Expanding the Knowledge of CECs in the Environment: Recent Research by the USGS

NORMAN Workshop, Amsterdam

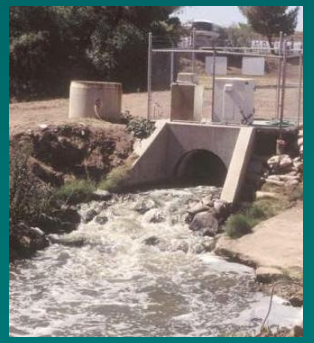
Dana W. Kolpin
Emerging Contaminants in the Environment Project

Toxic Substances Hydrology Program
29 November, 2012

U.S. Department of the Interior
U.S. Geological Survey

CECs
"umbrella term"

- Pharmaceuticals
- Fungicides
- Mycotoxins
- Fragrances
- Detergents
- Plastics
- PFCs
- Pathogens
- Hormones
- Fire retardants
- Disinfectants
- Fumigants
- Plant/animal sterols
- Phytoestrogens
- Algal toxins
- Nanomaterials



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Fundamental Research Questions

- *Are CECs entering our environment?*
- *What are the sources (signatures)?*
- *What happens to them in the environment?*
- *Do they have adverse ecological health effects?*
- *Do unintended exposures pose a human health risk?*
- *How can we minimize their entry to the environment or remove them?*

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USGS Team (multidisciplinary approach)

Hydrologists
Dana Kolpin (IA WSC)
Mike Focazio (Reston)
Frank Chapelle (SC WSC)
Ron Harvey (NRP)
Pat Phillips (NY WSC)
Jason Masoner (OK WSC)
Kathy Lee (MN WSC)
Kymm Barnes (IA WSC)
Laura Hubbard (IA WSC)
Denis LeBlanc (MA WSC)

Chemists
Ed Furlong (MRDP)
Bill Foreman (MRDP)
Steve Zaugg (MRDP)
James Gray (MRDP)
Mark Sandstrom (MRDP)
Dave Alvarez (CERC)
Keith Loftin (OGRL)
Michelle Hladik (CA WSC)

Microbial Ecologists
Sheridan Haack (MI WSC)
Paul Bradley (SC WSC)
Joe Duris (MI WSC)

Biologists
Vicki Blazer (LSC)
Luke Iwanowicz (LSC)
Marie-Noele Croteau (NRP)

Geochemists
Larry Barber (NRP)
Mike Meyer (OGRL)
Phil Verplanck (GD)

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Evolution of occurrence question

Are CECs entering our environment?

2455 citations

What CECs are entering our environment?

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Recent USGS Analytical Efforts

New Methods

- Hormones in water (19): GC/MS/MS
- Pharmaceuticals in water (112): DAI LC/MS/MS
- Halogenated OCs in solids and tissue (63): GC/MS

