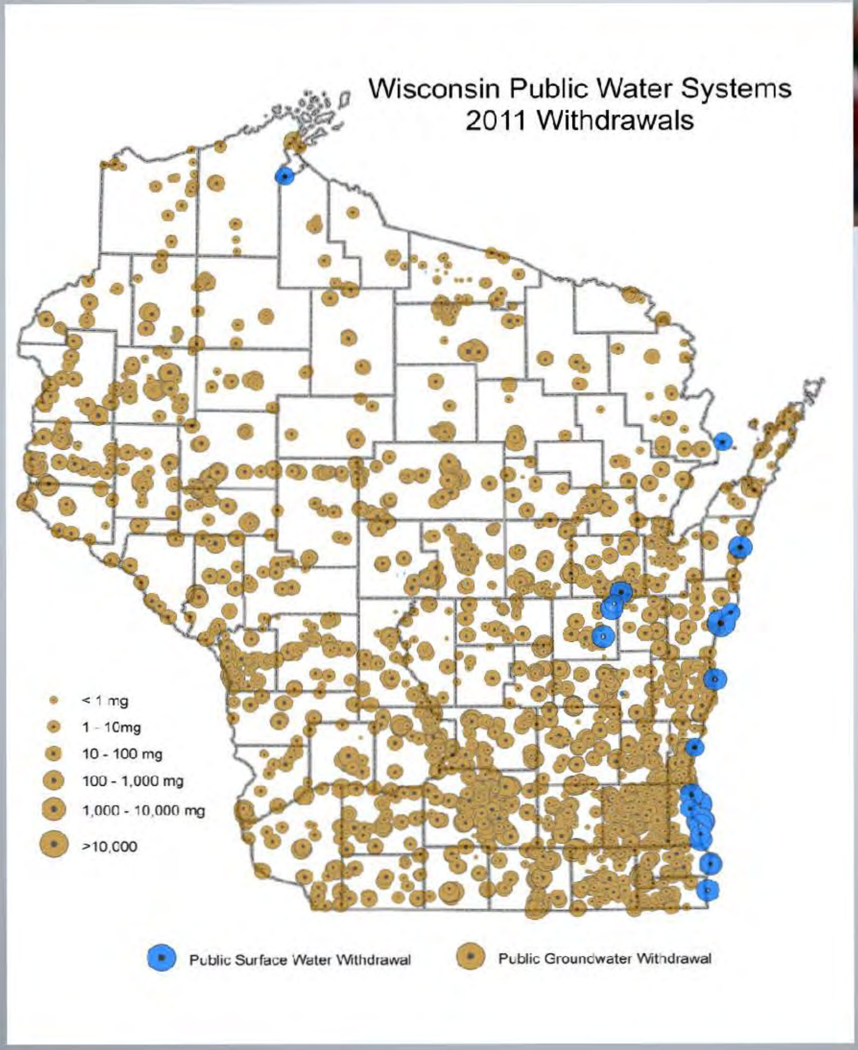
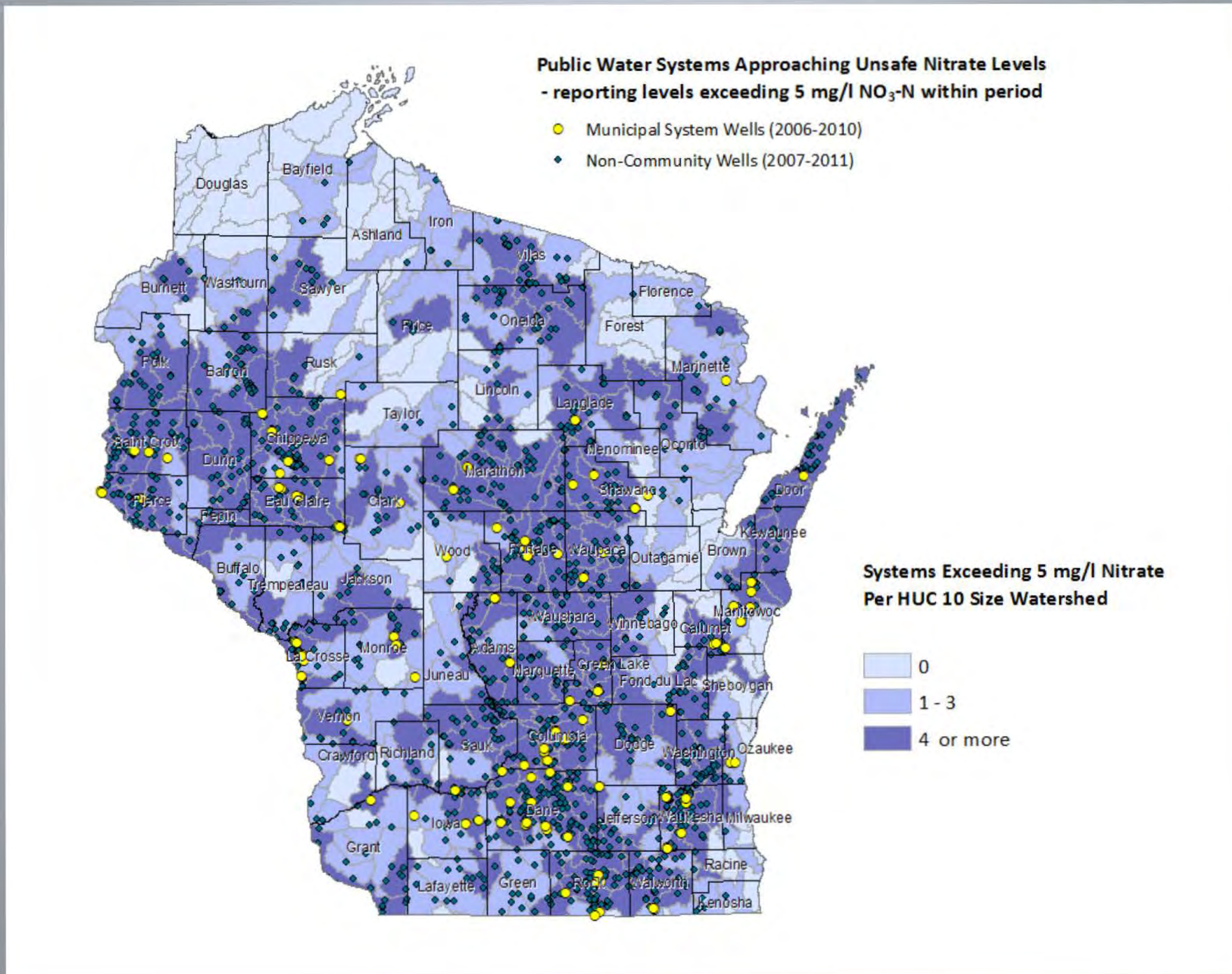
WISCONSIN'S NITRATE DEMONSTRATION PROJECT

Brian Austin &
Mary Ellen Vollbrecht
Bureau of Drinking Water & Groundwater
Department of Natural Resources

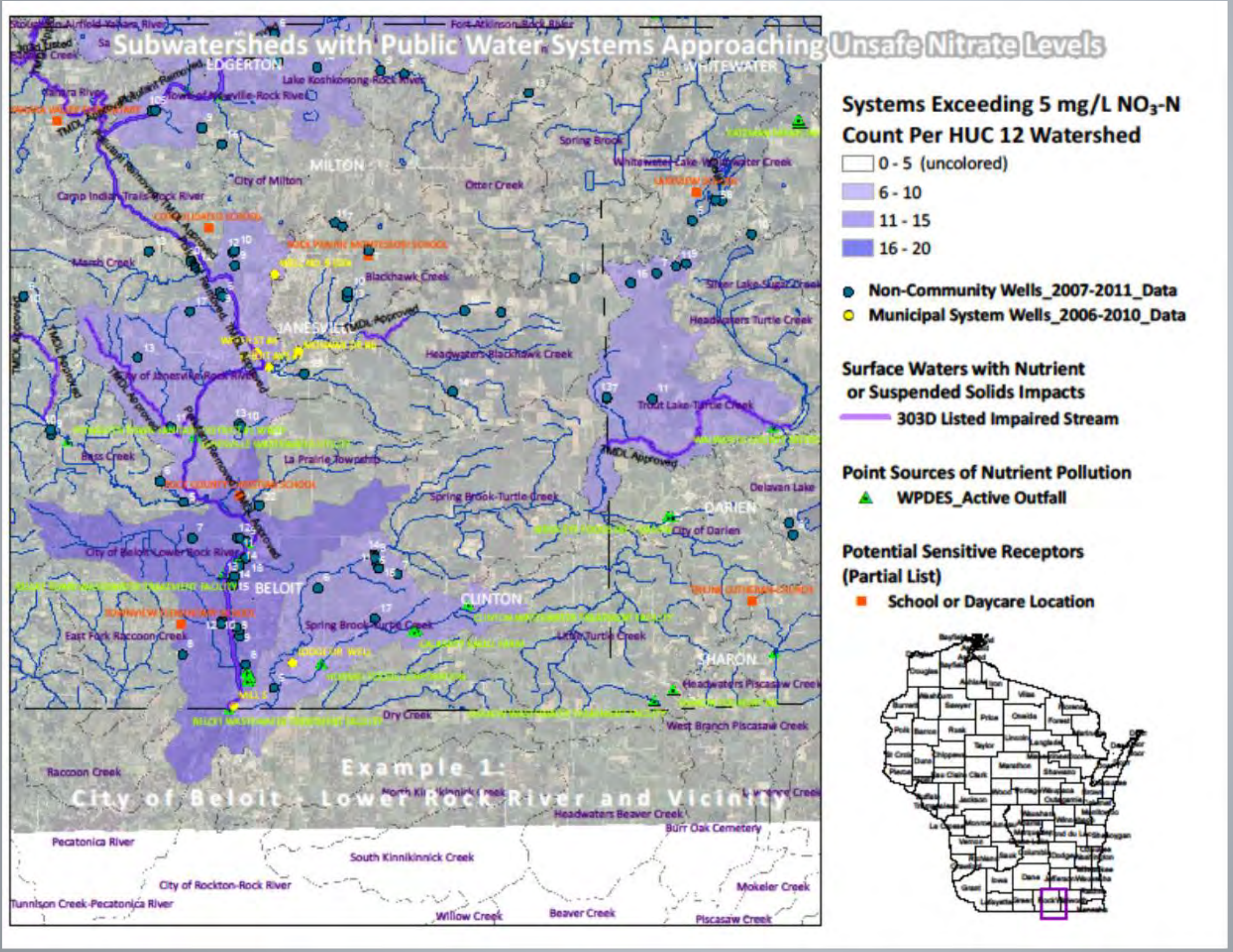
Wisconsin uses Groundwater



NITRATE IN WISCONSIN GROUNDWATER



Wisconsin Nitrate Project



Costs of compliance

- Municipal System Capital Outlays exceed $34M

System Name	***Population***	***Type of Treatment***	***Total Capital Cost***	***Cost per person***
Amherst	958	New well	$ 477,834	$ 499
Arlington, Village of	522	Possible new well	$ 650,000	$ 1,245
Cambria	785	Deepen well (2005)	$ 50,000	$ 64
Chippewa Falls	12925	New well, treatment	$ 2,540,761	$ 197
Clinton, Village of	1876	New Well	$ 575,970	$ 307
Crivitz Utilities	1,039	New Well	$ 377,000	$ 363
Dalton, Village of	300	Well reconstruction	$ 35,000	$ 117
Embarrass	399	None	$ 39,662	$ 99
Fitchburg	20501	Inactive well, will be abandone	$ 1,009,000	$ 49
Fontana	1852	New Well	$ 1,200,000	$ 648
Footville, Village of	788	Well Reconstruction	$ 133,597	$ 170
Friesland, Village of	298	None	$ -	$ -
Janesville Water Utility	59,498	Blending	$ 9,000,000	$ 151
Mattoon	387	New Well in 1997	$ 950,000	$ 2,455
Morrisonville	400	New Well	$ 279,000	$ 698
Oconomowoc	12382	New well	$ 416,197	$ 34
Orfordville	1272	New Well, New liner	$ 273,561	$ 215
Plover	10786		$ 4,000,000	$ 371
Rome	2656	New Well, Blending	$ 926,700	$ 349
Sauk City	3,109	New Well	$ 304,000	$ 98
Strum Waterworks	1100	Inactive well	$ -	$ -
Valders	948	Well Reconstruction	$ 34,000	$ 36
Waunakee	9536	Well Reconstruction	$ 69,694	$ 7
Waupaca	5,676	Blending	$ -	$ -
Whiting	1740	Anionic exchange, blending	$ 669,999	$ 385

Costs of Compliance

- Small System Treatment Cost Example:

