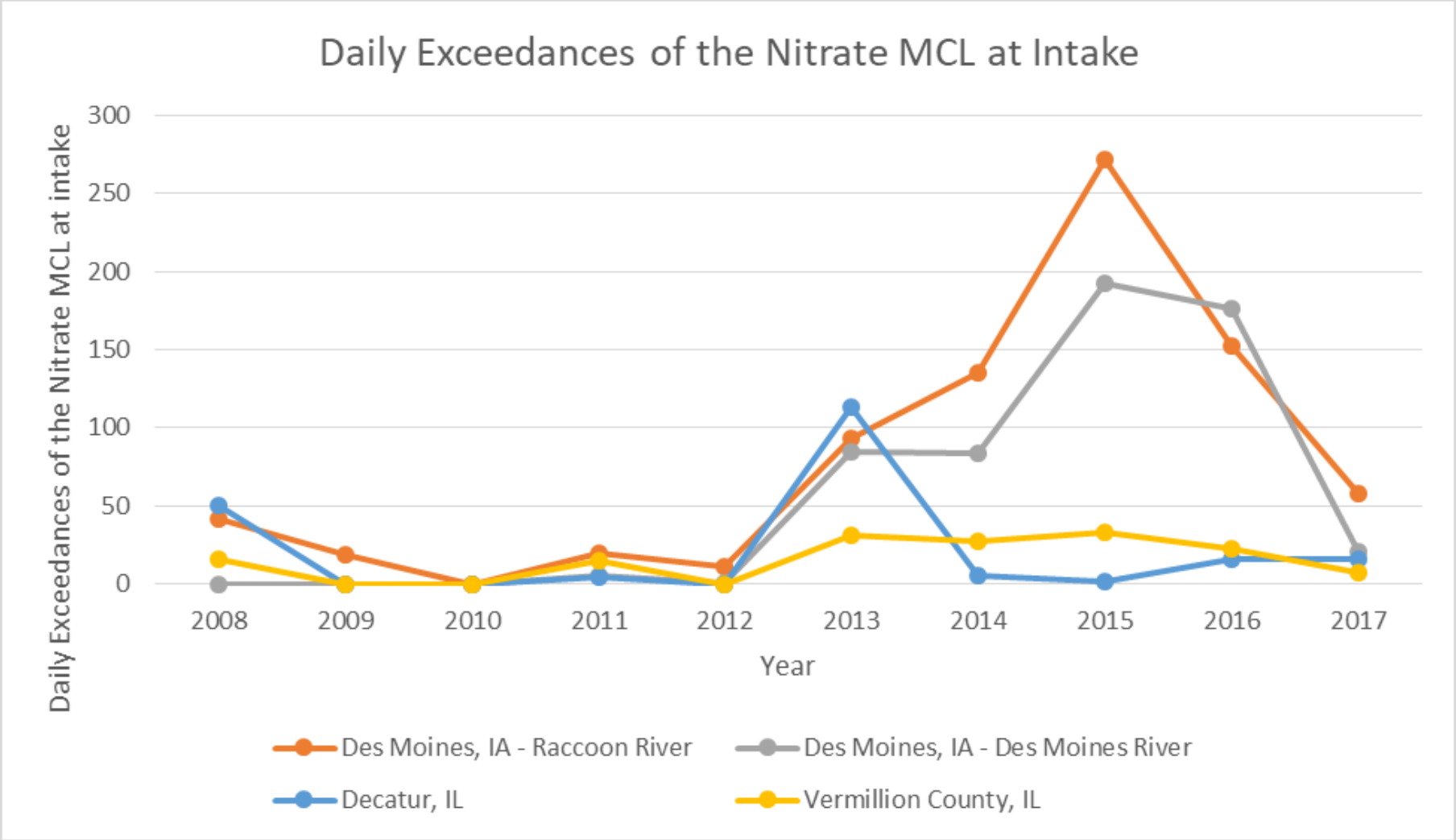




Influent Nitrate Concentrations – Des Moines – Raccoon River Intake



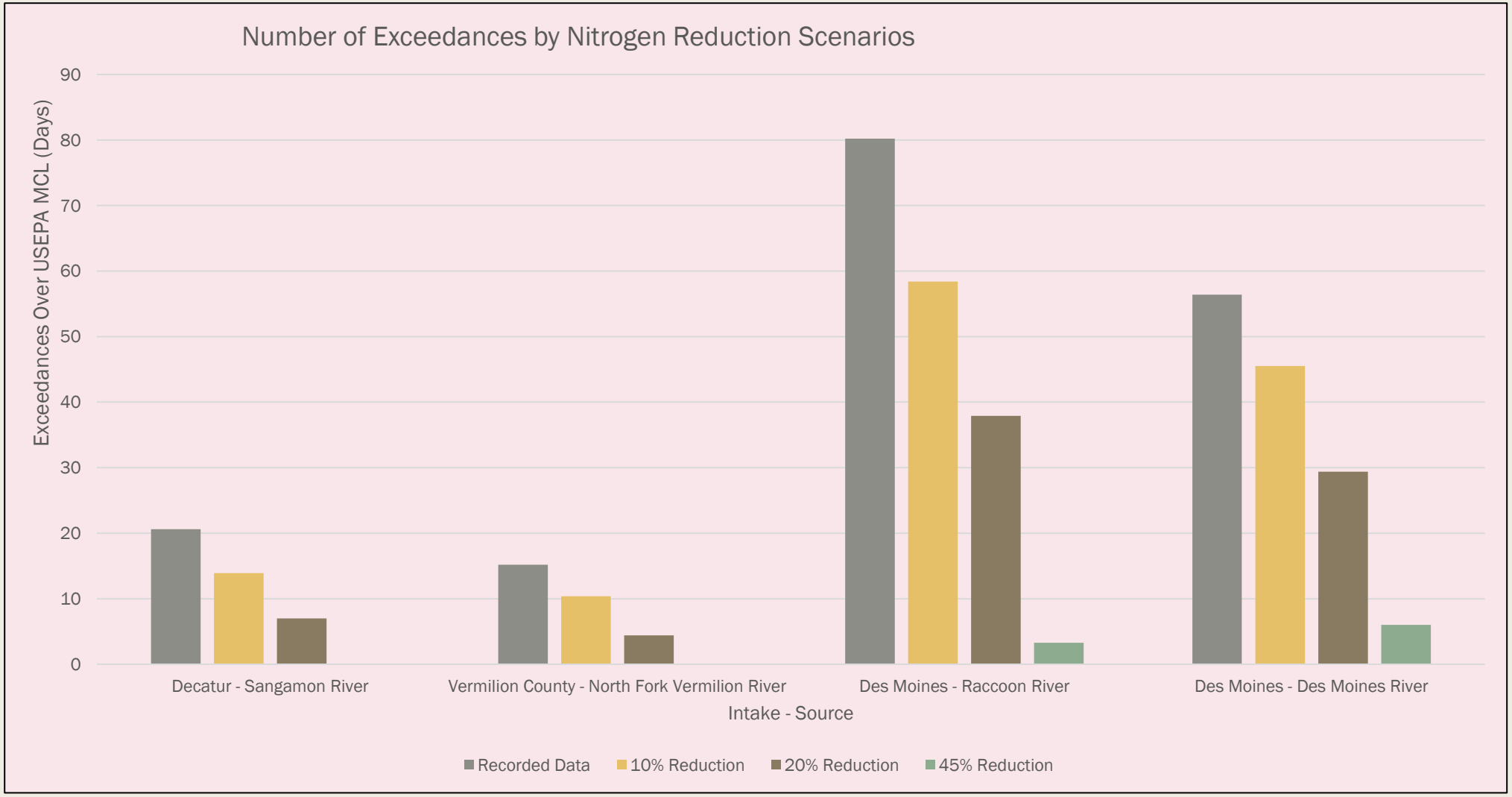
Nitrate MCL Exceedances



Nitrate MCL Exceedances

Utility	Annual Influent Concentration Exceedances (in Days)			
	10 mg/L	9.5 mg/L	8.5 mg/L	5 mg/L
Des Moines, IA (Raccoon River)	80	91	119	228
Des Moines, IA (Des Moines River)	56	63	90	212
Decatur, IL	21	25	37	134
Vermilion County, IL	15	19	39	167

