
# Emerging contaminants in Cape Cod drinking water: Where are they coming from and how worried should we be?

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Silent Spring Institute, Newton, MA

MWRA Water Supply Citizens Advisory Committee, December 8, 2015

Science on msnbc.com

# Study: Male bass in many U.S. rivers feminized

**Intersex fish linked to birth control pills, other hormones seeping into rivers**

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Dayton Daily News

## Testing reveals low levels of drugs in drinking water source

Agencies discourage flushing of prescriptions

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THE TENNESSEAN

## Chemicals on tap demand caution

**Consumers can do most to contain questionable substances in water**

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USA TODAY

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At the Orange County Sanitation District, a settling basin is used to filter water as part of the advanced secondary treatment, before the water is diverted into the ocean, in Fountain Valley, Calif. Pharmaceuticals in waterways are damaging wildlife across the nation and around the globe, research shows.

By Ric Francis, AP

## AP: Drugs found in drinking water

Updated 9/12/2008 2:02 PM | Comments 149 | Recommend 83

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**By Jeff Donn, Martha Mendoza and Justin Pritchard, Associated Press**

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What's this?

A vast array of pharmaceuticals — including antibiotics, anti-convulsants, mood stabilizers and sex hormones — have been found in the drinking water supplies of at least 41 million Americans, an Associated Press investigation shows.

To be sure, the concentrations of these pharmaceuticals are tiny, measured in quantities of parts per billion or trillion, far below the levels of a medical dose. Also, utilities insist their water is safe.

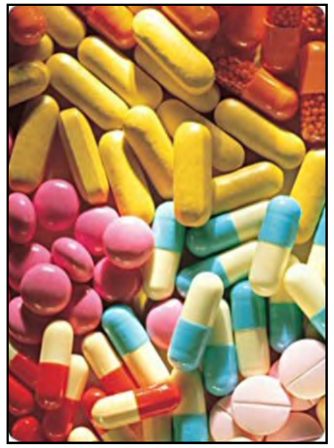
**WATER DEPARTMENTS:** Reports rarely released to public
**BOTTLED WATER:** Is it any safer?
**NEW YORK CITY:** Sedative traces found in water
**LOS ANGELES:** Water tops national taste test
**RELATED:** Problems in fish blamed on contamination

But the presence of so many prescription drugs — and over-the-counter medicines like acetaminophen and ibuprofen — in so much of our drinking water is heightening worries among scientists of long-term consequences to human health.

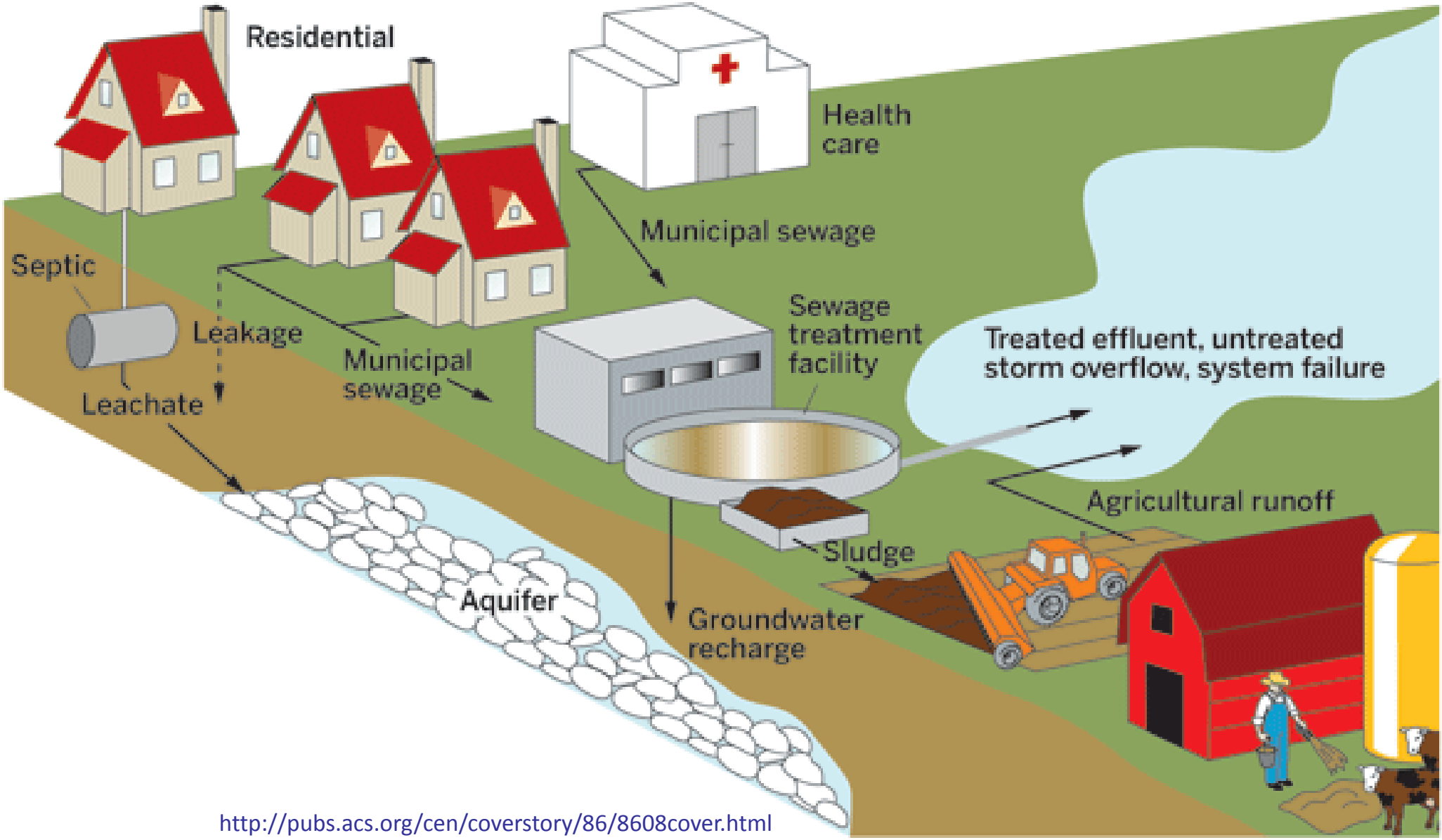

*http://www.b12partners.net/wp/wp-content/uploads/2008/05/mike_keefe_water.jpg*

# Emerging Contaminants
## or Contaminants of Emerging Concern, or Organic Wastewater Contaminants

- Examples: Pharmaceuticals and personal care products (PPCPs), hormones, perfluorinated chemicals, flame retardants
- Not currently regulated in drinking water, some are candidates (CCL3, UCMR3)
- Frequently detected in surface water, groundwater, and drinking water
- Ecological concerns, especially endocrine disruption, and human health concerns