Bonnet Prairie Lutheran Church – Point of Use Nitrate Treatment

Treatment type: Ion Exchange Unit

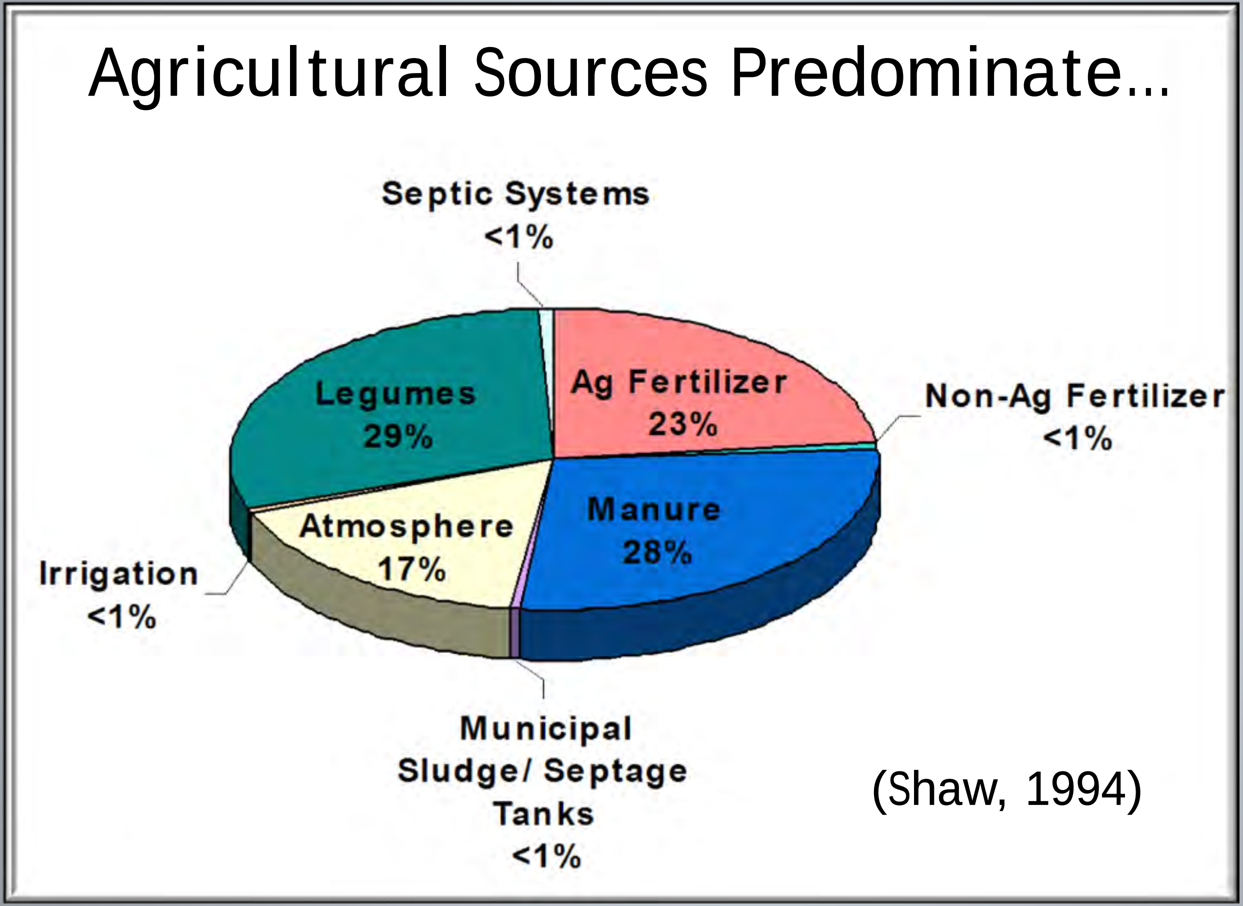
Installation cost: $400.
Rental of treatment unit: $620/yr
Salt: $300/yr
Sampling: $100/yr
1 year cost approximately: $1,100
5 year cost approximate $5,500
10 year cost approximately $11,000

Alternative:

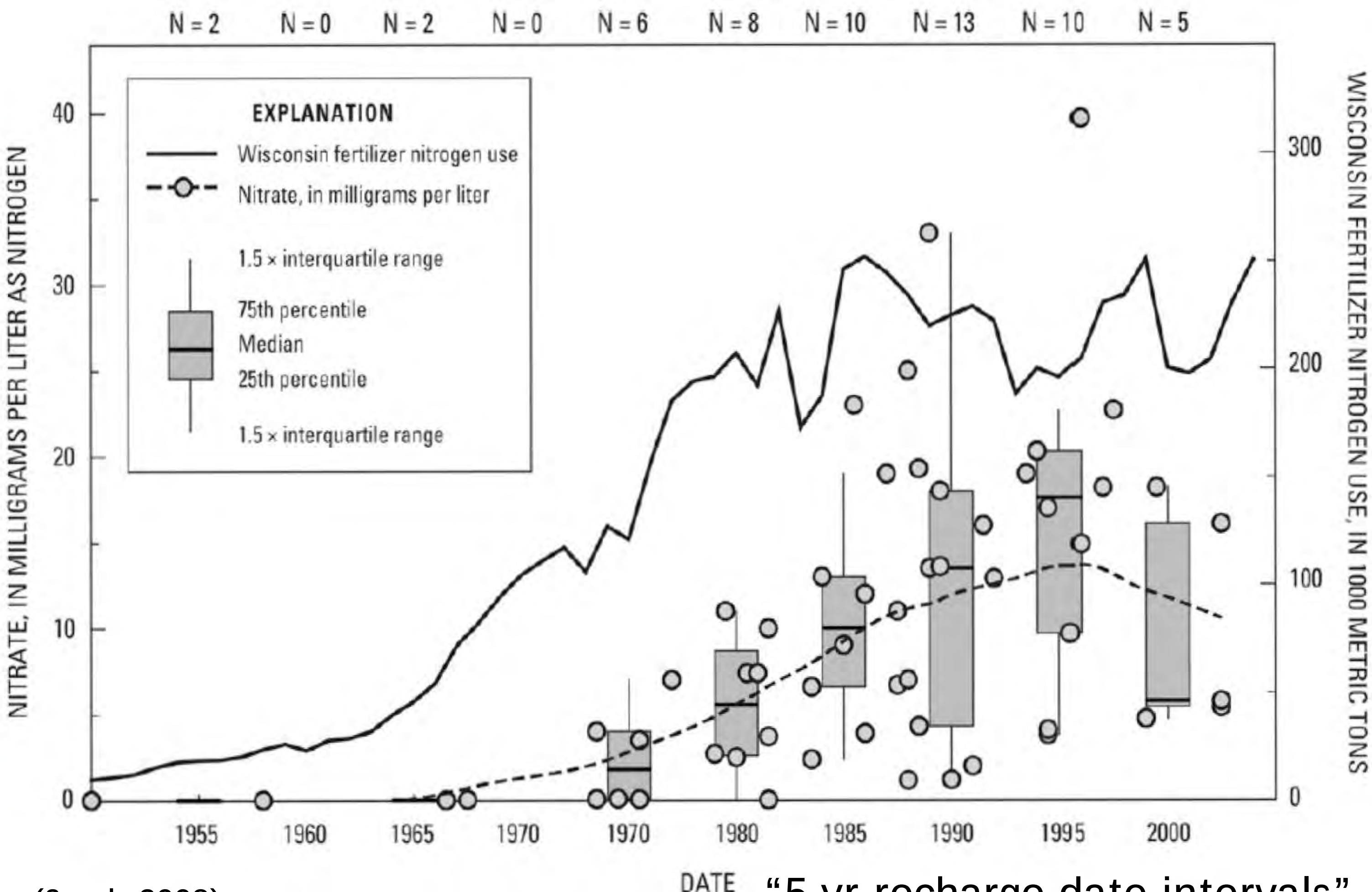
Replacement Well: Startup costs estimated at $11,000

Data Provided by Sandy Heimke

Sources of nitrate



Correlation with N Fertilizer Use



(Saad, 2008)

"5 yr recharge date intervals"

USGS Land Use Study (NAWQA)

Most N fertilizer goes to corn

- Approximately 66% of fertilizer used in wisconsin
- 50% or more of applied N can be lost to groundwater for sandy soils!
- For the example at the right, this loss rate might result in an average groundwater concentration under the field of 40 mg/L

Finding the Maximum Return To N and Most Profitable N Rate

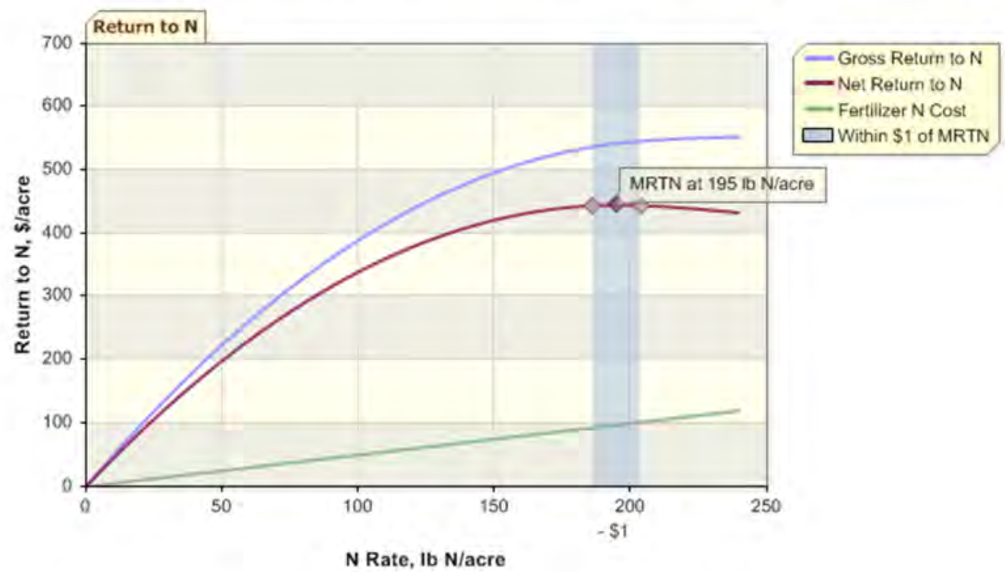
A Regional (Corn Belt) Approach to Nitrogen Rate Guidelines

State: Wisconsin – Irr. Sands
Number of sites: 4
Rotation: Corn Following Corn
Non-Responsive Sites Not Included

Nitrogen Price ($/lb): 0.50
Corn Price ($/bu): 5.00
Price Ratio: 0.10

MRTN Rate (lb N/acre):	**195**
Profitable N Rate Range (lb N/acre):	186 - 203
Net Return to N at MRTN Rate ($/acre):	$445.10
Percent of Maximum Yield at MRTN Rate:	99%
Anhydrous Ammonia (82% N) at MRTN Rate (lb product/acre):	238
Anhydrous Ammonia (82% N) Cost at MRTN Rate ($/acre):	$97.50

Most profitable N rate is at the maximum return to N (MRTN).
Profitable N rate range provides economic return within $1/acre of the MRTN.



RELIABILITY OF REDUCTION PRACTICES

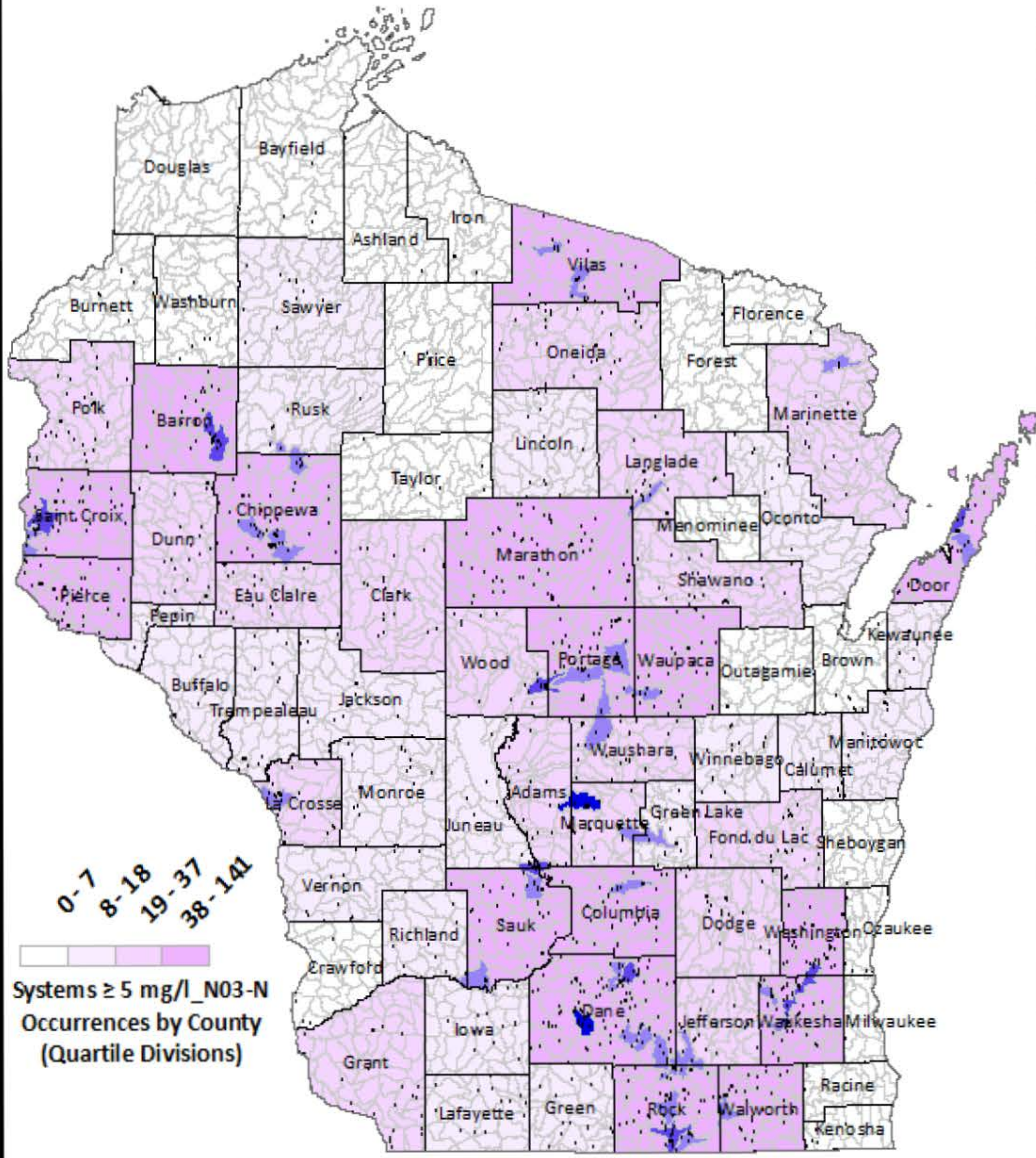
Table 2. Nitrogen reduction practices – potential impact on nitrate-N reduction and corn yield based on literature review.