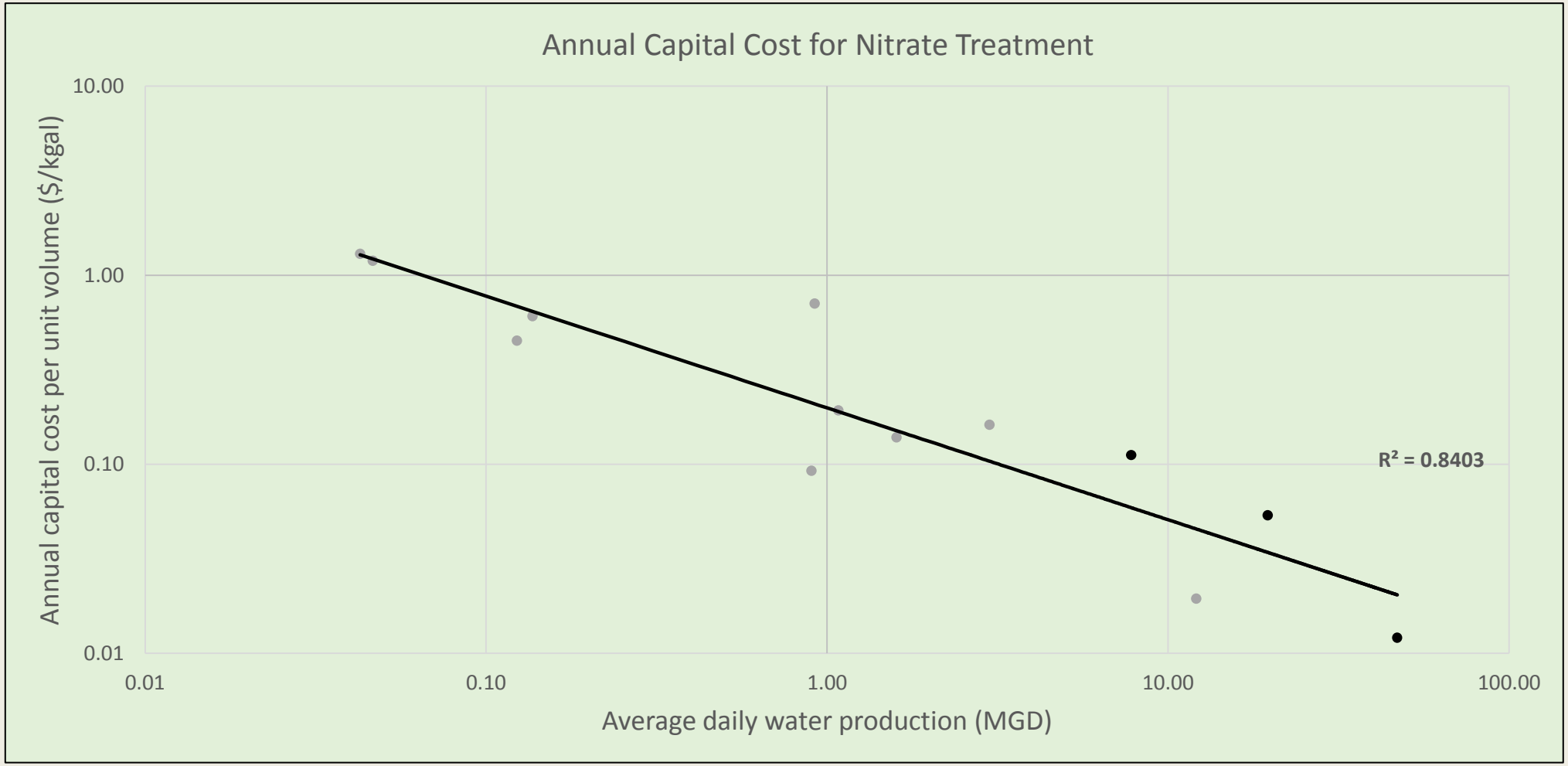
Nitrate MCL Exceedances



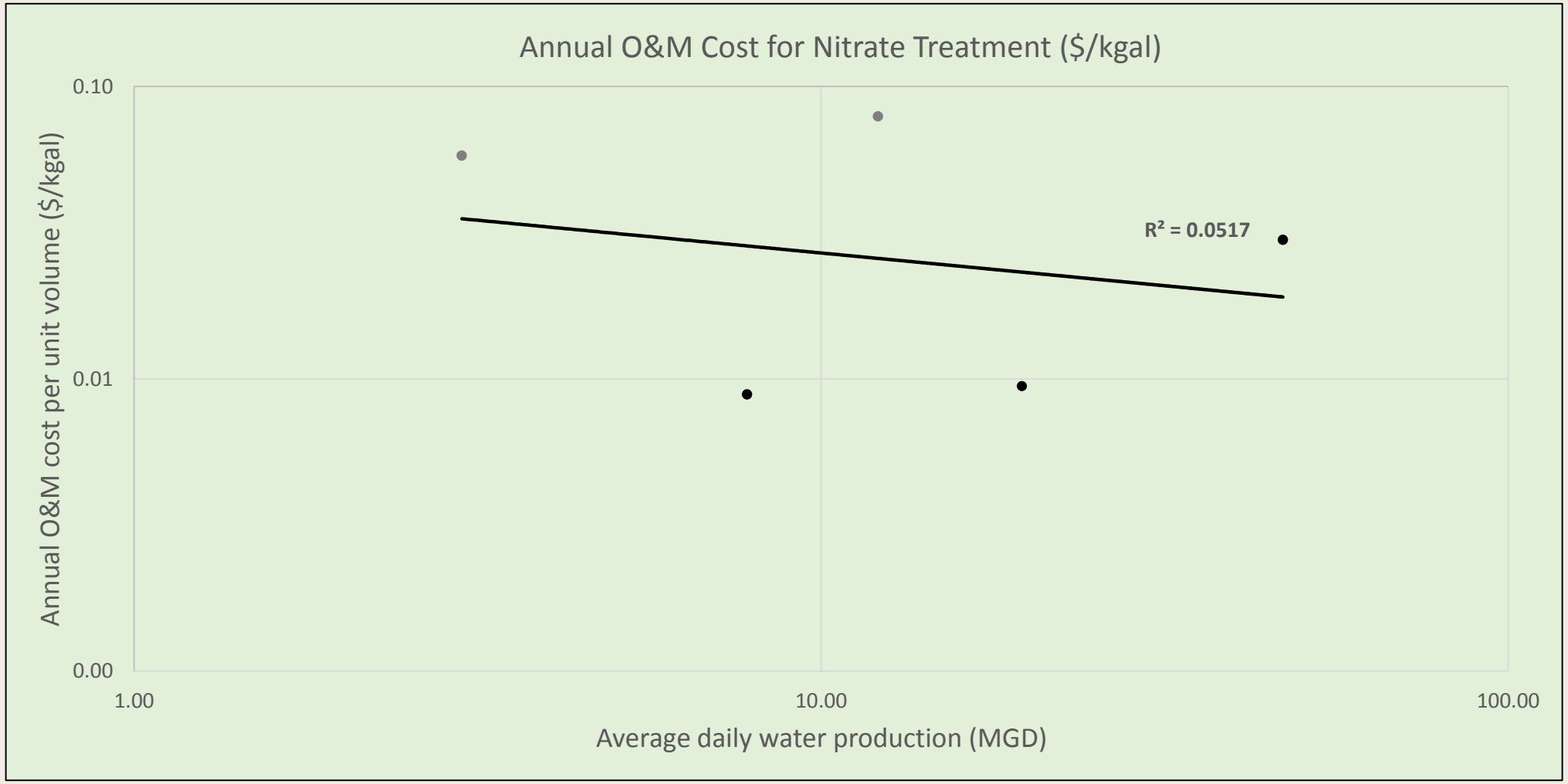
Nitrate Treatment Costs

Utility	Year of construct-ion	Product-ion (MGD)	Inflation-adjusted capital cost ($ million)	Amortized annual capital cost ($)	Average annual O&M cost ($)	Average annual cost per unit volume ($/kgal)		
						Capital	O&M	Total
Des Moines	1991	47	10.3	207,429	513,286	0.01	0.03	0.04
Decatur	2002	20	14.6	384,503	67,598	0.05	0.01	0.06
Vermilion County	2001	8	12.3	318,733	25,193	0.11	0.01	0.12

Nitrate Treatment Costs



Nitrate Treatment Costs



Key Findings

- Farm fertilizer was the largest contributor of nitrogen loading.
- Nitrogen reduction scenarios suggested that cross-sector reductions would be most effective in reducing nitrogen loads in the source waters.
- Nitrate concentrations generally increased over the 10-year study period, resulting in an increase in the daily exceedances of the nitrate MCL.
- Daily exceedances were significantly higher during the second half of the study period. A 45 percent reduction in the intake nitrate concentrations would virtually eliminate exceedances, but even a modest 10 percent reduction would bring down exceedances by 20-33 percent.
- Capital expense is a significant component of the overall cost of nitrate treatment at the three utilities.
- Amortized capital cost of the treatment unit outweighed annual O&M costs, except in Des Moines.
- In years when influent nitrate levels were the highest, utilities spent 4-9 percent of their overall operating budget on nitrate treatment.
- Smaller utilities face an undue burden of nitrate pollution in drinking water sources.
- Conservation programs have the potential to limit some of these costs to utilities, although the extent of their impact will depend on a variety of factors specific to the watershed.

Open questions

- Comprehensive assessment of nitrate treatment costs
- Measure the impact of conservation on water quality
- Identification of data gaps

Recommendations

- Capital support to small communities
- Facilitate reporting of nitrate treatment costs
- Consider regulation of ag discharges as point sources
- Encourage nutrient trading
- Technical assistance programs and research

