

Movement and fate of nitrate and select pesticides in groundwater

Carla Romano

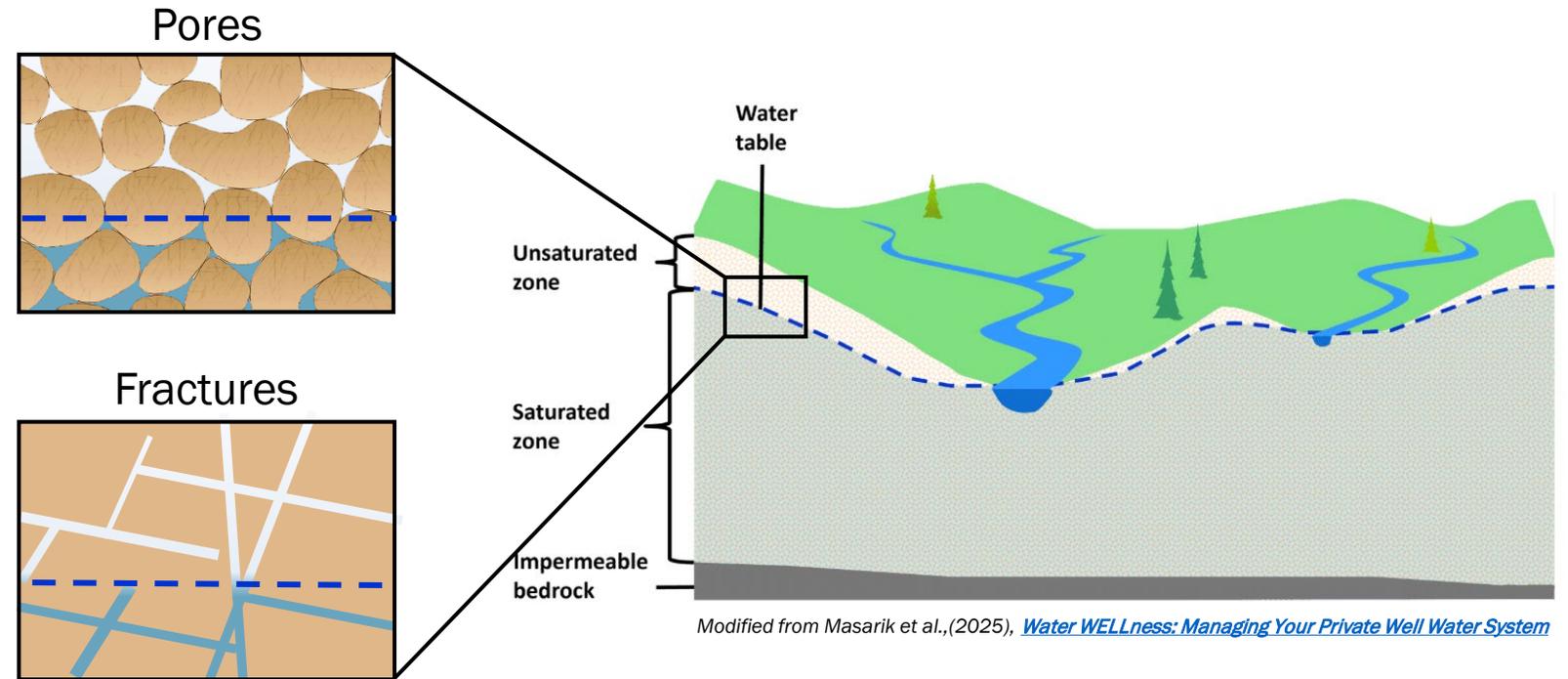
Groundwater Section, Drinking Water and Groundwater Program

Wisconsin Department of Natural Resources

02-18-2026

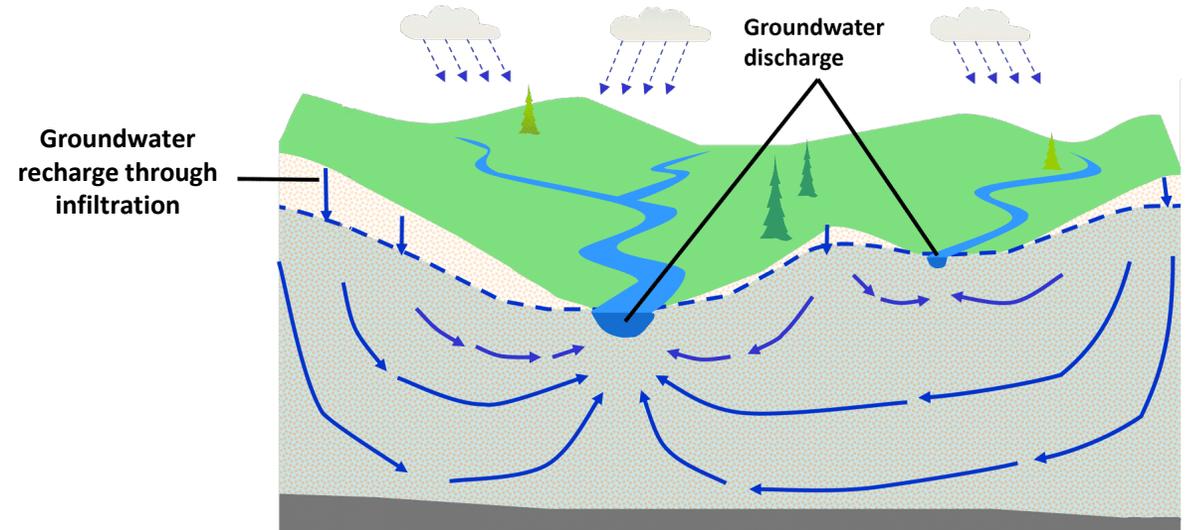
Groundwater: what is it?

- Groundwater is the water stored beneath the Earth's surface in pores and fractures of rocks and soils.
- Unsaturated zone: layer of rock or soil above the water table where pores contain both air and water.
- Saturated zone: layer below the water table where all pores are filled with water.



How does groundwater move?

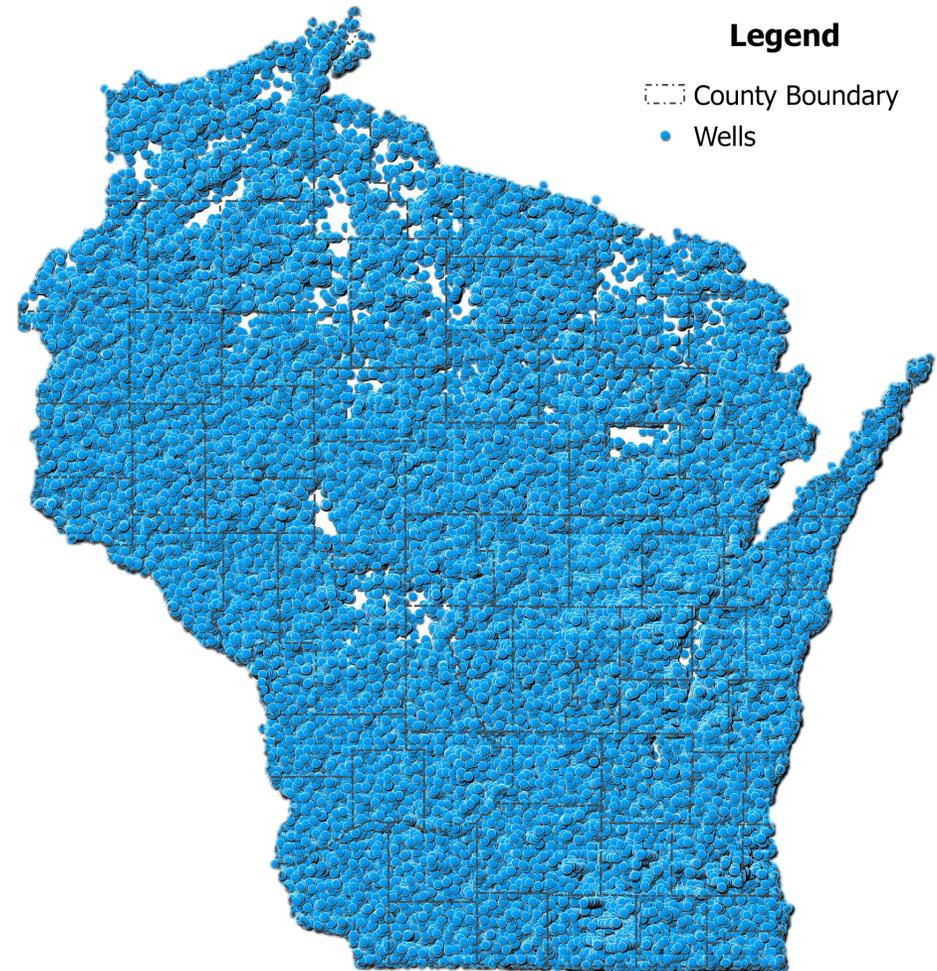
- When precipitations occur, water infiltrates into the ground and recharges groundwater.
- Infiltration rates depend on soil and rock type and subsurface layers.
 - Sandy soils: Large interconnected pores → high permeability and rapid downward movement.
 - Clay soils: Tiny particles → low permeability, and slow downward movement.
- Groundwater emerges when the water table intersects the land surface (through streams, rivers, etc.).



Masarik et al.,(2025), [Water WELLness: Managing Your Private Well Water System](#)

Why is groundwater so important for WI?