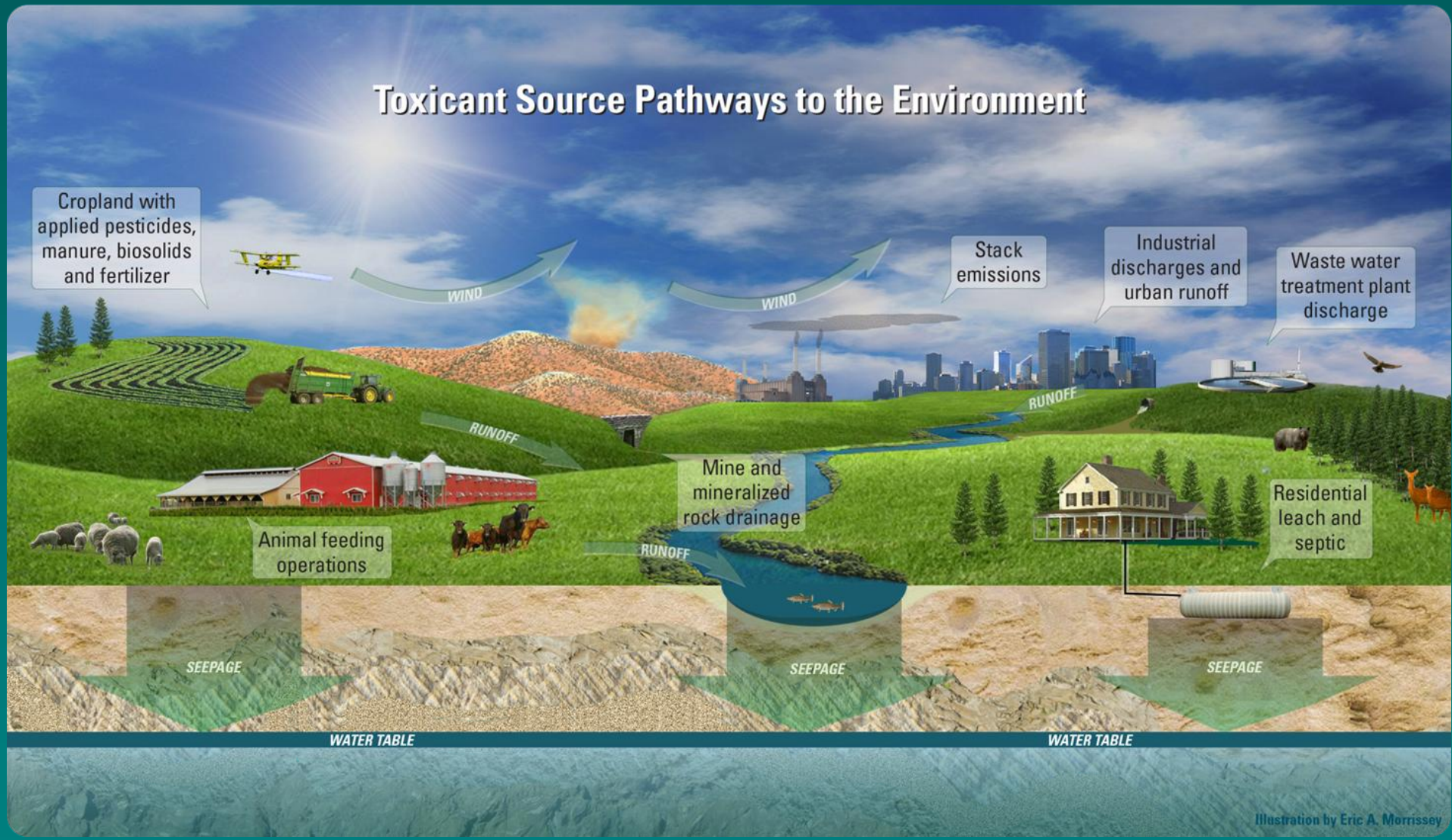
Ongoing methods development activities

- Phytoestrogens
- Hormone conjugates
- Veterinary growth promoters
- Mycotoxins
- Halogenated OCs in bird eggs
- Surfactants
- Next generation waste-indicator method

Recently purchased LC TOFs (2)

- Provide enhanced forensics capabilities

What are the potential sources?