Thank You

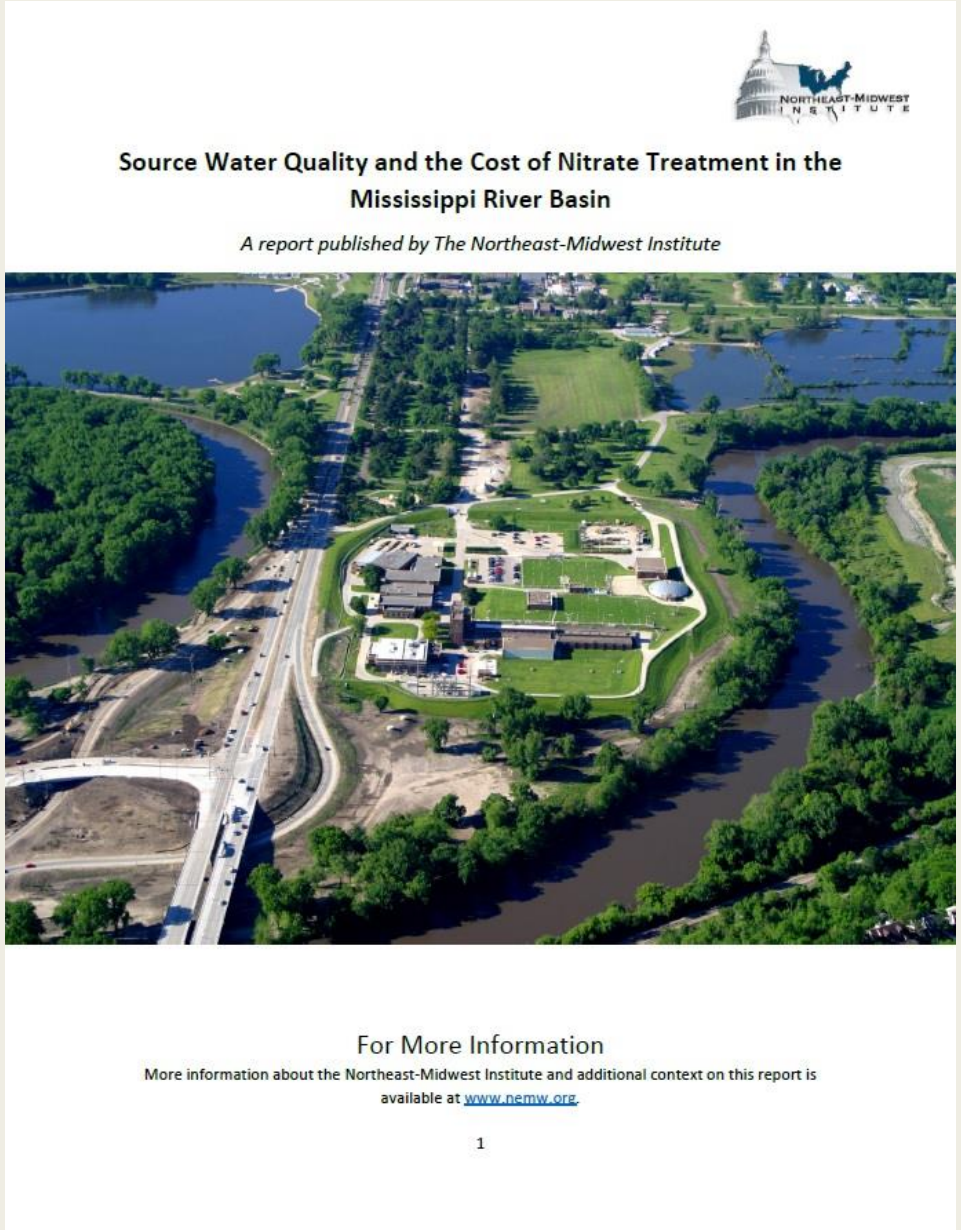
Sridhar Vedachalam

Northeast-Midwest Institute,

Washington, DC 20001

Ph: 202-464-4005

Email: svedachalam@nemw.org



Source Water Quality and the Cost of Nitrate Treatment in the Mississippi River Basin

A report published by The Northeast-Midwest Institute

For More Information

More information about the Northeast-Midwest Institute and additional context on this report is available at www.nemw.org.

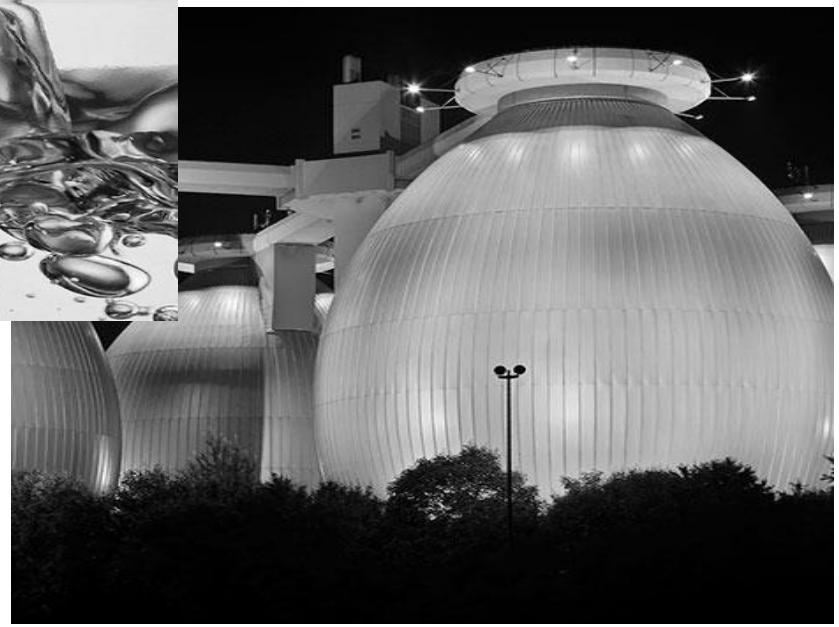
1

THE Water Research FOUNDATION

Research on Nutrients and Nitrate

Water Research Foundation

Advancing the science of water to improve the quality of life



THE
Water
Research
FOUNDATION

The integrated organization represents the evolution of water research issues, the overlap between water and wastewater, and efficiencies to be gained through a consolidated research program.

Learn more at www.waterrf.org and www.werf.org

$700 Million in Research

2,300 Projects

1,200 Subscribers

Outline

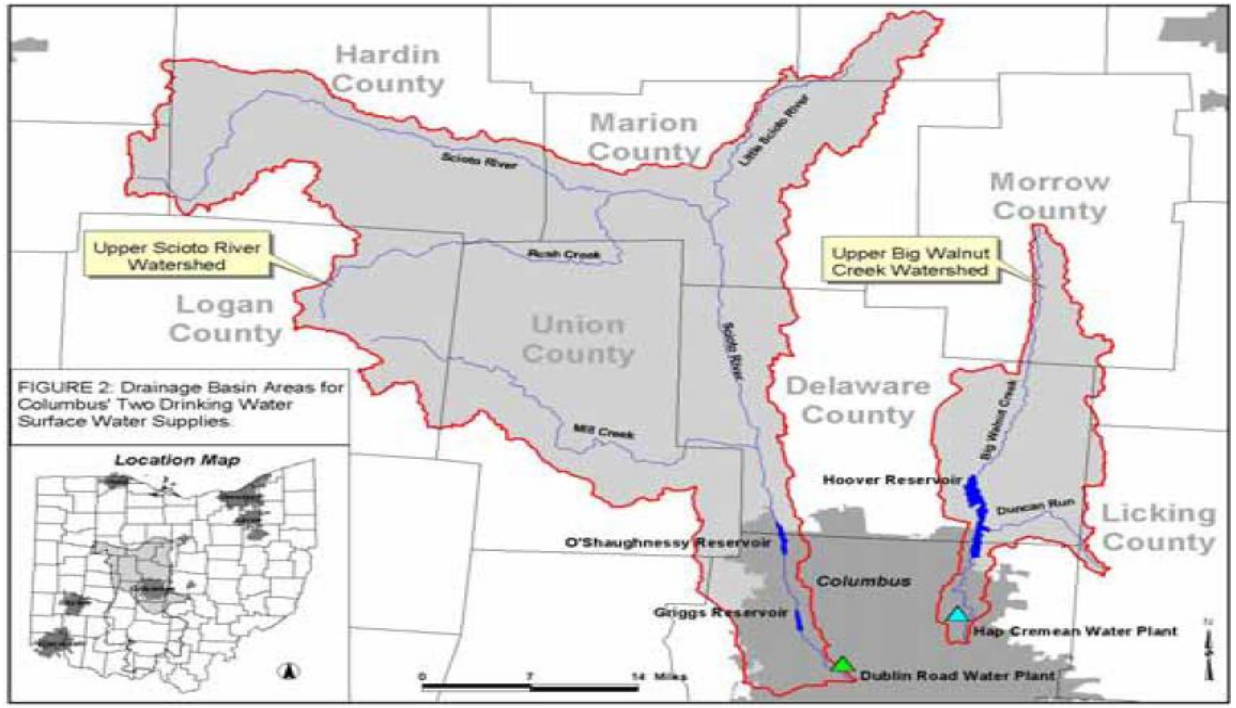
- Research on Source Water Protection
  - -Focus on Nutrient Control
- Research on Nitrate Control Technologies
- Future Research

Source Water Protection Research Planning Workshop - 4091

- 25 attendees representing DW, WW, regulators, academics, NGOs, and consultants
- 16 projects in three goal areas → $5.5M

Developing a Roadmap and Vision for Source Water Protection for U.S. Drinking Water Utilities - 4176

- Vision/Roadmap
- Strategy
- Framework
- Decision-Making: Process and Tools



Watersheds of the Upper Scioto River and the Upper Big Walnut Creek

Barriers to Source Water Protection Programs

- Lack of authority to do anything to protect the source water
- Restricted resources that are directed toward other higher-priority utility functions
- Belief that some other entity is responsible for source water protection
- Government agencies (other than the municipalities) controlling the lakes/reservoirs used

Nitrate Technology Options

- Conventional Ion Exchange (IX)
  - Standard resin
  - Nitrate selective resin (10-20% more expensive)
- Biological Nitrate Treatment
  - Microvi Biological Nitrate Removal System
  - BKT Biofiltration
  - Biottta
- Brine Reuse with Electrochemical Denitrification

Biological and Ion Exchange Nitrate Removal Evaluation - 4131

MBfR + Ozone + Biologically Active Carbon Filtration

Fixed Bed Bioreactor with Plastic Media + Ozone + Biologically Active Carbon Filtration

