Nitrogen and Phosphorus Pollution Series: Nitrate in Ground Water

Watershed Academy Webcast

Tuesday, March 29, 2011

1:00–3:00 Eastern

Instructors:
Jill Jonas, Director, Bureau of Drinking Water and Groundwater, Wisconsin Department of Natural Resources
Audrey Eldridge, Coordinator for the Southern Willamette Valley Groundwater Management Area, Oregon Department of Environmental Quality
Neil Dubrovsky, PhD, Chief, Nutrients and Trace Elements National Synthesis Project, National Water Quality Assessment (NAWQA), U.S. Geological Survey

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Topics for Today's Webcast

- Nitrate in Drinking Water: Overview of the Issue
- Support and Progress for Implementing a Groundwater Protection Plan in Southern Willamette Valley in Oregon
- Nutrients in the Nation's Streams and Groundwater, 1992–2004

Nitrate in Drinking Water: Overview of the Issue

Jill Jonas

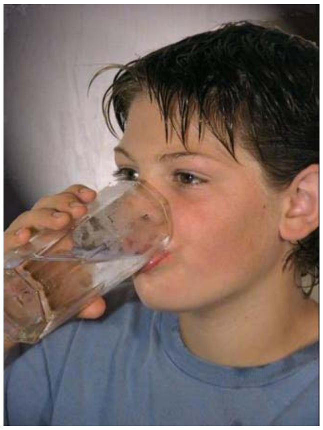
Director, Bureau of Drinking Water & Groundwater

Wisconsin Department of Natural Resources

President, Association of State Drinking Water Administrators

Nitrate in Drinking Water: Overview of the Issue

- What We Know
- What's Being Done
- Call to Action



What are the health risks?

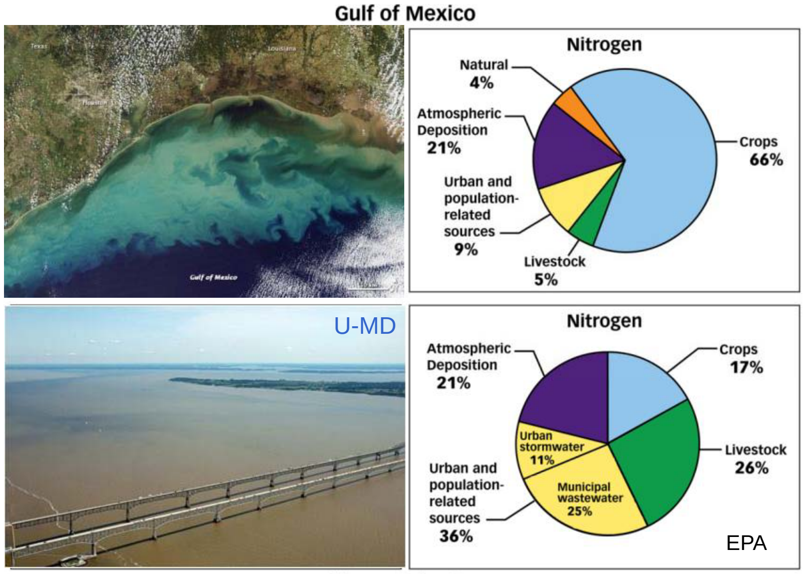
- Blue baby syndrome (metheglobinemia), low frequency but fatal risk for infants (10mg/L)
- Chronic use linked to miscarriages, lymphoma, gastric cancer, hypertension, thyroid disorder
- Reduced livestock growth & reproduction; can be fatal
- Affects fish reproduction
- Co-contaminants are viruses, bacteria, toxins, pesticides

At what cost? Health care

- Total healthcare cost from water-borne causes are large & well documented – but rarely separated by root causes
- $539 million annual hospitalization cost for top three water-borne diseases in the U.S.
- Cryptosporidium cost Milwaukee, WI $96.2 million total; $64.6 million in lost productivity over 60 days

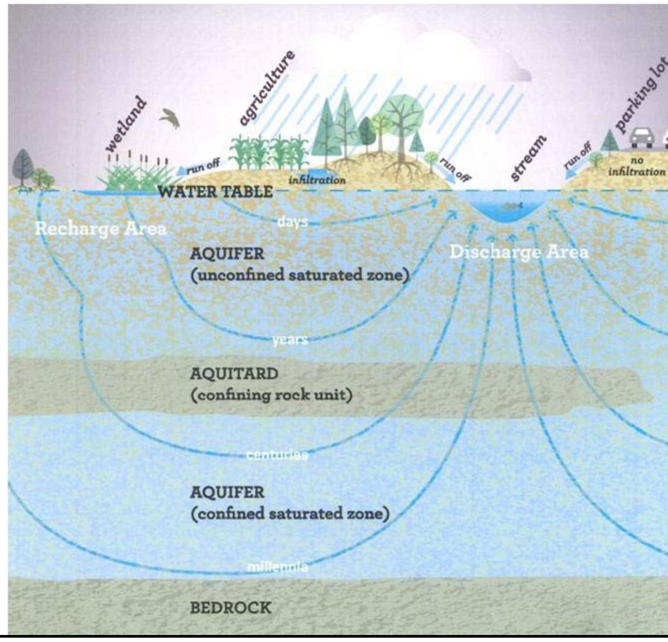
Surface Water Nitrogen Sources

Gulf of Mexico

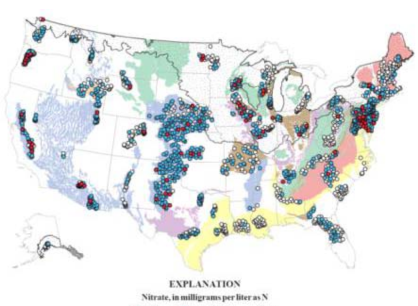


Chesapeake Bay

Groundwater contamination paths



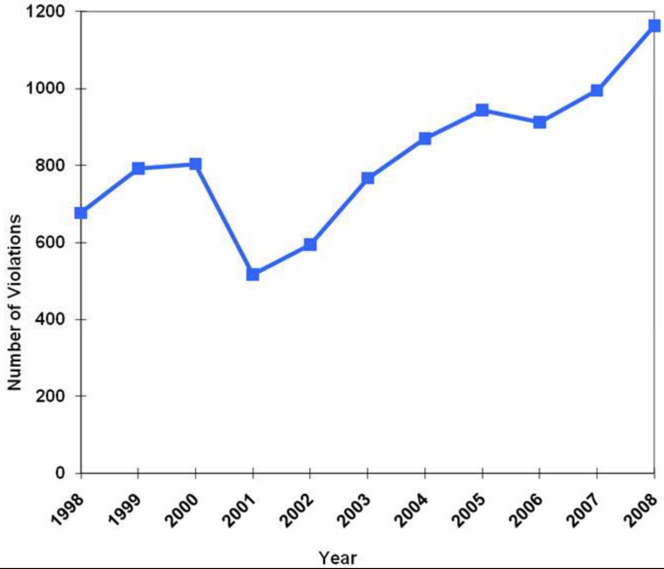
Drinking Water Impacts Nationwide



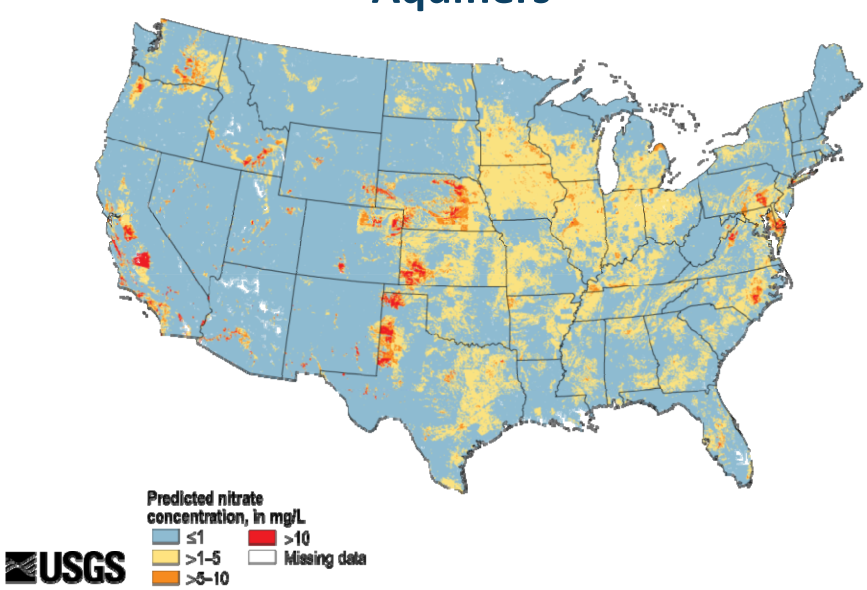
USGS

- Some shallow wells exceed 10 mg/L coast-to-coast
- Rate of nitrate violations in community water systems has doubled over past 7 years
- Algal toxins found in finished water
- Precursors for disinfection-by-products (DBPs) significant & costly

Increasing Nitrate Violations in U.S. Community Water Systems



Estimated Nitrate Concentrations in Major Aquifiers



Non-agricultural sources of nitrogen in groundwater

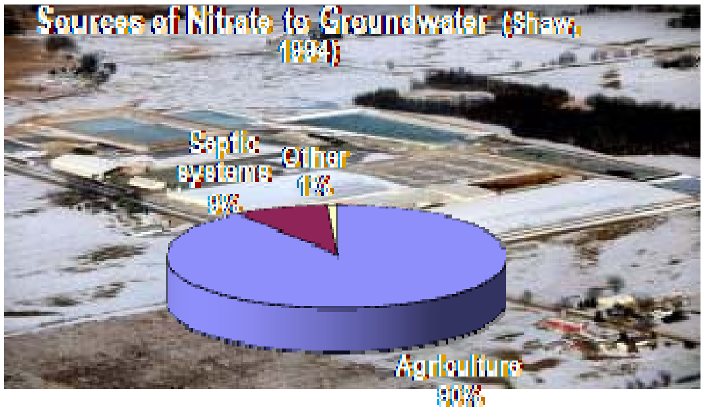
- Leakage from wastewater disposal network
- High density development using conventional on-site wastewater systems
- Turf grass fertilization
- Contaminated lands
- Select industrial sites
- Land clearing
- Waterway-aquifer interaction
- Improper stormwater management