- About 70% of Wisconsinites rely on groundwater as their drinking water source.
- We estimate that statewide there are:
 - About 800,000 private potable wells
 - Over 18,000 public wells
- In Green County we have records on:
 - 107 public wells
 - 4,650 private potable wells



Data from the DNR [Groundwater Retrieval Network \(GRN\)](#)

Examples of WI groundwater contaminants

- Nitrate
- Bacteria
- PFAS
- Pesticides
- Metals
- Arsenic
- Radium



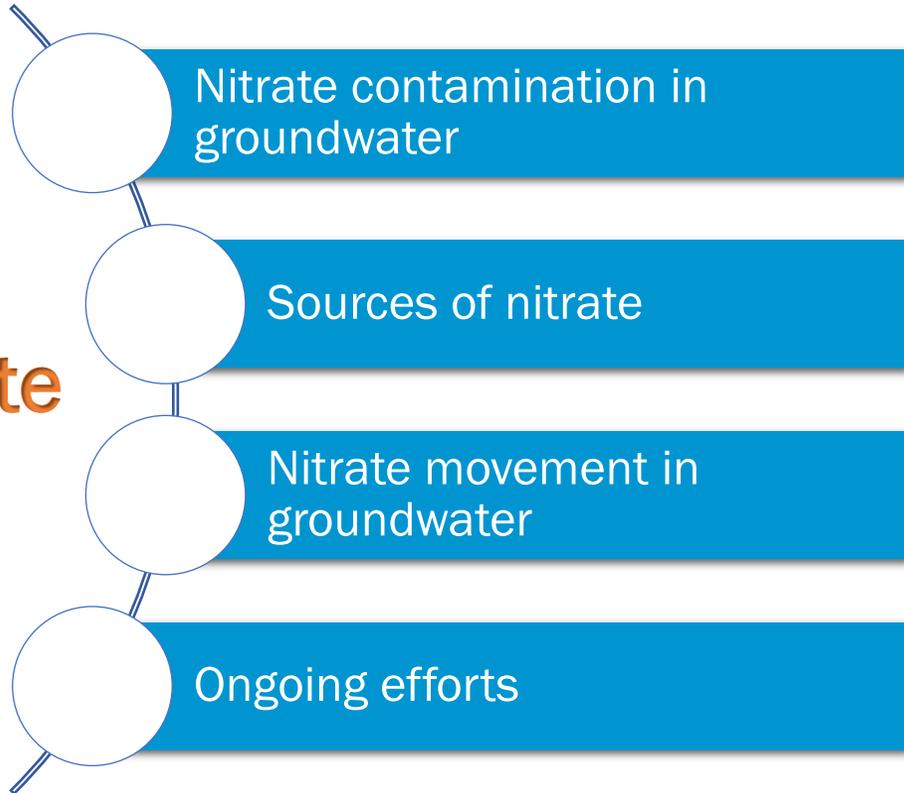
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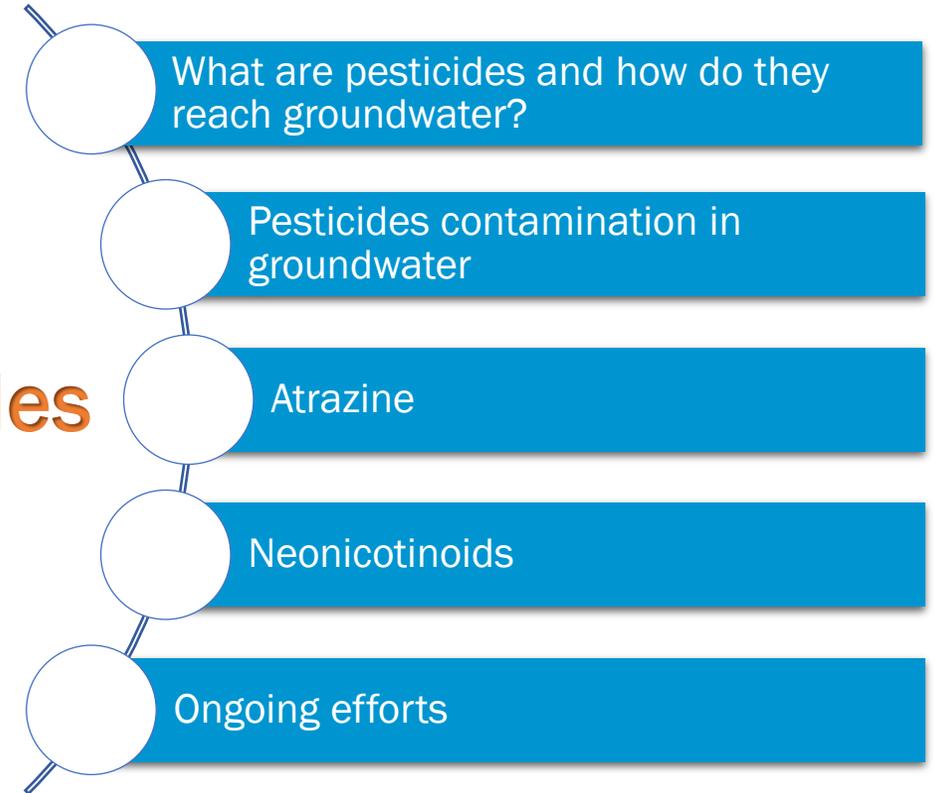