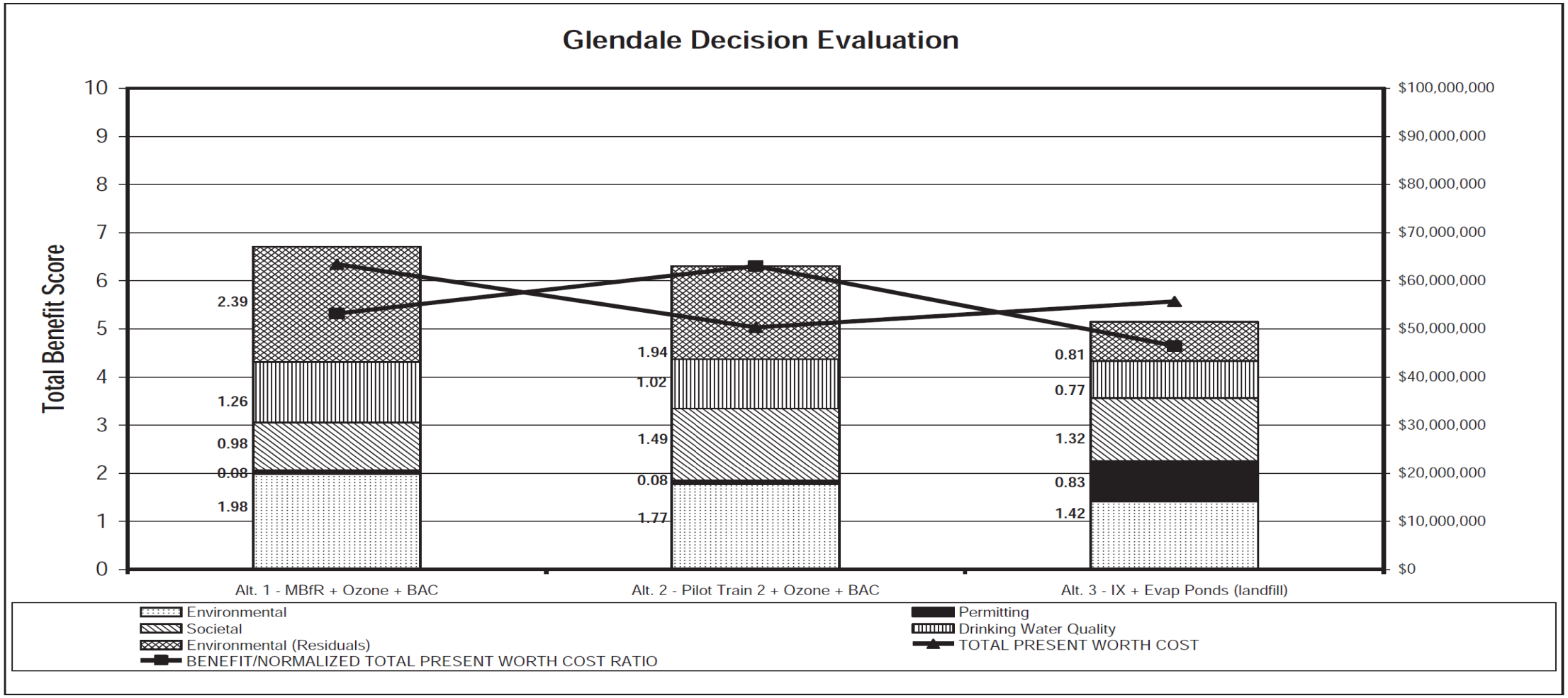
Fixed Bed Ion Exchange + Evaporation Ponds/Landfill

Cost Estimates

Cost summary for nitrate treatment alternatives

Alternative	Project construction cost* ($)	Annual O&M cost* ($/year)	Net present worth* ($)
Alt. 1—MBfR + Ozone + BAC	$23,844,600	$3,429,100	$66,593,700
Alt. 2—Fixed Bed Bioreactor with Plastic Media + Ozone + BAC	$19,652,400	$2,712,200	$53,450,100
Alt. 3—Ion Exchange + Evaporation Ponds	$16,446,000	$3,175,200	$56,014,900

* Rounded up to the nearest hundred dollars.



Pilot Testing Nitrate Treatment Processes with Minimal Brine Waste - 4578

- A proprietary biological denitrification system (MB-N2)
- Standard IX resin without brine reuse
- Nitrate selective IX resin with electrochemical denitrification (ECD)system

Cost Estimates

Cost comparison of technologies

Treatment alternatives	Capital cost	Annual O&M cost	20-year present worth cost
Alternative 1 - 1,600 gpm MB-N2 system	$6,293,000	$234,300	$9,212,000
Alternative 2 - 1,930 gpm conventional IX system	$5,317,000	$763,400	$14,829,000
Alternative 3 - 1,600 gpm IX-ECD system	$10,945,060	$331,700	$15,078,000

Non-cost comparison of technologies

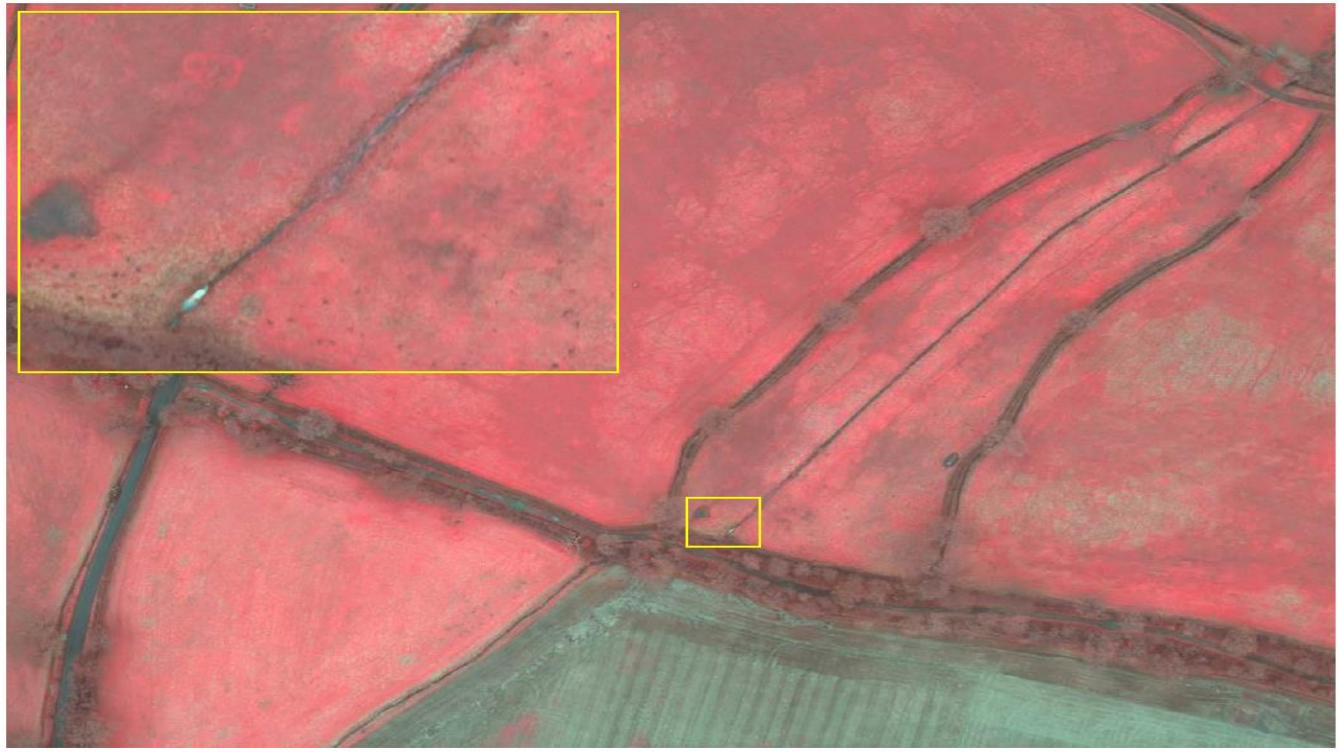
Parameters	Alternative 1 - 1,600 gpm MB-N2 system	Alternative 2 - 1,930 gpm conventional IX system	Alternative 3 - 1,600 gpm IX-ECD system
Operational complexity	High (1)	Low (3)	High (1)
Waste disposal and environmental sustainability	High (3)	Low (1)	Moderate (2)
Overall safety (dealing with hazardous chemicals, toxic gas release, etc.)	Moderate (2)	High (3)	Low (1)
Process reliability	Moderate (2)	High (3)	Moderate (2)
Footprint	High (1)	Low (3)	Moderate (2)
Source water variability	Moderate (2)	High (3)	High (3)
Technology / treatment history	Moderate (2)	High (3)	Low (1)
Total scores =	13	19	12

Treatment Conclusions

- Biological treatment processes are showing promises
  - -No brine disposal
  - -Enhanced Nitrate removal
- Ion Exchange
  - -Increased efficiency with new advancements
  - -also results in less brine
- Cost alone should not drive decisions

Future Research on Nutrient Control

Remote Sensing: Areal and Satellite Data



Evidence of runoff identified in the aerial data but no accessible to ground team.

THE Water Research FOUNDATION

Thank you!!