	Practice	Comments	% Nitrate-N Reduction[+]	% Corn Yield Change++
			Average (SD*)	Average (SD*)
Nitrogen Management	Timing	Moving from Fall to Spring Pre-plant Application	6 (25)	4 (16)
		Spring pre-plant/sidedress 40-60 split Compared to Fall Applied	5 (28)	10 (7)
		Sidedress - Compared to Pre-plant Application	7 (37)	0 (3)
		Sidedress – Soil Test Based Compared to Pre-plant	4 (20)	13 (22)
	Source	Liquid Swine Manure Compared to Spring Applied Fertilizer	4 (11)	0 (13)
		Poultry Manure Compared to Spring Applied Fertilizer	-3 (20)	-2 (14)
	Nitrogen Application Rate	Reduce to Maximum Return to Nitrogen value 149 kg N/ha (133 lb N/ac) for CS and 213 kg N/ha (190 lb N/ac) for CC	10‡	-1‡‡
	Nitrification Inhibitor	Nitrapyrin – Fall - Compared to Fall-Applied without Nitrapyrin	9 (19)	6 (22)
	Cover Crops	Rye	31 (29)	-6 (7)
		Oat	28 (2)**	-5 (1)

Achieving Safe Drinking Water Nitrate Levels

Geographic Areas / Subwatershed Selection Process

Part 1 - Preliminary Pilot Study Area Candidate List

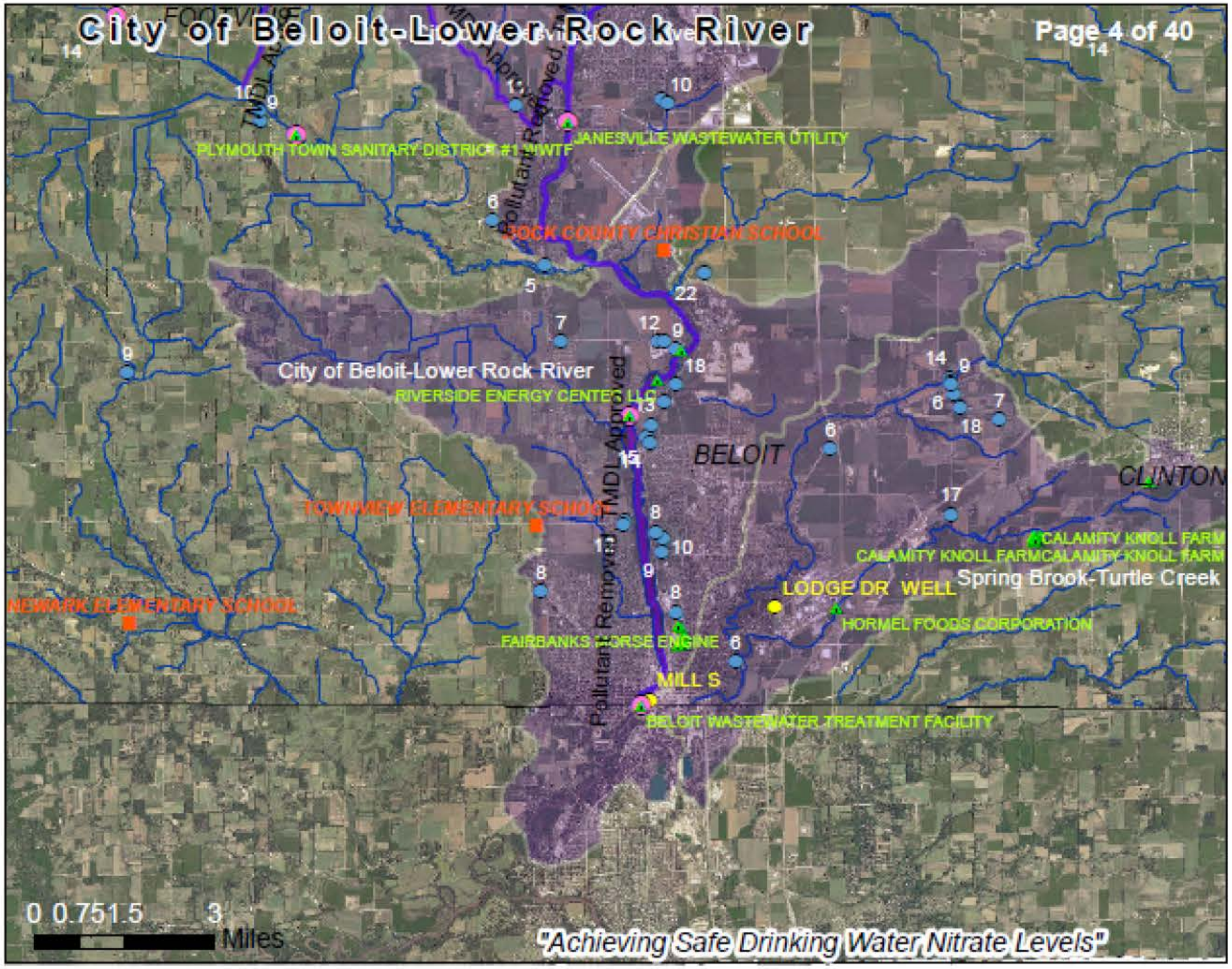


2007-2011 Public Water System Nitrate Data

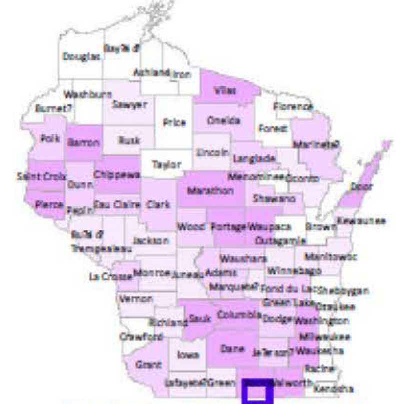
Non-Community Wells

Map	Syst > 5 per	Subwatershed Name	County	Acres
1	20 / 37_54%	Badger Mill Creek	Dane	21,661
2	19 / 63_30%	Westfield Creek	Adams-Marquette	31,250
3	17 / 62_27%	Hulburt Creek-Wisconsin River	Jun-Sauk-Adms-Colum	18,485
4	16 / 32_50%	City of Beloit-Lower Rock River	Rock	30,612
5	15 / 76_20%	Lake Chetek	Barron	38,607
6	15 / 89_17%	Headwaters Bark River	Washington_Waukesh	29,718
7	14 /100_14	Egg Harbor-Frontal Green Bay	Door	16,929
8	13 / 21_62%	Token Creek	Dane	16,032
9	13 / 35_37%	Bass Lake-Willow River	Saint Croix	32,887
10	13 / 61_21%	Nepco Lake	Wood-Portage	22,946
11	12 / 18_67%	South Fork of Paint Creek-Paint Cre	Chippewa-Eau Claire	24,829
12	10 / 17_59%	Lower Duncan Creek	Chippewa	22,417
13	10 / 23_43%	Town of Newville-Rock River	Rock	8,326
14	10 / 31_32%	City of Janesville-Rock River	Rock	26,038
15	9 / 10_90%	Saunders Creek	Dane-Rock	27,321
16	9 / 11_82%	Buena Vista Creek	Portage	34,423
17	9 / 17_53%	Spring Brook-Turtle Creek	Rock	18,429
18	9 / 17_53%	Lake Onalaska-Mississippi River	La Crosse	33,629
19	9 / 18_50%	Lake Wissota	Chippewa	15,014
20	9 / 19_47%	Lilly Bay Creek	Door	25,104
21	9 / 24_38%	Cruson Slough-Wisconsin River	Sauk-Richland-Iowa	34,359
22	9 / 28_32%	Scuppernong Creek	Waukesha	12,938
23	9 / 63_14%	Plum Creek-Big St. Germain Lake	Vilas	30,944
24	9 / 134_7%	Lake Delton-Dell Creek	Sauk	21,551
25	8 / 13_62%	City of Stoughton-Yahara River	Dane	16,037
26	8 / 15_53%	Bear Creek-Waupaca River	Portage	33,926
27	8 / 32_25%	Cherokee Lake-Yahara River	Dane	18,244
28	8 / 36_22%	Puckaway Lake-Fox River	Green Lake-Marquette	36,072
29	8 / 49_16%	Island Lake-Manitowish River	Vilas	14,820
30	8 / 52_15%	Crystal River	Waupaca - Portage	21,749
31	7 / 8 _88%	Swan Lake-Fox River	Columbia	20,852
32	7 / 12_58%	Trout Lake-Turtle Creek	Walworth-Rock	19,444
33	7 / 13 _54%	Elmwood Cemetary-Spring Brook	Langlade-Marathon	18,656
34	7 / 17_41%	Non-Contributing-Tenmile Creek	Waushara-Portage	54,565
35	7 / 19 _37%	South Branch Pemebonwon River	Marinette	22,484
36	7 / 20_35%	Trout Brook-Lake Saint Croix	St Croix-Pierce	33,404
37	7 / 28_25%	Lake Kegonsa-Yahara River	Dane	18,406
38	7 / 28_25%	Holcolmbe Flowage-Chippewa Rive	Chippewa - Rusk	31,294
39	7 / 32_22%	Lac La Belle-Oconomowoc River	Waukesha-Jefferson	12,015
40	7 / 32_22%	Lake Koshkonong-Rock River	Jefferson-Rock-Dane	39,524

Top 40 Subwatersheds
As Geographic Areas of Concern
Using PWS Nitrate as Ground Water Impact Indication
Criteria: 7 or more NN or TN systems per HUC12
With NO_3-N ≥ 5 mg/L
"Approaching Unsafe DW Levels"



Subwatershed Pilot Candidates



HUC12 Code:070900021502

Groundwater Impacts

Public Water Systems
Reporting Nitrate Levels >=5 mg/L

- Non-Community Wells (2007-2011)
- Municipal System Wells (2006-2010)

Surface Water Impacts

Impaired Streams
- 303D Listed (for P or TSS)

Point Sources

- WPDES_Active Outfall
- Low P Limit System & Adaptive_Mgmt Eligible

Potential Sensitive Receptors (partial list)

- School or Daycare Location

Among Impacted Areas: Selection Criteria

Project Facilitating Factors - Existing Resources

Knowledge, Infrastructure, Tools, Partners -Examples:
- Previous studies & existing monitoring networks
- Existing GW flow models & well capture delineations
- Existing Non-Point Source BMP implementations
- Project Management capabilities unique to region
- Agricultural interests documenting nutrient efficient practices
- Large proportion of cultivated lands implementing NMPs

Hydrogeologic factors that may promote project utility:
- Most representative susceptible settings for State
- Less complexity / Well behaved / Easier to model pathways
- GW Velocity / Shallow Flow / Fewer High Cap Wells

Towards a Solution - Supporting Analysis and Tool Development: Needs and Objectives

Local & Regional Condition Assessment

Goal:Develop metrics for ambient GW NO_3
Goal:Robust techniques to quantify GW quality changes
Goal:Integrate disparate GW quality indicator data:
- Spatial/ temporally distributed and episodic well data sets
- Municipal wells treating or blending
- Costs for treatment / well replacement
- Per capita costs
- Populations exposed to elevated levels
- Surface water impacts from baseflow N concentrations
- Well depth progression

Predicting GW Concentrations and Costs

Goal: Create tools to manage and reduce N impacts
Goal: Adaptable to changing crop and land use patterns
Goal: Develop comprehensive economic decision tools
Supporting Data and Analysis:
- Nutrient loading data (Organic / Chemical / Land Spread)
- Spatial and temporal distribution of N loading
- Water inputs (e.g. regional precipitation data, irrigation)
- Percolation and Nitrate Leaching Index tool development
- Quantify influence of soils, surficial deposits and bedrock
- Agronomic productivity, profitability and efficiency index
- Critical GW NO_3 factors for wisconsin (regression model)
- Define programmatic efforts required to sustain progress