Agenda

Nitrate

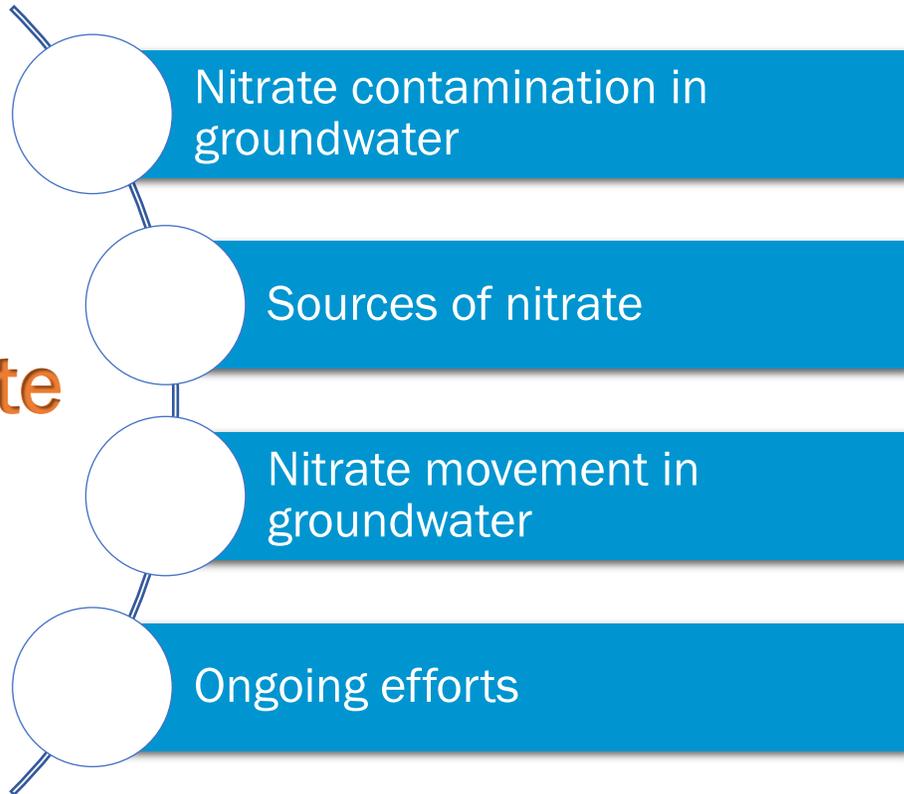


Pesticides

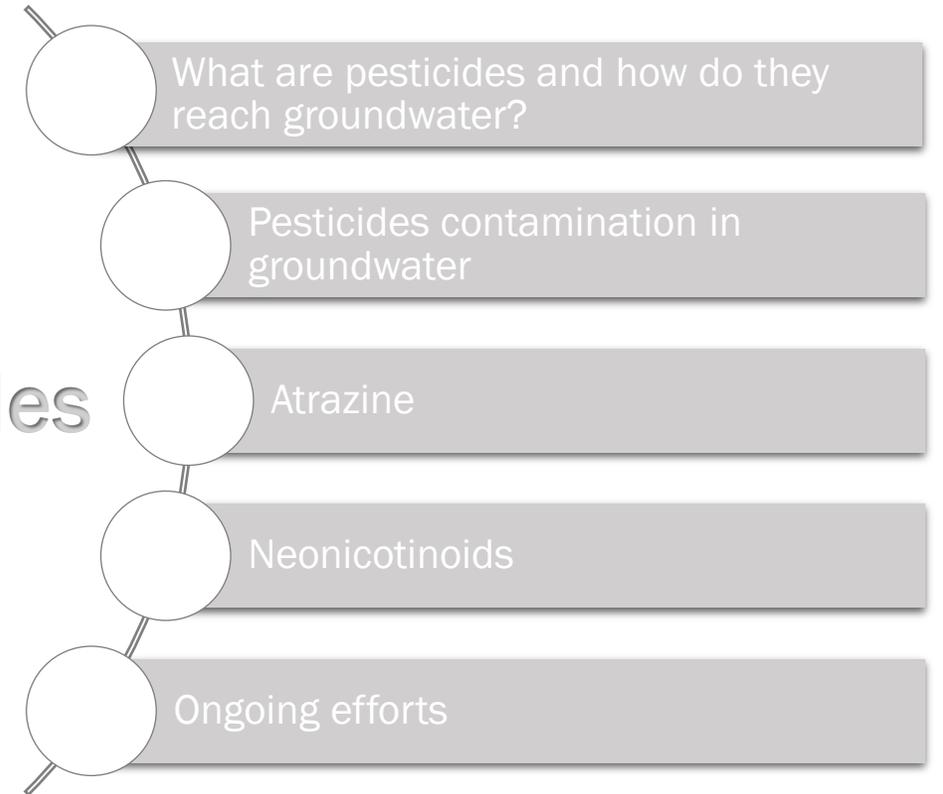


Agenda

Nitrate

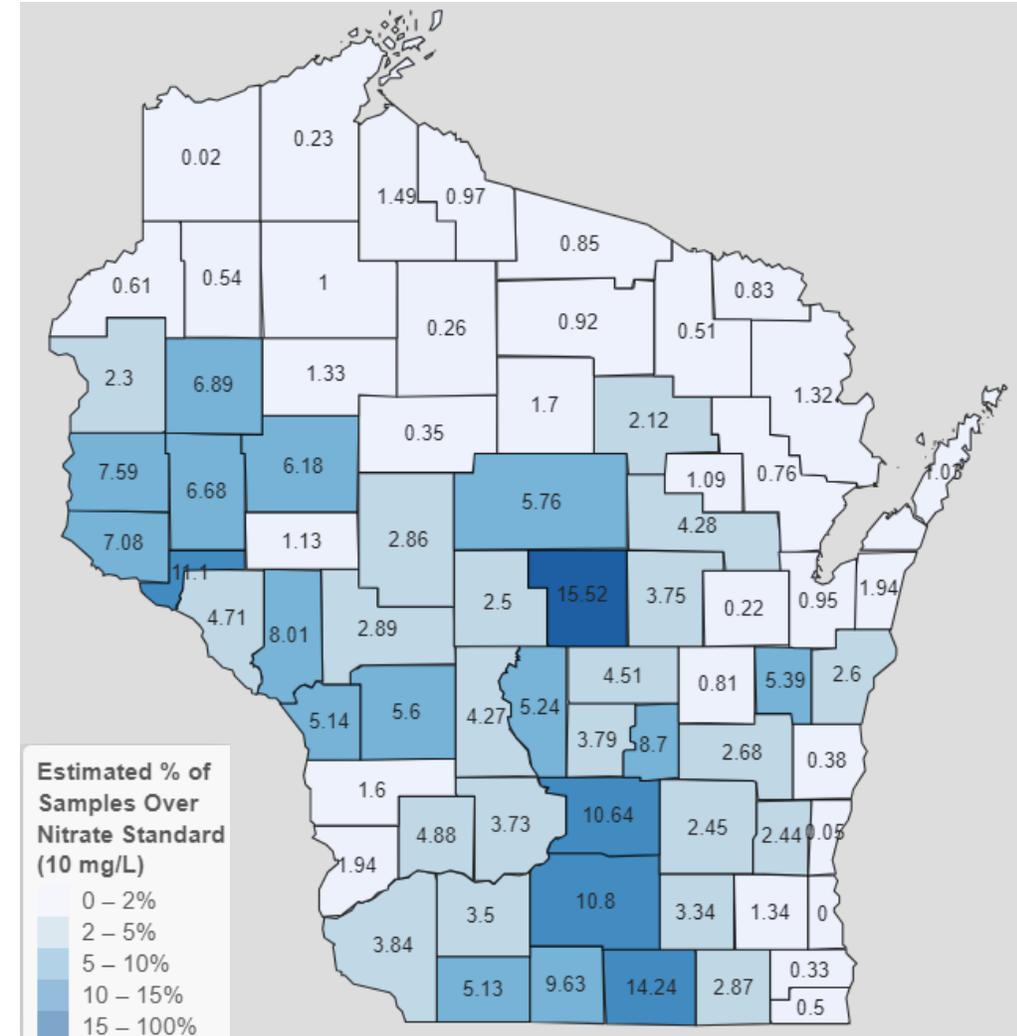


Pesticides



Nitrate in WI groundwater

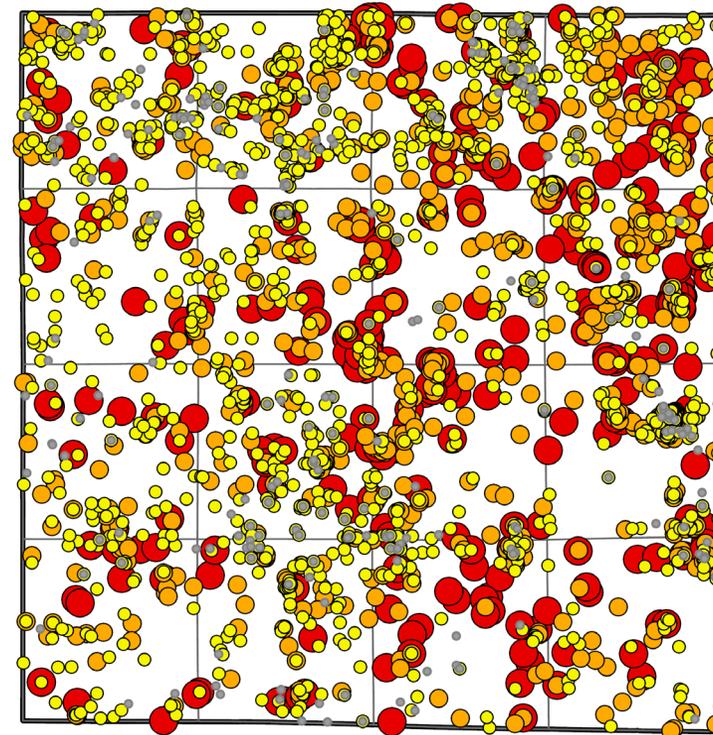
- Nitrate is Wisconsin's most widespread groundwater contaminant.
- Nitrate levels > 10 mg/L are considered unsafe.
- Drinking water with high levels of nitrate is unsafe for everyone. Potential health effects include:
 - Blue baby syndrome in infants
 - Central nervous system malformations
 - Miscarriages
 - Various cancers (ex. gastric, bladder)
 - Thyroid function
 - Diabetes in children



Data from the DNR [Groundwater Retrieval Network \(GRN\)](#)

Nitrate in Green County

- Since 2000, about 10% of samples collected from private and public wells exceeded the regulatory threshold of 10 mg/L (red large circles).
- Since 2000, about 13% of samples collected from private wells exceeded the regulatory threshold of 10 mg/L.



Data from the DNR [Groundwater Retrieval Network \(GRN\)](#)

Legend

Nitrate or Nitrate+Nitrite as Nitrogen (N) in mg/L

• Non detected

• 0.1-5

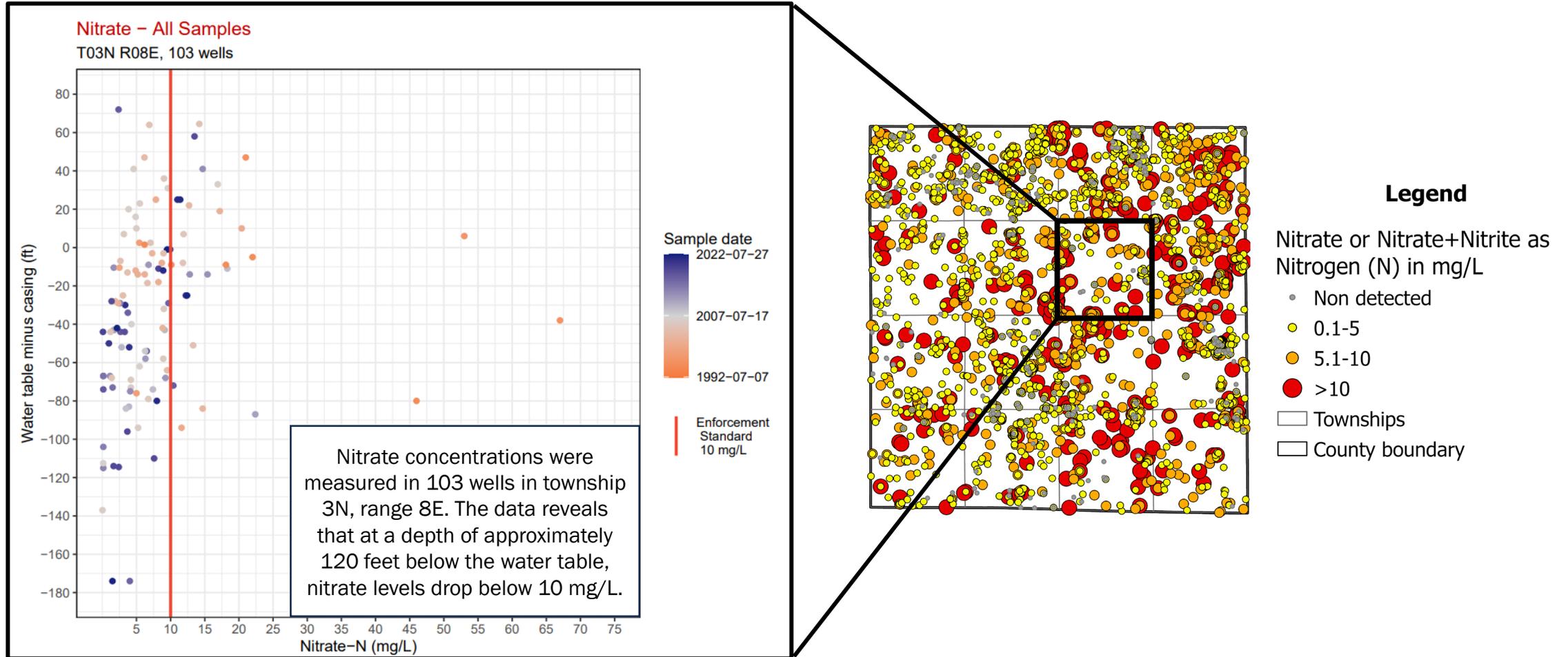
• 5.1-10

• >10

□ Townships

□ County boundary

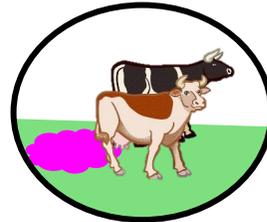
Nitrate in Green County – A 3D problem



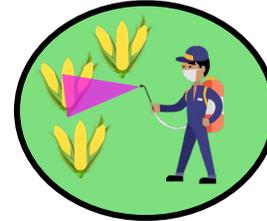
[GRN Nitrate penetration graphs](#)

Sources of Nitrogen

- Nitrogen is a naturally occurring compound, that is also one of the most manufactured chemical on earth.
- Nitrogen becomes nitrate through nitrification
- Agricultural sources:
 - Synthetic fertilizer
 - Livestock waste
 - Contaminated irrigation water.
- Urban sources:
 - Lawn fertilizer
 - Septic systems
 - Wastewater and treated sewage.