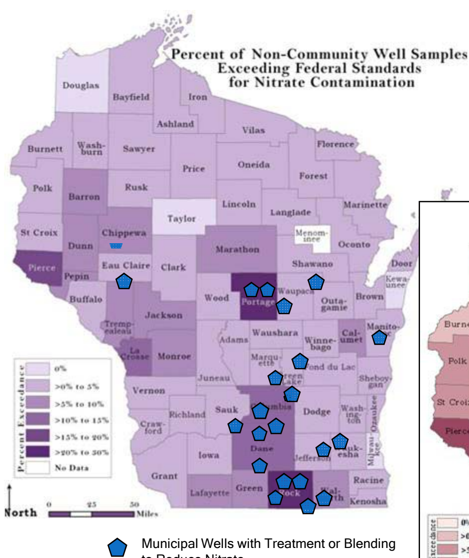
ASDWA Findings

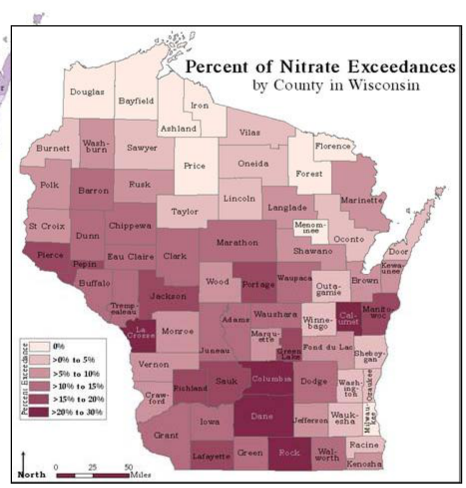
- Extensive data on nitrates in finished water; correlations to sources sometimes available
- Nitrate data for private wells exists in some locations
- Nitrate data for source water not routinely collected but available in many places
- Algal toxin data not routinely collected but some comprehensive studies done in some locations
- Some correlation data for pesticides, viruses and other pathogens
- Relatively little direct correlation data for nutrient-driven DBP precursors and DBPs
- Cost data to address impacts extensive in many places (especially for DWSRF program)

ASDWA
Association of State Drinking Water Administrators

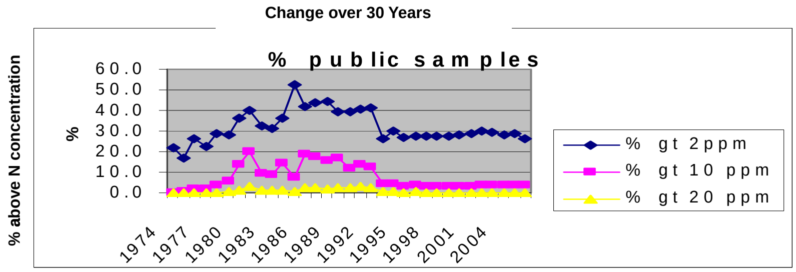
In Wisconsin







Nitrate levels in Wisconsin Public Water Supplies



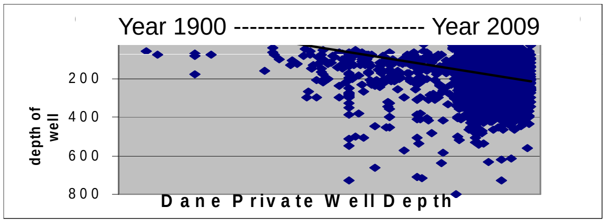
At what cost? Local governments

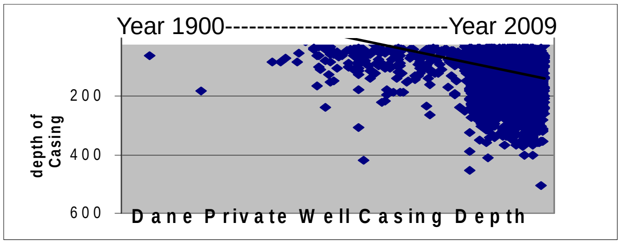
In 2004 survey,

- 25 Wisconsin municipalities spent $24 million to replace wells or install treatment & spend from $2500 to $72,000 annually on operations
- Ten new municipalities needing action over 5 year period

At what cost?

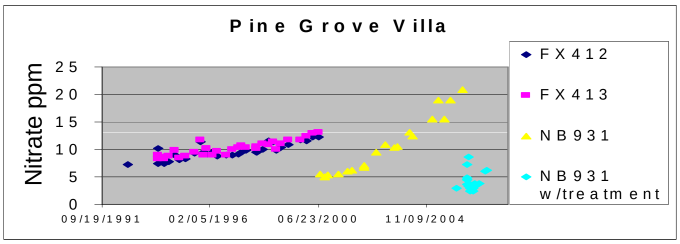
Increasing residential construction cost

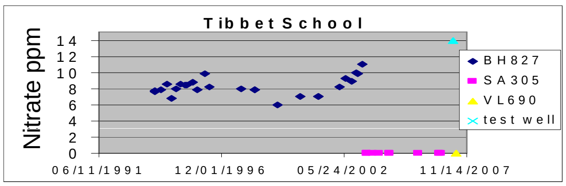


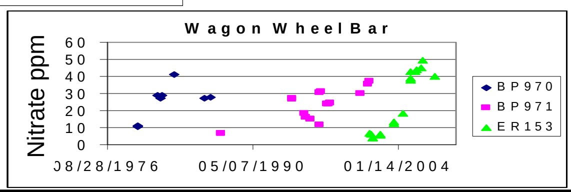


At what cost?

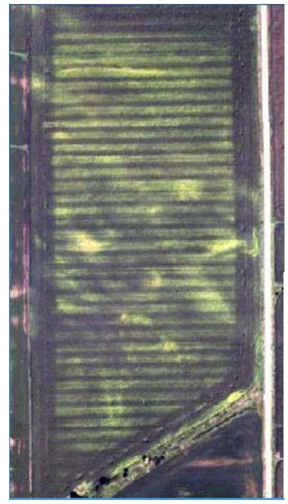
Increasing well replacement & treatment cost







Does it add up?
Treatment or prevention



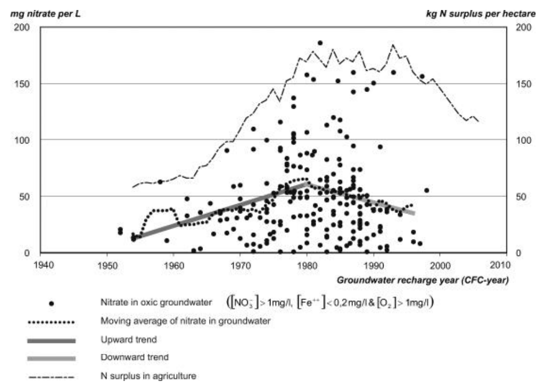
- Most profitable WI farmers use less commercial N - don't follow corn with corn; use legume & manure credits to reduce fertilizer; substitute free information for purchased inputs
- Many studies show individual on-farm analysis using available information can reduce N application ranging from 20 – 50% (and N loss to waters ranging from 10 – 30%)

Does it add up?
Treatment or prevention

- Nitrogen-reducing on-site wastewater systems are available with costs comparable to conventional systems

- Efficient scheduling & use of fertilizer and irrigation on highly maintained turf grasses

Does it add up? On larger scale…



Time series of N surplus in agriculture and nitrate in oxic groundwater versus recharge age (CFC age) on an annual mean level.

ACS Publications
High quality. High impact.

3/28/2011

Nationwide Vital Signs

- Increasing collaboration between federal agencies (EPA, USDA, USFS, FSA) on water quality
- NAWQA and CEAP scientific progress
- Iowa Soybean Association, Bay Farmers

Wisconsin's Vital Signs

- Groundwater Coordinating Council strategic priority
- State Ag Department's on-line, real-time risk map for manure spreading
- Spring runoff PSAs
- Updating analysis of existing data; designing targeted study
- Joint training of animal waste & drinking water inspectors
- Compliance inspection strategy
- Numeric phosphorus standard spurs trading – we hope…
- Seeking geographic opportunities, e.g., Green Tier & Forest2Faucets

State-EPA Nutrient Task Group Action Principles

- All sources must be accountable
- Act on what we know
- Fully use the tools we have
- Explore new authorities & approaches
- National framework needed

Call to Action

- Keep all sources accountable
- Use available data about contaminated drinking water to target most effective new policies
- Unify messages and strategy from EPA, USDA & state partners
- Enlist trusted messengers for all sources
- Cross-educate drinking water and clean water staff
- Compliance monitoring is critical; plans & permits are one piece
- Address onsite wastewater disposal systems more holistically
- Revise TMDL process as appropriate
- Invest in protection; shift from permitting of contamination
- Promote corporate stewardship

Questions & Discussion

Jill Jonas
Wisconsin Department
of Natural Resources

60 Ways to Leave Your Groundwater…Cleaner

Support and Progress for Implementing a Groundwater Protection Plan

Audrey Eldridge
Oregon Department of Environmental Quality
Denise Kalakay
Lane Council of Governments
Kevin Fenn
Oregon Department of Agriculture

What is a GWMA?

is a tool used by the Oregon Department of Environmental Quality to address a large scale groundwater contamination when the contaminants originate from non-point sources.

GWMA Process (in general)

(1) Document contamination

(2) Declare a Groundwater Management Area (GWMA)

(3) Appoint an Advisory Committee

(4) Form an Action Plan

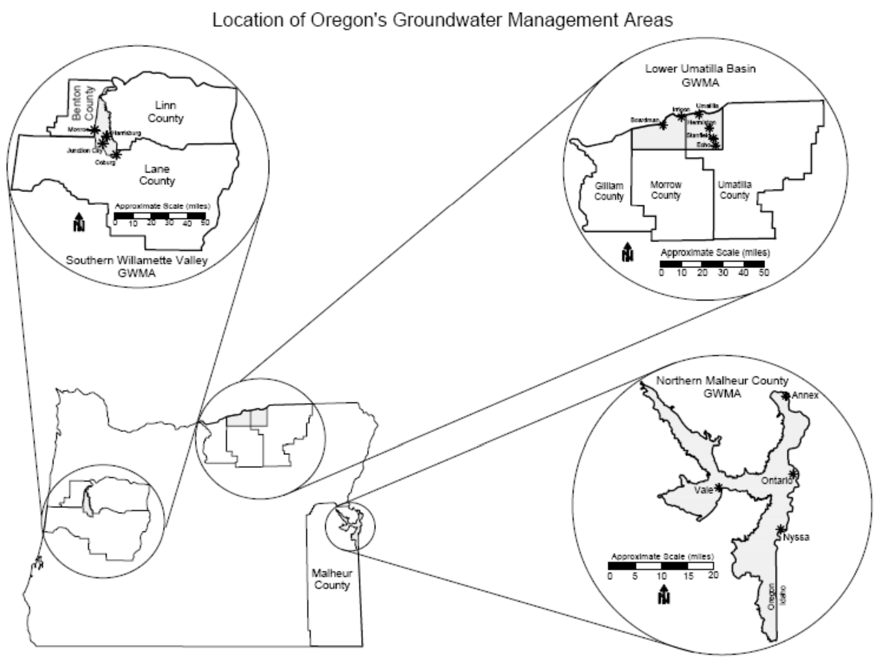
(5) Implement the Action Plan

(6) Rescind the GWMA declaration

Nitrate Standards

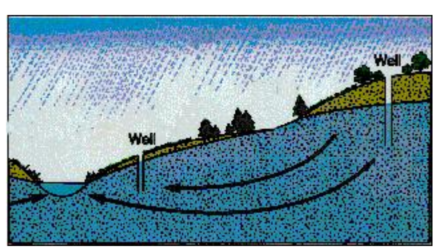
- The public drinking water standard is 10 mg/L