# How do emerging contaminants get into the environment?




http://pubs.acs.org/cen/coverstory/86/8608cover.html

# How do emerging contaminants get into Cape Cod groundwater?

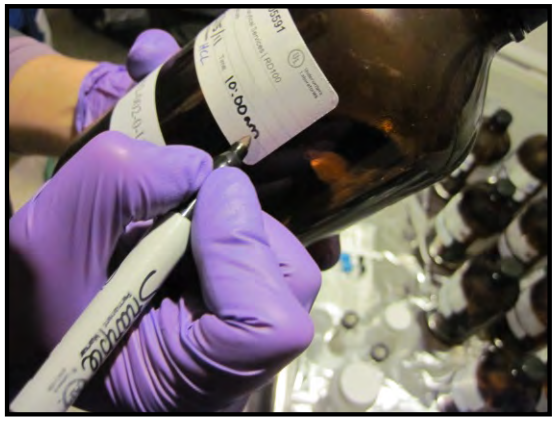

http://pubs.acs.org/cen/coverstory/86/8608cover.html

**Cape Cod drinking water supplies are vulnerable**

- 85% of homes have septic systems
- Sand and gravel sole source aquifer
- Rapid development

# Silent Spring Institute water quality research

- Measure endocrine disruptors and other emerging contaminants in drinking water, groundwater, ponds
- Evaluate septic systems as sources of contaminants and characterize subsurface transport
- Inform Cape wastewater management and drinking water protection decision-making



# Silent Spring Institute
# Cape Cod water research

**Septic systems**

- First study to identify estrogen mimics in household wastewater and groundwater
- Comprehensive survey of OWCs from septic systems and comparisons to sewage treatment plant discharges

*Environ. Sci. Technol.* **1998**, *32*, 861–869

## Identification of Alkylphenols and Other Estrogenic Phenolic Compounds in Wastewater, Septage, and Groundwater on Cape Cod, Massachusetts

RUTHANN A. RUDEL,*,† STEVEN J. MELLY,† PAUL W. GENO,‡ GANG SUN,‡ AND JULIA G. BRODY†

*Silent Spring Institute, 29 Crafts Street, Newton, Massachusetts 02158, and Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas 78228-0510*

# Silent Spring Institute
# Cape Cod water research

Septic systems

**Groundwater**

*Environ. Sci. Technol.* **2006**, *40*, 4894–4902

**Steroid Estrogens, Nonylphenol Ethoxylate Metabolites, and Other Wastewater Contaminants in Groundwater Affected by a Residential Septic System on Cape Cod, MA**

CHRISTOPHER H. SWARTZ,*,†,‡ SHARANYA REDDY,§ MARK J. BENOTTI,§ HAIFEI YIN,§ LARRY B. BARBER,⊥ BRUCE J. BROWNAWELL,§ AND RUTHANN A. RUDEL†

- Some hormone disruptors and other OWCs are persistent in groundwater
- Persistence of OWCs depends on dissolved oxygen levels

Environmental Toxicology and Chemistry, Vol. 27, No. 12, pp. 2457–2468, 2008

# WASTEWATER-CONTAMINATED GROUNDWATER AS A SOURCE OF ENDOGENOUS HORMONES AND PHARMACEUTICALS TO SURFACE WATER ECOSYSTEMS

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Septic systems

Groundwater

Ponds more impacted by residential development have more hormones and pharmaceuticals

**Ponds**

# Today's presentation

Science of the Total Environment 468–469 (2014) 384–393

Pharmaceuticals, perfluorosurfactants, and other organic wastewater compounds in public drinking water wells in a shallow sand and gravel aquifer ☆

Laurel A. Schaider *, Ruthann A. Rudel, Janet M. Ackerman, Sarah C. Dunagan, Julia Green Brody

*Silent Spring Institute, 29 Crafts Street, Newton, MA 02458, USA*

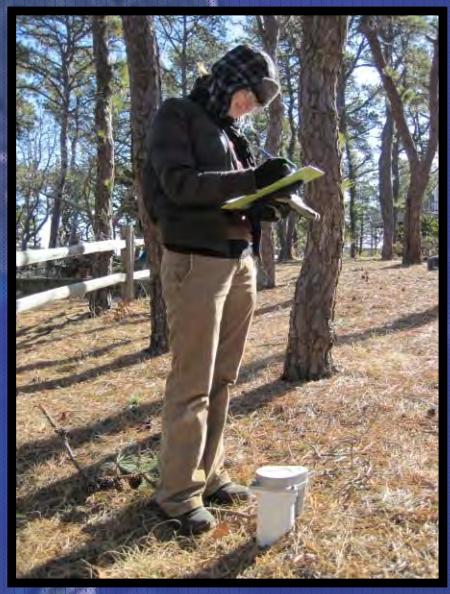
Septic systems

Groundwater

Ponds

Public wells

Private wells



# Drinking water study objectives

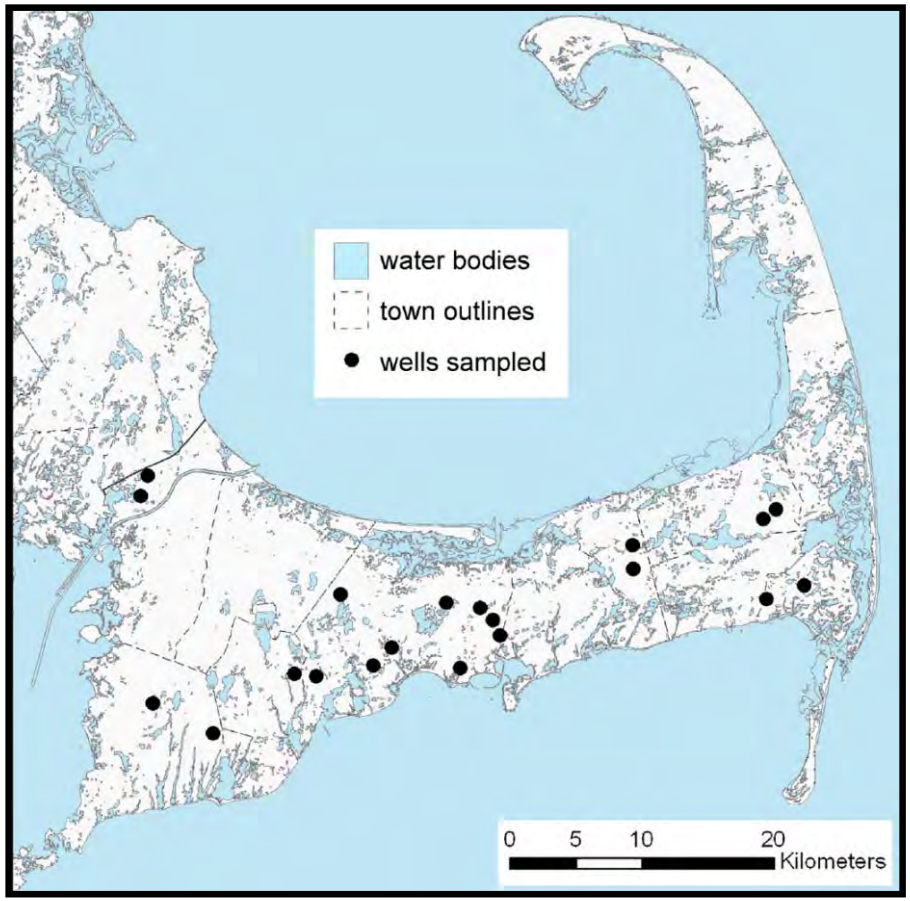
- Measure OWCs in Cape Cod public drinking water wells
- Compare results to other U.S. drinking water sources and to health-based guideline values
- Determine whether land use and chemical wastewater markers are predictors of OWCs
- Inform local discussion of wastewater management and drinking water protection