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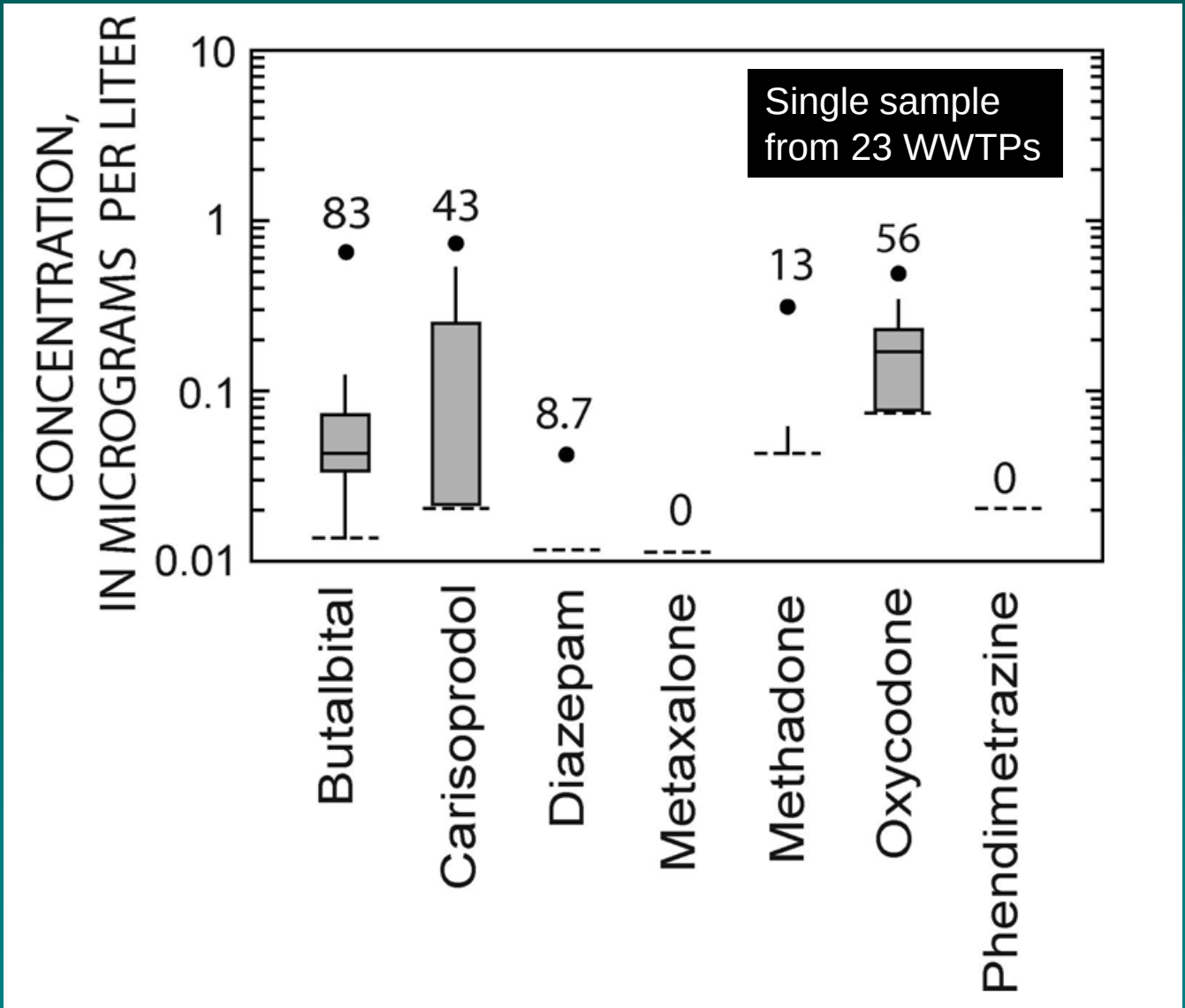
National WWTP Network