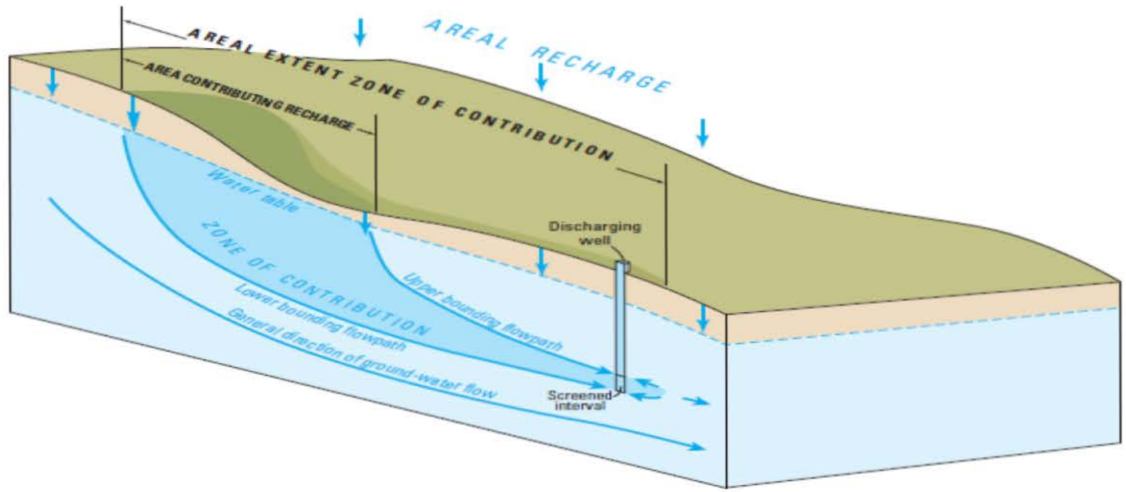
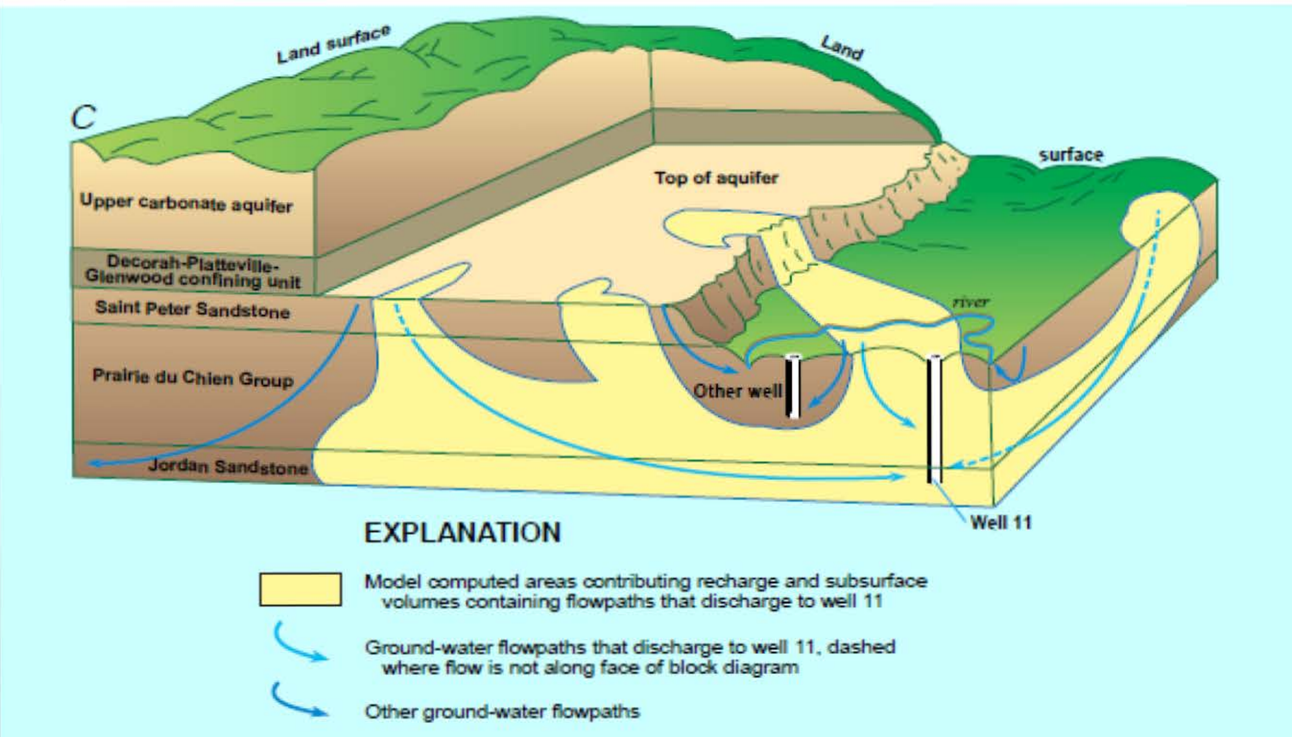
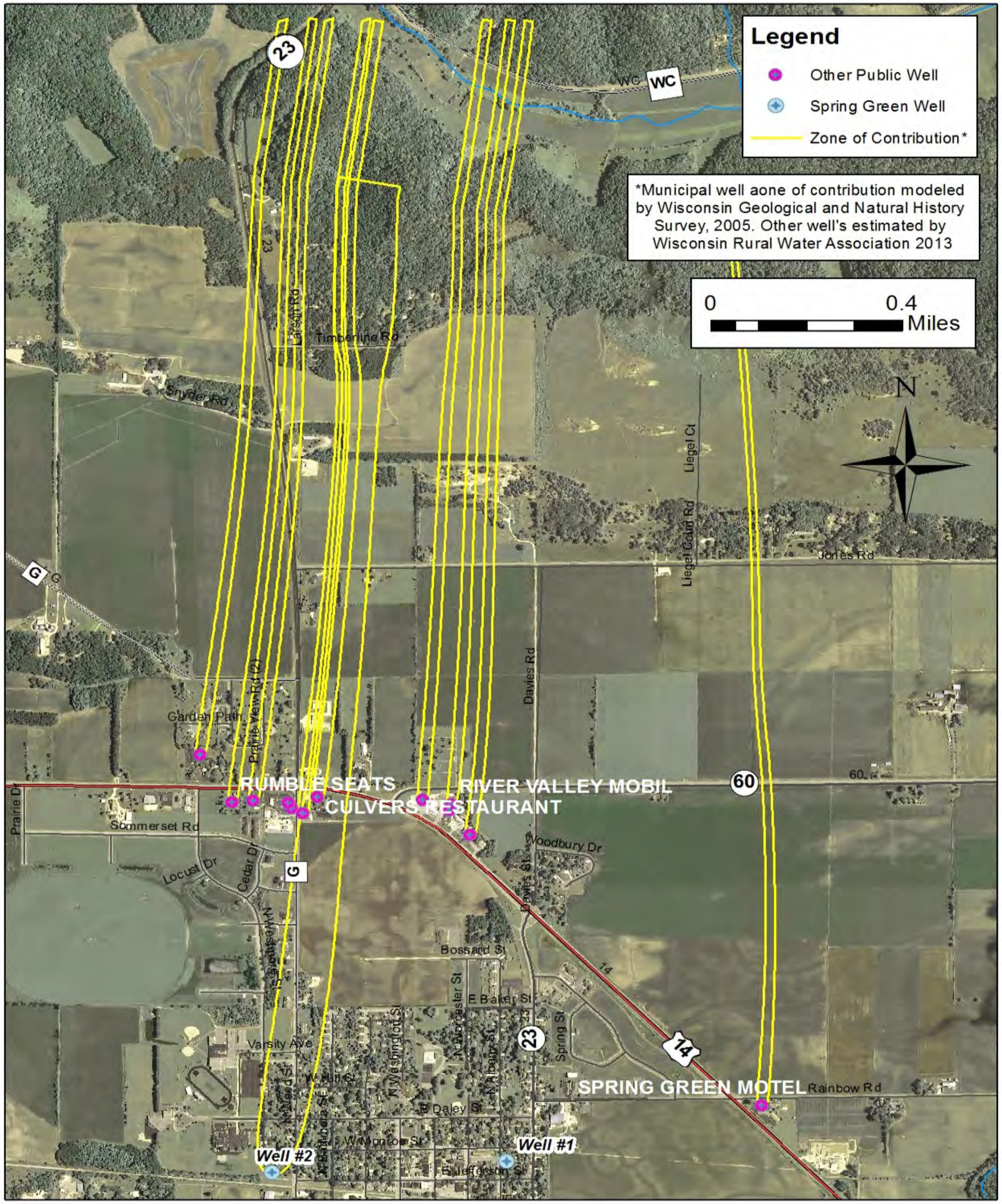


Figure 1.3. Area contributing recharge and zone of contribution for a single discharging well in a simplified hypothetical ground-water system.