John Albert

Chief Research Officer

jalbert@waterrf.org

303.734.3413

@JohnAlbertWRF

United States Department of Agriculture

National Headquarters

Natural Resources Conservation Service

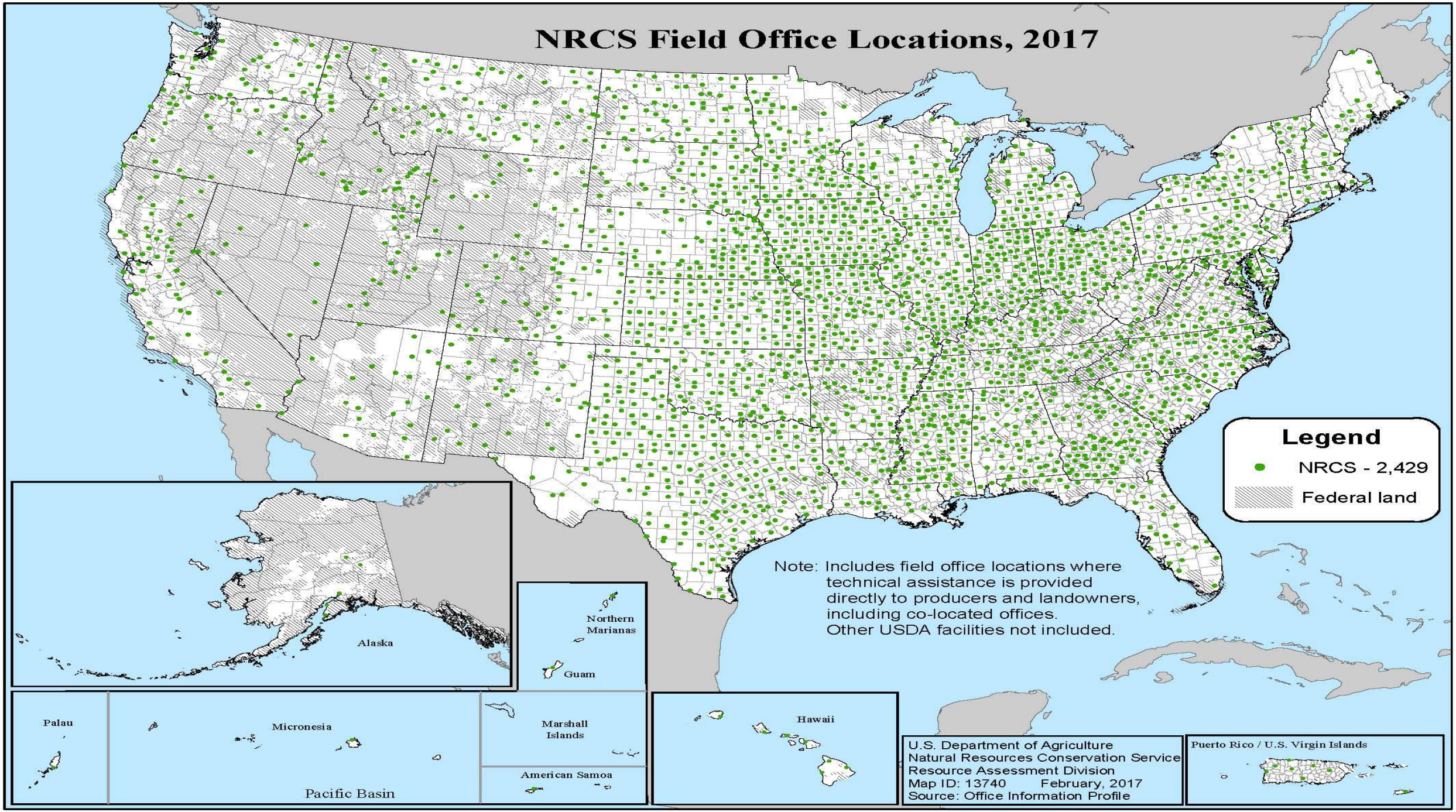
Northeast-Midwest Institute

May 23, 2018 | Jimmy Bramblett

Natural Resources Conservation Service

nrcs.usda.gov/

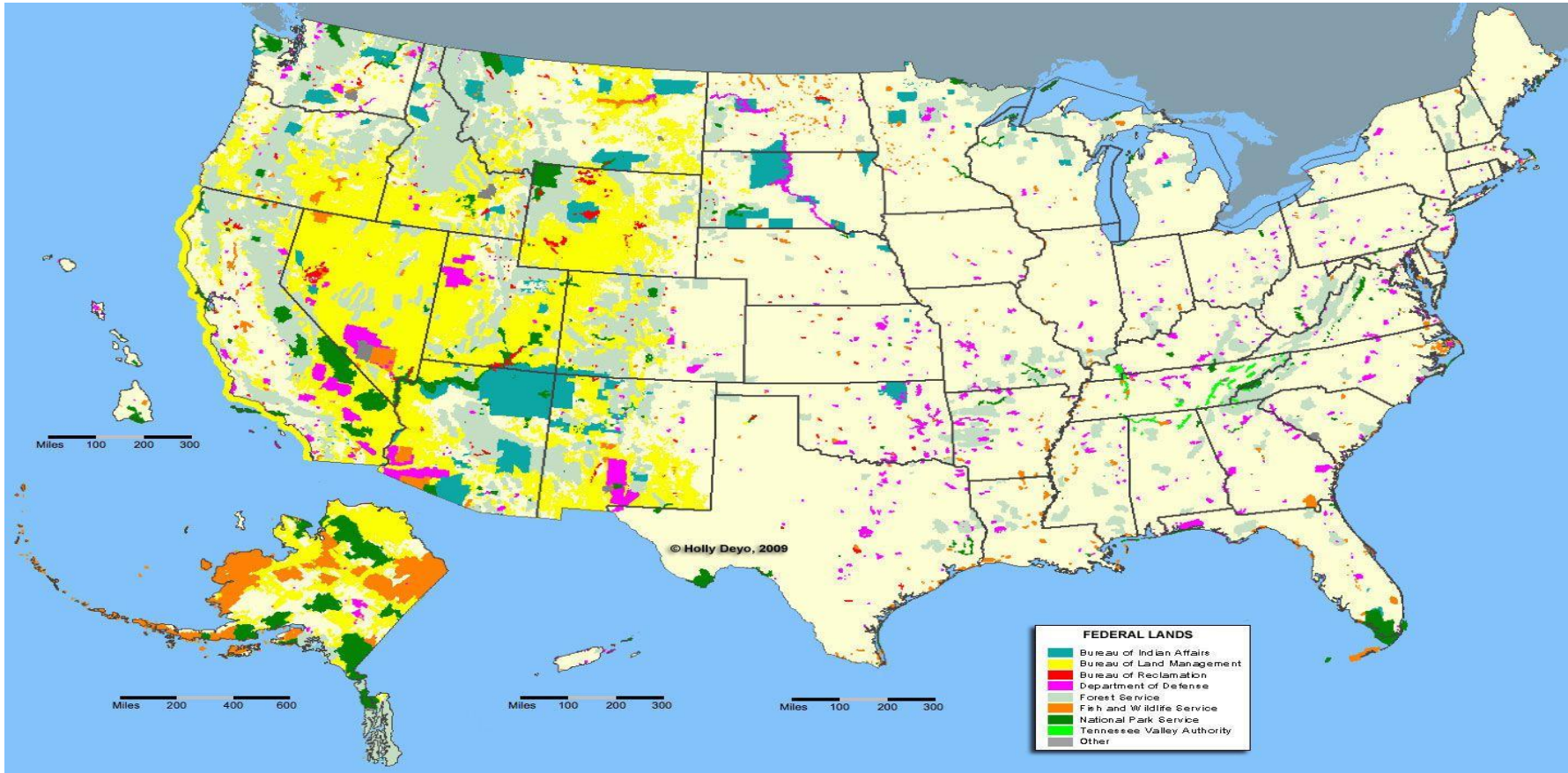
NRCS Field Office Locations, 2017



CPTAD – Conservation Planning

Conservation Technical Assistance

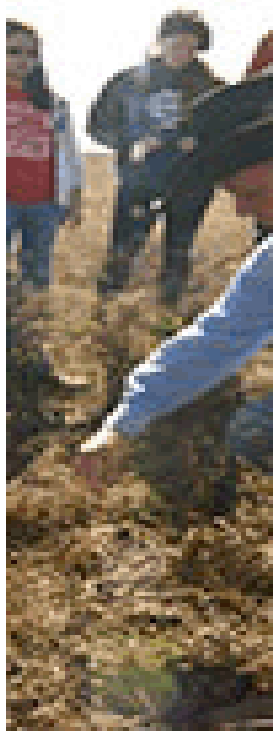
- 70% of Landownership is Private
- NRCS provide voluntary, science-based technical and financial assistance to landowners to address resource concerns (e.g. soil erosion, water quality, wildlife habitat, etc.)