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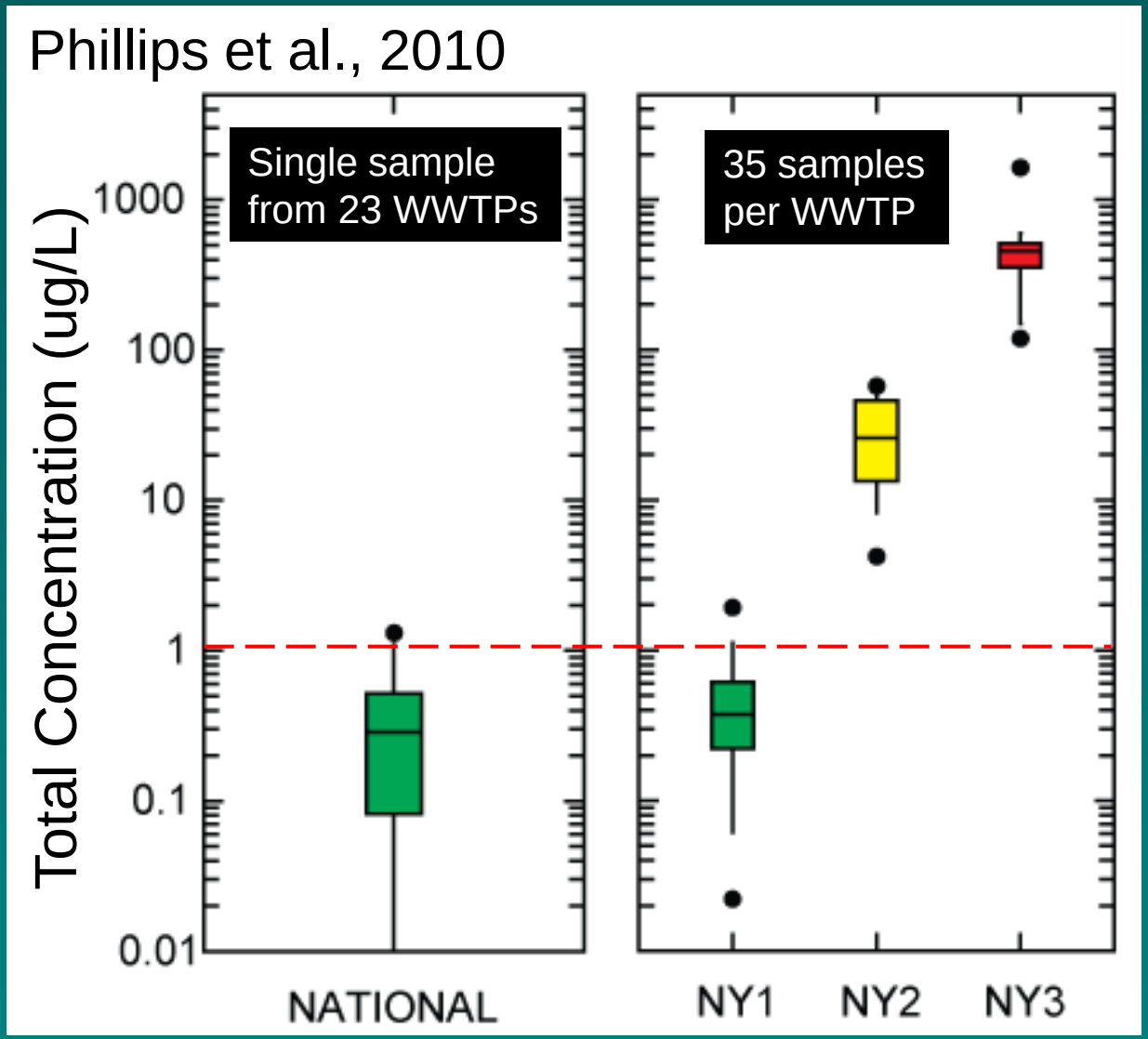
http://toxics.usgs.gov/highlights/PMFs.html

PMFs – Environmental Sources of CECs



Max Conc. (ug/L)

3800 metaxalone

1700 oxycodone

>400 methadone

160 butalbital

>40 phendimet.

>40 carisoprodol

4 diazepam

USGS

http://toxics.usgs.gov/highlights/PMFs.html

PMFs – Additional Research

Comprehensive analysis of effluent (DAI method)

- 6 additional pharms at elevated levels (>10 µg/L)
  - buproprion (antidepressant)
  - chlorpheniramine (antihistamine)
  - fexofenadine (antihistamine)
  - hydrocodone (narcotic analgesic)
  - metformin (anti-diabetic)
  - temazepam (psychoactive)