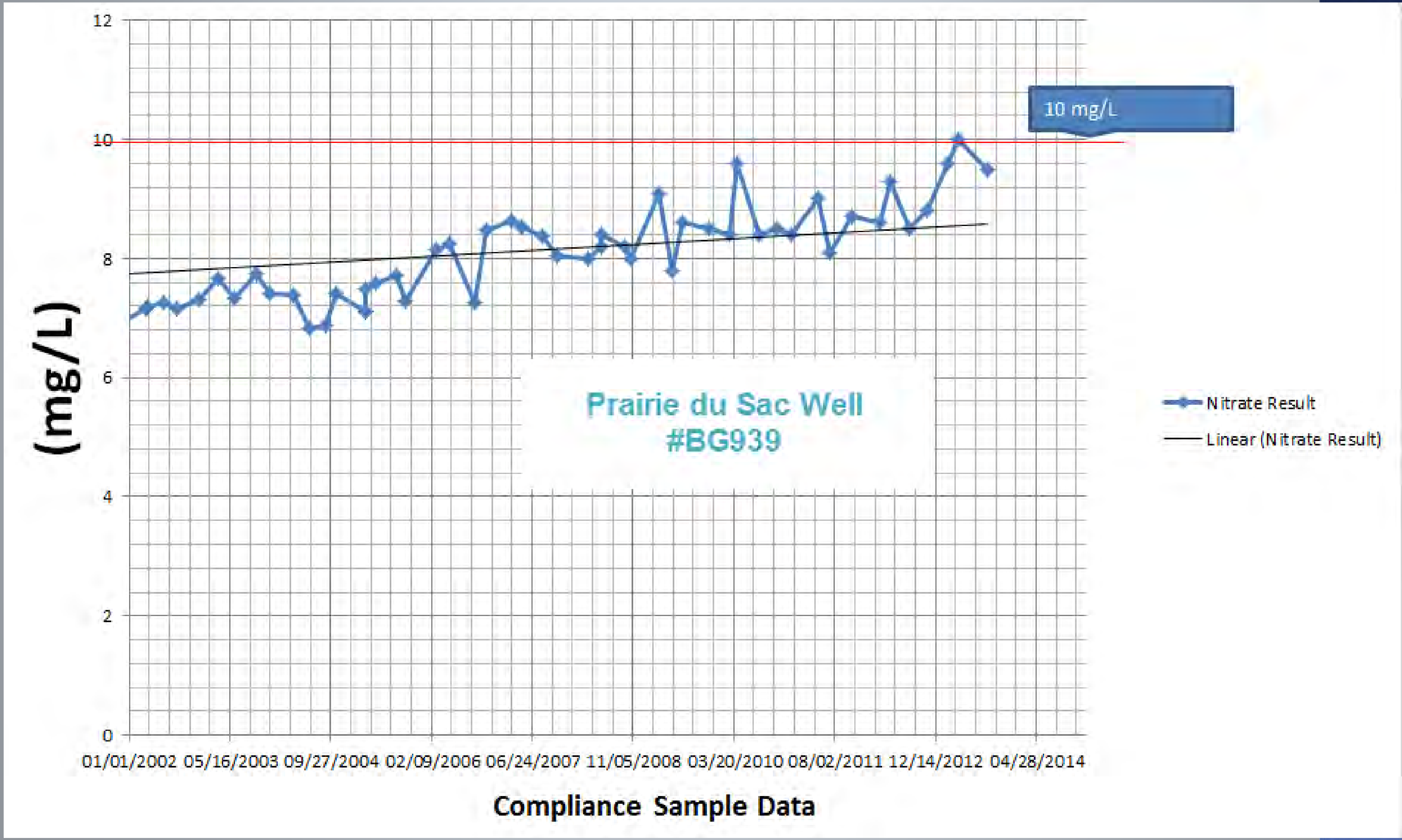
Wisconsin Nitrate Project



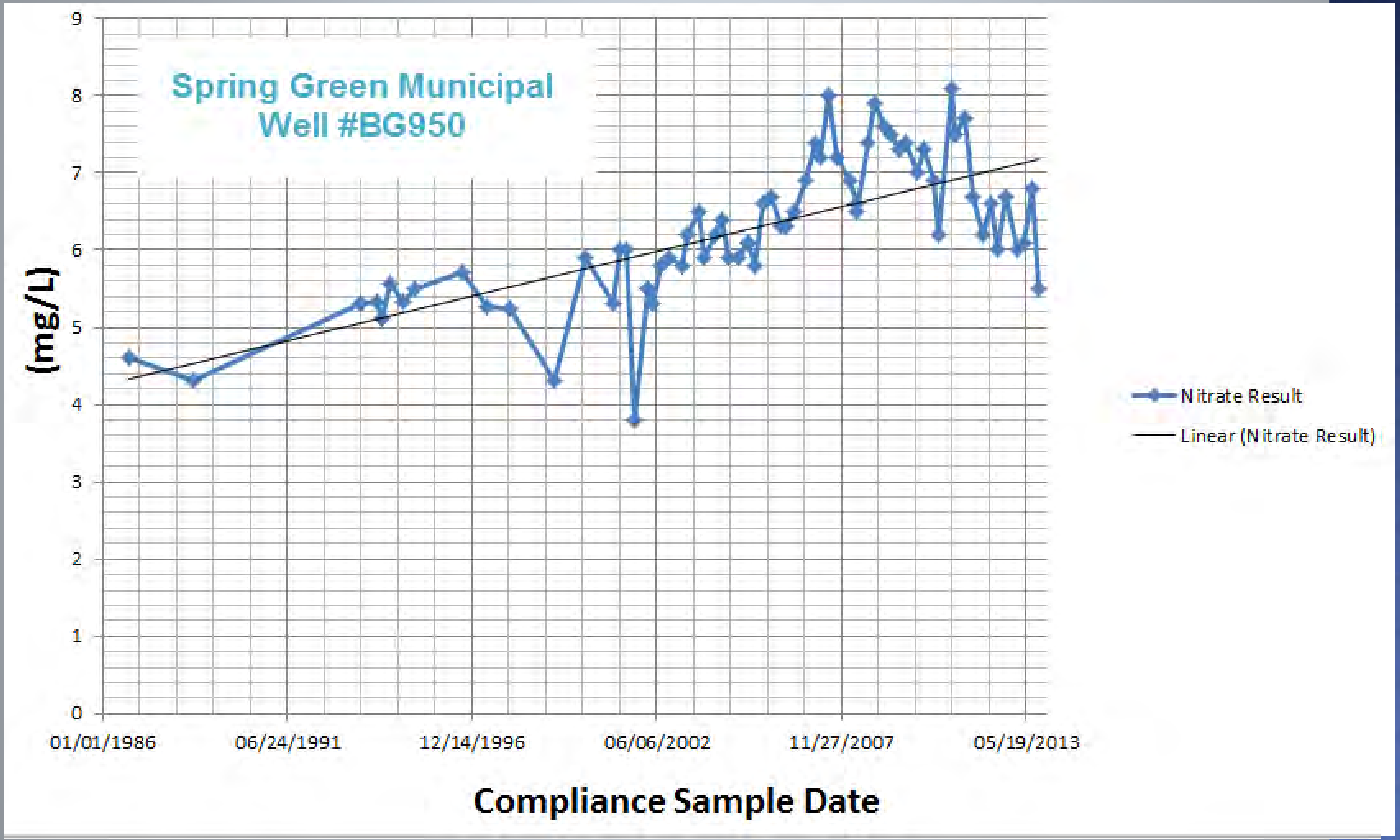
Phase 1

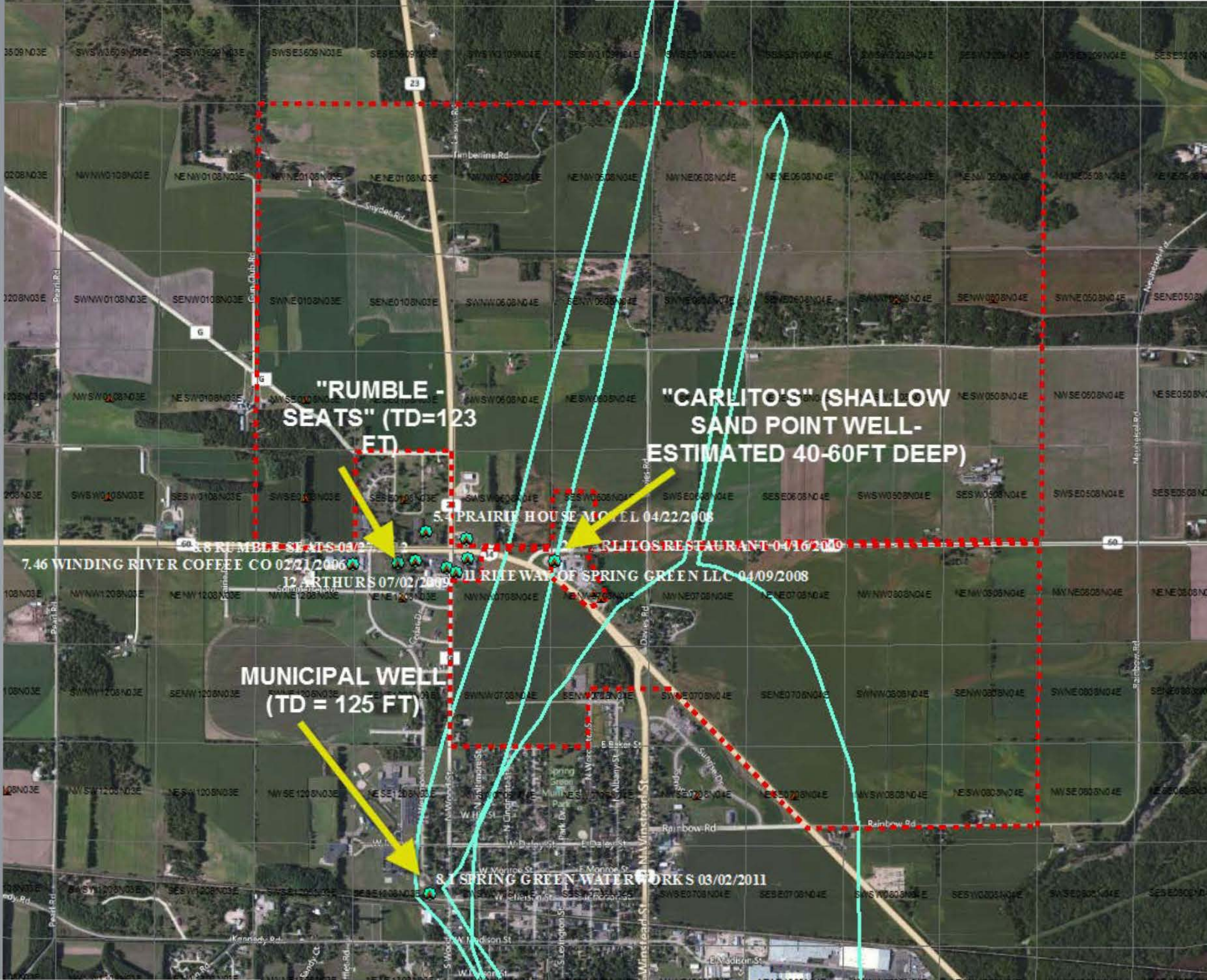
- ❖ Statewide assessment for need and likely success
- ❖ Select site with volunteer landowners & wellhead contributing area
- ❖ Lay out demonstration and control fields in relation to groundwater flow
- ❖ Design & test methods to measure nutrient loading to groundwater
- ❖ Estimate & measure nitrate loading from current practices
- ❖ Document agricultural input costs and crop yields
- ❖ Set efficiency & groundwater quality goals for the demonstration fields
- ❖ Design practices to achieve nitrogen efficiency goal