CPTAD – Conservation Planning

Conservation Planning Certification

- Apprentice Planner
  - Support Certified Conservation Planners in Planning Process
- Certified Conservation Planner
  - Serve as Responsible Federal Official (RFO)
- Master Conservation Planner
  - Watershed Planning
  - Quality Assurance Responsibilities



Conservation Planning Process

August 2017

→ *ENG – I&E*

- ✓ Survey
- ✓ Hydrology
- ✓ Soils/Geological

FOTG-I, II, and III

- ✓ Preliminary/Concept Design
- ✓ Cost Estimate

FOTG-I, IV, and V

CAPs

Step-1 - Problem ID
Step-2 - Objectives

Step-3 – Inventory
Step-4 – Analyze

Step-5 – Formulate
Step-6 – Evaluate

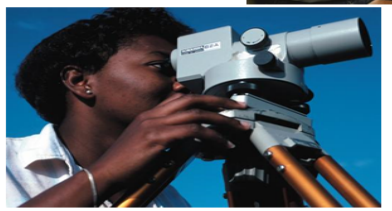
Step-7 – Decision

CPA-52 E/D | *CPA-52 F/G* | *CAET* | *CPA-52 H - I/J* | *CAET* | *CPA-52 K/M/P/S*

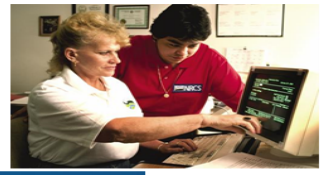
- ✓ Establish Relationship
- ✓ Soil Erosion
- ✓ Soil Quality
- ✓ Water Quality
- ✓ Water Quantity
- ✓ Plant Degradation
- ✓ Fish/Wildlife Habitat
- ✓ Livestock Limits
- ✓ Air Quality
- ✓ Energy
  - Cropland
  - Pasture
  - Rangeland
  - Forest
  - Farmstead

- ✓ Quantify Benchmarks
- ✓ ***= Quality Criteria?***
- ✓ ***= Evaluation Criteria?***
  - No = EQIP
  - Yes = CSP (2 RCs)

❖ **IET**
❖ **RSET**
❖ **MP (pending)**



- ✓ Conservation Practices (170)
- ✓ Quantify to ***Quality Criteria***
- ✓ Enhancements/Bundles (220+)
- ✓ Meet Additional RC
- ✓ Cost Estimator



- ✓ Component Plans (certified TSPs)
- ✓ RFO Certification
- ✓ ***Conservation Plan***
  - Maps (location, soils planned practices)
  - Final CAET Acres

❖ **Toolkit/CD**
❖ **NPAD**

Step-8a – Design

- ✓ Plans and Specifications/Job Sheets
- ✓ Detailed Geological Investigation
- ✓ Final Design
- ✓ Design Folder
- ✓ Permitting

→ *ENG – Design*

Step-8b – Contracting

- ✓ Application
- ✓ Eligibility
- ✓ Screening
- ✓ Ranking
- ✓ Contract
- ✓ Schedule of Operations
- ✓ Contract Modifications

❖ **CCG**
❖ **DMS**
❖ **PSS**
❖ **Protracts**
❖ **FA Tracker**

Step-8c – Installation

- ✓ Non-Eng. Practice Installation

→ *ENG – Constr.*

- ✓ Pre-Construction Meeting
- ✓ Construction Inspection
- ✓ As-Built Plans
- ✓ JAA Practice Check-Out
- ✓ O& M Plan

Step-8d – Certification

- ✓ Line Officer Practice Certification
- ✓ Financial Payment

Step-9 – Evaluation

- ✓ How Effective
- ✓ CEAP
- ✓ Maintain Relationship

Natural Resources Conservation Service

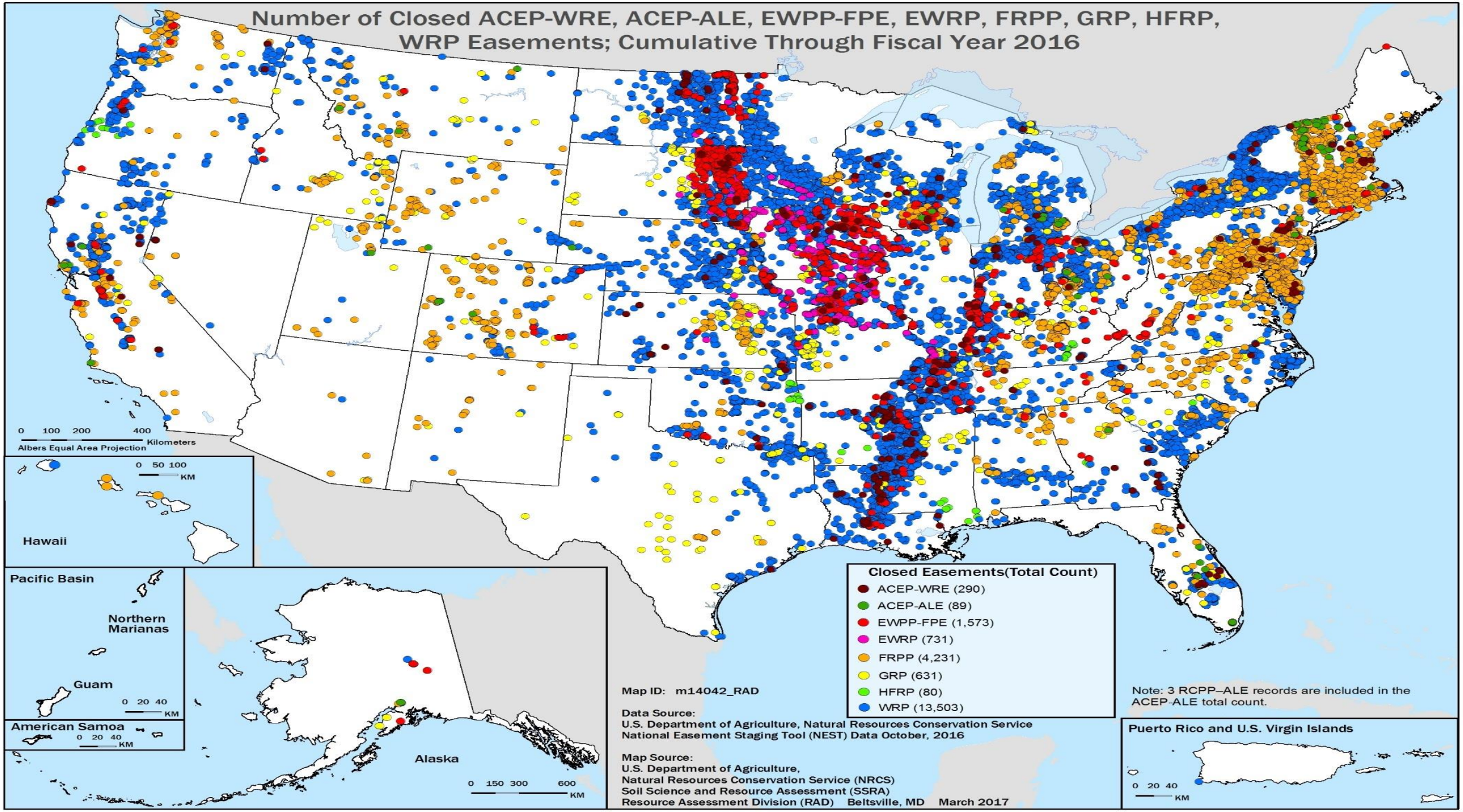
nrcs.usda.gov/

EPD – Easement Programs

Easement Portfolio

	NUMBER OF EASEMENTS	ACRES
TOTAL	21,481	5,214,333

NRCS manages nearly 50,000 miles of boundaries – if added together they would stretch around the earth twice!


Number of Closed ACEP-WRE, ACEP-ALE, EWPP-FPE, EWRP, FRPP, GRP, HFRP, WRP Easements; Cumulative Through Fiscal Year 2016
0 100 200 400
Kilometers
Albers Equal Area Projection
0 50 100
KM
Hawaii
Pacific Basin
Northern Marianas
Guam
0 20 40
KM
American Samoa
0 20 40
KM
Alaska
0 150 300 600
KM
Closed Easements(Total Count)
ACEP-WRE (290)
ACEP-ALE (89)
EWPP-FPE (1,573)
EWRP (731)
FRPP (4,231)
GRP (631)
HFRP (80)
WRP (13,503)
Map ID: m14042_RAD
Data Source:
U.S. Department of Agriculture, Natural Resources Conservation Service
National Easement Staging Tool (NEST) Data October, 2016
Map Source:
U.S. Department of Agriculture,
Natural Resources Conservation Service (NRCS)
Soil Science and Resource Assessment (SSRA)
Resource Assessment Division (RAD) Beltsville, MD March 2017
Note: 3 RCPP–ALE records are included in the ACEP-ALE total count.
Puerto Rico and U.S. Virgin Islands
0 20 40
KM

FAPD – EQIP

Program Purpose

Primary Goals:

1. Financial Assistance to address resource concern(s)
2. Almost 200 conservation practices available

354,000 + conservation practices per year

FAPD – EQIP

Locally Led Conservation

State Conservationist

State Technical Committee

Examples

- Conservation Practices
- Payment Limits
- Payment Rates
- Prioritization
- Resource Concerns