# Chemical analyses


- Raw water tested for ~100 OWCs
  - PPCPs (pharmaceuticals, fragrances)
  - Hormones (synthetic and endogenous)
  - Perfluorinated chemicals (PFOS, PFOA)
  - Alkylphenols and AP ethoxylates
  - Herbicides
  - Organophosphate flame retardants (e.g., TCEP, TDCPP)
- QA/QC samples (blanks, matrix spike, duplicates)
- Methods: SPE followed by LC/MS/MS or GC/MS
- Analyses conducted by Underwriters Laboratories

# Sample collection

- Collected October 2009
- 20 wells in 9 water districts
- Wastewater impact assessed using recent nitrate ($NO_3^-$) and extent of development in recharge areas
- Range of pollution impact
  - $[NO_3^-]$: <0.1 to 5.3 mg/L
  - Median $[NO_3^-]$: 1 mg/L
  - Median for 9 districts:  0.7 mg/L

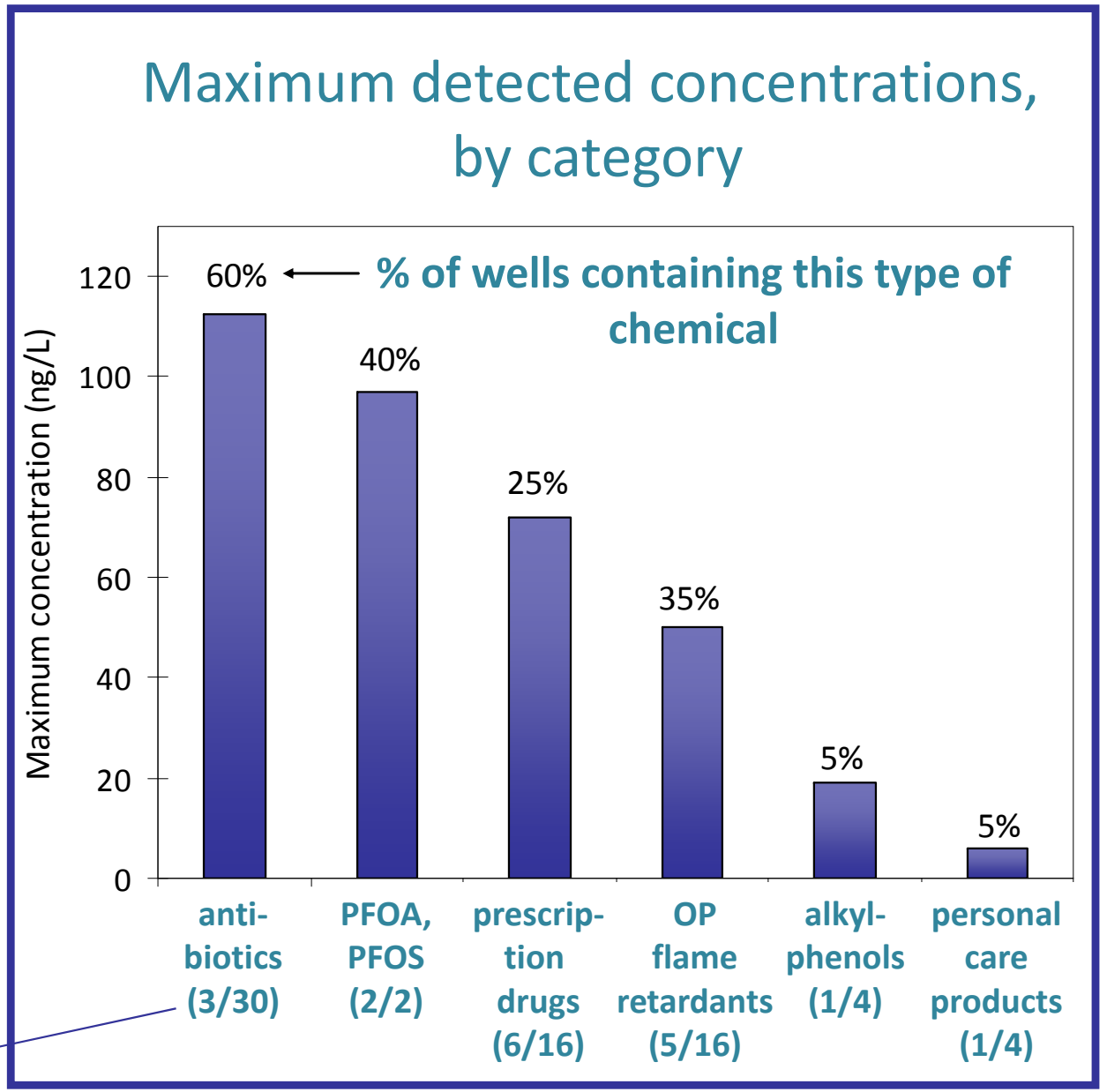



Schaider et al. 2014. *Sci Tot Env*. 468-9:384-93.