TRENDING MUNICIPAL WELLS

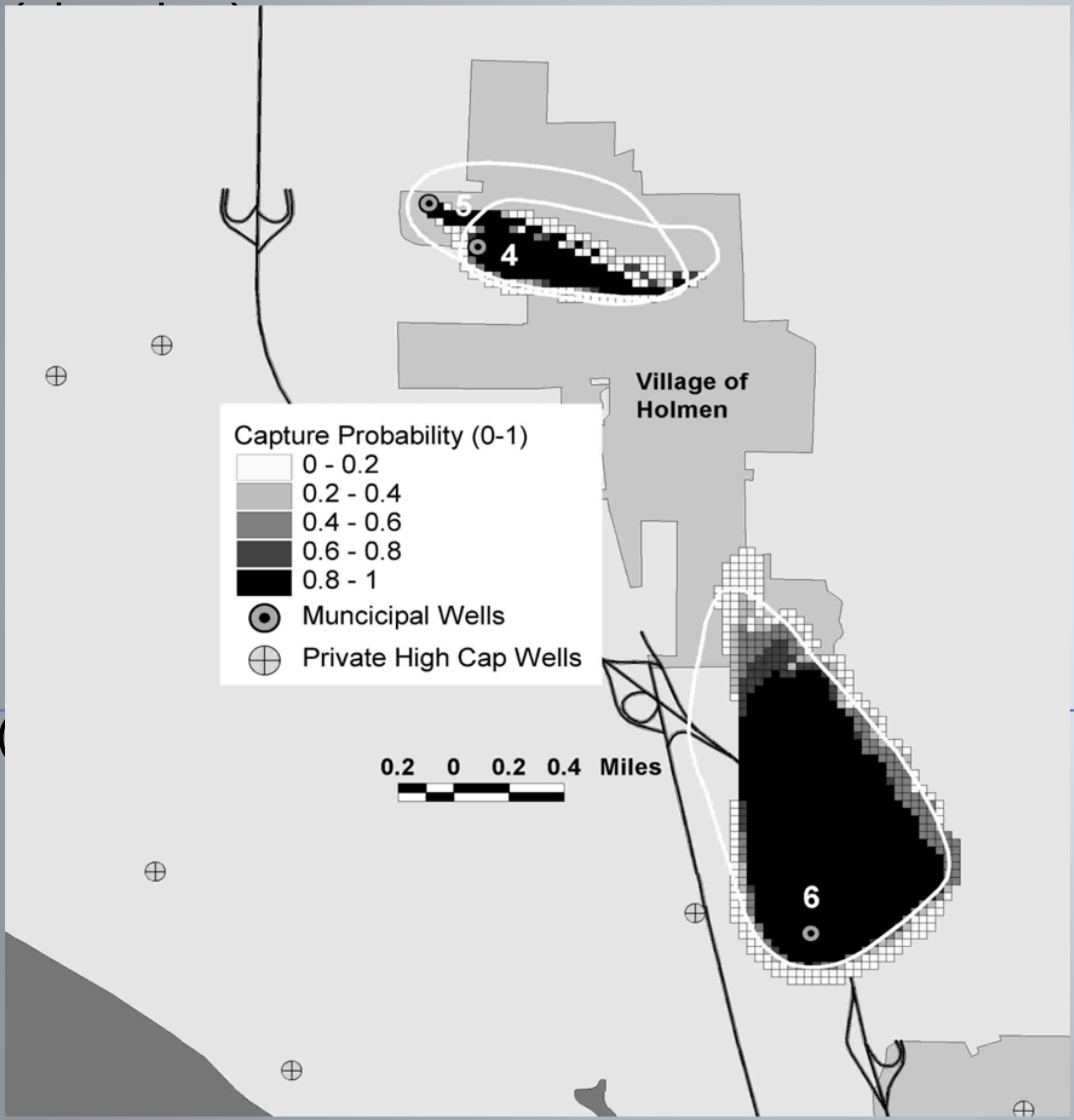


TRENDING MUNICIPAL WELLS



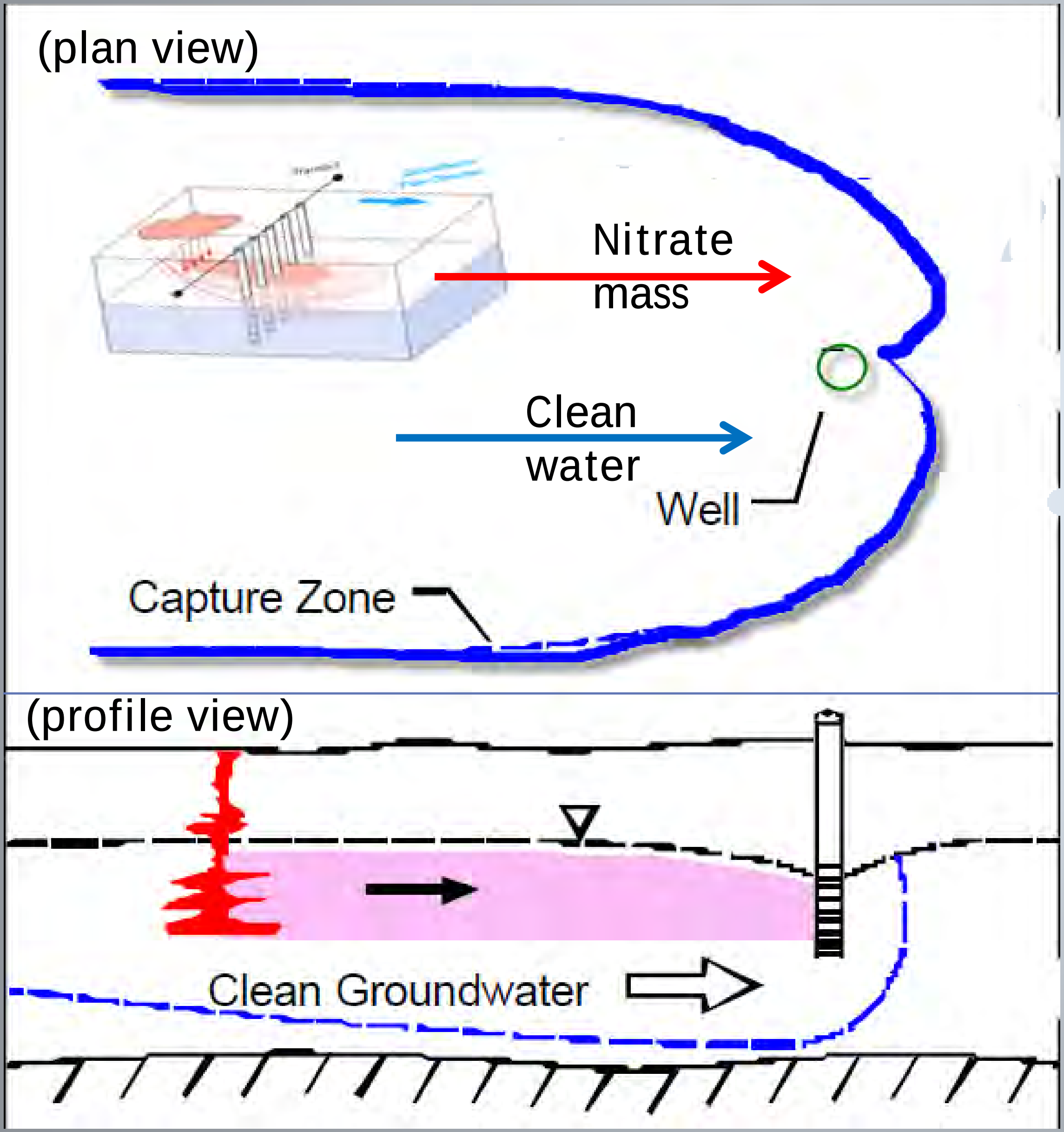

"RUMBLE - SEATS" (TD=123 FT)
"CARLITO'S" (SHALLOW SAND POINT WELL- ESTIMATED 40-60FT DEEP)
MUNICIPAL WELL (TD = 125 FT)
5.4 PRAIRIE HOUSE MOTEL 04/22/2008
7.46 WINDING RIVER COFFEE CO 02/21/2006
12 ARTHURS 07/02/2009
8.1 SPRING GREEN WATERWORKS 03/02/2011
Timberline Rd
Snyder Rd
Rainbow Rd

Calculating the N Loss Goals



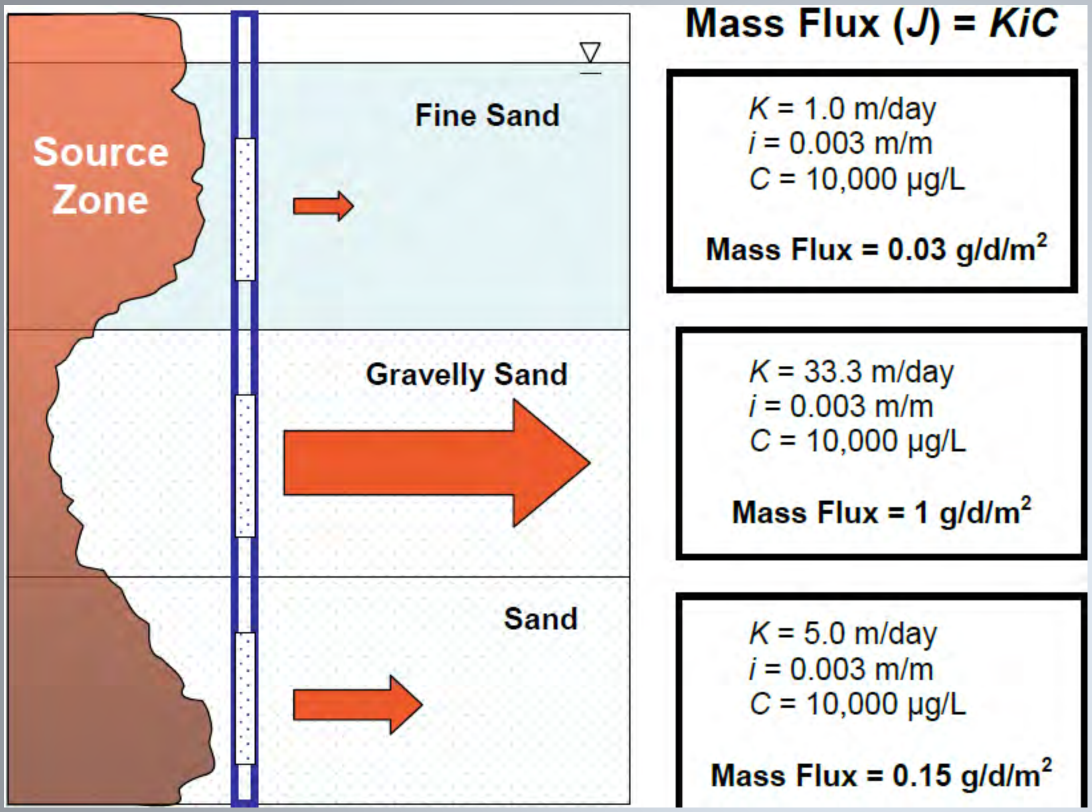
- First step is to determine areas contributing recharge to wells of concern.

Calculating the N Loss Goals



- Measure or estimate sources of nitrate, especially "recently recharged water"
- Determine expected water quality at well, accounting for dilution with clean water: Concentration at well = Total Mass of Nitrate / Pumping Rate
- Work out equitable reductions for the distribution of nitrate sources within wellhead protection area

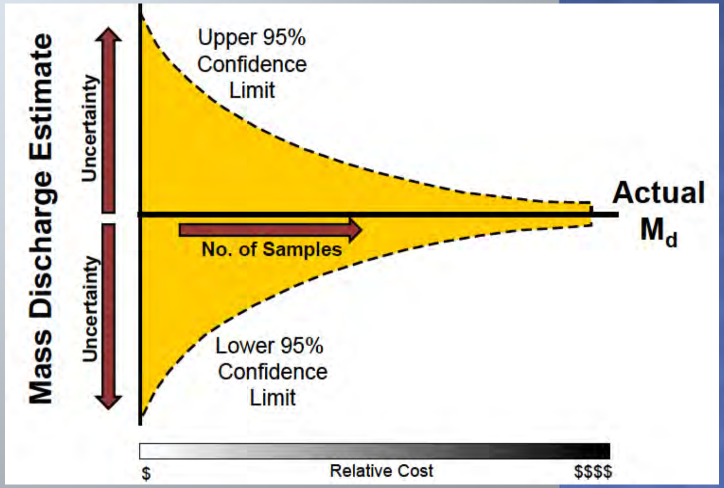
Monitoring Considerations



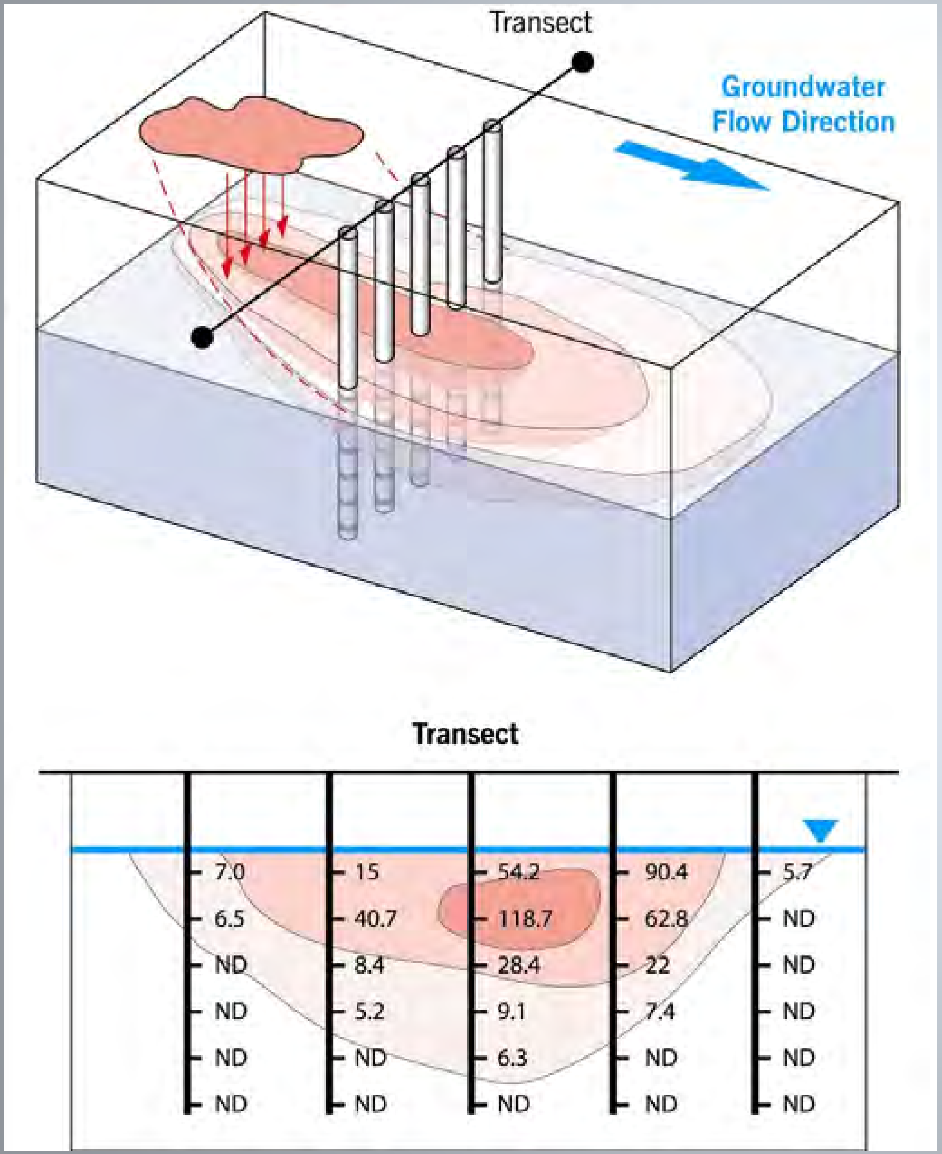
- Most of the mass (Md) is transported through conductive layers