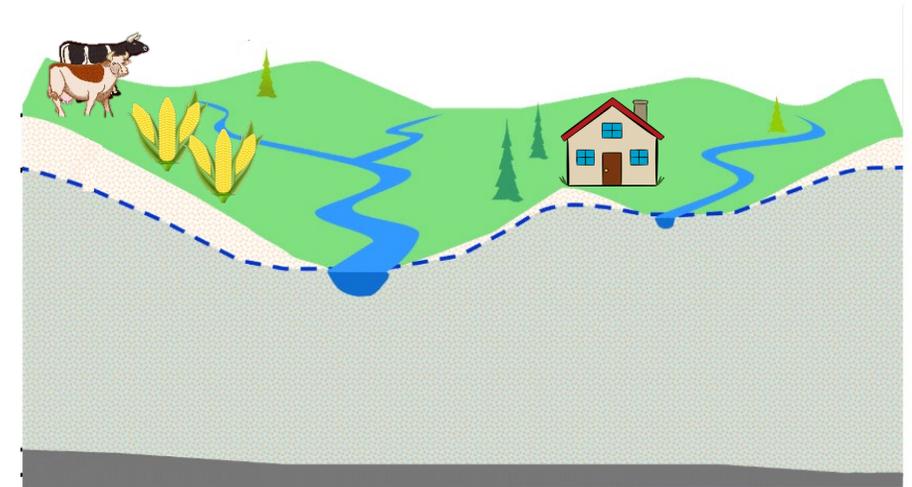
Livestock waste



Chemical fertilizer application



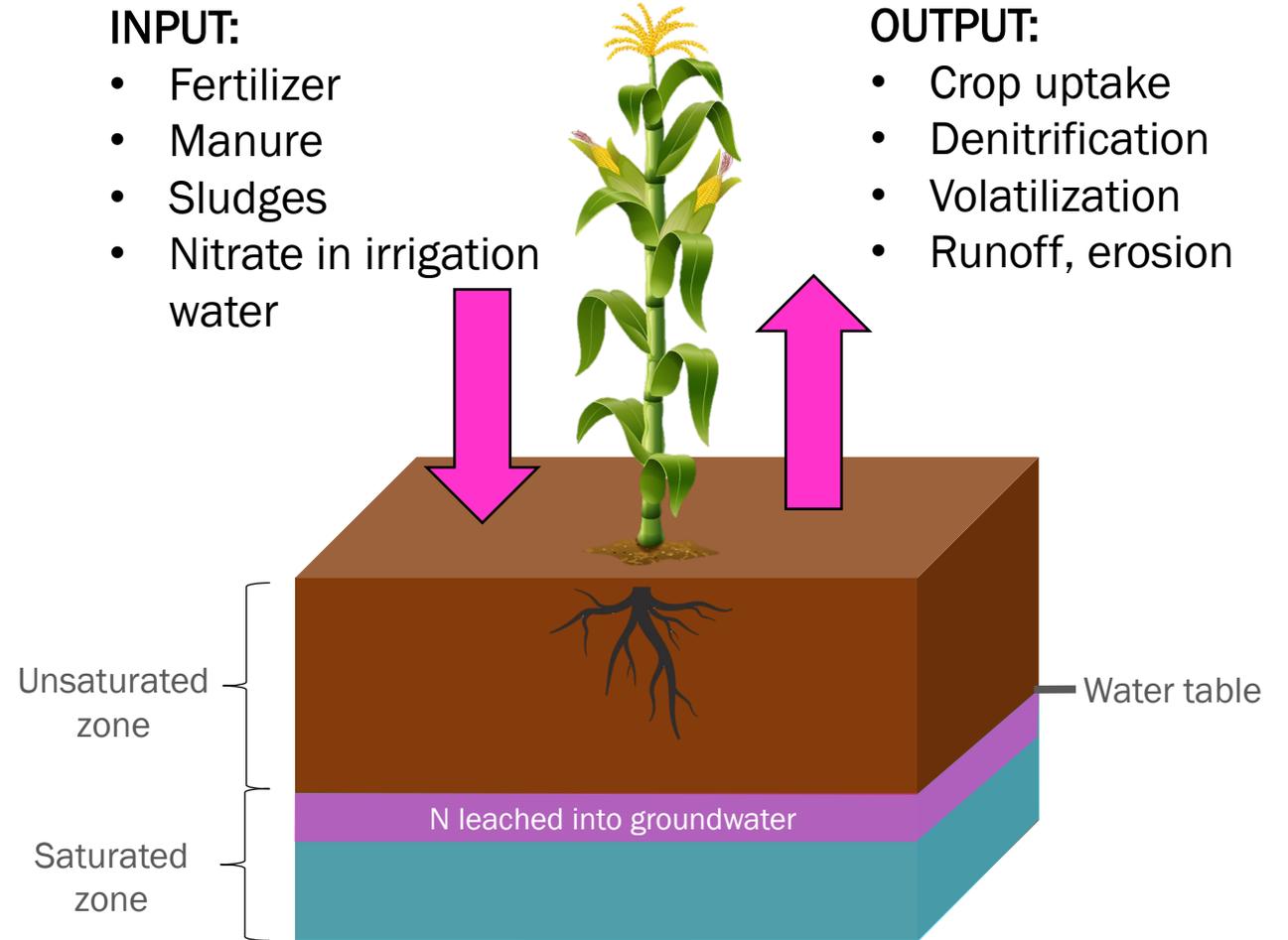
Leaky septic system



Modified from Masarik et al.,(2025), [Water WELLness: Managing Your Private Well Water System](#)

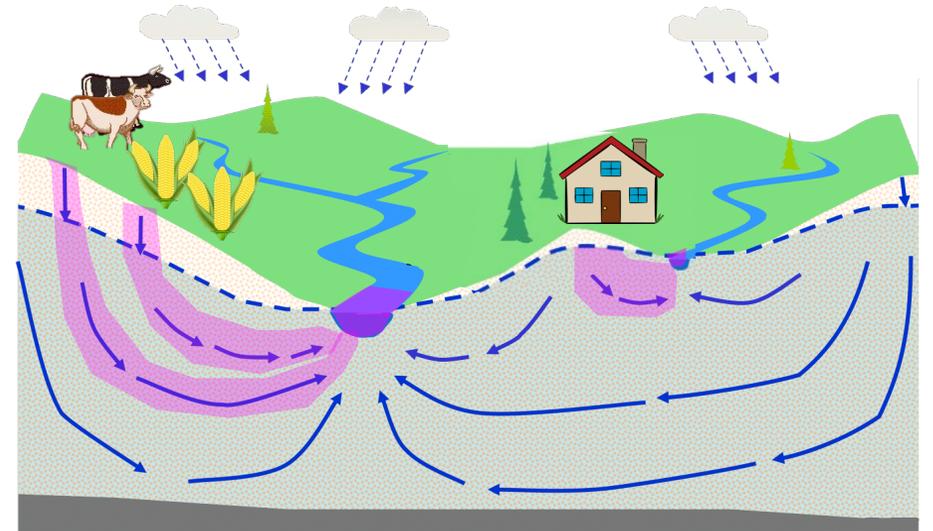
Nitrogen budget

Nitrogen leaching into groundwater
=
INPUT - OUTPUT



Nitrate movement in groundwater

1. Nitrate is highly soluble. When it rains or snow melts, or crops are irrigated, excess nitrate on the land surface or in the soil dissolves into the water.
2. Nitrate does not absorb easily to soil particles, rather moves downward with infiltrating precipitation or irrigation water.
3. Nitrate leaches through the unsaturated zone, until it reaches groundwater.
4. Once in groundwater, nitrate does not break down easily.



Modified from Masarik et al.,(2025), [Water WELLness: Managing Your Private Well Water System](#)

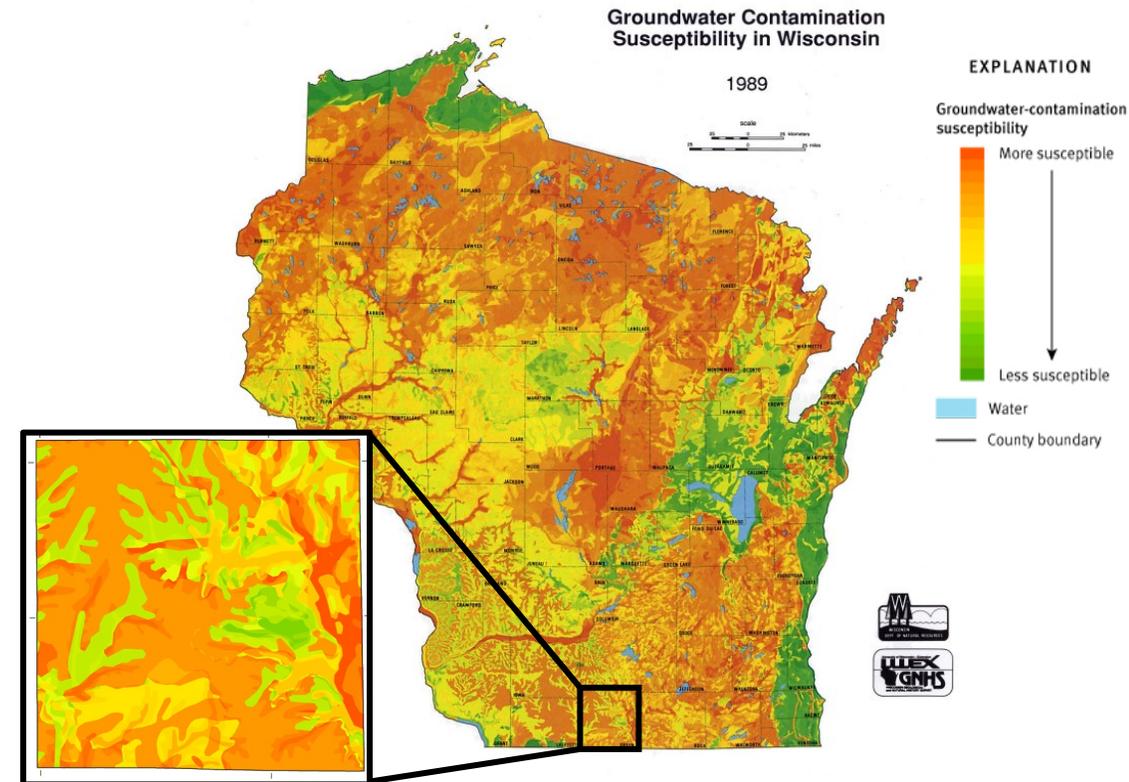
What are the factors influencing leaching of nitrate in groundwater?

Natural factors

- Type of bedrock
 - Fractured bedrock allows rapid movements of water and contaminants
- Depth to bedrock
 - If the bedrock is shallow, the type of bedrock is more important
- Soil type
 - Sandy and coarse grained soils allow contaminants to migrate to groundwater more quickly.
- Water table
 - The closer the water table is to the land surface, the less contact contaminants have with filtering materials
- Absence of clay layers that act as a “barrier” for deep aquifers or groundwater resources

Non- natural factors

- Excessive Nitrogen input



Factors influencing leaching of nitrate in groundwater?

Natural factors

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Non- natural factors

- Excessive Nitrogen input

Can we reduce
nitrogen input?

Ongoing efforts – nitrogen calculators

- An online tool funded by DNR and developed by UW-Madison (Kucharick et al.), using Agrolbis.
- Provides results for the Midwest based on local variables for each grid.
- Useful for corn management, with a focus on nutrient use and groundwater quality.