# Results: OWCs in public wells

- 18 OWCs detected
- OWCs detected in 15 of 20 wells
- 0–12 OWCs per well
- Most frequently detected:
  - Sulfamethoxazole *(antibiotic)*
  - PFOS *(perfluorinated chemical)*

For each category,
(number detected / number tested)

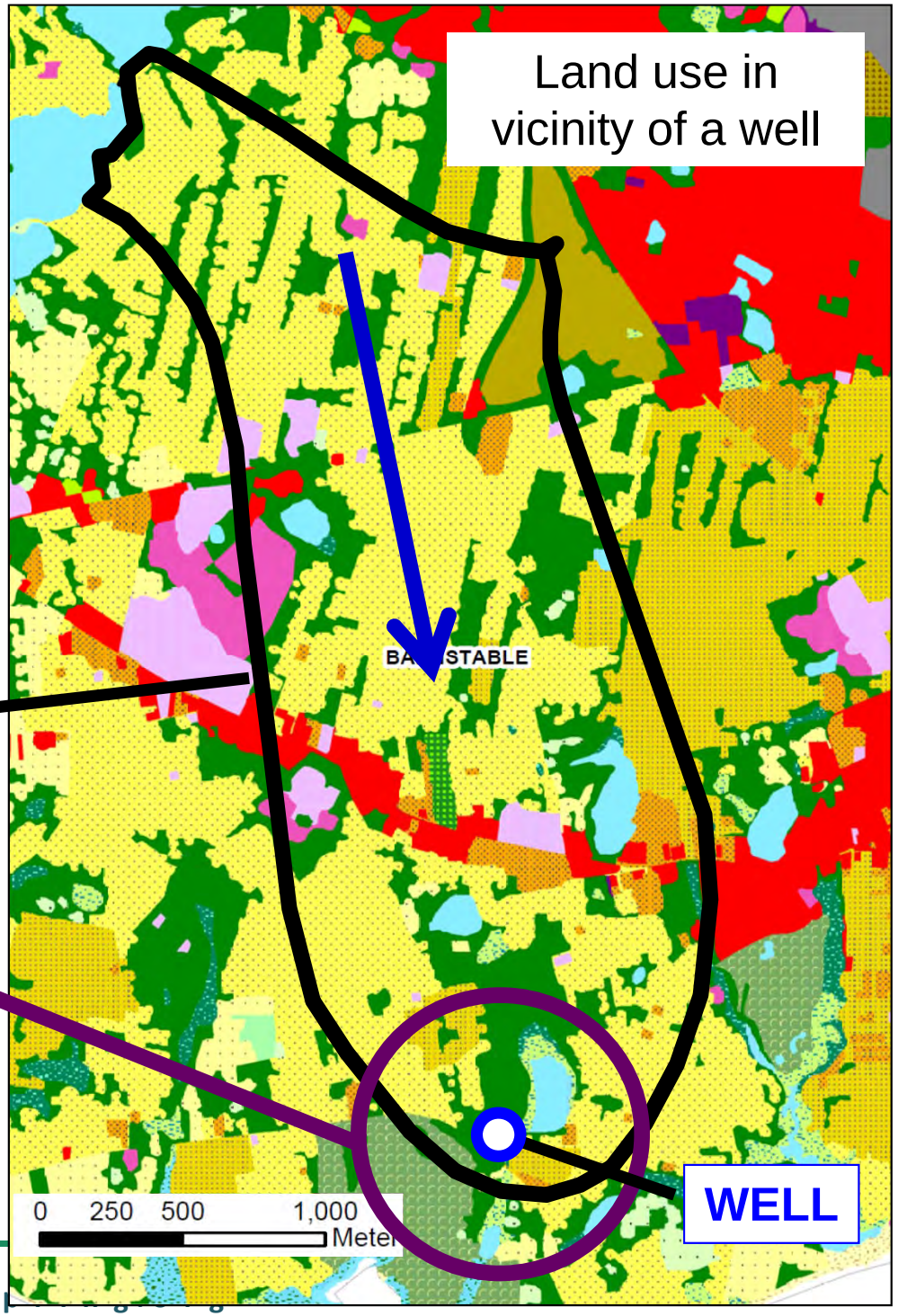


# Most frequently-detected chemicals

| Chemical | Category | Number of detections (of 22) | Maximum conc. (ng/L) | Reporting limit (ng/L) |
|---|---|---|---|---|
| sulfamethoxazole | antibiotic | 13 | 113 | 0.1 |
| PFOS | perfluorinated | 9 | 110 | 1 |
| carbamazepine | anticonvulsant | 6 | 72 | 1 |
| TEP | flame retardant | 6 | 20 | 10 |
| dilantin | anticonvulsant | 5 | 66 | 2 |
| meprobamate | antianxiety | 5 | 5.4 | 0.1 |
| TCPP | flame retardant | 5 | 40 | 10 |

# Predictors of OWCs

- Nitrate
- Boron
- Well depth
- Unsewered development
  - Zone of contribution
  - 500-m zone