- Must address heterogeneity

- Tradeoff between accuracy and cost



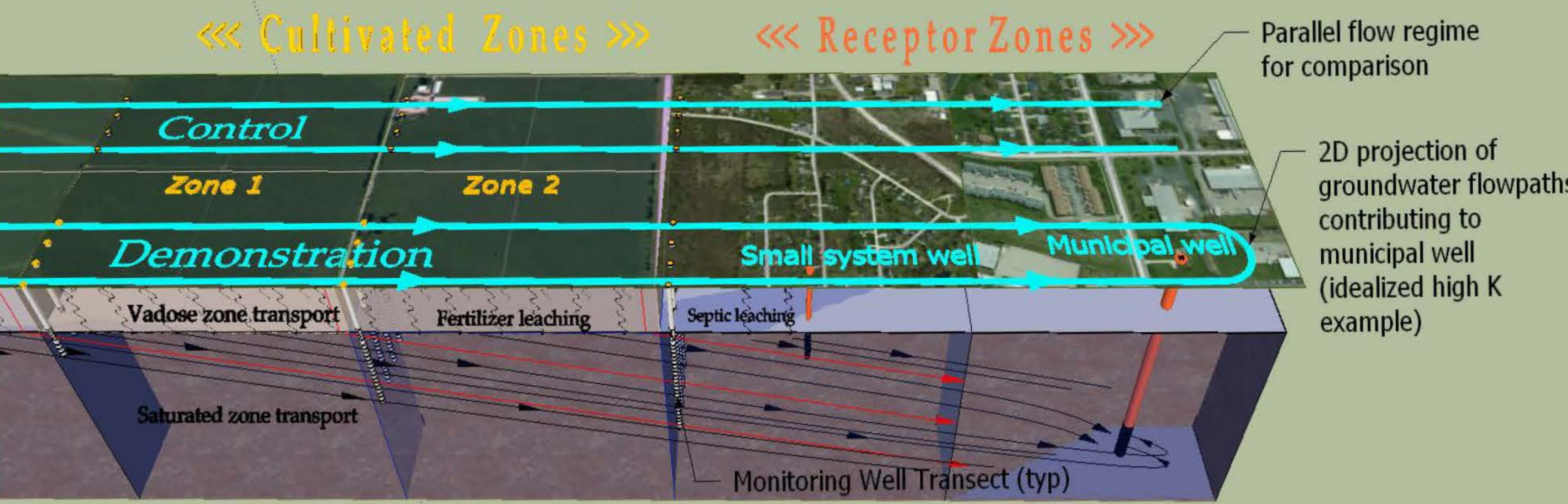
MONITORING CONSIDERATIONS

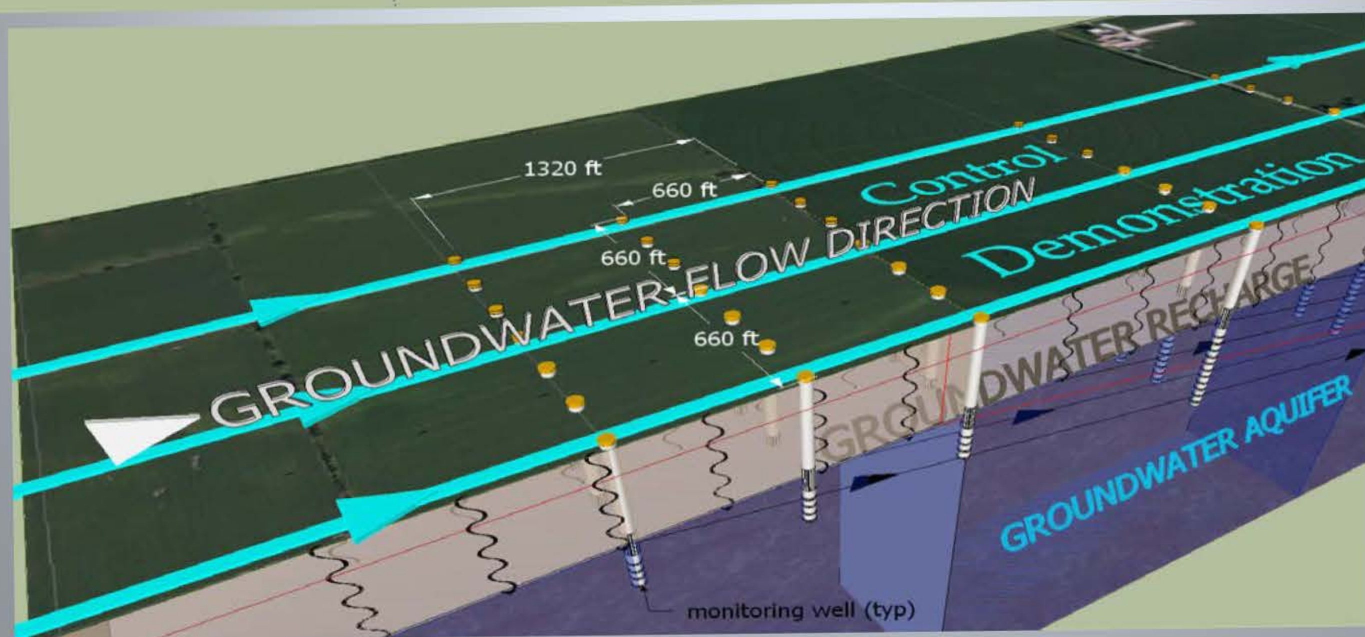


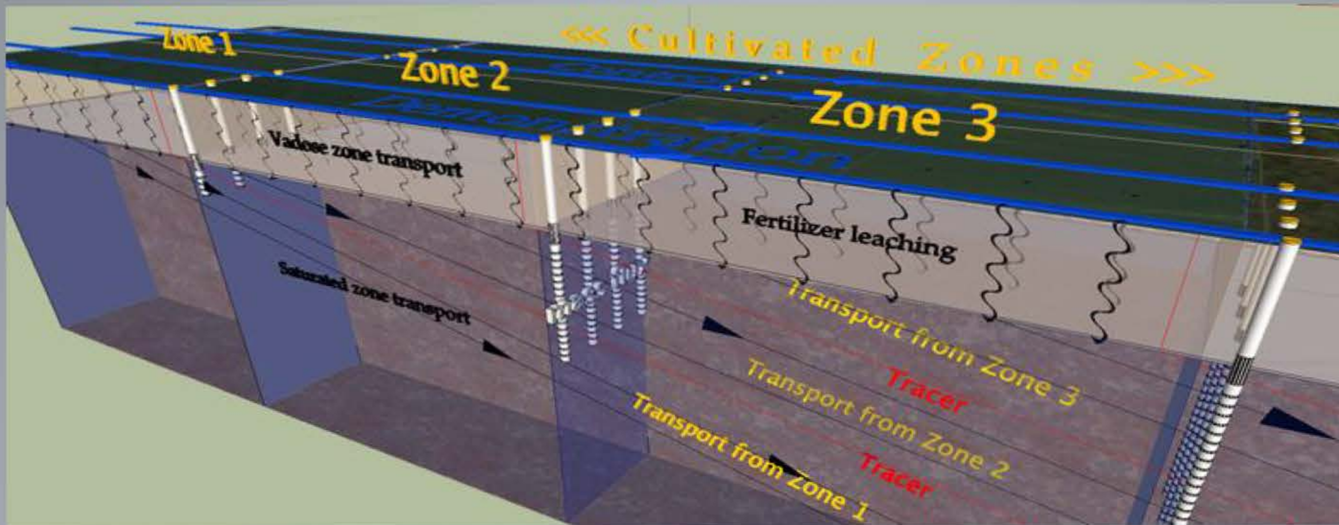
- Adapted from remediation industry

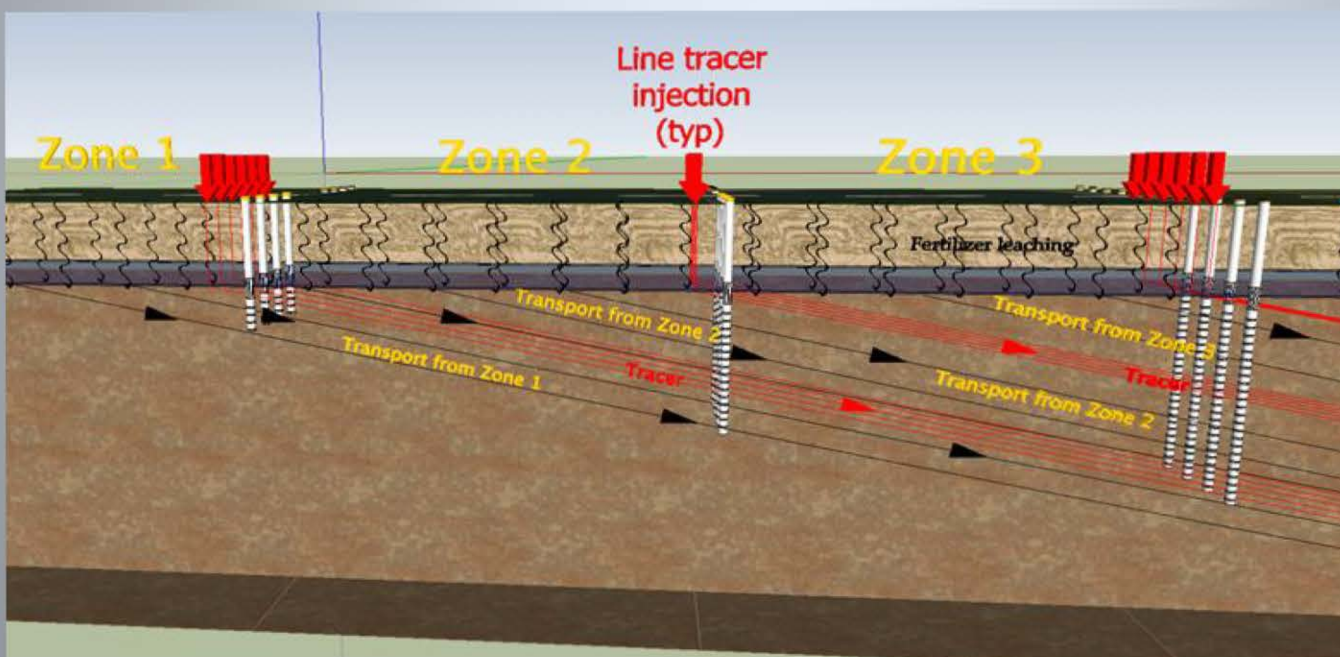
- Transect represents a "control plane"

- Mass flux is summed to calculate mass discharge at the control plane (edge-of-field)

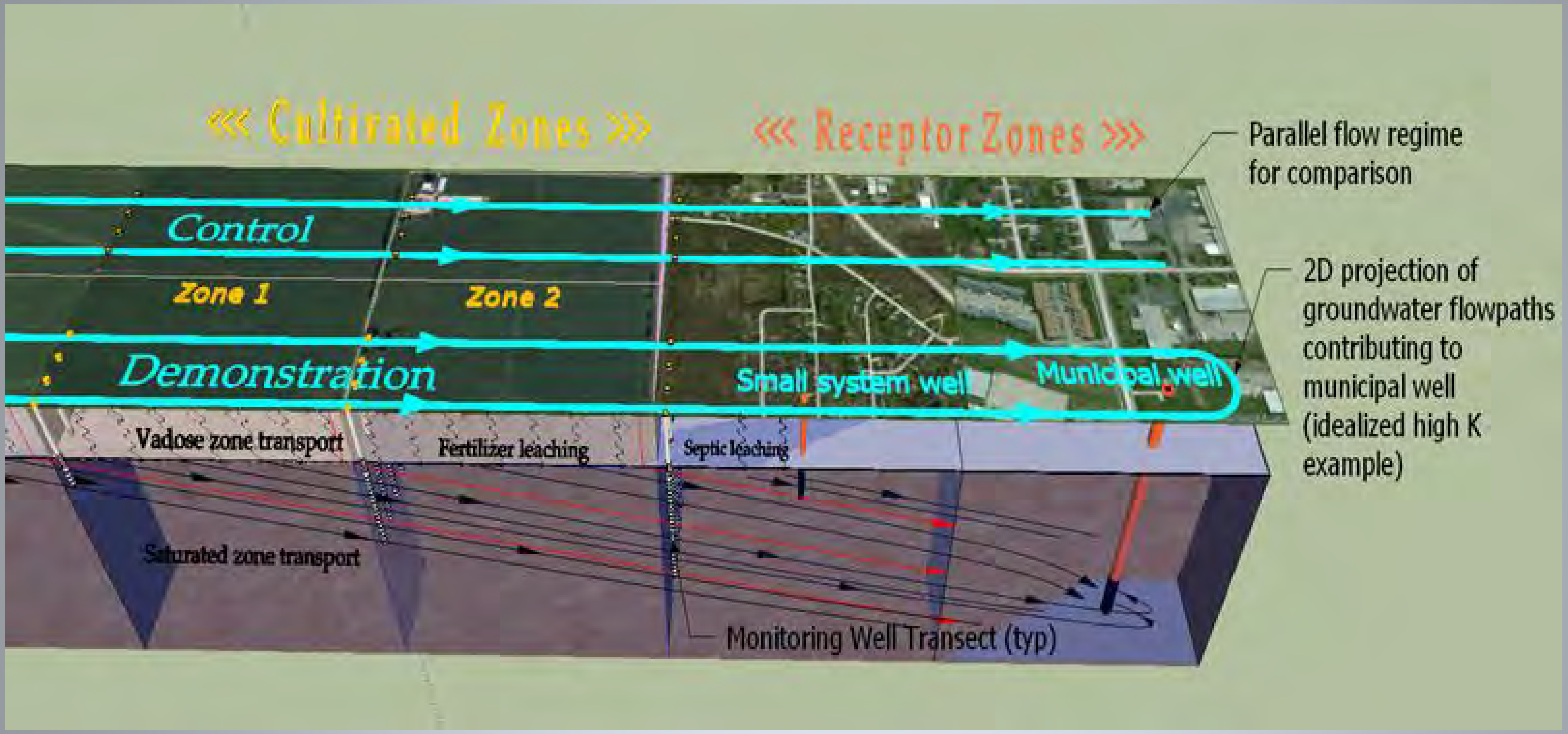

«« Cultivated Zones »»
«« Receptor Zones »»
Parallel flow regime for comparison
2D projection of groundwater flowpaths contributing to municipal well (idealized high K example)
Control
Zone 1
Zone 2
Demonstration
Small system well
Municipal well
Vadose zone transport
Fertilizer leaching
Septic leaching
Saturated zone transport
Monitoring Well Transect (typ)


1320 ft
660 ft
660 ft
660 ft
Control
Demonstration
GROUNDWATER FLOW DIRECTION
GROUNDWATER RECHARGE
GROUNDWATER AQUIFER
monitoring well (typ)