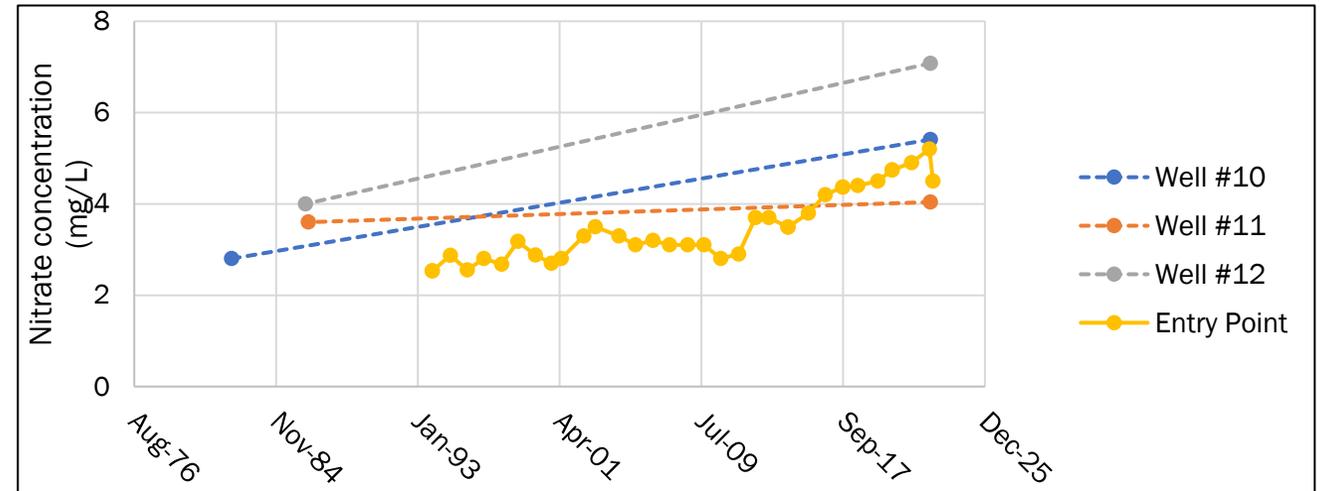


LIVE DEMO

<https://connect.doit.wisc.edu/agrolbisDST/>

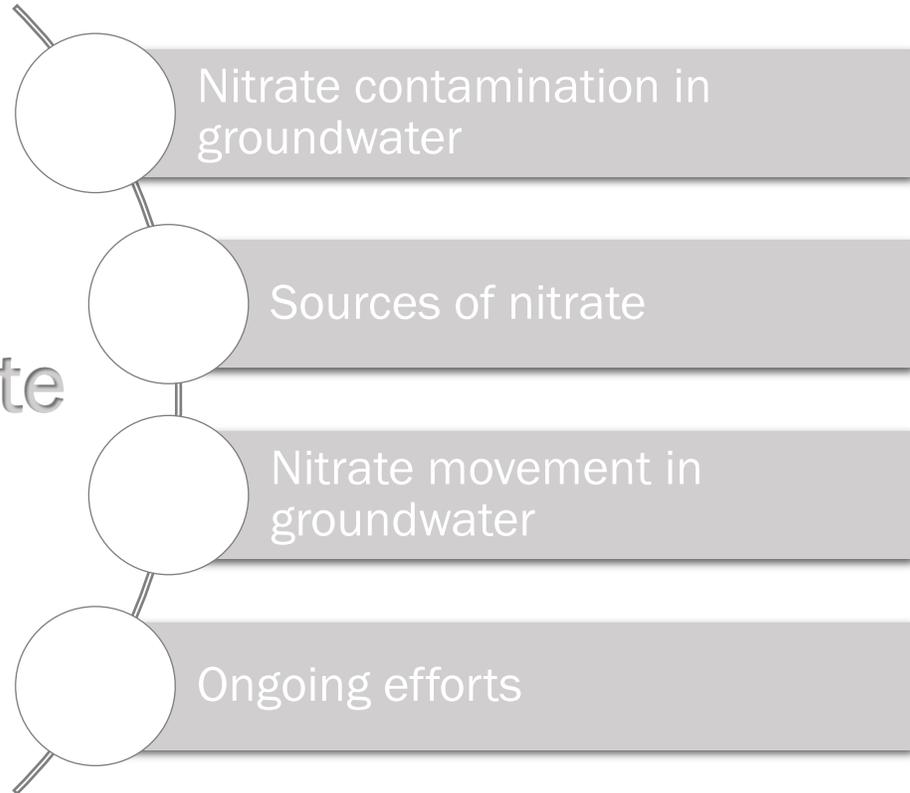
Ongoing efforts – Athens case study

- Analyzed data to pinpoint wells with rising nitrate levels.
- Worked with the County, Wisconsin Rural Water Association, local farmer, municipality.
- Actions:
 - Modeling to determine nitrate contributions.
 - Engaged a local farmer to adopt land practices that would reduce N input.
 - Increased sampling frequency at shallow public wells for enhanced monitoring.

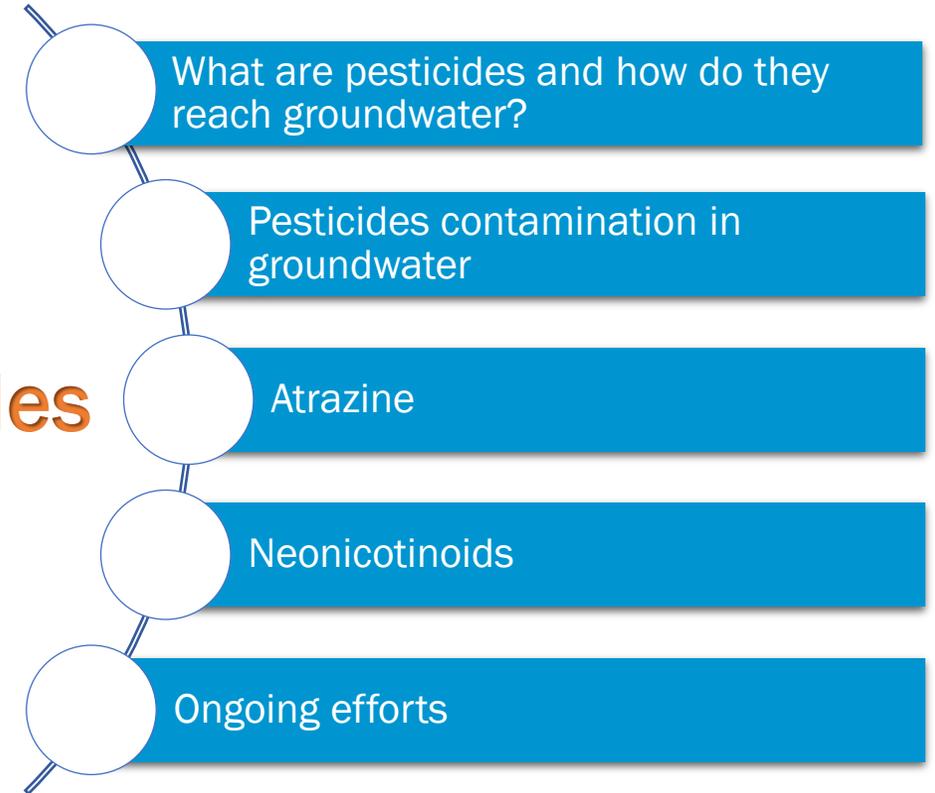


Agenda

Nitrate



Pesticides



What are pesticides?

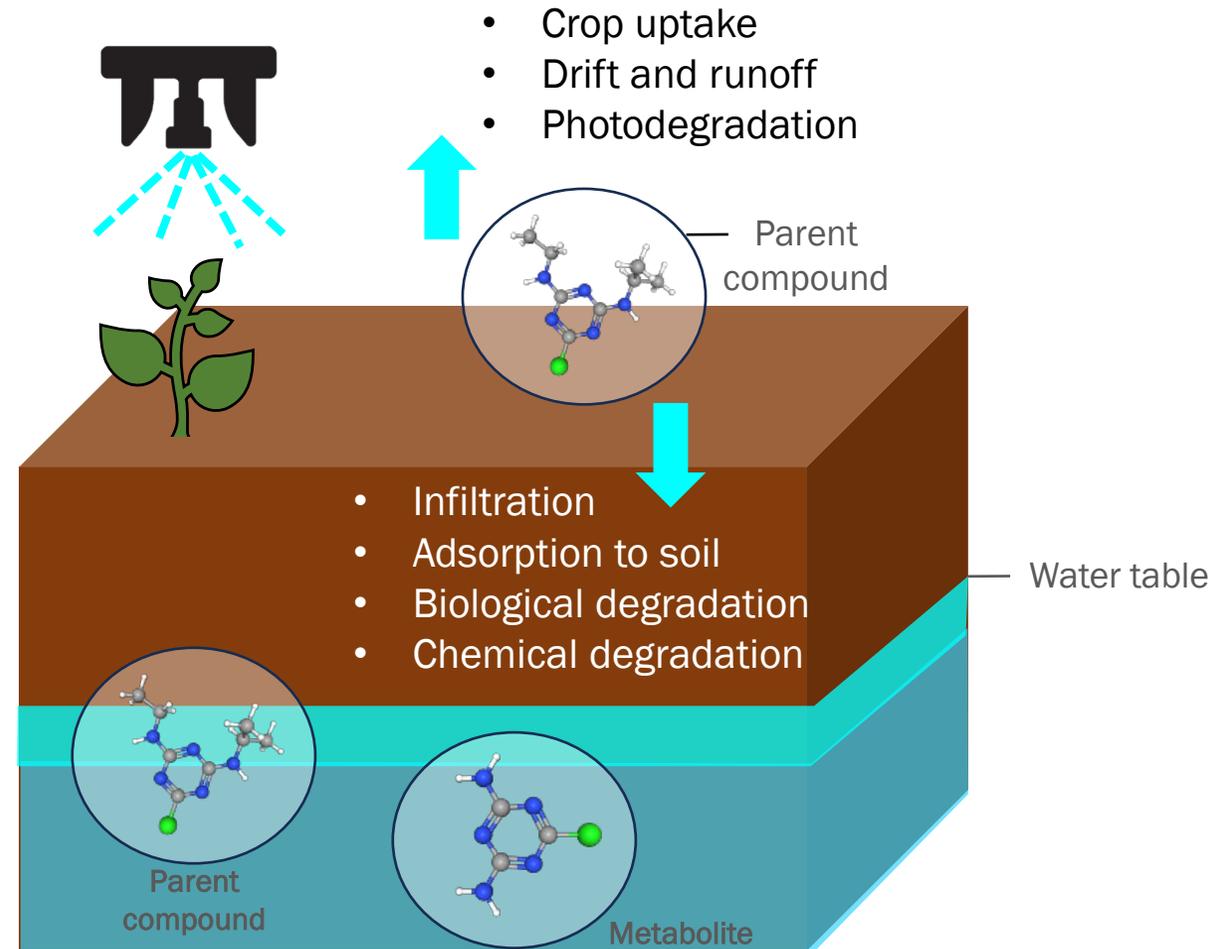
A pesticide is a substance used to kill, repel, or control certain forms of organisms that are considered to be pests. The pesticide category includes herbicides, insecticides, rodenticides, fungicides, and bactericides.

- About **13,000 pesticide products** are currently registered in WI
- There are approximately **500 unique pesticide active ingredients** used in Wisconsin



General fate of pesticides

1. A pesticide is applied as an active ingredient.
2. Part of the applied pesticide is taken up by the crop, and part may drift or runoff.
3. The applied parent compound degrades into metabolites through:
 - Photolysis (sunlight exposure) and/or;
 - Microbial decomposition (fungi and bacteria in the soil) and/or;
 - Hydrolysis (chemical reaction with water).
4. Pesticide compounds (parent material and/or metabolites) may stick to soil particles.
5. Pesticide compounds leach into groundwater.



Factors influencing leaching of pesticides into groundwater

1. Input & Application

- Method: e.g., soil injection increases leaching risk vs. foliar sprays.
- Formulation: e.g., liquids move faster; granules provide a "slow release" over time.
- Timing: application just before heavy rain/irrigation triggers immediate transport.

2. Pesticides Properties

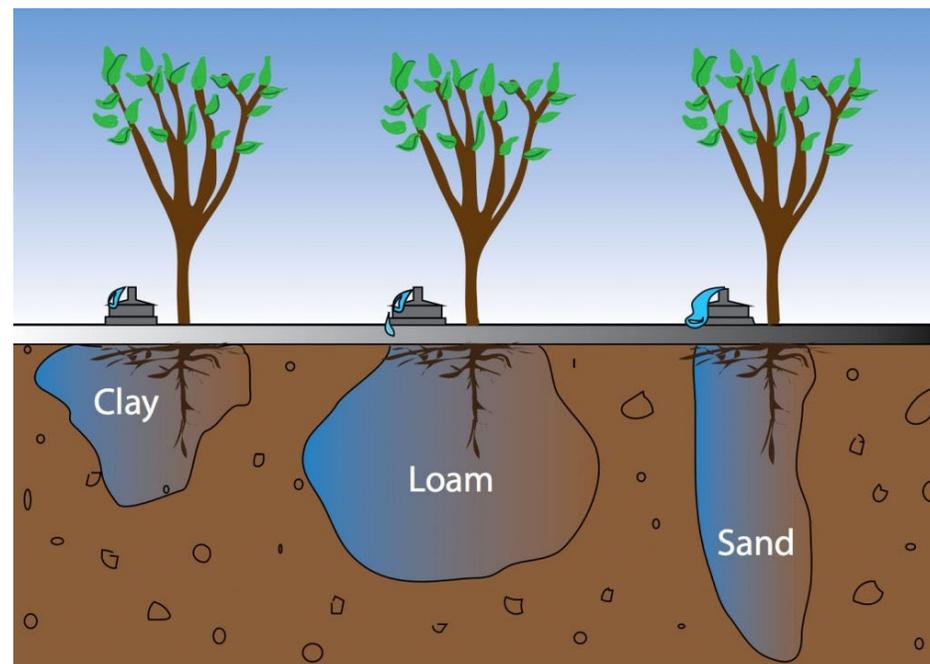
- Solubility: high solubility increases the likelihood of the chemical dissolving in rain or irrigation water and moving downward.
- Adsorption: high adsorption means the chemical stays bound to the soil; this may allow the pesticide to have more time to breakdown in soil before reaching groundwater.
- Persistence (half life in soil): dictates how fast a compound will degrade into a metabolite.