- "Action Level" for Oregon GWMA declaration is 7 mg/L



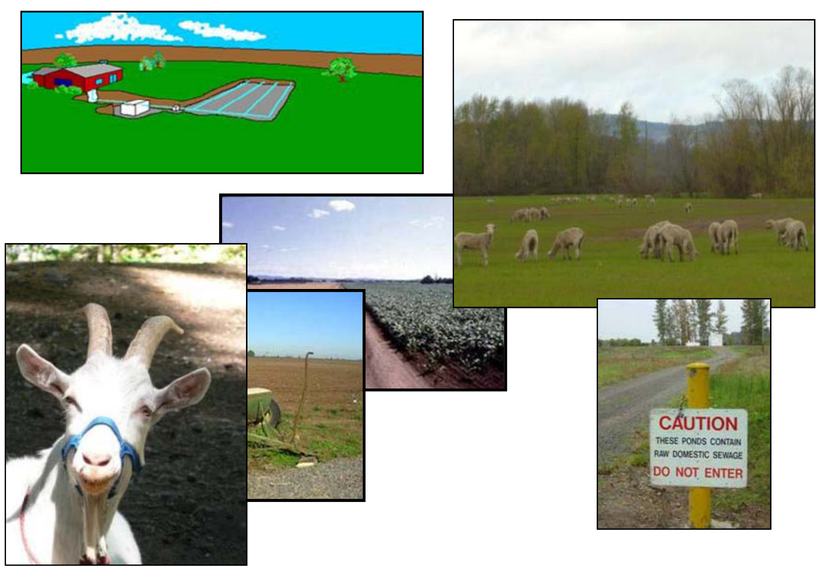
Southern Willamette Valley Groundwater Resources

- Shallow (20–40 ft.)
- Unconfined
- In some areas, the shallow groundwater overlies a larger and deeper regional aquifer

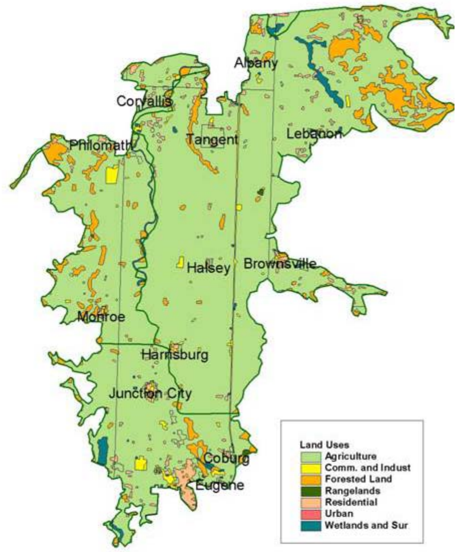


Nearly all of the GWMA Residents Rely on Groundwater

Potential Nitrate Sources Fertilizers, Human and Animal Waste



Land Use is Predominately Agriculture



Sampling Programs using Domestic Wells

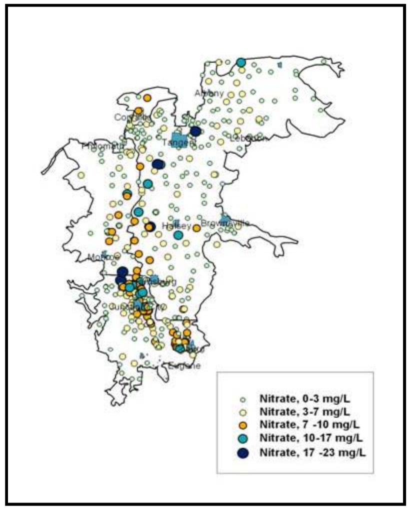
- **2000-2001 Nitrate Testing**
  - **Looked for good coverage of the area, and targeted shallow wells**
- **2002 Study**
  - **Looked to confirm earlier results and determine if any other parameter of concern was present**

2000–2001 Nitrate Study

Shallow wells
(less than 75 feet deep)

Good overall coverage

476 Wells
- **437 Private Wells**
- **29 PWS**
- **10 Irrigation Wells**



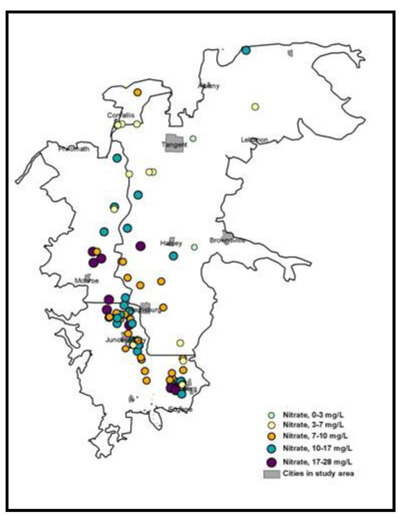
2002 Nitrate Results

10.1-28 mg/L = 49 wells

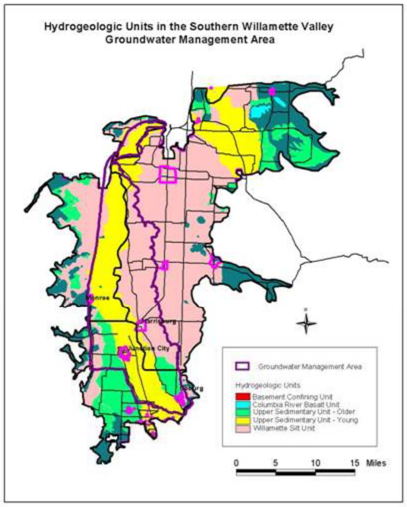
7.1-10.0 mg/L = 43 wells

3.1 -7.0 mg/L = 9 wells

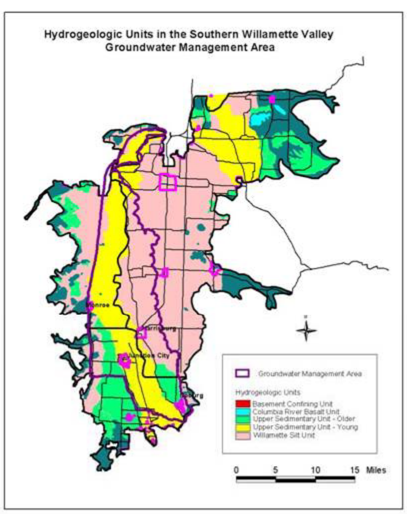
> 3 mg/L = 6 wells

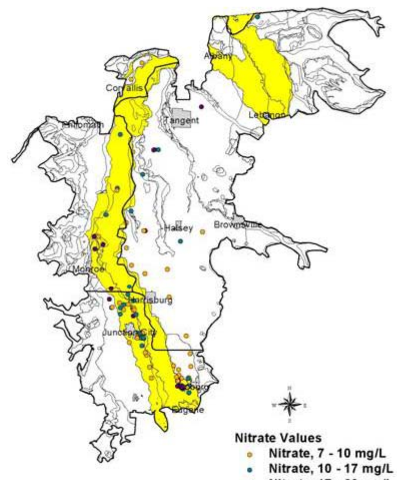


Hydrogeologic Composition and Nitrate Values



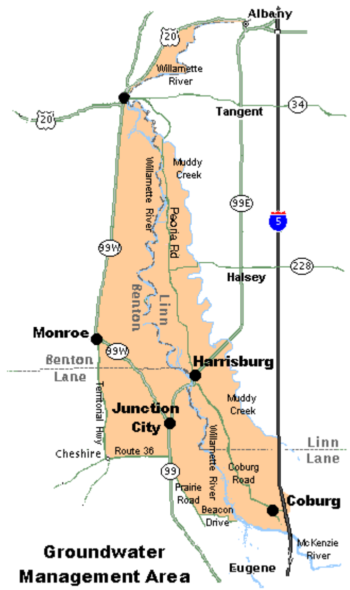
Hydrogeologic Composition and Nitrate Values





The SWV GWMA boundaries were also designed to

- Be recognizable to the general public, so they would know if they are "in"
- Capture most of the high nitrate values seen in the 2000-2002 studies



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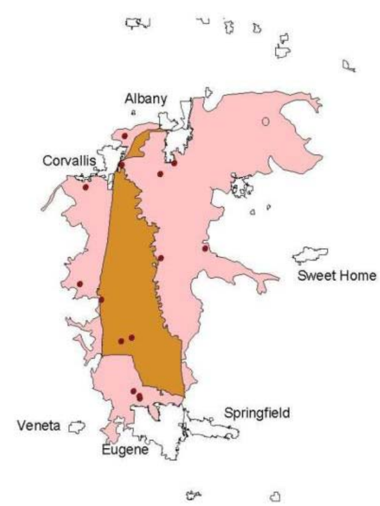

CURRENT GWMA
"TOGA OF THE DANCING PIG"

Where Are We Now?