Example land use types

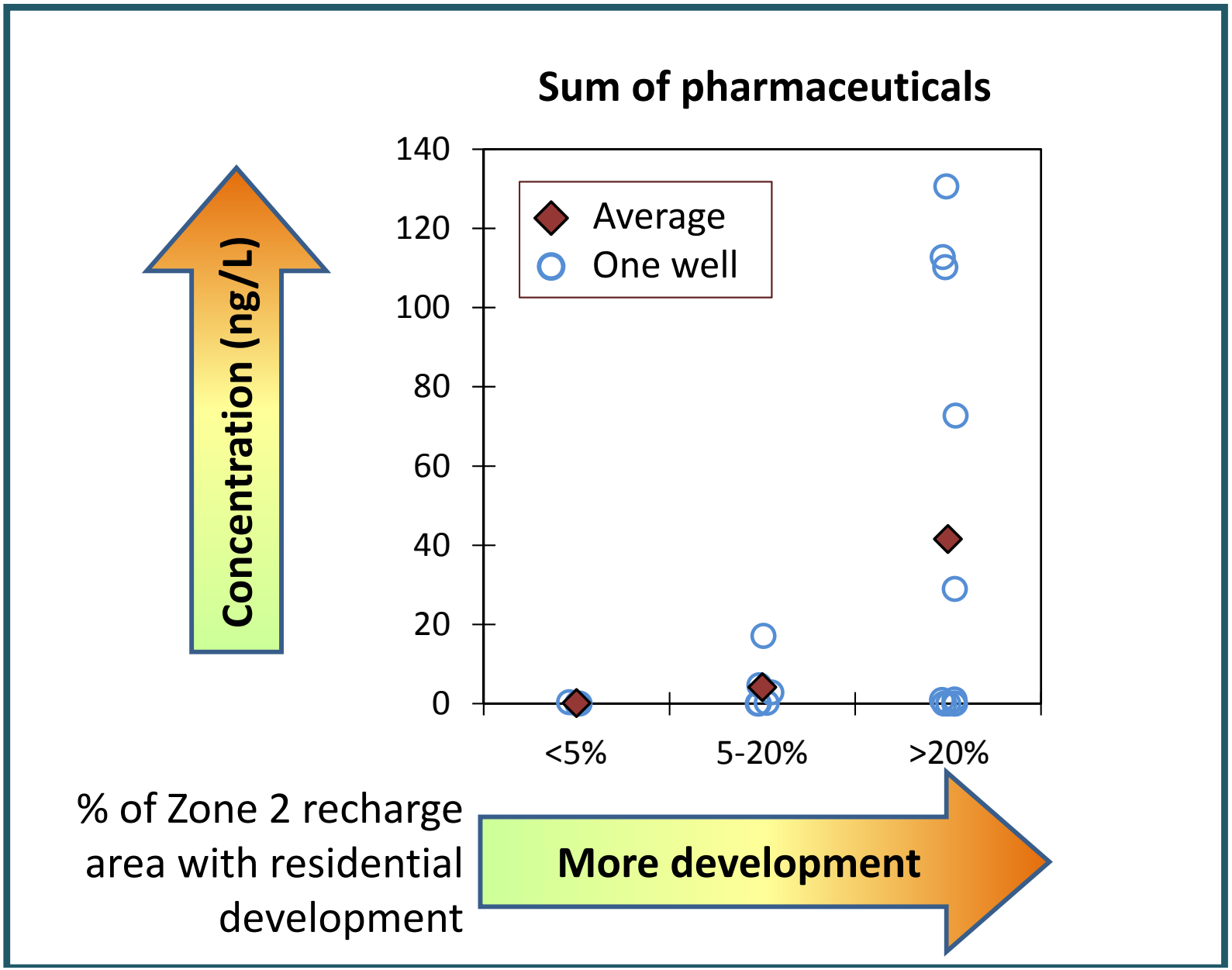
Residential

Commercial

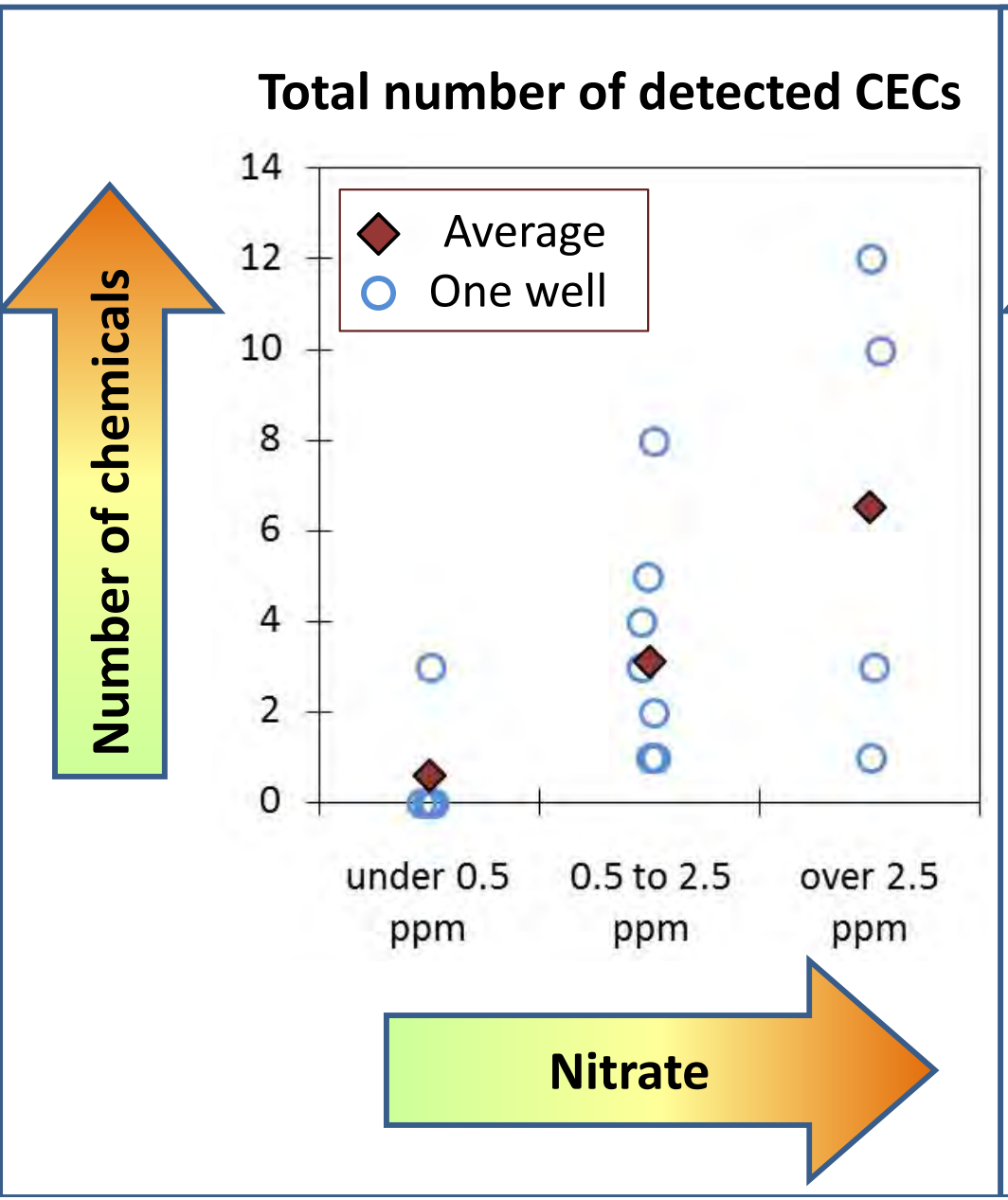
Industrial

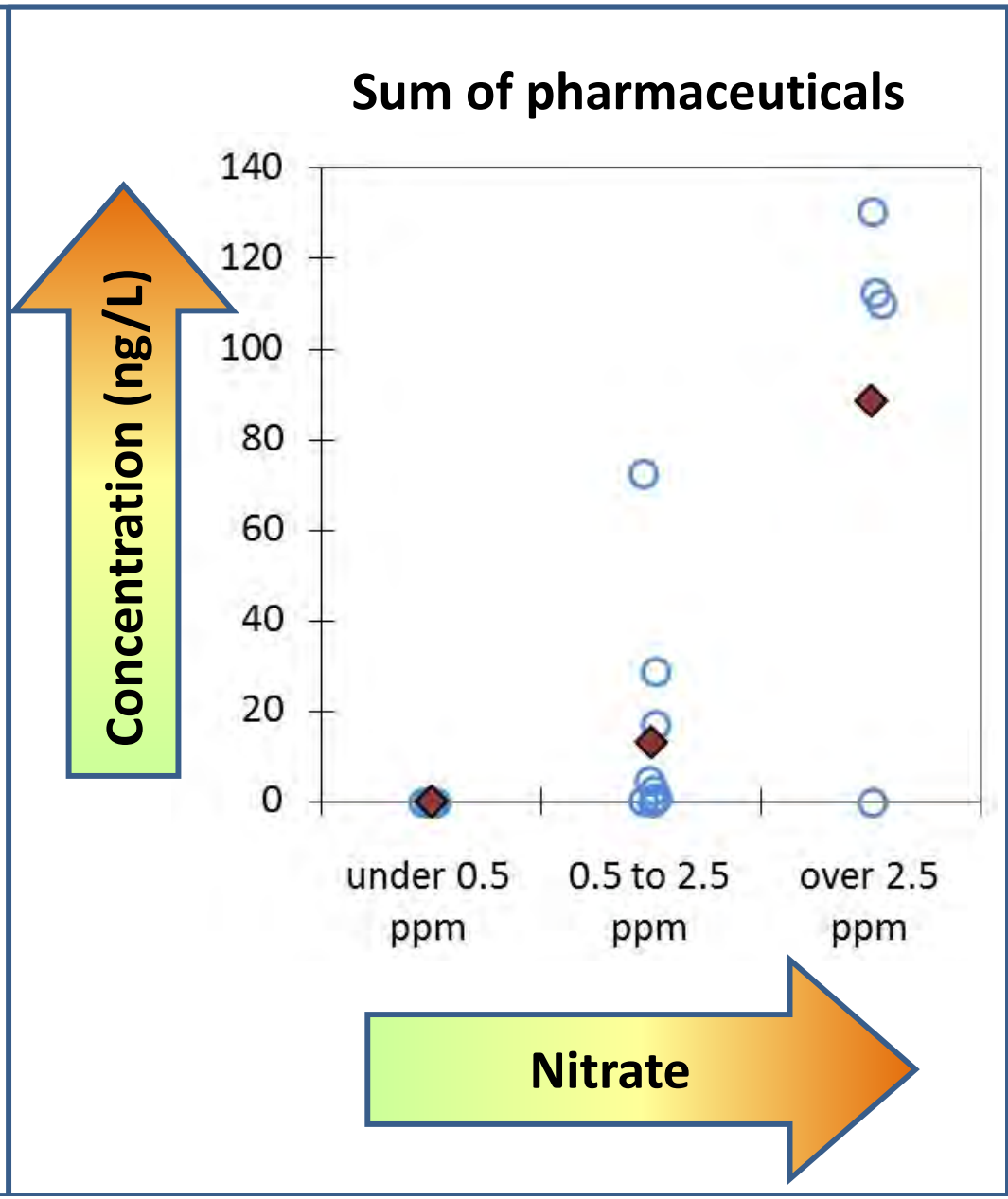
Forest & open land

# Wells near more residential development had more emerging contaminants



# Wells with higher nitrate had more emerging contaminants



# Predictors of OWCs detected

*Spearman correlation coefficients*