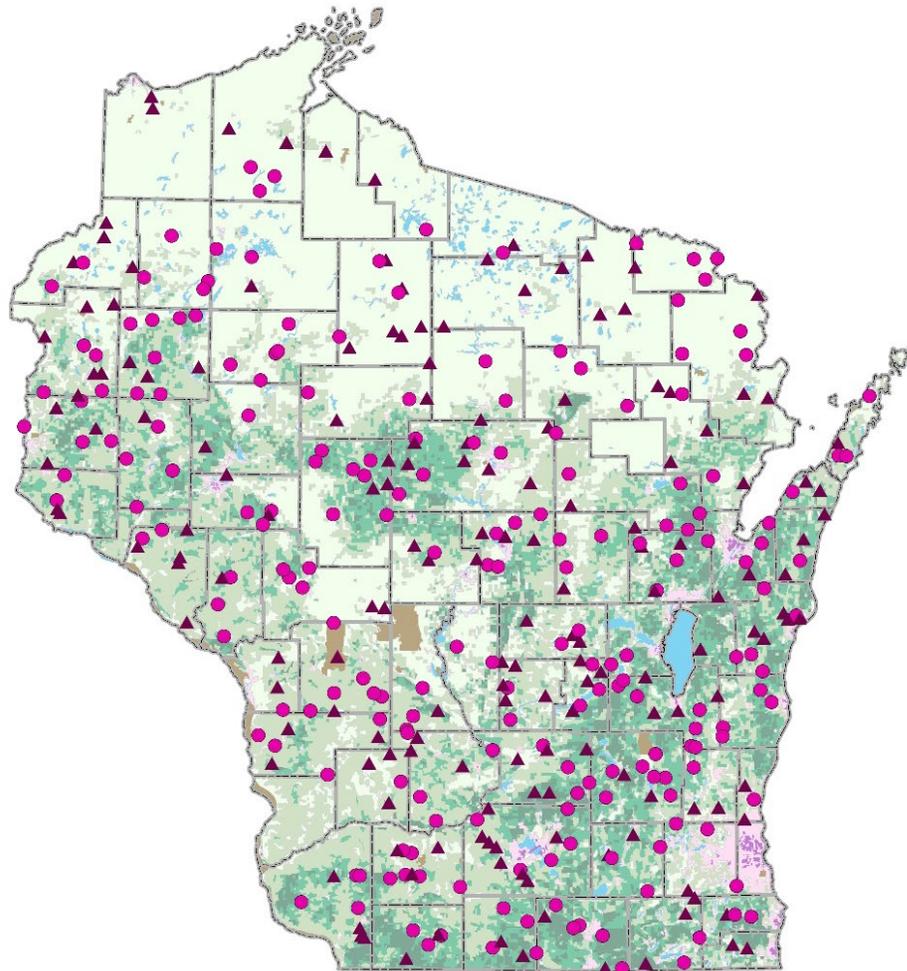
Factors influencing leaching of pesticides into groundwater

3. Natural factors

- Soil texture: sand (coarse/large pores) leaches faster than clay (fine/tight pores).
- Soil organic Matter: high organic matter increases sorption of the pesticide to the soil.
- Water Volume: Excess rain or irrigation promotes infiltration of pesticides downward.
- Water Table: Shallow aquifers are reached more quickly than deep ones.
- Other hydrogeological conditions (bedrock depth, bedrock type, etc.)



2023 DATCP survey



DATCP, [Agricultural chemicals in Wisconsin groundwater](#) (2023)

- In 2023, DATCP collected a total of 380 untreated water samples from randomly selected private potable wells.
- Each sample was analyzed for nitrate and 106 pesticide compounds (parent material and metabolites).

Legend

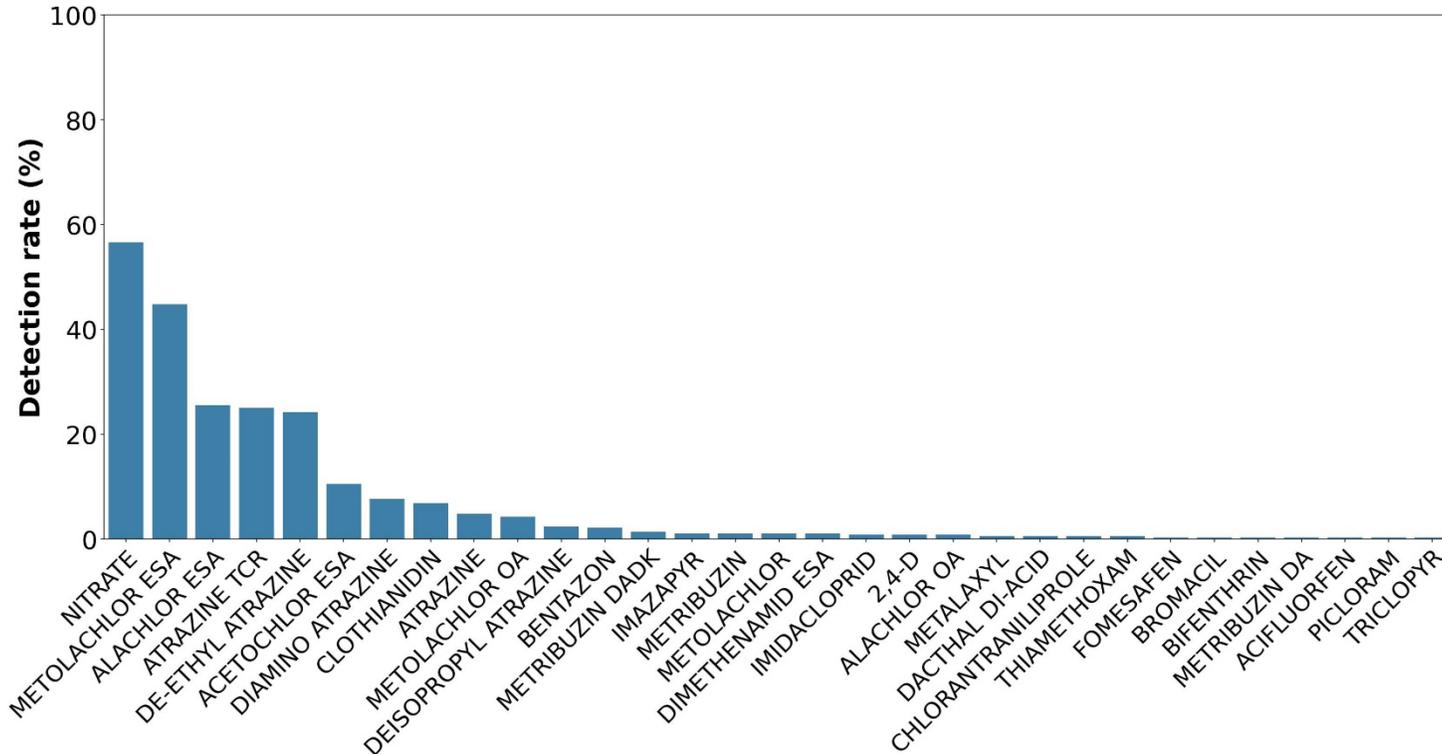
2023 Sampling Locations

- Wells sampled in 2023
- ▲ Wells sampled in 2016 and 2023
- Wisconsin Counties

NASS 2016 Land Use Strata

- < 15% Cultivated
- 15 - 50 % Cultivated
- 51 - 75 % Cultivated
- > 75 % Cultivated
- Agri-Urban
- Commercial
- Non Agricultural
- Water

2023 DATCP survey - detections



- Nitrate + nitrite as N was the most detected compound.
- 30 pesticide compounds detected.
- Metolachlor ESA, alachlor ESA, and atrazine total or TCR, were the most detected pesticide compounds.
- Estimated 43.1% of wells in Wisconsin contained at least one pesticide or pesticide metabolite.

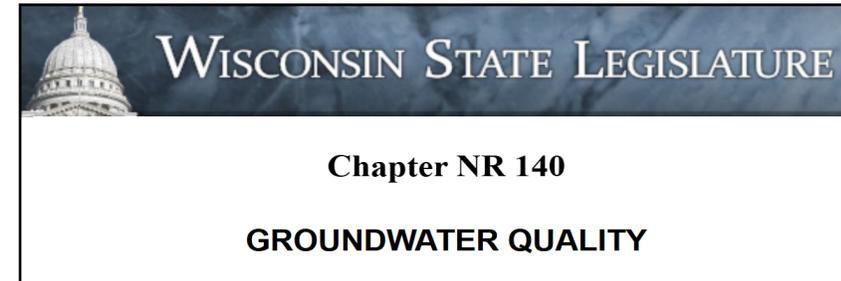
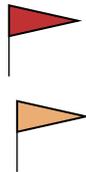
*Atrazine TCR or Total = Atrazine Total Chlorinated Residue, i.e. the sum of atrazine and its metabolites (de-ethyl atrazine, diamino atrazine and deisopropyl atrazine)

Health-based thresholds

Pesticide concentrations are compared with available health-based groundwater standards to evaluate potential human health concerns.