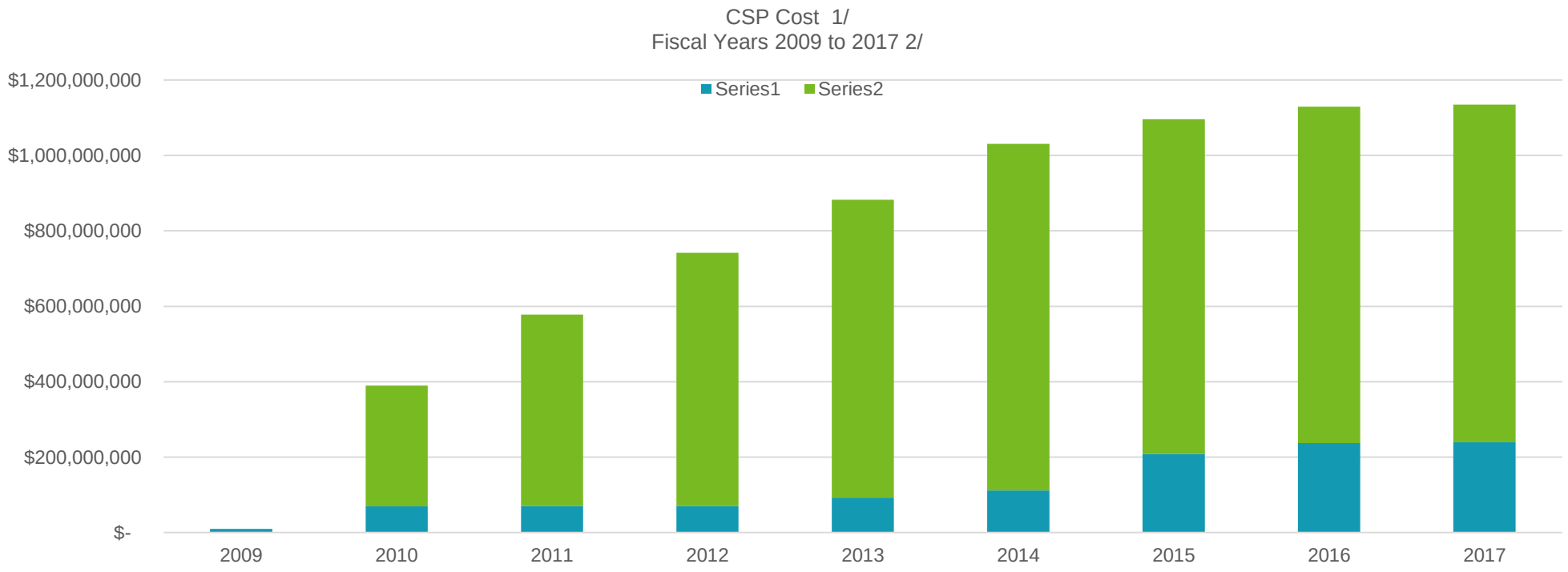
47 Resource Concerns => WQ competition

FAPD – EQIP

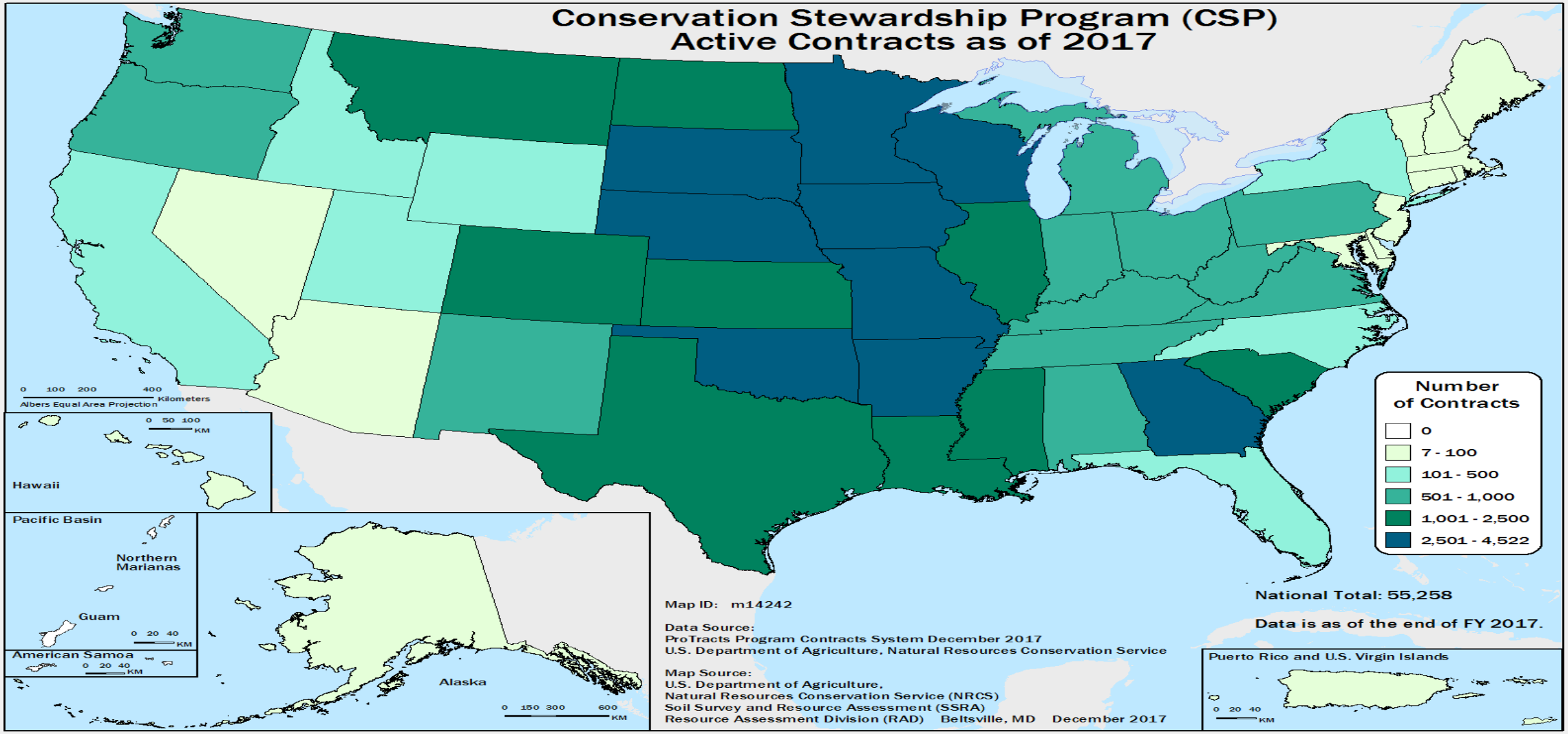
Top Practices – 2014 Farm Bill

Practice Name	Number	Dollars
Cover Crop	57,791	$295,608,194
Fence	54,996	$231,639,820
Brush Management	34,529	$206,389,345
Irrigation System, Sprinkler	6,571	$204,645,533
Waste Storage Facility	4,847	$202,370,766
Irrigation Pipeline	11,549	$166,364,188
Irrigation System, Micro	5,446	$134,572,460
Pipeline	33,829	$121,853,865
Waste Facility Cover	4,529	$116,092,229
Pasture & Hayland Planting	22,390	$105,841,936
Heavy Use Area Protection	31,446	$99,466,305
Forest Stand Improvement	16,753	$94,695,469
Pumping Plant for Water Control	16,367	$86,999,642
Trough or Tank	40,891	$83,677,626
Combustion System Improvement	2,128	$73,828,447

FAPD – CSP



1/ Source: FFIS for 2009 to 2011 and FMMI for 2012 to 2017. Includes Conservation Security and Conservation Stewardship Programs.
2/ Original obligations which do not reflect downward adjustments. Fiscal year 2017 obligations are preliminary pending final approval.


Conservation Stewardship Program (CSP)
Active Contracts as of 2017
0 100 200 400
Kilometers
Albers Equal Area Projection
Hawaii
0 50 100
KM
Pacific Basin
Northern Marianas
Guam
0 20 40
KM
American Samoa
0 20 40
KM
Alaska
0 150 300 600
KM
Number of Contracts
0
7 - 100
101 - 500
501 - 1,000
1,001 - 2,500
2,501 - 4,522
National Total: 55,258
Data is as of the end of FY 2017.
Map ID: m14242
Data Source:
ProTracts Program Contracts System December 2017
U.S. Department of Agriculture, Natural Resources Conservation Service
Map Source:
U.S. Department of Agriculture,
Natural Resources Conservation Service (NRCS)
Soil Survey and Resource Assessment (SSRA)
Resource Assessment Division (RAD) Beltsville, MD December 2017
Puerto Rico and U.S. Virgin Islands
0 20 40
KM

FAPD – CSP

Practice Code	Practice Name	Frequency Count
E595116X	Reduce risk of pesticides in surface water by utilizing precision pesticide application techniques	931
E595116Z	Reduce risk of pesticides in surface water by utilizing IPM PAMS techniques	691
E340107Z	Cover crop to minimize soil compaction	544
E340106Z2	Use of multi-species cover crops to improve soil health and increase soil organic matter	516
E328136Z	Leave standing grain crops unharvested to benefit wildlife food sources	497
E528140Z1	Maintaining quantity and quality of forage for animal health and productivity	442
E340106Z1	Intensive cover cropping to increase soil health and soil organic matter content	428
E590118Z	Improving nutrient uptake efficiency and reducing risk of nutrient losses to surface water	148
E511137Z1	Harvest of crops (hay or small grains) using measures that allow desired species to flush or escape	132
E666137Z1	Snags, den trees, and coarse woody debris for wildlife habitat	123

USDA
United States Department of Agriculture

Regional Conservation Partnership Program

Science Based Evaluations

CEAP-Cropland

CEAP-Grazing Lands

CEAP-Wetlands

CEAP-Wildlife

CEAP-Watersheds

Mississippi River Basin = 20+%

Great Lakes = 43%

Western Lake Erie = 36%

Chesapeake Bay = 38+%

NRI Data Points, Aerial Photos,
NRCS Delivery System, Landowner Surveys

Science Based Outcomes

Mature Science

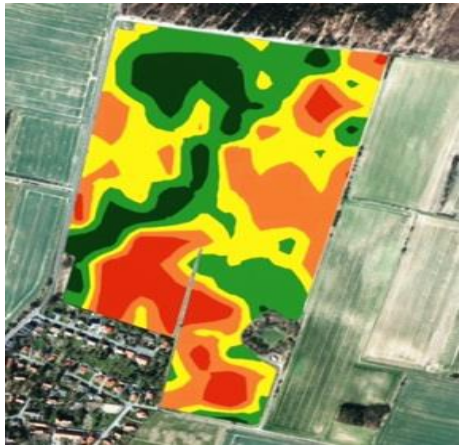
- Resource Concerns unequal
  - sheet/rill vs. streambank and legacy sediments
  - surface water vs groundwater