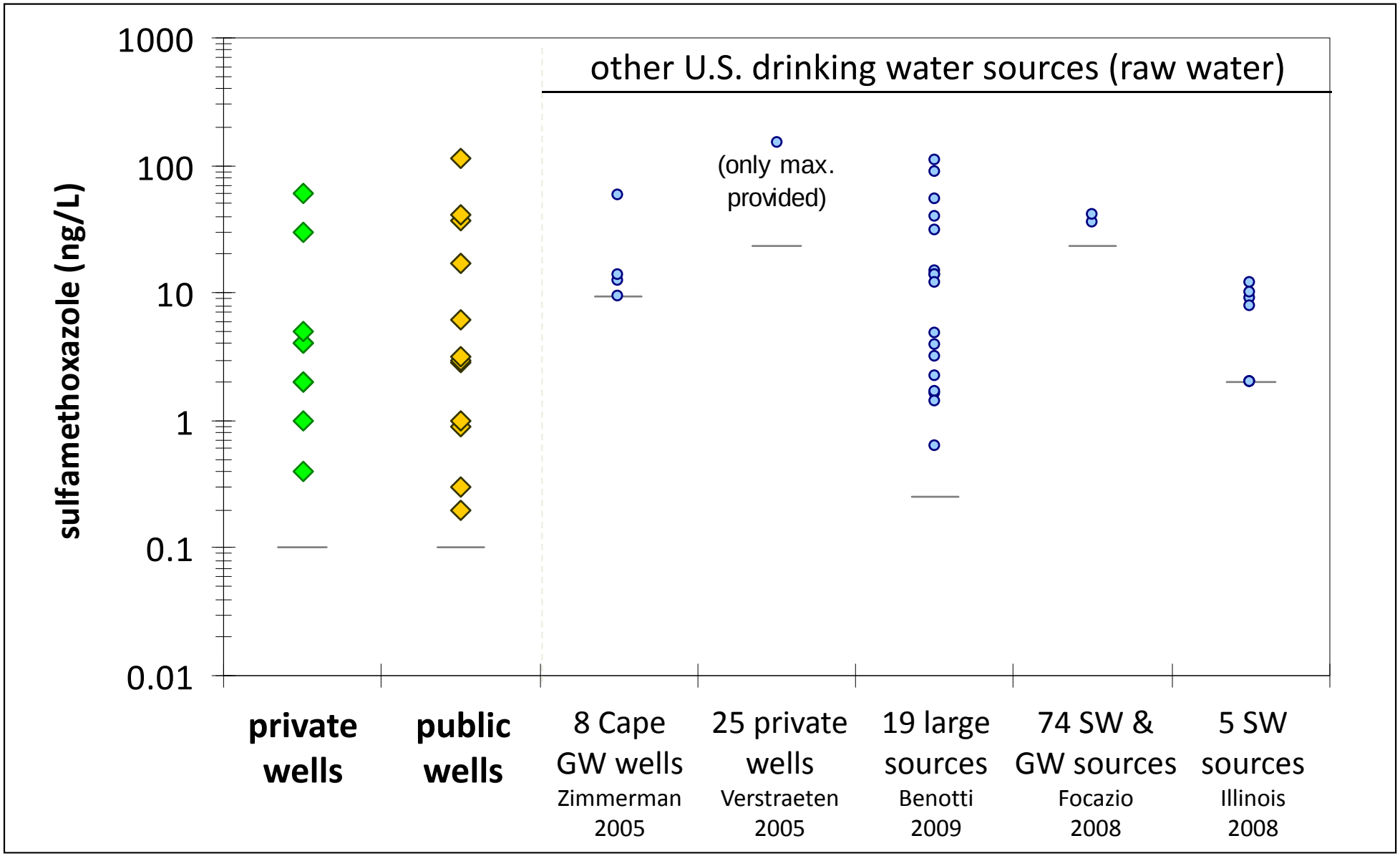
| | nitrate | boron | %DEV in zone of contrib. | %DEV within 500m | well depth |
|---|---|---|---|---|---|
| **Σ[pharmas]** | **0.77*** ** | **0.63** ** | 0.43· | **0.67** ** | -0.33 |
| **# of detects** | **0.71*** ** | **0.73*** ** | 0.32 | **0.52*** | -0.26 |

· p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Schaider et al. 2014. *Sci Tot Env*. 468-9:384-93.