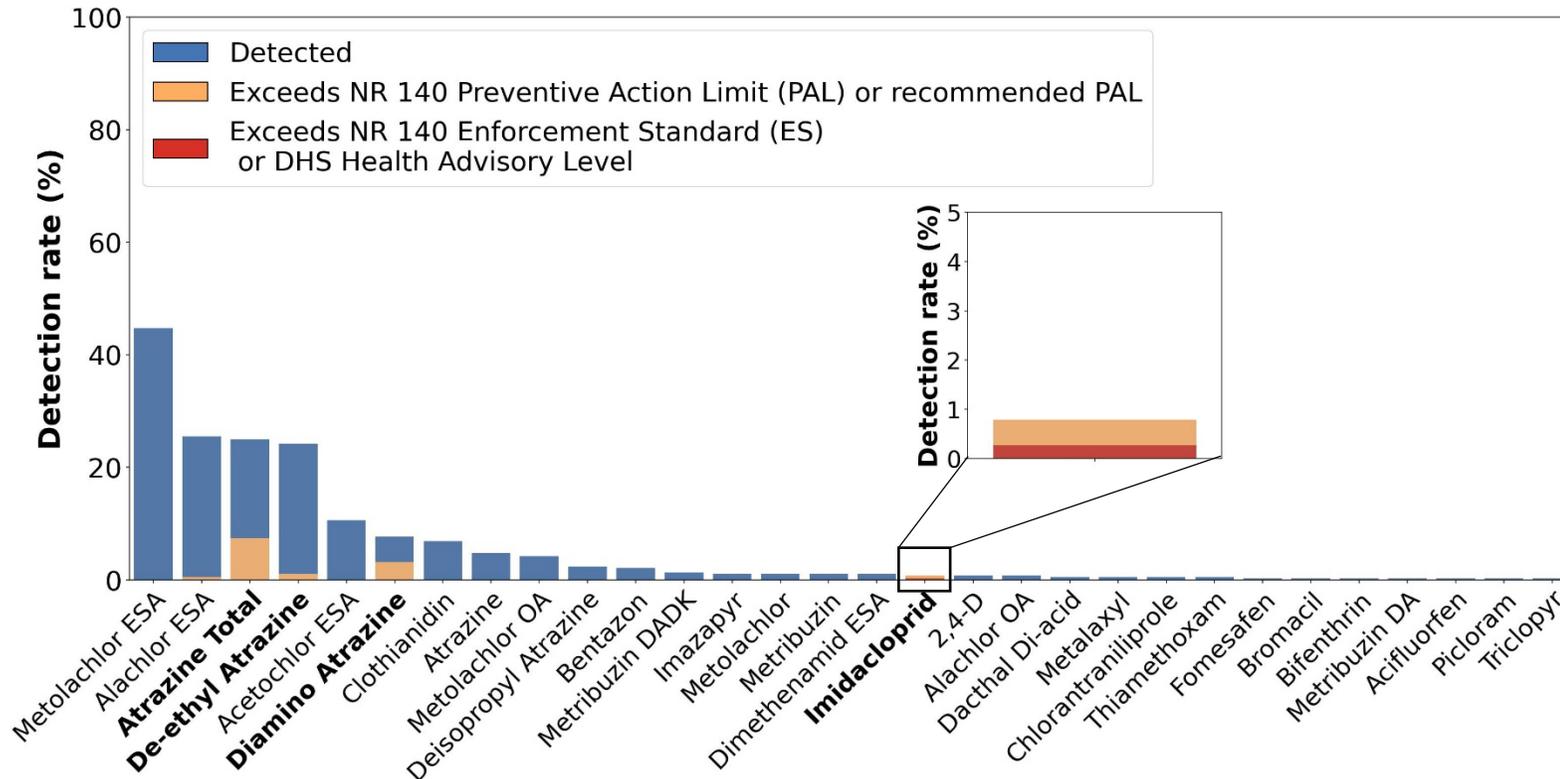
Groundwater standards are established by the WI Admin. Code, Ch. NR 140

- *Enforcement Standards (ES)*
- *Preventive Action Limit (PAL)*



If groundwater standards are not established, refer to available Department of Health Services Health Advisory Levels (DHS HALs)

2023 DATCP survey results - exceedances



- Atrazine Total (atrazine + metabolites) was found in exceedance of the Preventive Action Limit of 0.3 µg/l
- Imidacloprid was found in exceedance of the DHS Health Advisory Level of 0.2 µg/l

*Atrazine TCR or Total = Atrazine Total Chlorinated Residue, i.e. the sum of atrazine and its metabolites (de-ethyl atrazine, diamino atrazine and deisopropyl atrazine)

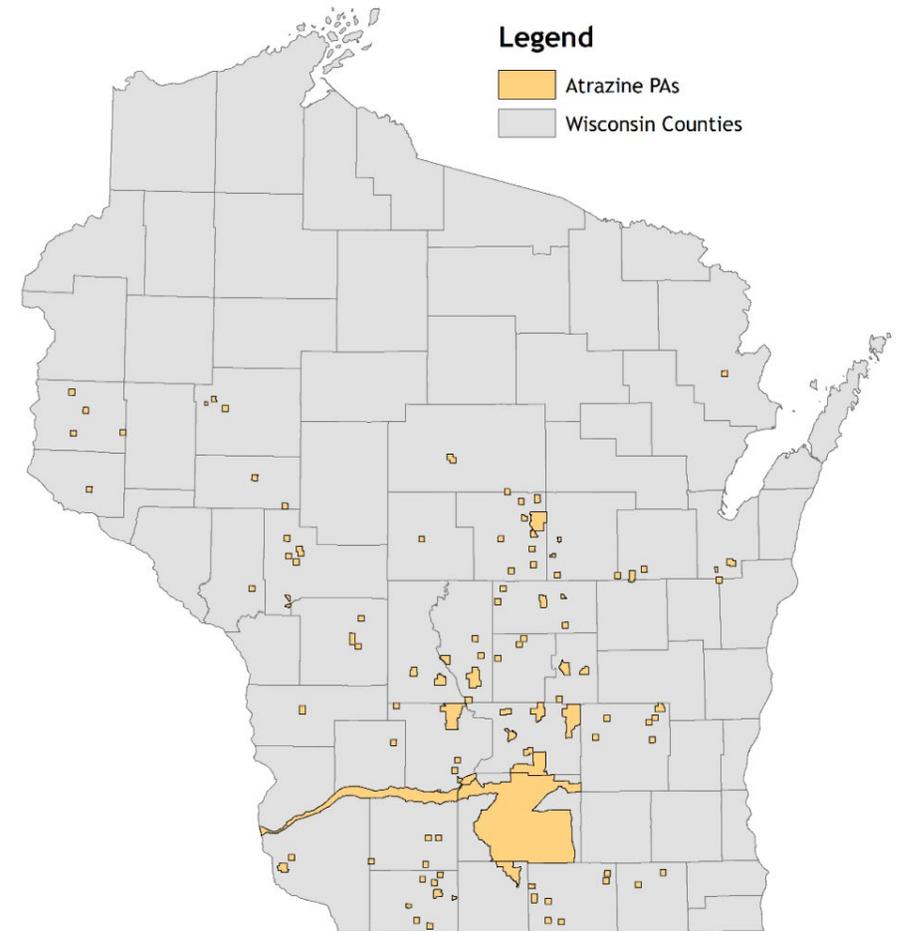
Atrazine

- Herbicide that has been used in Wisconsin for over six decades.
- Atrazine breaks down primarily in de-ethyl atrazine, deisopropyl atrazine, diamino atrazine, and hydroxyatrazine.
- Properties
 - Moderately soluble, allowing to easily move in water.
 - Low adsorption.
 - Half life in soil between 28 and 150 days (biological degradation).
 - Very persistent in groundwater due to low microbial activity and absence of light.
- Damage to the liver, kidneys, and heart has been observed in animals exposed to atrazine. Research also suggests a link between atrazine exposure and several types of cancer.



Atrazine restricted use in WI

- In 1988 NR 140 groundwater standards were established for atrazine total (ES= 3 µg/l; PAL= 0.3 µg/l).
- DATCP investigations linked the exceedances to a non-point source pollution.
- DATCP updated ATCP 30 to restrict the use of atrazine in Wisconsin by:
 - Limiting timing and application rates statewide.
 - Prohibiting use in 101 areas.
- DATCP recently assessed that at least 60% of the atrazine prohibition areas appear to be effective.



DATCP (2025). [An Evaluation of Atrazine in Wisconsin Groundwater.](#)

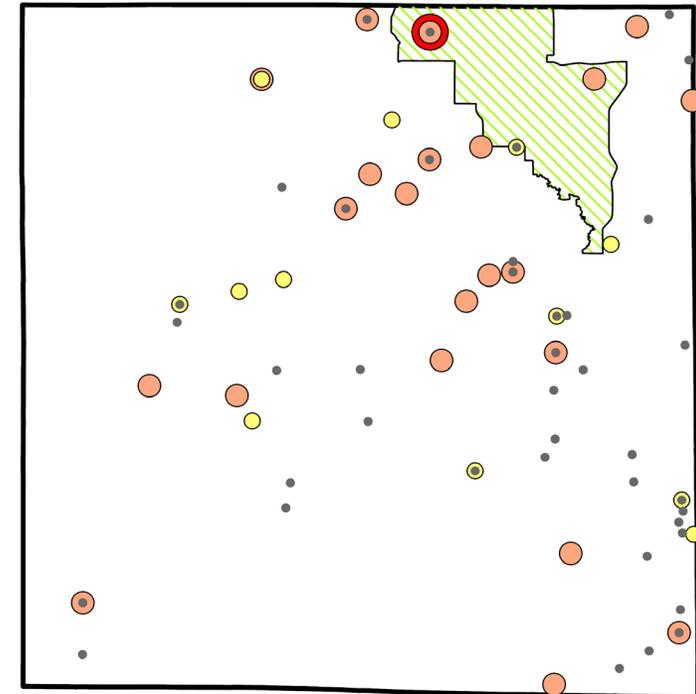
Atrazine in Green County

- Atrazine Prohibition Area was established in Green County in 1996.
- Since 2000, Atrazine Total (atrazine plus de-ethyl atrazine, deisopropyl atrazine, and diamino atrazine) concentrations exceeded the ES of 3 µg/l only in one instance.

Legend

Atrazine Total concentration (µg/l) since 2000

- Non detected
- 0.01 - 0.3
- 0.3 - 3
- >3
- ▨ Atrazine Prohibition Area
- County boundary



Data provided by the Wisconsin Department of Agriculture, Trade and Consumer Protection.