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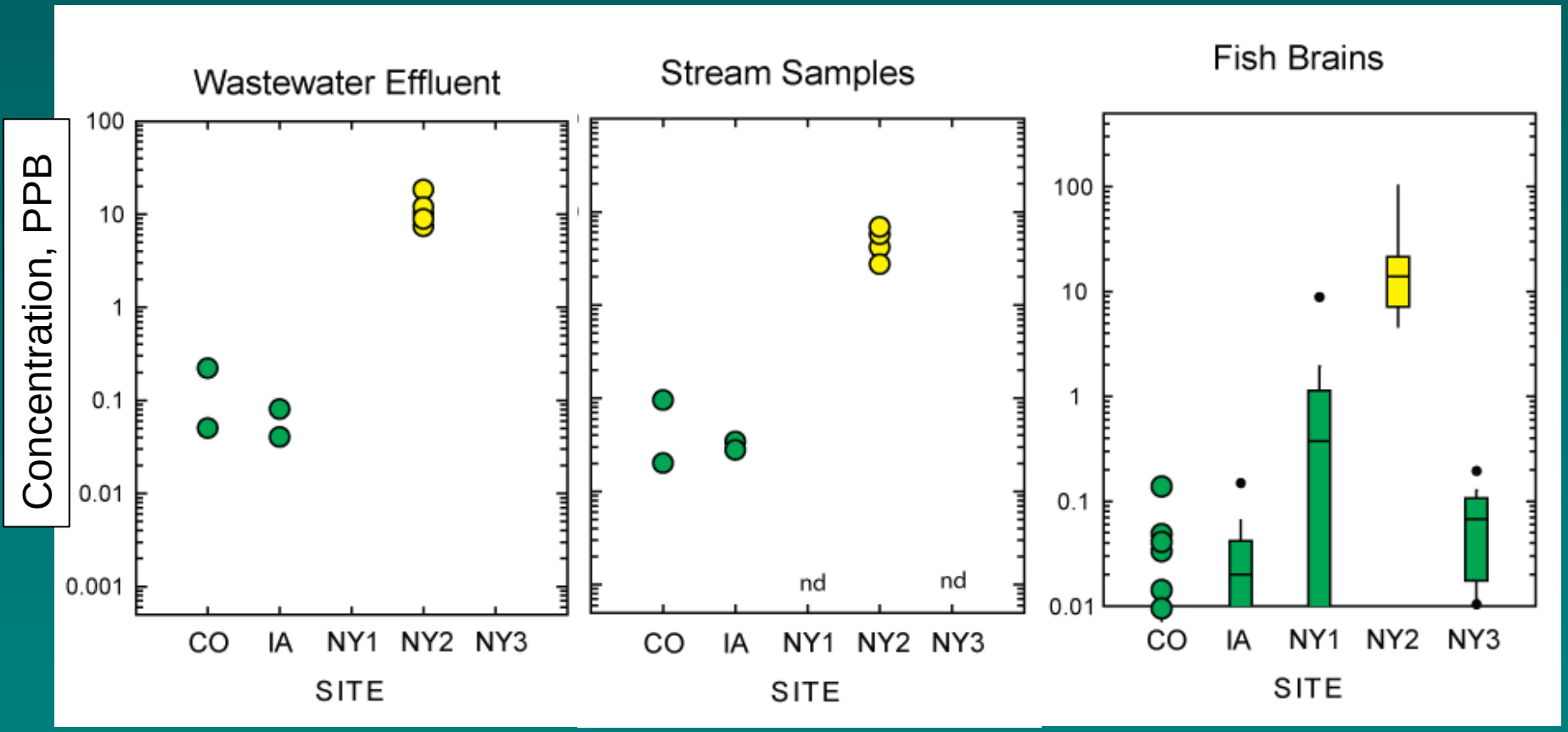
Bupropion Env'l Exposure @ PMF



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Data provisional

Laboratory Exposure Experiment 2012:

- Antidepressants (4)
- Opioids (4)
- Muscle Relaxant (methocarbamol)
- Sleep Aid (temazepam)
- Opiate Agonist (tramadol)
- Complete Mixture
- Carrier Control