- GWMA declared in 2004
- A committee was appointed
- An Action Plan was finalized Dec 2006
- Outreach and implementation continues

Measuring Overall Groundwater Quality - Long Term Programs

- Long Term Network - a mix of 40 domestic and monitoring wells
- Synoptic Sampling Events ~3-4 years
- PWS and RET data

Overall 2010 Trend Comparisons

Well	Increase	Decrease	Steady
Domestic Wells (DW)	**1-2**	**7**	**5-6**
Monitoring Wells (GW)	**7**	**7**	**9**

Nitrate Values …

- Background (1st 9Q) nitrate values of all GW wells = 5.37 mg/L
- Background (1st 9Q) nitrate values of all DW wells = 4.94 mg/L

Nitrate Values …

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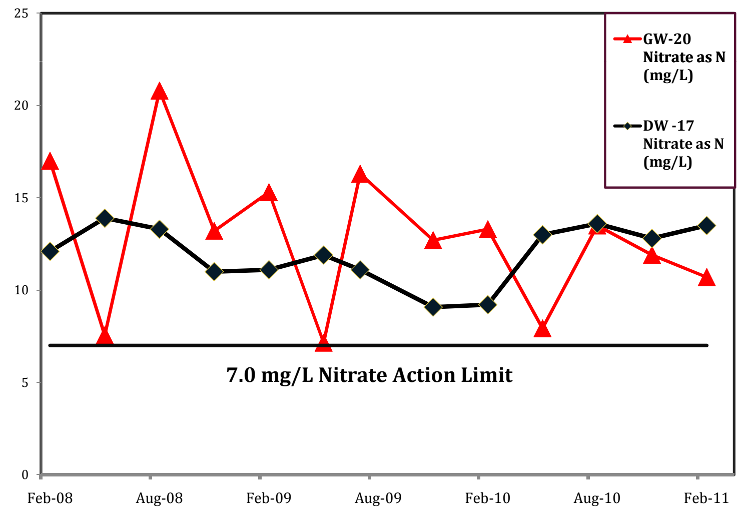
- Background (1st 9Q) nitrate values of all DW wells = 4.94 mg/L

Average Nitrate over the last year (2010)

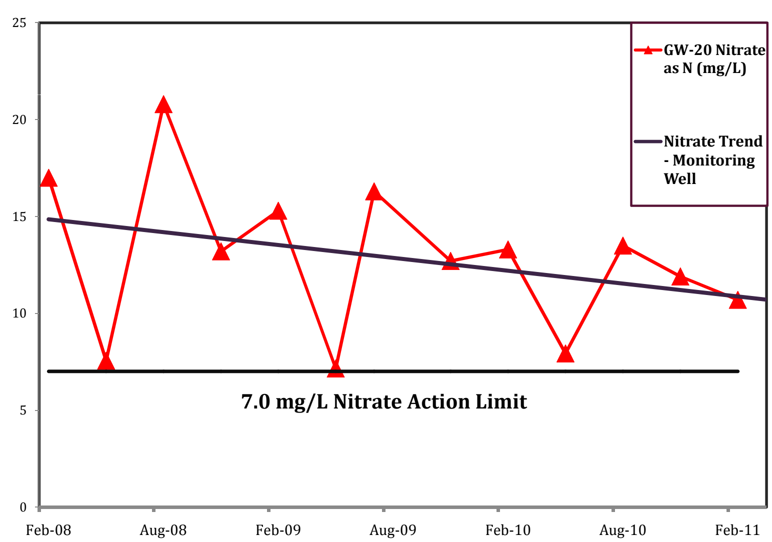
GW average = 5.24

DW average = 4.76

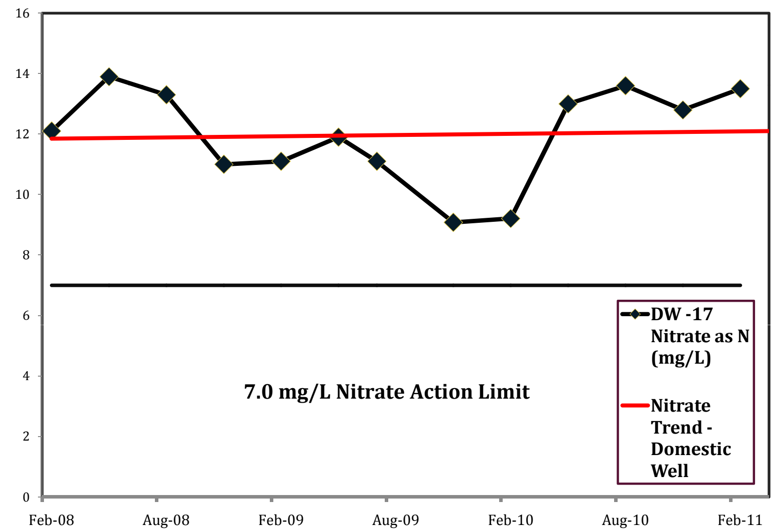
Domestic Well (DW-17) and Companion Monitoring Well (GW-20)



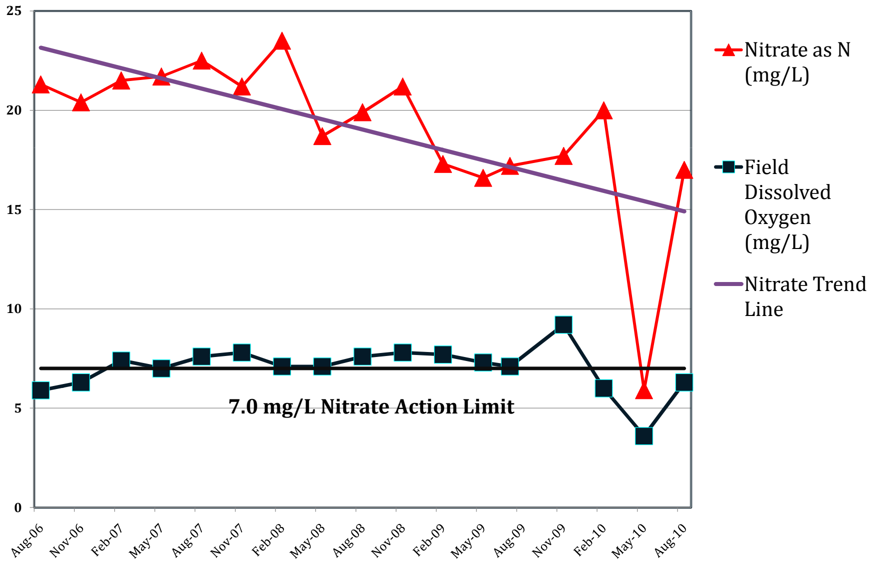
Monitoring Well (GW-20) Trend

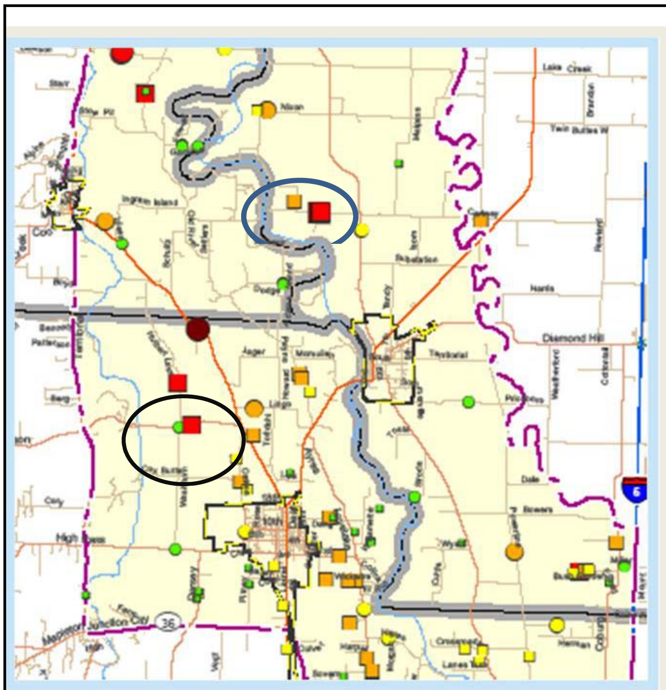


Domestic Well (DW-17) Trend



GW-12 Crook Road





Nitrate Values in the Long-Term Monitoring Sites & The One-Time Monitoring Event

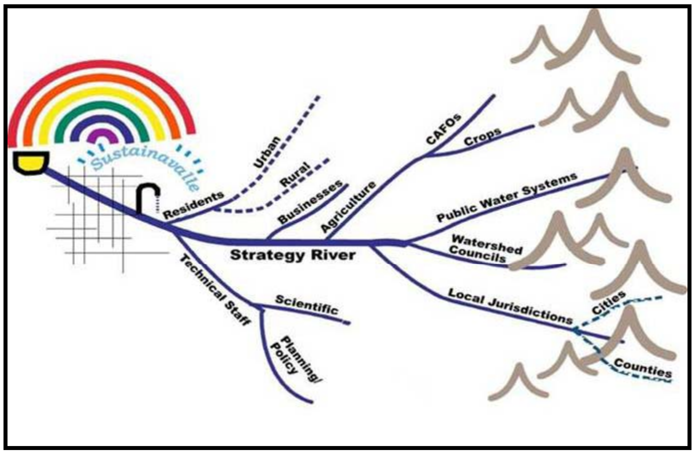
Spring 2009

Long Term Monitoring Wells
Nitrate/nitrite as N mg/L
- 0.0 - 2.4
- 2.5 - 6.9
- 7.0 - 9.9
- 10.0 - 20.0
- 20.1 - 27.5

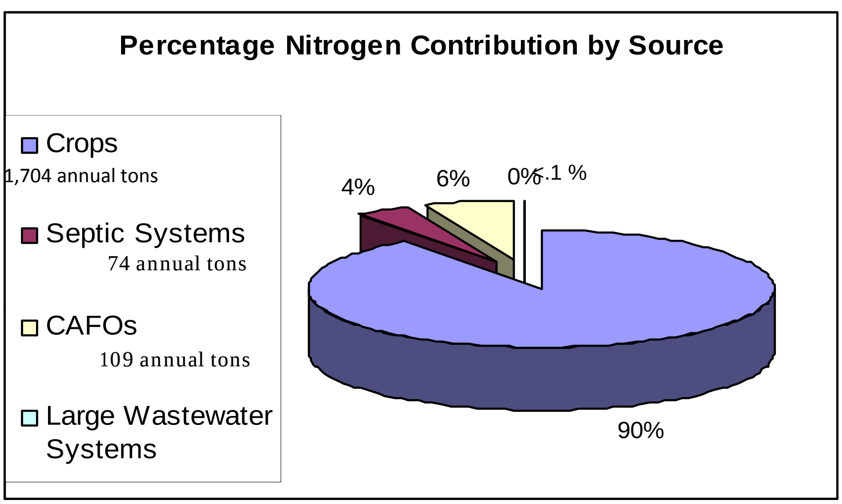
One-Time Event Well Samples
Nitrate/nitrite as N mg/L
- 0.0 - 3.0
- 3.1 - 6.9
- 7.0 - 9.9
- 10.0 - 20.0
- 20.1 - 35.9

Groundwater Management Area
Urban Growth Boundaries
County Boundary

60 Voluntary Strategies From All Land Use Sectors



Four Sources of Nitrate Analyzed by the Nitrogen Budget



Residential Focus

- Approximately 21,000 people living in the GWMA and nearly all of the GWMA residents rely on groundwater for their drinking water supply.
- Many landowners still use hand-dug or driven wells.
- Septic Systems—68% of the septic systems in the GWMA do not have a septic system record.
- Home and garden fertilizer use

Education and Outreach

- Free nitrate well water testing
- Volunteer monitoring network
- Rural Living Basics Classes
- Festivals—Daffodil Festival
- Kids Day for Conservation
- Envirothon