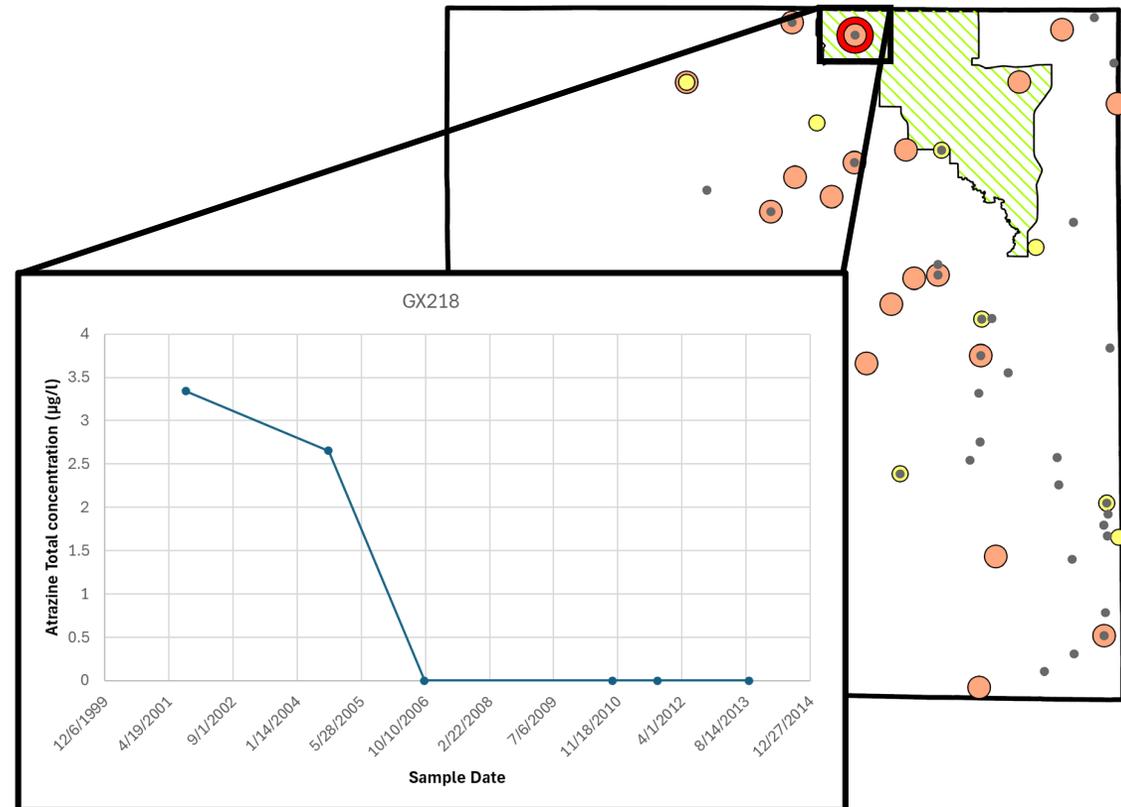
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- Since 2000, Atrazine Total (atrazine plus de-ethyl atrazine, deisopropyl atrazine, and diamino atrazine) concentrations exceeded the ES of 3 µg/l only in one instance.
- The well with the recorded exceedance is in a prohibition area; concentrations of Atrazine Total decreased over time.

Legend

Atrazine Total concentration (µg/l) since 2000

- Non detected
- 0.01 - 0.3
- 0.3 - 3
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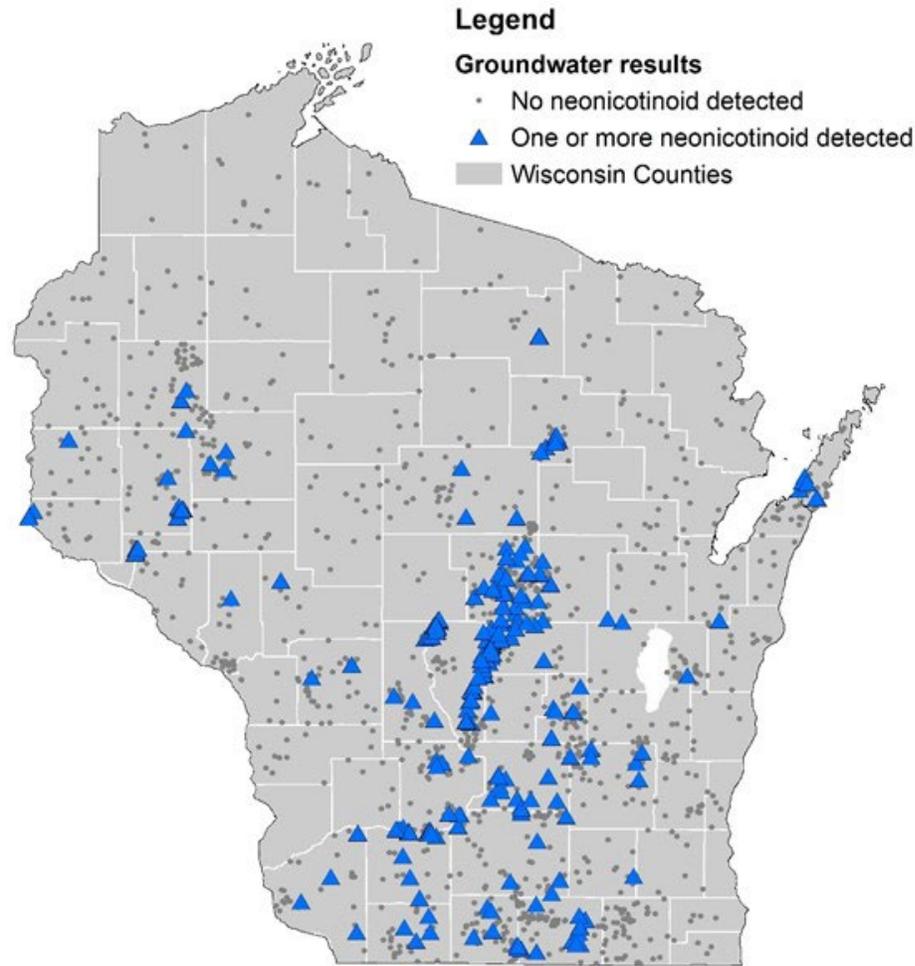


Imidacloprid and other neonicotinoids

- Imidacloprid, clothianidin and thiamethoxam are widely used insecticides in the US.
- Primarily applied as seed treatment to avoid drift and runoff.
- Properties
 - Highly water soluble
 - Moderate to long half-life in soil (1 to >1,000 days)
 - Stable to hydrolysis
 - Faster degradation under UV light (photodegradation)
 - Low to moderate soil adsorption
- Potential adverse human health effects, including impact on development, and on nervous and reproductive systems.



Neonicotinoids detections in groundwater



Wisconsin Department of Agriculture, Trade and Consumer Protection (2024)

- From 2008 to 2023, DATCP tested 1,690 monitoring and private potable wells at least once for one or more neonicotinoid compounds; collected a total of 3,486 groundwater samples.
- One or more neonicotinoids were detected in:
 - 287 wells (~17%)
 - 1,029 groundwater samples (~30%)

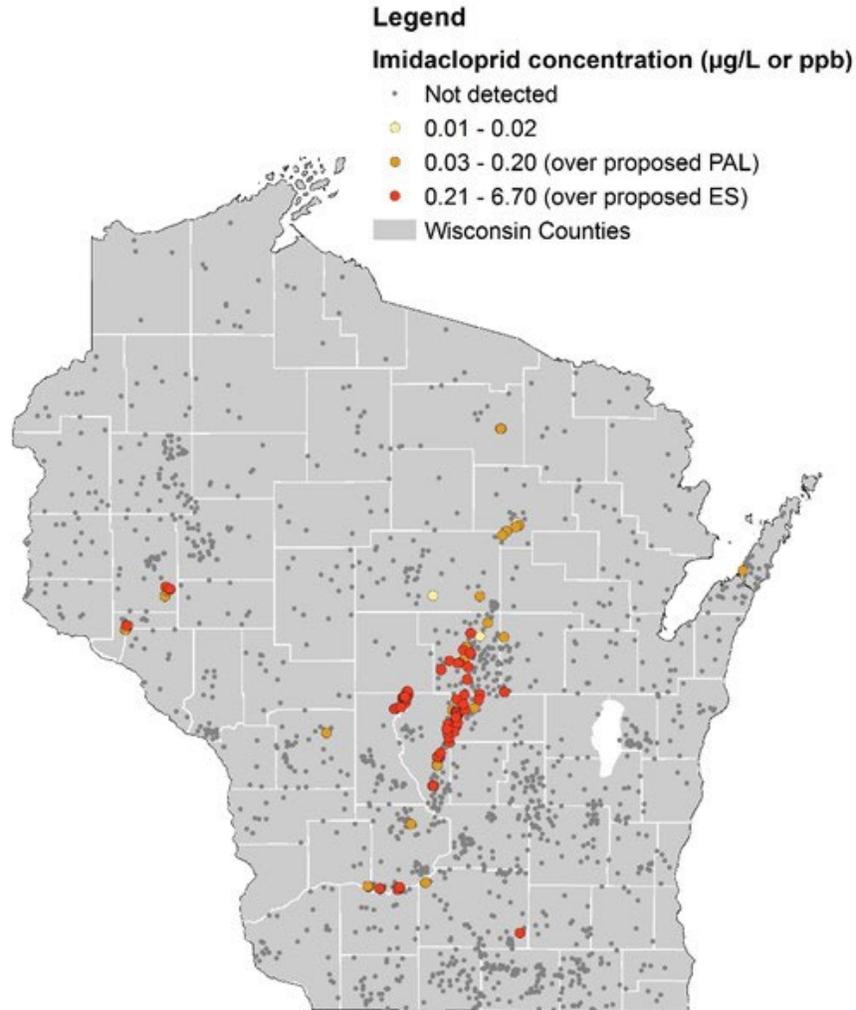
Health benchmarks in Wisconsin

There are currently no federal or state drinking water standards or NR 140 groundwater standards established for neonicotinoids.

Compound	2019 DHS Health Advisory Level ($\mu\text{g}/\text{L}$ or ppb)
Clothianidin	1,000
Imidacloprid	0.2
Thiamethoxam	120

For more information, visit <https://www.dhs.wisconsin.gov/water/gws.htm>

Imidacloprid exceedances in groundwater



Wisconsin Department of Agriculture, Trade and Consumer Protection (2024)

DATCP data from 2008 to 2023 reported that:

- Clothianidin or thiamethoxam have not been found in exceedances of DHS Health Advisory Levels.
- Imidacloprid concentrations exceeded the DHS Health Advisory Level of 0.2 $\mu\text{g/L}$, mostly in the Central Sands Region, Lower Wisconsin River Valley, and parts of western Wisconsin.
- No imidacloprid exceedances have been found in Green County.

Groundwater standards for neonicotinoids

DNR asked DHS to develop recommendations for several pesticides including clothianidin, imidacloprid and thiamethoxam

2018

2019

DHS developed recommendations for clothianidin, imidacloprid and thiamethoxam

DNR started rulemaking to establish NR 140 groundwater quality standards for the three neonics

2019

2022

The Natural Resource Board did not approve the rule

DNR asked DHS to develop recommendation for several pesticides, including neonicotinoids.

2026

Groundwater standards for neonicotinoids

- DNR manages the rulemaking process of NR140 for establishing groundwater standards for pesticides.
- Implementing groundwater standards in NR 140 does not automatically change pesticide use.
- If NR140 groundwater standards are exceeded, DATCP may impose pesticide use restrictions.
- Any potential pesticide use change require a rulemaking process led by DATCP.



Conclusions

Nitrate

- Nitrate is the most widespread contaminant in Wisconsin groundwater
- Targeted actions can be taken to reduce inputs (diversifying of crop rotation, cover crops, efficiently use nitrogen inputs).
- We will continue to work collaboratively with stakeholders to protect drinking water in a sustainable manner.

Pesticides

- Multiple pesticide compounds are detected in Wisconsin groundwater.
- Despite restrictions, atrazine and atrazine metabolites continue to be detected, though prohibition areas have been mostly effective to date.
- Neonicotinoids, including imidacloprid, remain a concern, and DNR is actively working to establish groundwater standards.

CONNECT WITH US

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OFF THE RECORD"