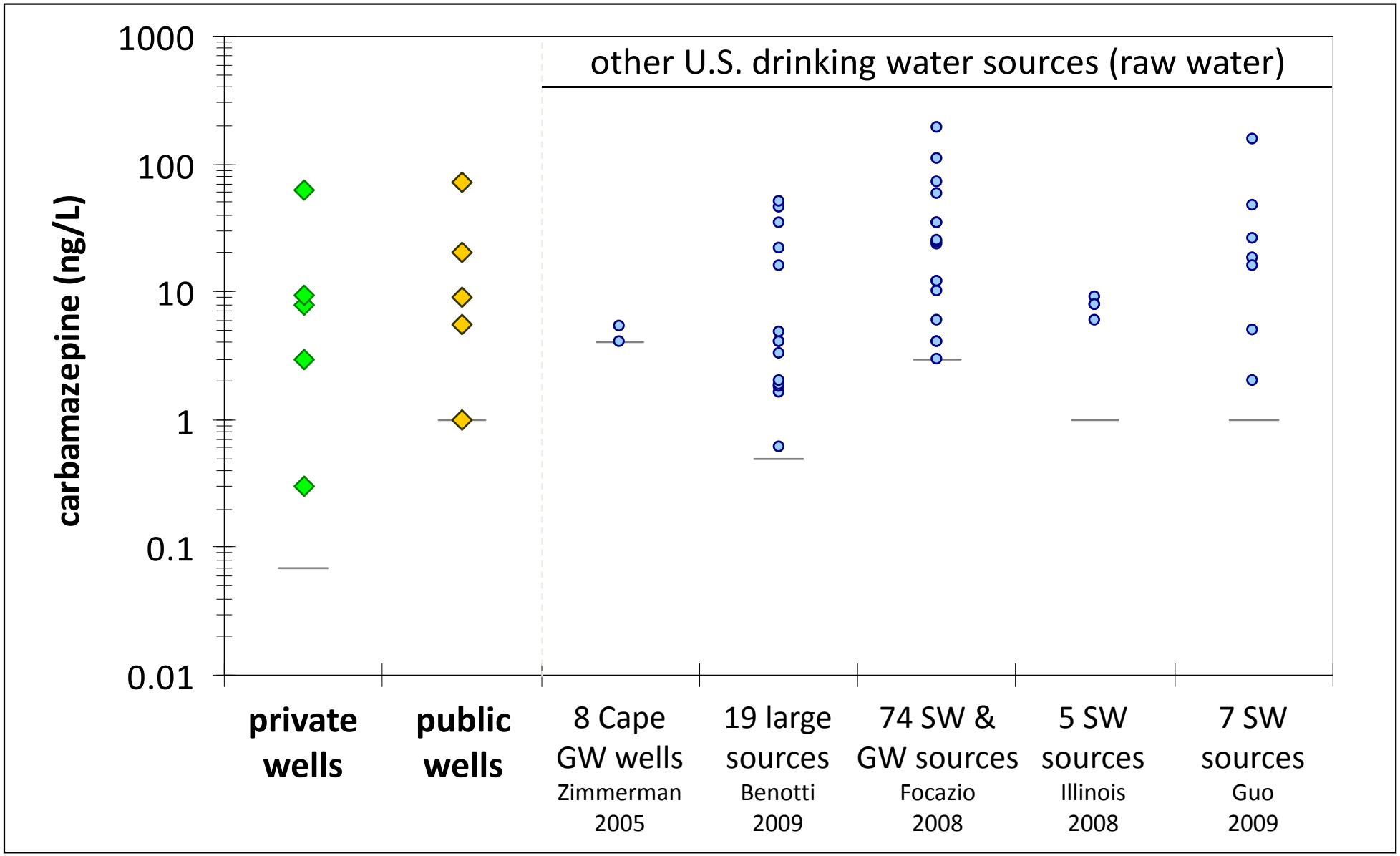
**N, B and %DEV within 500 m all correlated with pharmaceutical concentrations and with # of detects.**