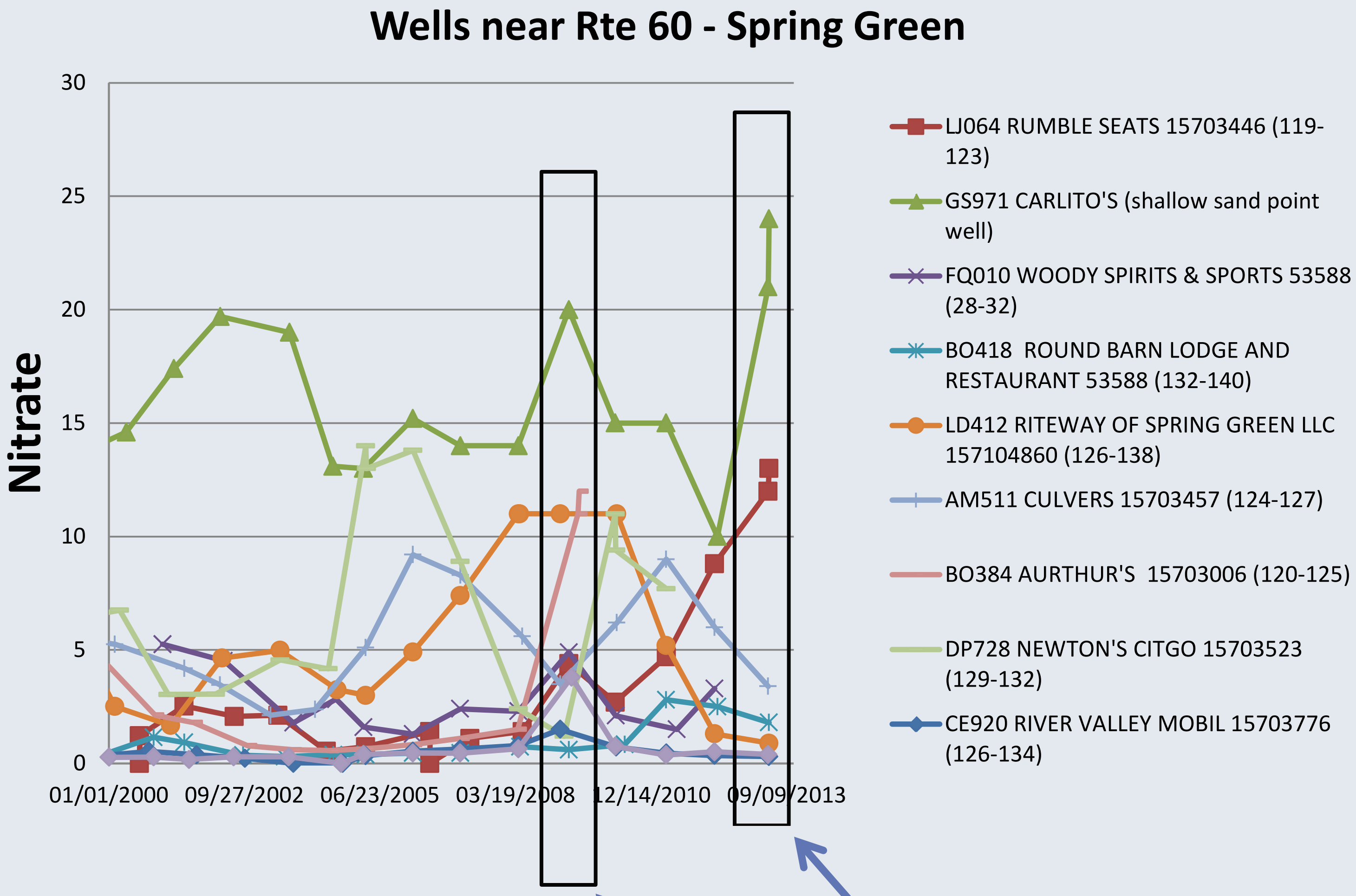

Zone 1
<<< Cultivated Zones >>>
Zone 2
Zone 3
Vadose zone transport
Fertilizer leaching
Saturated zone transport
Transport from Zone 3
Tracer
Transport from Zone 2
Tracer
Transport from Zone 1


Line tracer
injection
(typ)
Zone 1
Zone 2
Zone 3
Fertilizer leaching
Transport from Zone 2
Transport from Zone 3
Transport from Zone 1
Tracer
Tracer
Transport from Zone 2

Pilot Project Steps

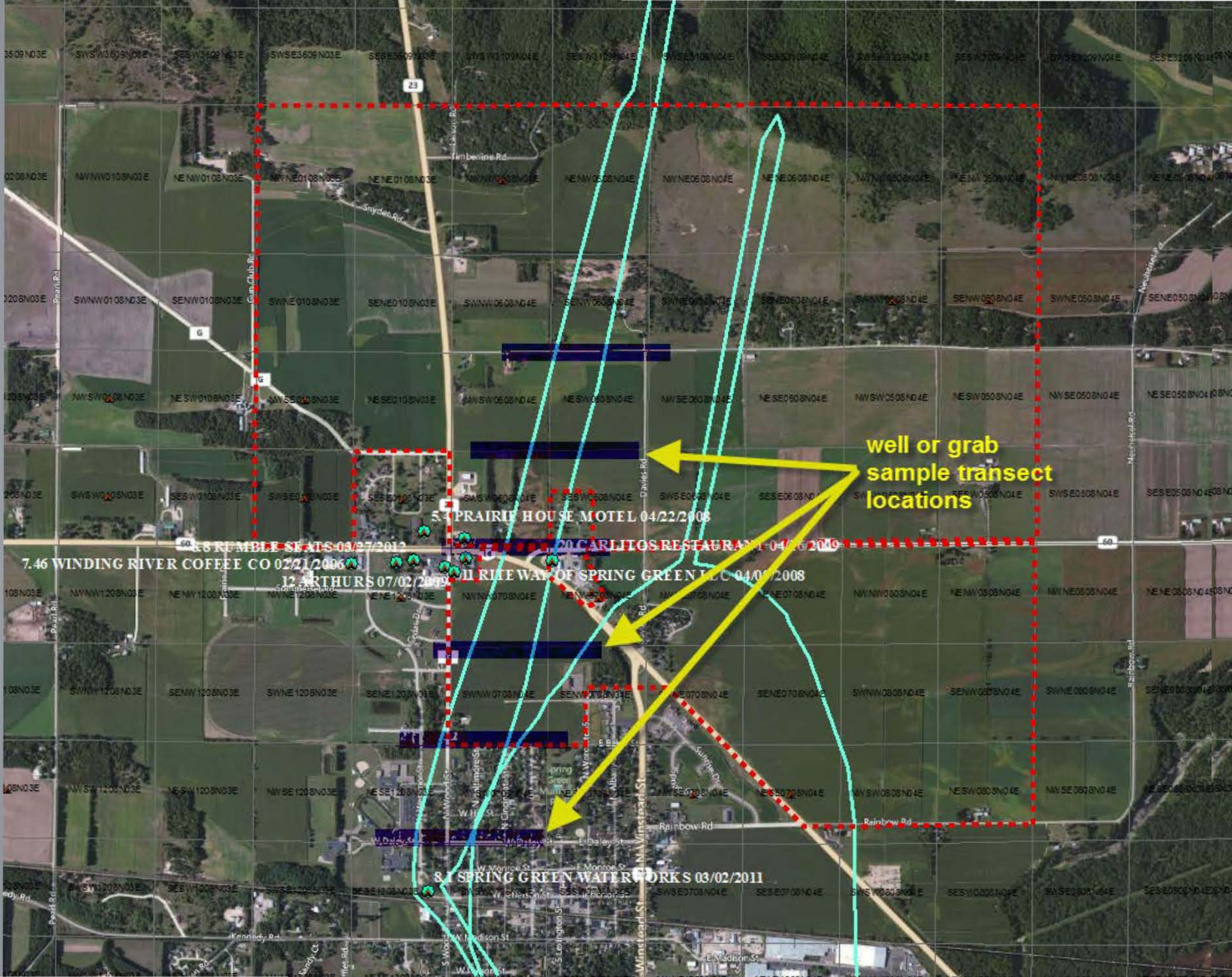


1) Develop N loss goal to meet SDWA standard at specific public wells
2) Design nutrient management system to achieve N loss
3) Measure actual groundwater, crop yield, and cost effects
4) Adapt as needed to achieve groundwater, crop yield and cost goals
5) Make the method practical for use at unmonitored sites

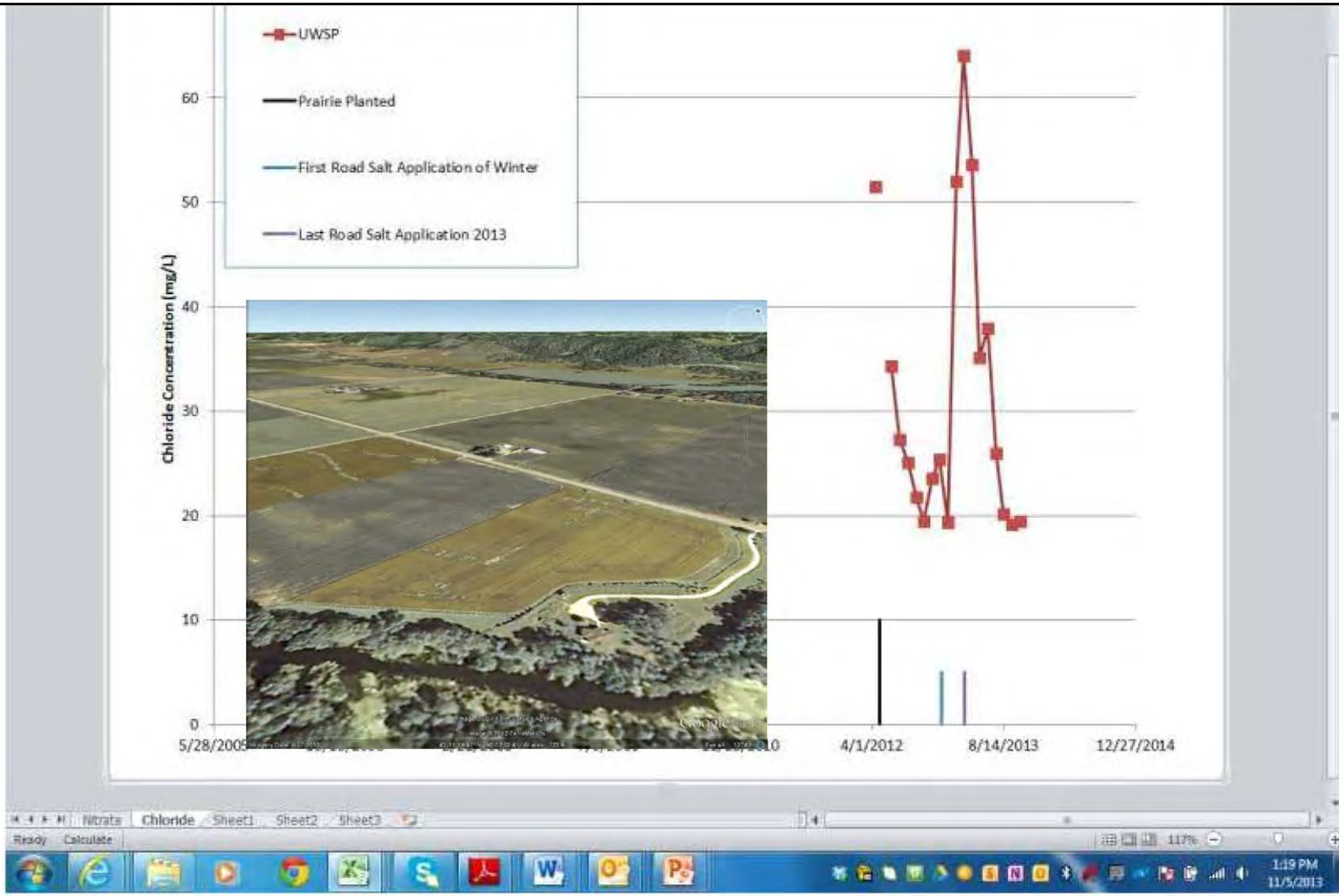


6 of 9 systems exhibit peak (Feb – June 2009)

2 of 6 systems exhibit peak (April – May 2013)


well or grab
sample transect
locations
5.4 PRAIRIE HOUSE MOTEL 04/22/2008
7.46 WINDING RIVER COFFEE CO 02/21/2006
12 ARTHURS 07/02/2009
8.1 SPRING GREEN WATERWORKS 03/02/2011
Rainbow Rd
Snyder Rd
Timberline Rd
23
60
G

Chloride example – serving as a fortuitous groundwater tracer

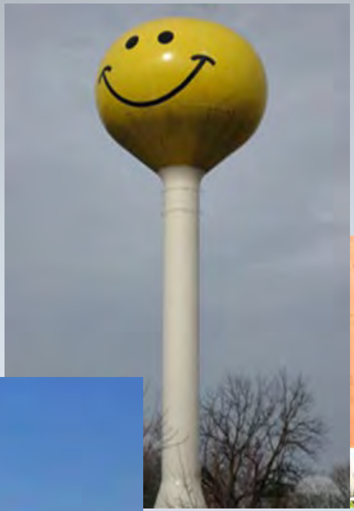


(Masarik –UW-SP)

Phase 2

- Implement crop and nitrogen management systems designed to meet nitrate goal
- Monitor nitrate in groundwater
- Document agricultural input costs and yield
- Document cost of drinking water supply compliance alternatives
- Make groundwater modeling, practice design & economic analysis tools practical & accessible
- Adapt crop and nitrogen management systems

BARRIERS
&
BRIGHT SPOTS



THANKS TO OUR COLLABORATORS

Sauk & Rock Counties

U.S. Environmental Protection Agency Region V

U.S. Geological Survey

Source Water Collaborative

Wisconsin Rural Water Association

Natural Resources Conservation Service

Wisconsin Water Association

Wisconsin Land and Water Conservation Association

Wisconsin Geologic and Natural History Survey

Wisconsin Department of Agriculture, Trade & Consumer Protection

Wisconsin Department of Health Services

University of Wisconsin – Madison and Stevens Point

PLEASE JOIN US.

QUESTIONS?

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Bureau of Drinking Water & Groundwater

Wisconsin Department of Natural Resources