Agricultural Focus

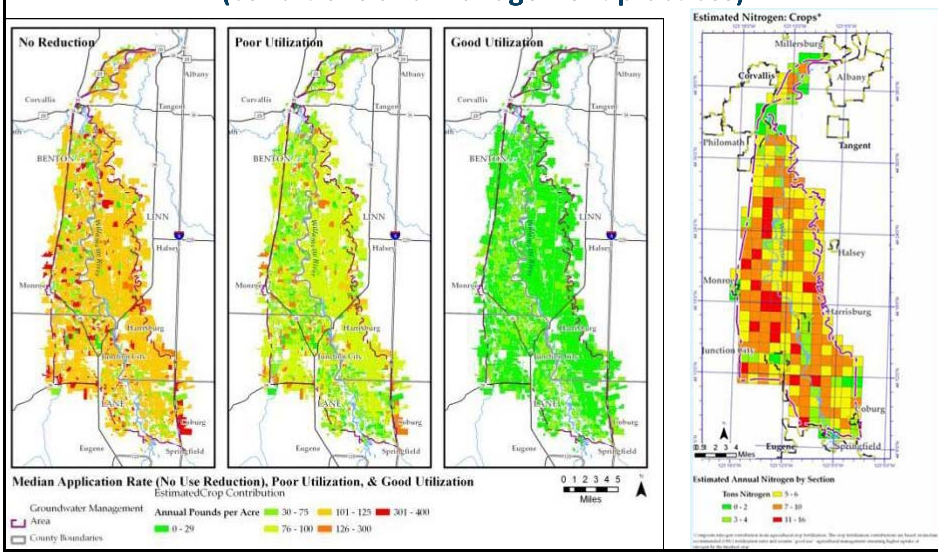
- ~177 square miles (93 % of the area) Includes grains, hay and forage, seed crops, row crops, vegetables, fruits, and various specialty seed crops. Known as the "grass seed capitol of the world."
- Eight permitted Confined Animal Feeding Operations (CAFOs)
- Small acreage agricultural landowners.

Uptake ratios take into account conditions and management practices

Field Classification	Percent of Crop Lands	Poor Utilization (low) Uptake Ratio	Good Utilization (high) Uptake Ratio
Alfalfa	.29%	15%	60%
Beans/peas	.19%	10%	60%
Berries & vineyards	1.29%	30%	70%
Christmas trees	.34%	50%	80%
Clover	1.13%	15%	60%
Corn	.13%	30%	65%
Double cropping	.10%	30%	70%
Grains	4.26%	10%	80%
Grass seed rotation	56.60%	40%	85%
Hayfield	6.59%	40%	85%
Irrigated annual rotation	12.55%	50%	50%
Irrigated perennial	3.18%	60%	90%
Mint	2.52%	40%	65%
Orchard	.96%	60%	90%
Pasture	3.93%	40%	85%
Sugar beet seed	.69%	50%	70%
Turfgrass	.90%	40%	85%

Nitrogen Potentially Lost Per Acre Depending on Utilization

(conditions and management practices)



Agricultural Changes - Unpredictable

- **Rise in fertilizer and fuel cost**
- **Loss of vegetable processing ability**
- **Recent decrease in grass seed planting, due to stockpile of seed**
- **Declining peppermint price**

Agricultural Changes – Active Management

- Dropped irrigation nozzles – less water needed to irrigate the same crop thus less potential for over-irrigation
- Veris Mapping and adoption of precision agriculture practices
- Updated fertilizer guidances and practices
- Anaerobic digesters
- Awareness and money

These changes equal less nitrogen input and loss

Overall Goal
Clean Drinking Water
http://gwma.oregonstate.edu/

Questions & Discussion

Audrey Eldridge
Oregon Department of
Environmental Quality

USGS
science for a changing world

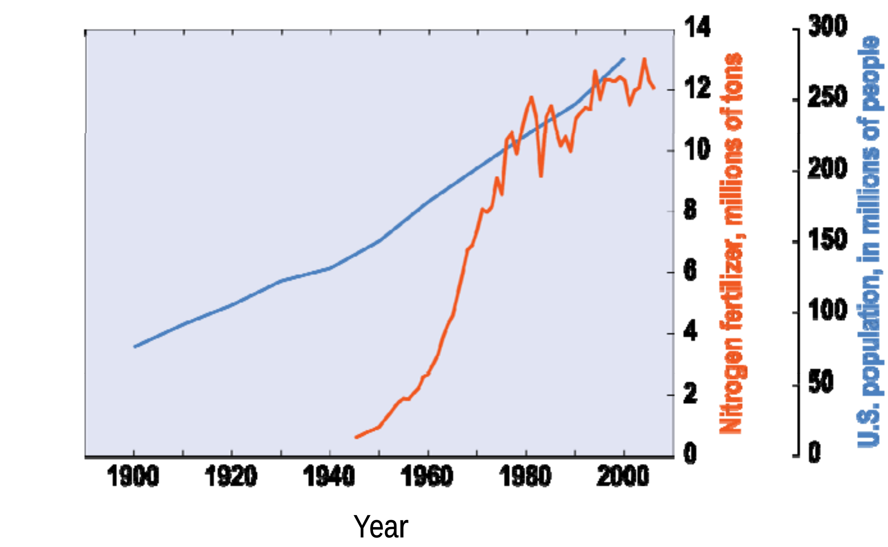
National Water-Quality Assessment (NAWQA) Program

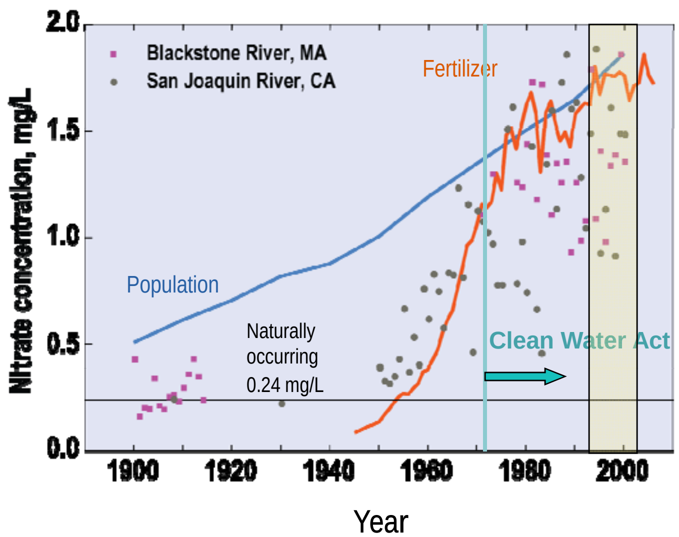
Nutrients in the Nation's Streams and Groundwater, 1992–2004

Circular 1350

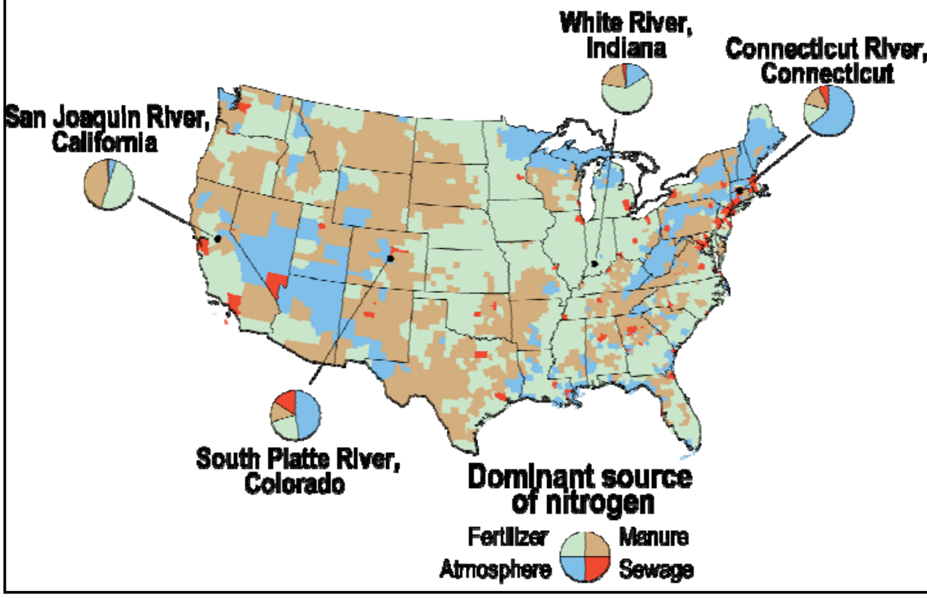
http://water.usgs.gov/nawqa/nutrients/pubs/circ1350/

Neil M. Dubrovsky, PhD
U.S. Geological Survey

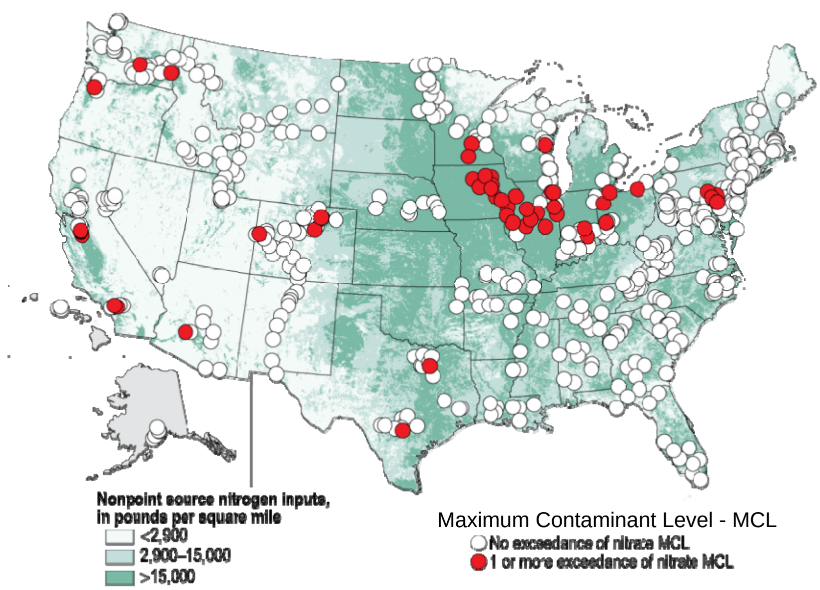

14
12
10
8
6
4
2
0
300
250
200
150
100
50
0
Nitrogen fertilizer, millions of tons
U.S. population, in millions of people
1900
1920
1940
1960
1980
2000
Year


2.0
1.5
1.0
0.5
0.0
Nitrate concentration, mg/L
Blackstone River, MA
San Joaquin River, CA
Fertilizer
Population
Naturally occurring 0.24 mg/L
Clean Water Act
1900
1920
1940
1960
1980
2000
Year