# Sulfamethoxazole (antibiotic)




GW = groundwater, SW = surface water, —= MRL, DL, or lowest value reported

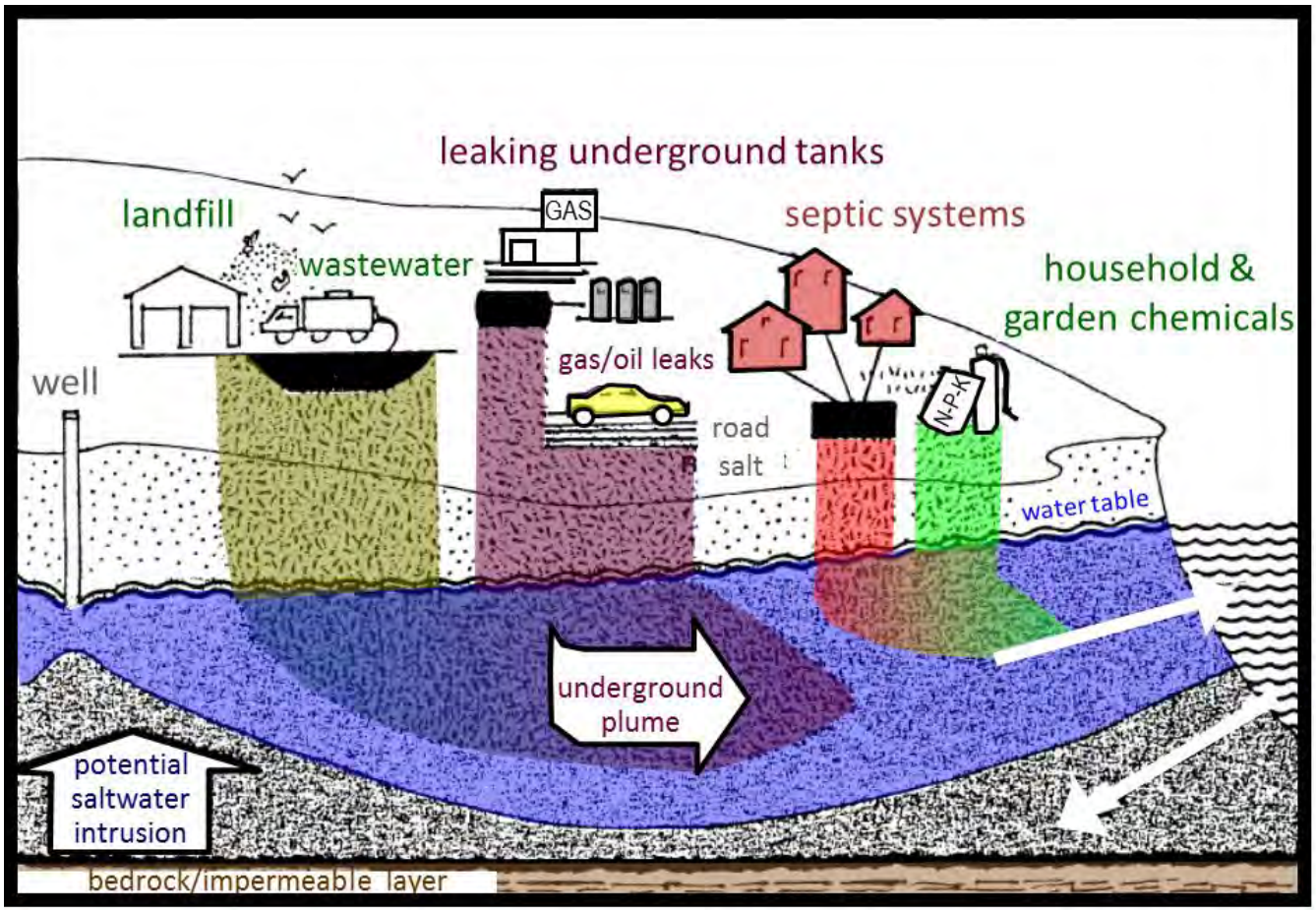
# Carbamazepine (antiepileptic)




GW = groundwater, SW = surface water, —= MRL, DL, or lowest value reported

# Septic systems are likely main source, but other sources contribute

- Wastewater treatment plant effluent
- Fire fighting foams, aviation-related sources
- Runoff
- Landfills




Adapted from http://www.capecodgroundwater.org/groundwateredpage/groundwater.pdf

# Putting it all together: Weighing effects of low-dose exposure

Magnitude of exposures (what is a part per trillion?)

- Pharmaceuticals in drinking water << therapeutic doses
- Exposures through product usage may be much higher
- Current drinking water regulations in µg/L not ng/L

Nevertheless, OWCs in drinking water do raise concerns

- Drugs are potent, intended for specific conditions, and can have side effects
- Regulations do not consider low-dose endocrine disruption
- Potential synergistic effects of chemical mixtures

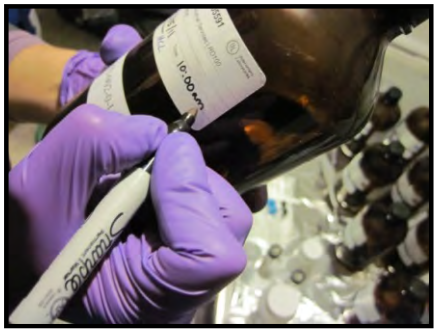
# Involvement of water suppliers

- Interested to learn more, despite lack of regulations and knowledge of health effects
- Aware that regulations may be coming, but not right away
- How can Cape communities work together to better protect drinking water supplies
  - Reducing sources
  - Protecting zones of contributions
  - Raise awareness of groundwater vulnerability

“These study results demonstrate the importance of source water protection. We look forward to working with the community and regulators to enhance protection efforts.”

- Participating supplier

# Summary

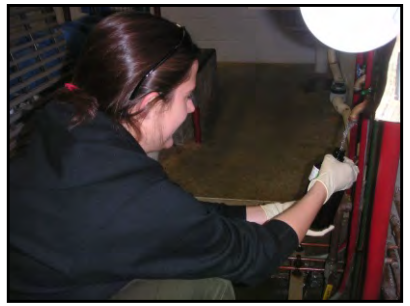


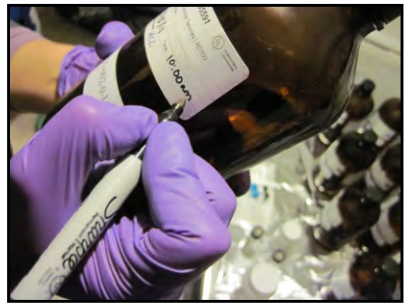
- Emerging contaminants detected in most public wells tested on Cape Cod
- Levels for several pharmaceuticals span the range detected in other US water supplies
- Wells in more densely developed areas had more emerging contaminants
- Nitrate and boron were markers of emerging contaminants

# Acknowledgements



- Ruthann Rudel, Janet Ackerman, Sarah Dunagan, Julia Brody
- Participating water supply districts
- Mass. Environmental Trust
- U.S. Centers for Disease Control and Prevention
- Cape Cod Foundation
- George Heufelder, Barnstable Co. Dept of Health & Environment
- Yongtao Li, Jessie Varab, *Underwriters Laboratories, Inc.*
- Ali Criscitiello, Farley Lewis



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## Water Research

**Pharmaceuticals, hormones, and consumer product chemicals are showing up in drinking water throughout the U.S. Our wastewater and our drinking water are connected through the same water cycle. How can we safely treat and dispose of our waste without damaging our drinking water quality?**

To protect Cape Cod's coastal marine sanctuary, wastewater is disposed on land, primarily in septic systems. These systems allow pollutants to seep through porous soils, often reaching shallow drinking water wells. Silent Spring Institute is undertaking a number of initiatives aimed at understanding the role that polluted water may play in the disproportionately high levels of breast cancer on Cape Cod.

Drinking water for Cape Cod residents comes from a sole-source aquifer. Because the Cape has a shallow water table and sandy, porous soil, the aquifer is particularly vulnerable to land use activity. Silent

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**Invited Talk**

Pharmaceuticals and Other Emerging Contaminants in Public and Private Drinking Water Wells on Cape Cod, Massachusetts.

Wastewater and Emerging Contaminants of Concern

**Scientific Article or Summary**