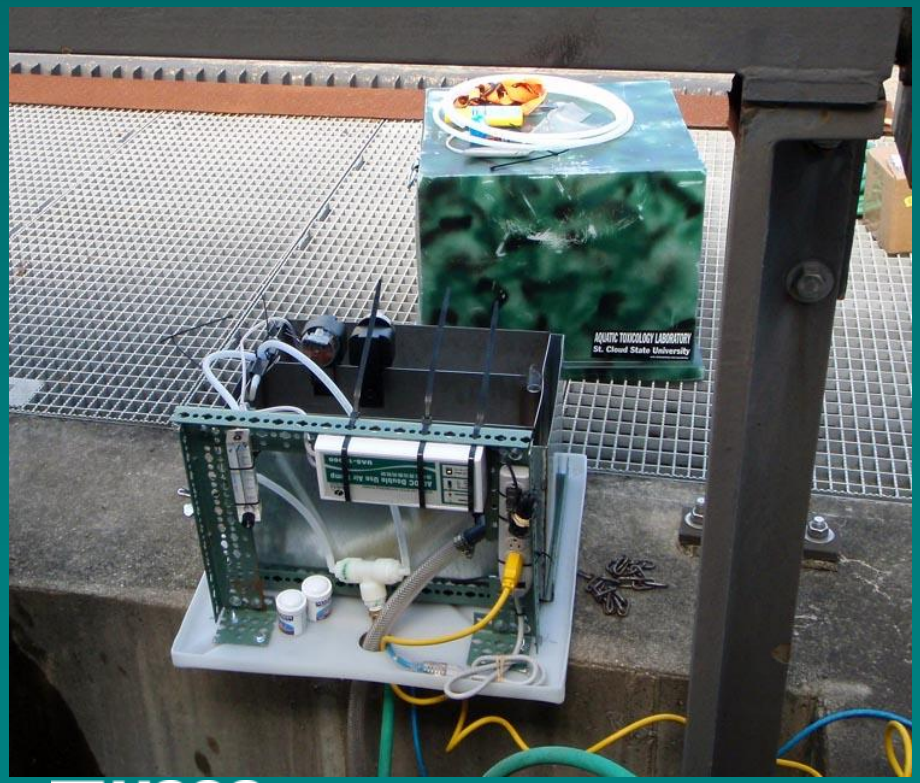
- Water Chemistry (USGS - NWQL)
- Fecundity, fertility, hatching (SCSU)
- Liver, gonad histopathology (SCSU)
- Vitellogenin concentrations (SCSU)
- Gene expression (U. of St. Thomas)
- Immunological response (SCSU)
- Bioaccumulation (Wooster College)

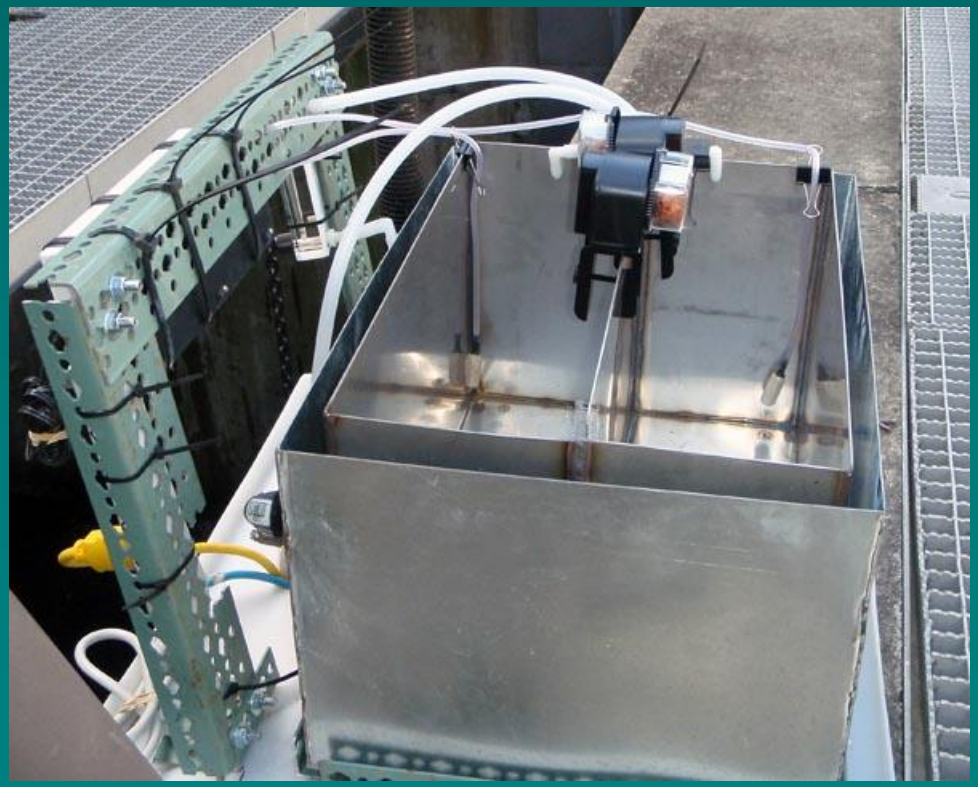
21-day flow-through mature fathead minnow exposure (two week pre-exposure baseline). Ten spawning scenarios (1 male, 2 females) per treatment.