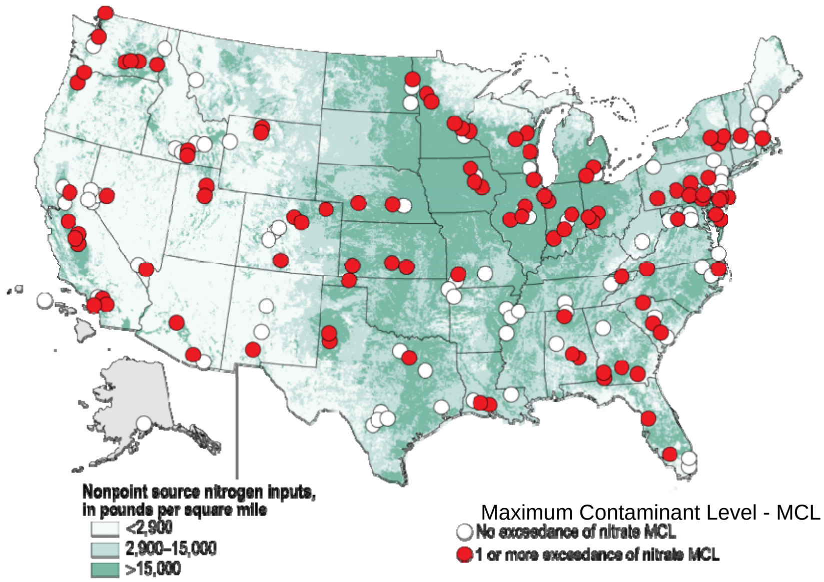
Different sources of nitrogen predominate in different regions



Nitrate concentrations in streams



Nitrate concentrations in groundwater studies



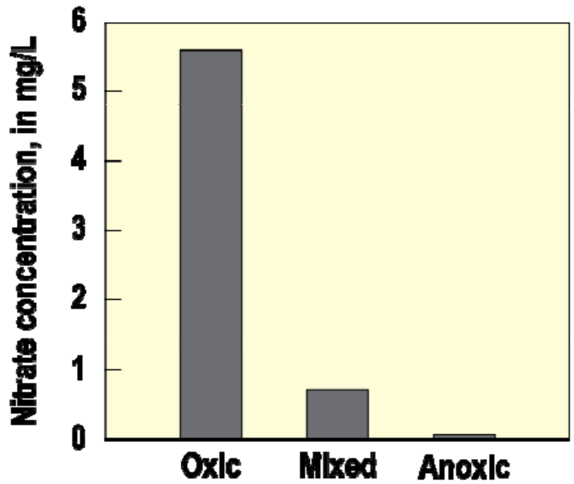
- Biogeochemical controls on nitrate in groundwater
- Contribution of nitrate in groundwater to streams
- Change over time: implications of the slow movement of groundwater

Biogeochemical control of nitrate

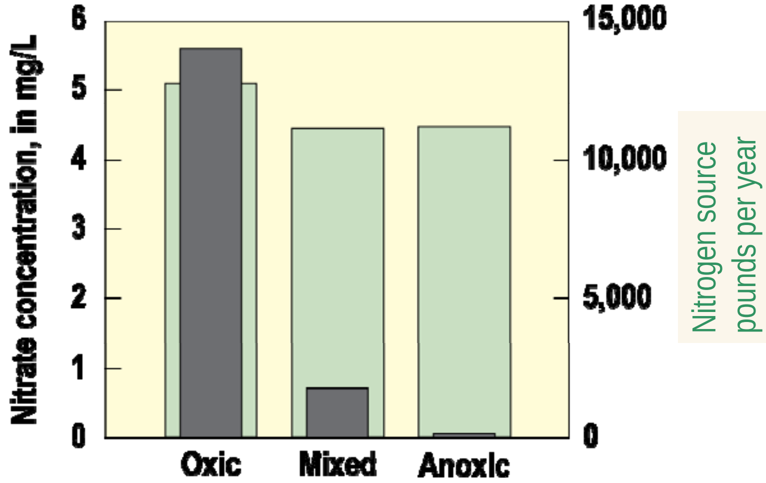
Nitrate concentrations are significantly higher in well-oxygenated groundwater regardless of the amount of nitrogen inputs

- Removal by denitrification

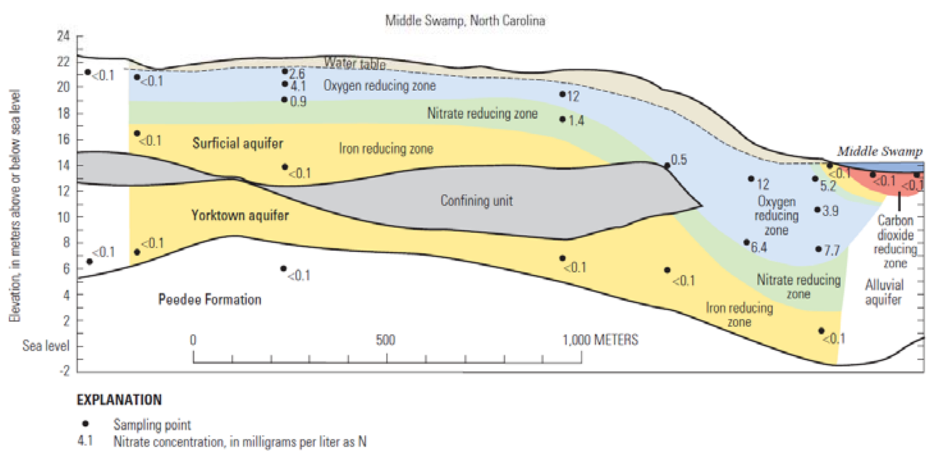
Nitrate concentrations in shallow agricultural wells



Nitrate concentrations in shallow agricultural wells

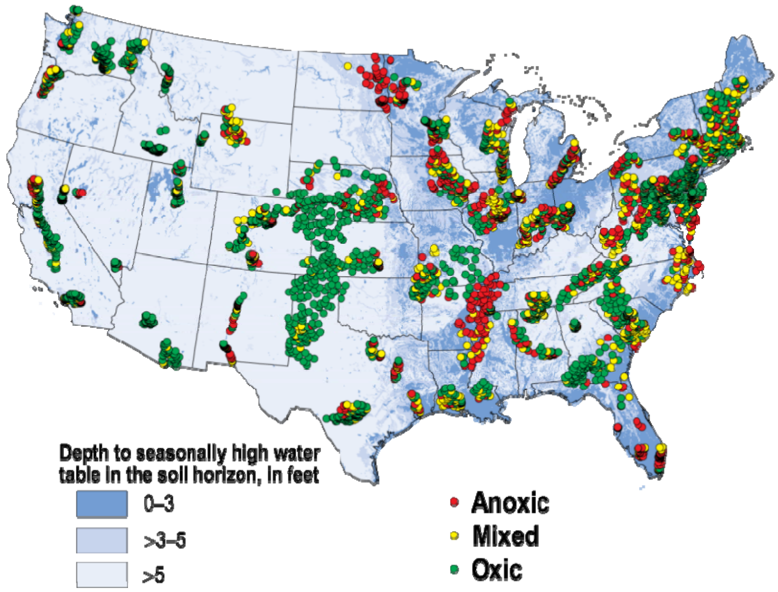


Nitrate removed from discharging groundwater by denitrification

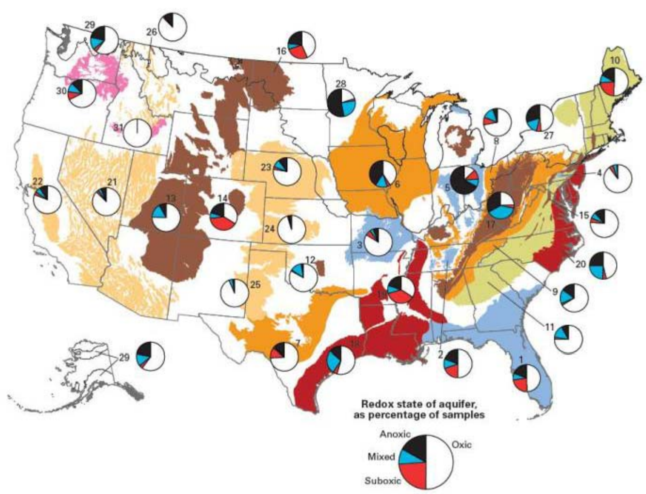


Tesoriero and others, 2005
http://www.agu.org/journals/wr/wr0502/2003WR002953/

Biogeochemical condition of wells

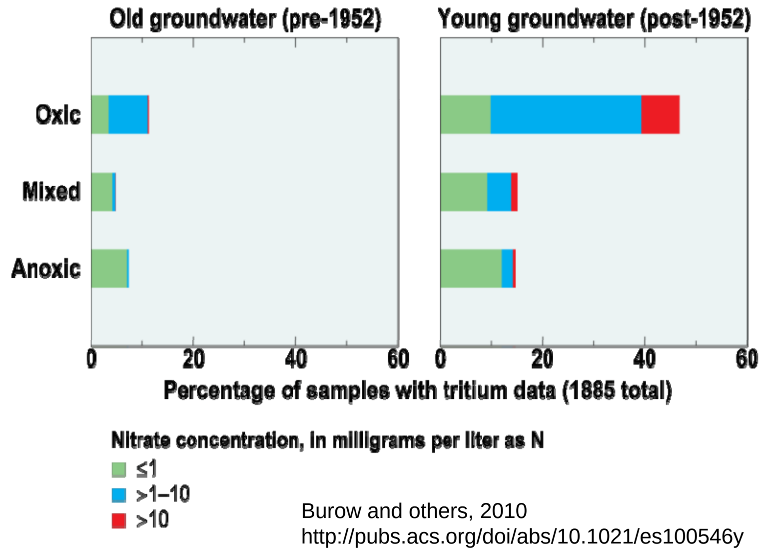


Redox Conditions in Selected Principal Aquifers of the United States



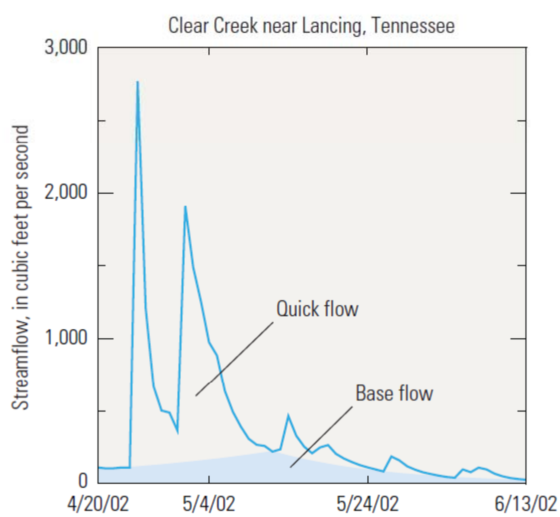
McMahon and others, 2009
http://pubs.usgs.gov/fs/2009/3041/pdf/FS09-3041.pdf