> 7 Million Fields

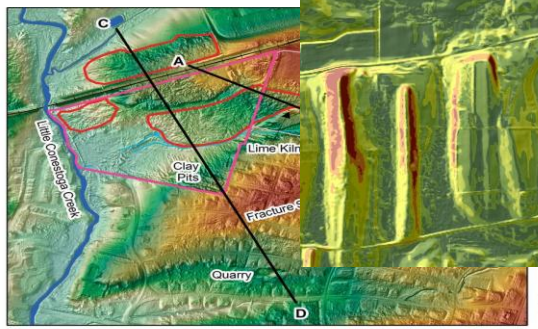
Less Mature Science

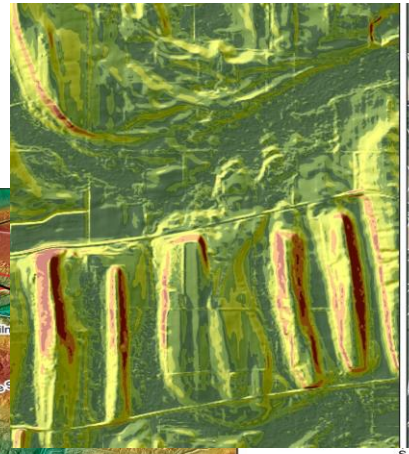
CPTAD – Precision Conservation

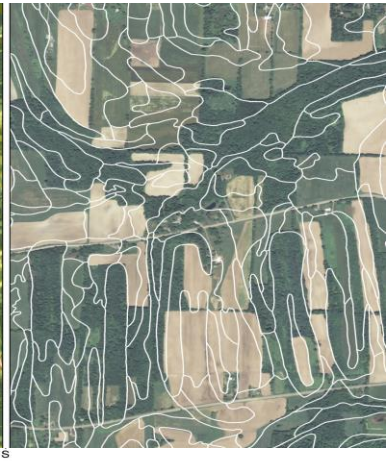
Precision Agriculture

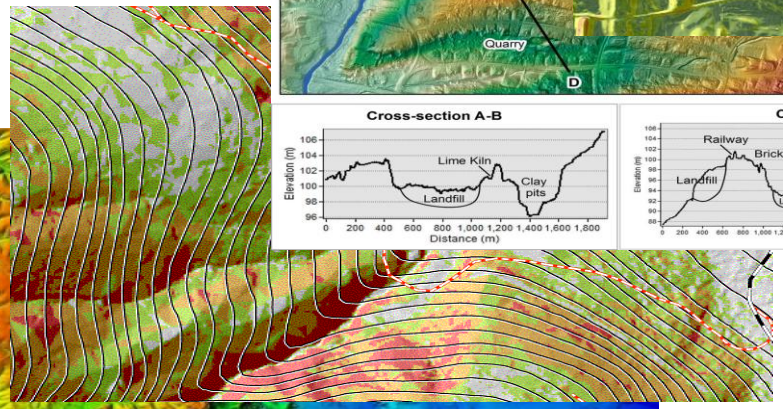


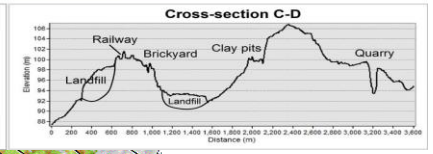
CAP 132

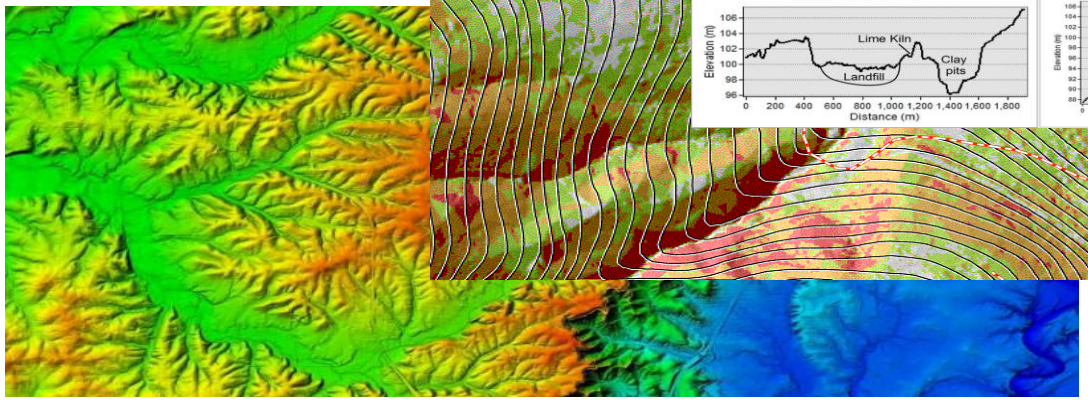












DRIVERS

Consistency
Heritage Foundation
President's Budgets

Farm Bill

Hiring Limits
Funding Carryover
NRCS Standards
NRCS Agreements

Questions?

Policy Implications

I. Immediate Policy Implications (Do No Harm)

A. The Farm Bill
B. The Clean Water Rule
C. U.S. – China Trade Relations

II. General Policy Implications (Nitrate Removal Is Expensive)

-Regulatory changes can increase treatment costs

-These costs generally hit smaller, rural communities hardest

-Certain Conservation Programs Can Lower These Cost

-We Need Better Data

III. Legislative Solutions (How to Fix It)

III. Legislative Solutions (How to Fix It)

- Provide capital support to small communities
- Facilitate nitrate removal cost reporting
- Explore the possibility of regulating agricultural discharges as point source
- Nutrient trading
- Technical assistance
- Mindful appropriations

Thank You

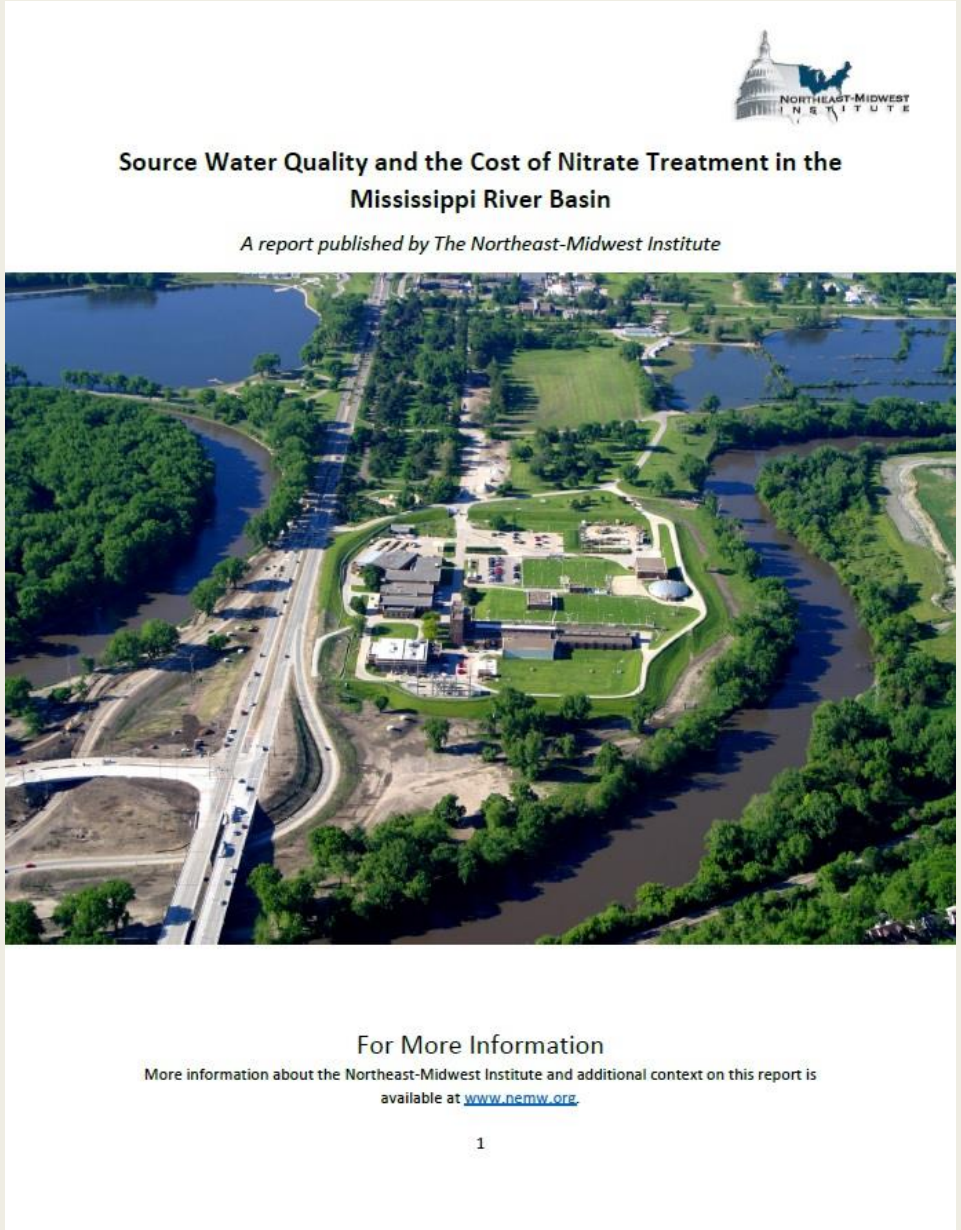
Eric Heath

Northeast-Midwest Institute,

Washington, DC 20001

Ph: 202-464-4019

Email: eheath@nemw.org



Source Water Quality and the Cost of Nitrate Treatment in the Mississippi River Basin

A report published by The Northeast-Midwest Institute

For More Information

More information about the Northeast-Midwest Institute and additional context on this report is available at www.nemw.org.

1