The highest nitrate occurs where redox conditions and aquifer properties favor nitrate transport and persistence - in young, oxic groundwater



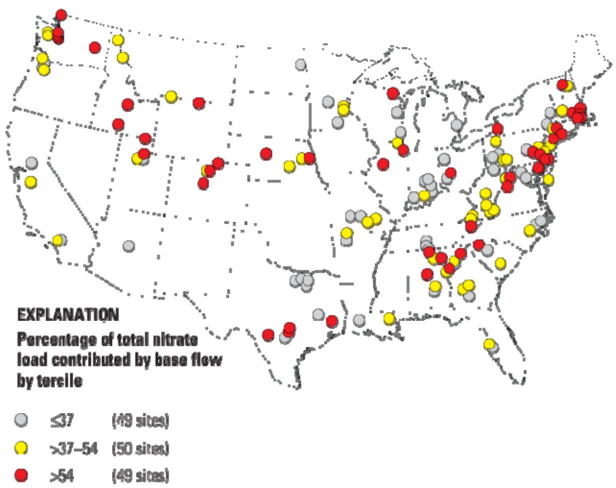
Burow and others, 2010
http://pubs.acs.org/doi/abs/10.1021/es100546y

Groundwater contributions to streams

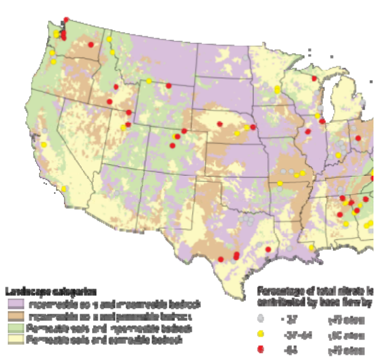


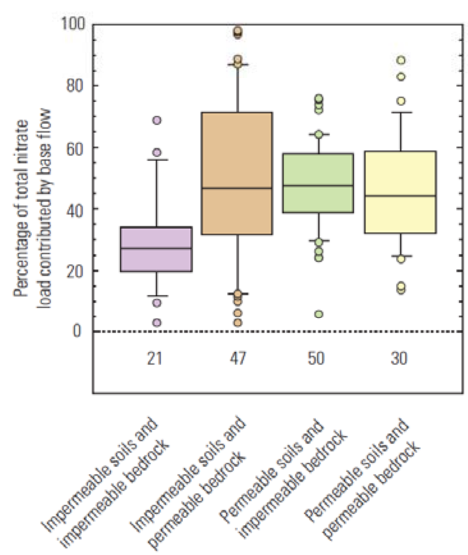
Spahr and others, 2010
http://pubs.usgs.gov/sir/2010/5098/

Groundwater contribution to nitrate in streams

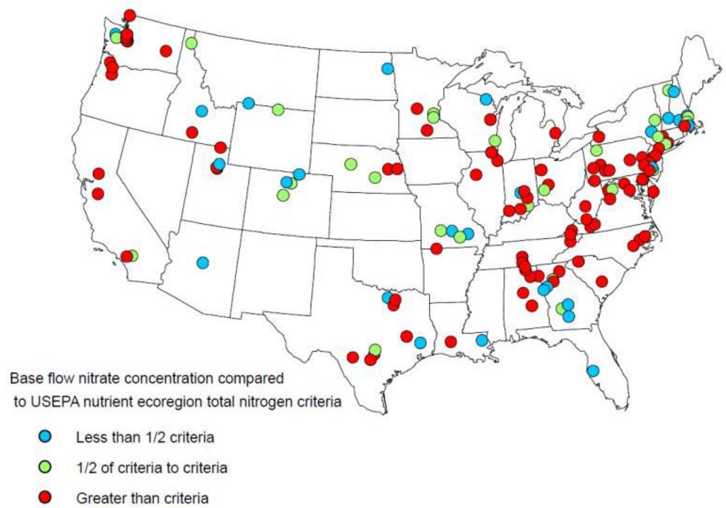


The amount of groundwater contribution depends on the permeability of the soils and bedrock



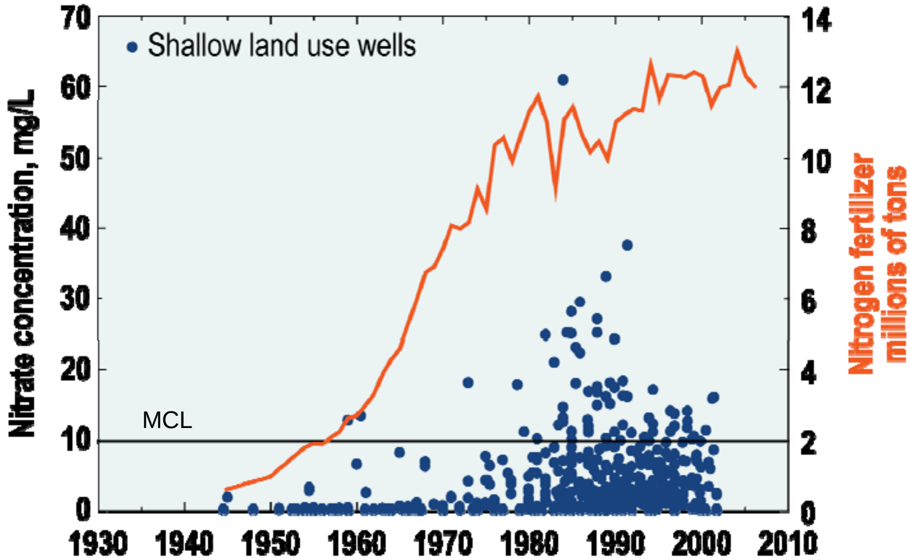


The average concentration of nitrate in base flow often exceeds recommended ecoregional criteria for total nitrogen in streams

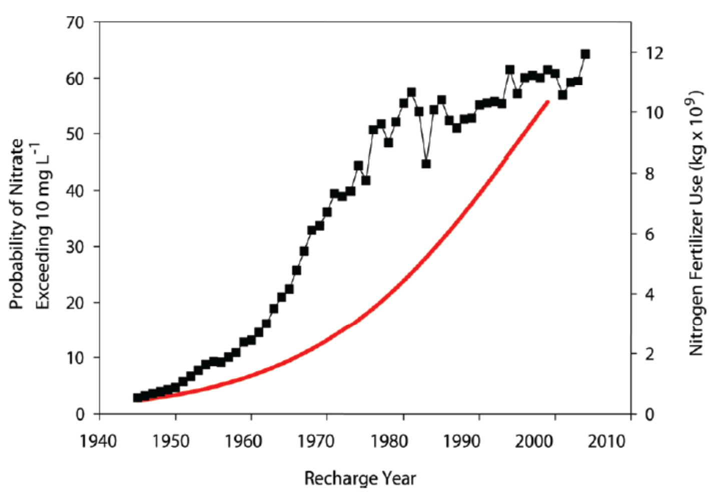


Change over time: Implications of the slow movement of groundwater

Change in nitrate concentration in groundwater

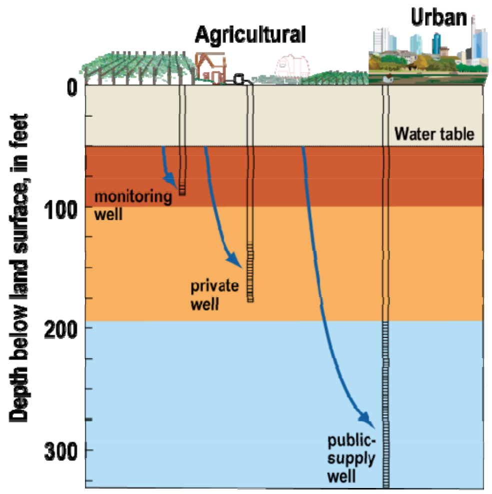


The probability of nitrate concentrations exceeding 10 mg/L in recharging groundwater at agricultural sites (red line) has increased from <1% in the 1940s to >50% by 2000

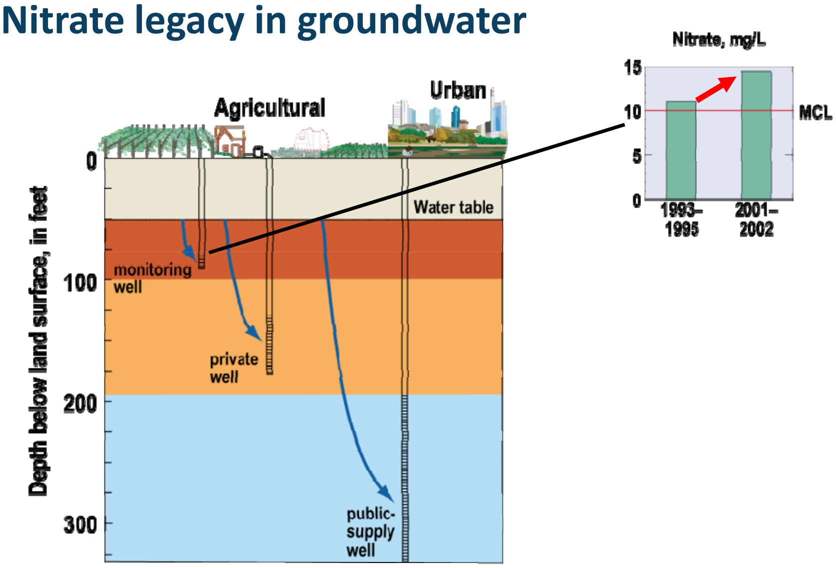


Puckett and others, 2011, ES&T
http://pubs.acs.org/doi/abs/10.1021/es1038358

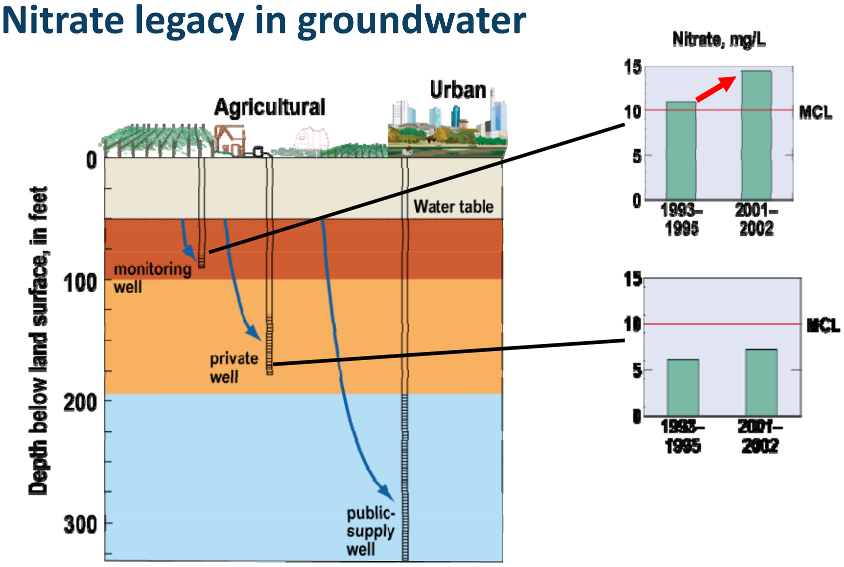
Nitrate legacy in groundwater



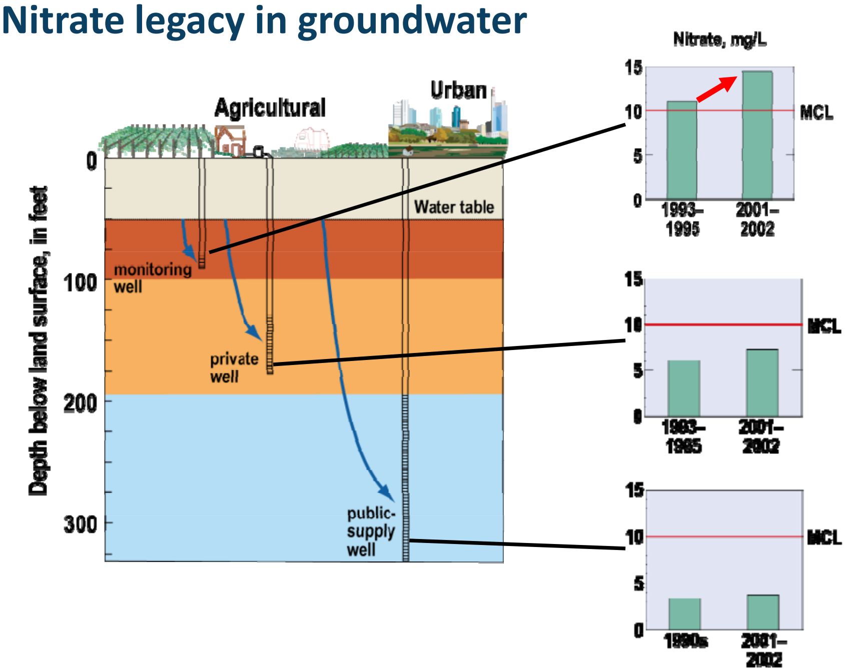
Nitrate legacy in groundwater

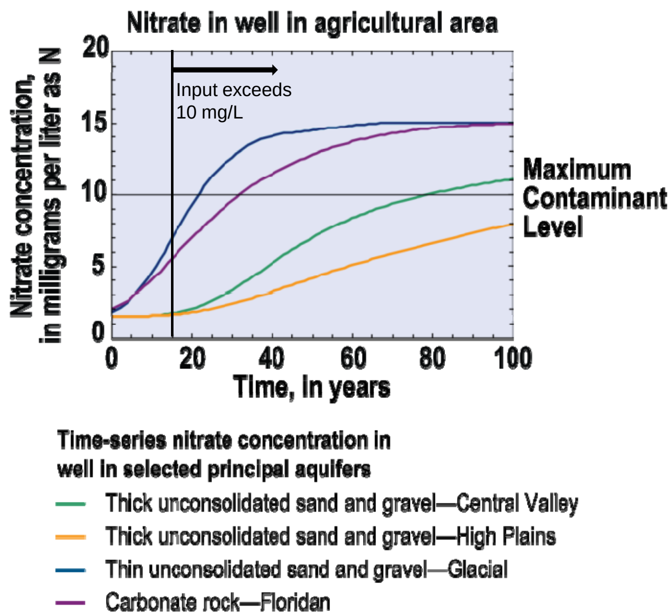


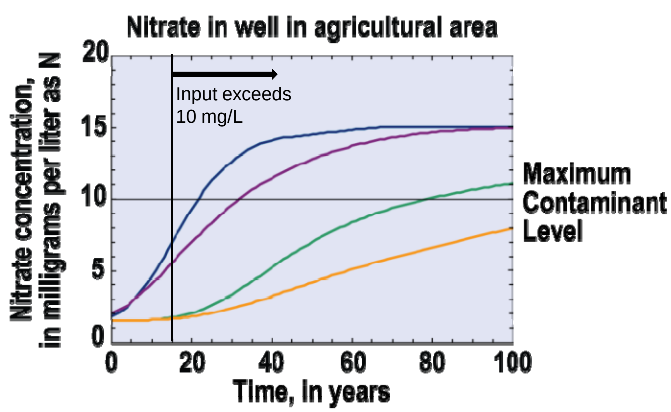
Nitrate legacy in groundwater



Nitrate legacy in groundwater



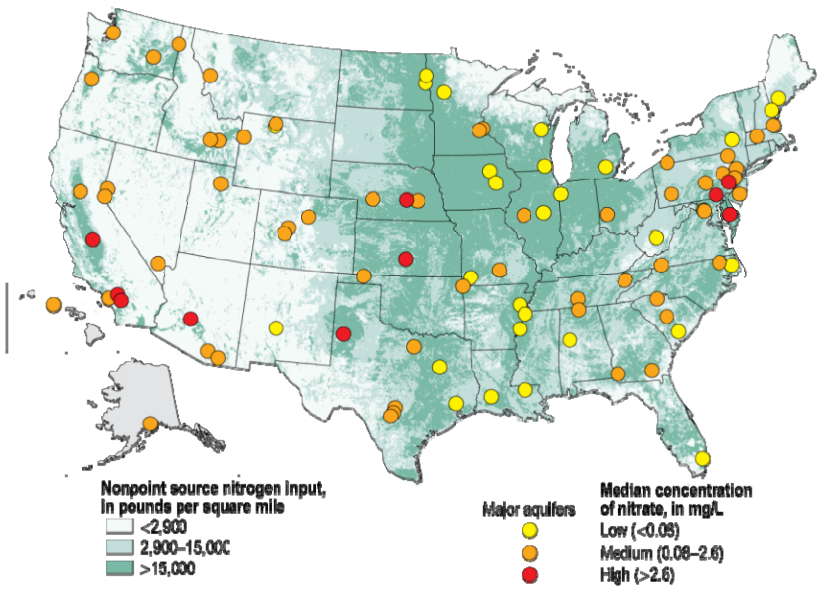




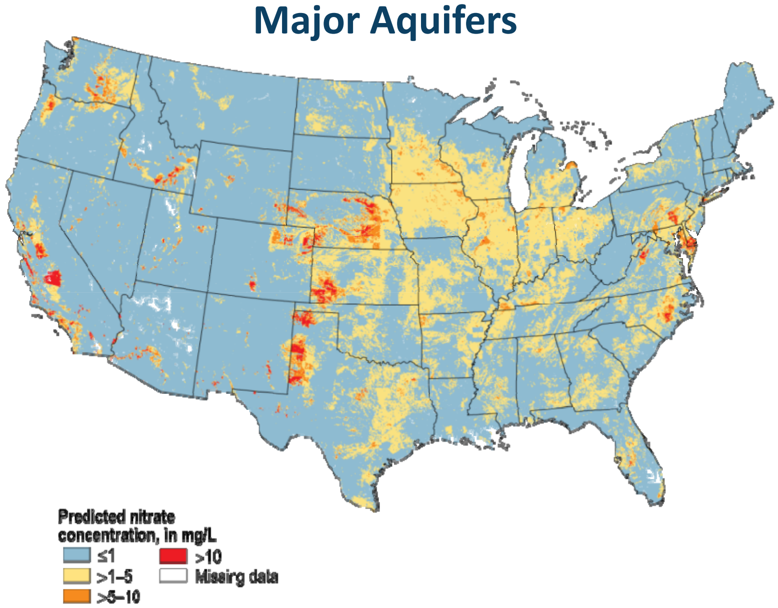
Note: many systems have “short circuits” that result in rapid movement of contaminants to public wells

USGS NAWQA Transport of Anthropogenic and Natural Contaminants to Supply Wells
http://oh.water.usgs.gov/tanc/NAWQATANC.htm

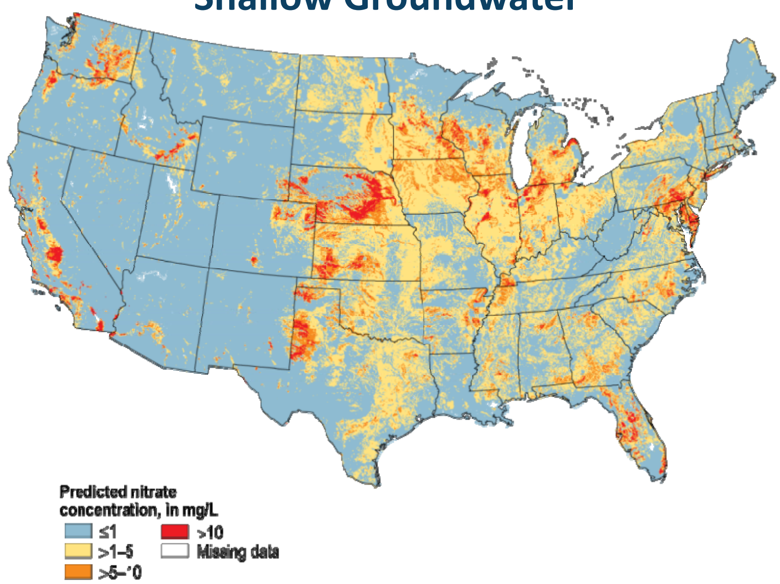
Nitrate concentration in major aquifers



Estimated Nitrate Concentrations in Major Aquifers



Estimated Nitrate Concentrations in Shallow Groundwater



Implications

- Stable and upward trends in nitrate in most groundwater indicate that, at the national scale, current efforts to limit nutrients in water are not producing measureable improvements.
- Contributions of nitrate in groundwater to streams must be taken into account in developing nutrient source allocations, for example TMDLs. If you don't account for this, you may incorrectly attribute loads to other sources.
- Identifying areas where denitrification limits nitrate in groundwater tells us where wells and streams are least vulnerable. This knowledge could allow you to focus monitoring on the most vulnerable waters.
- The slow rate of groundwater flow means that changes in nitrate input on the land may take years to decades to produce changes in wells and some streams. And given the high concentrations in shallow groundwater, we can expect more MCL exceedances in drinking water in the future.

Questions & Discussion

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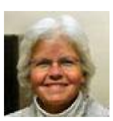
U.S. Geological Survey

Speaker Contact Information



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