Field Exposure Experiment 2012:

Assessing the effects of pharmaceuticals in whole effluent.

21-day *in-situ* flow-through mature fathead minnow exposure. 20 males, 20 females in on-site mini-mobile exposure unit (MMU). March 2012.





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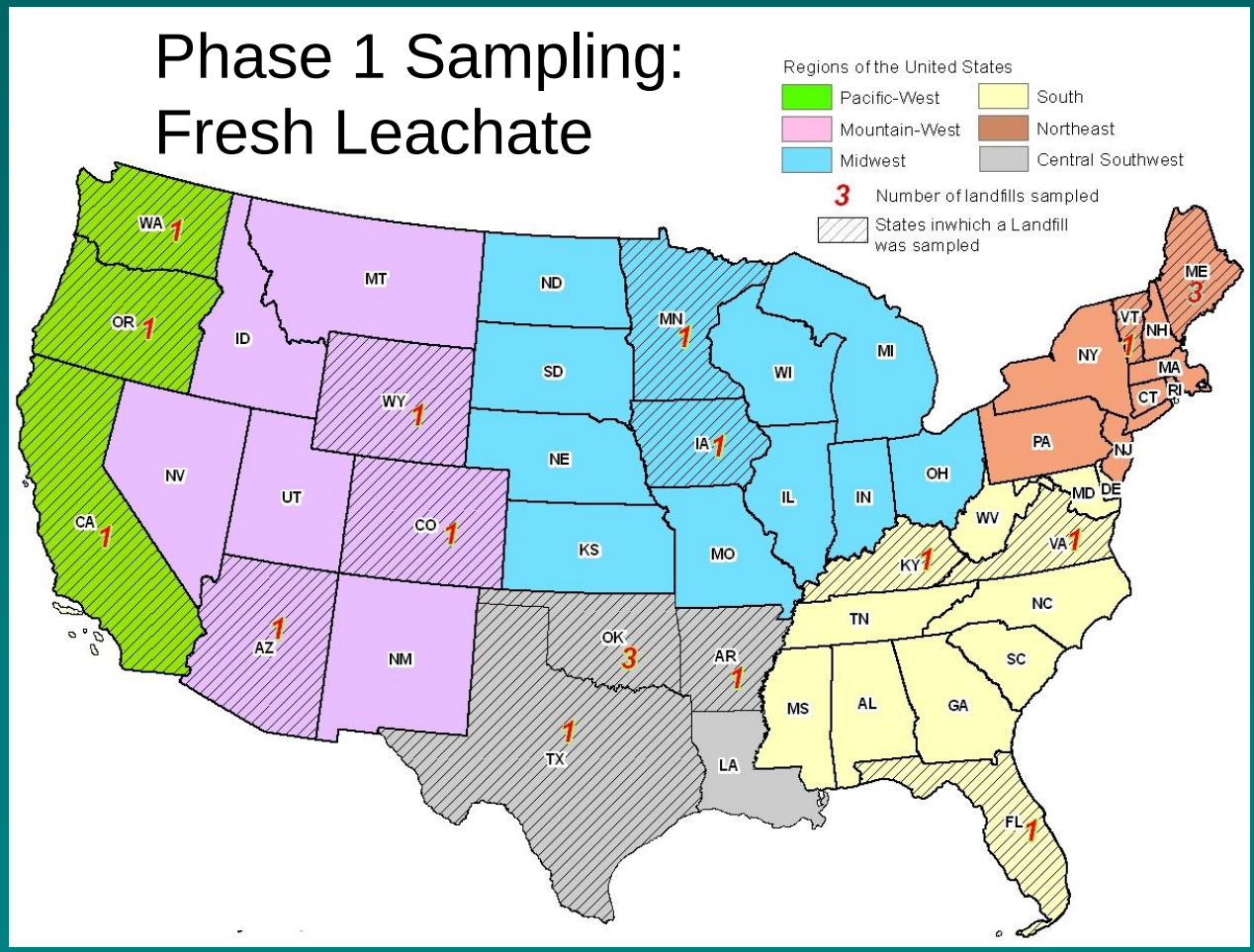
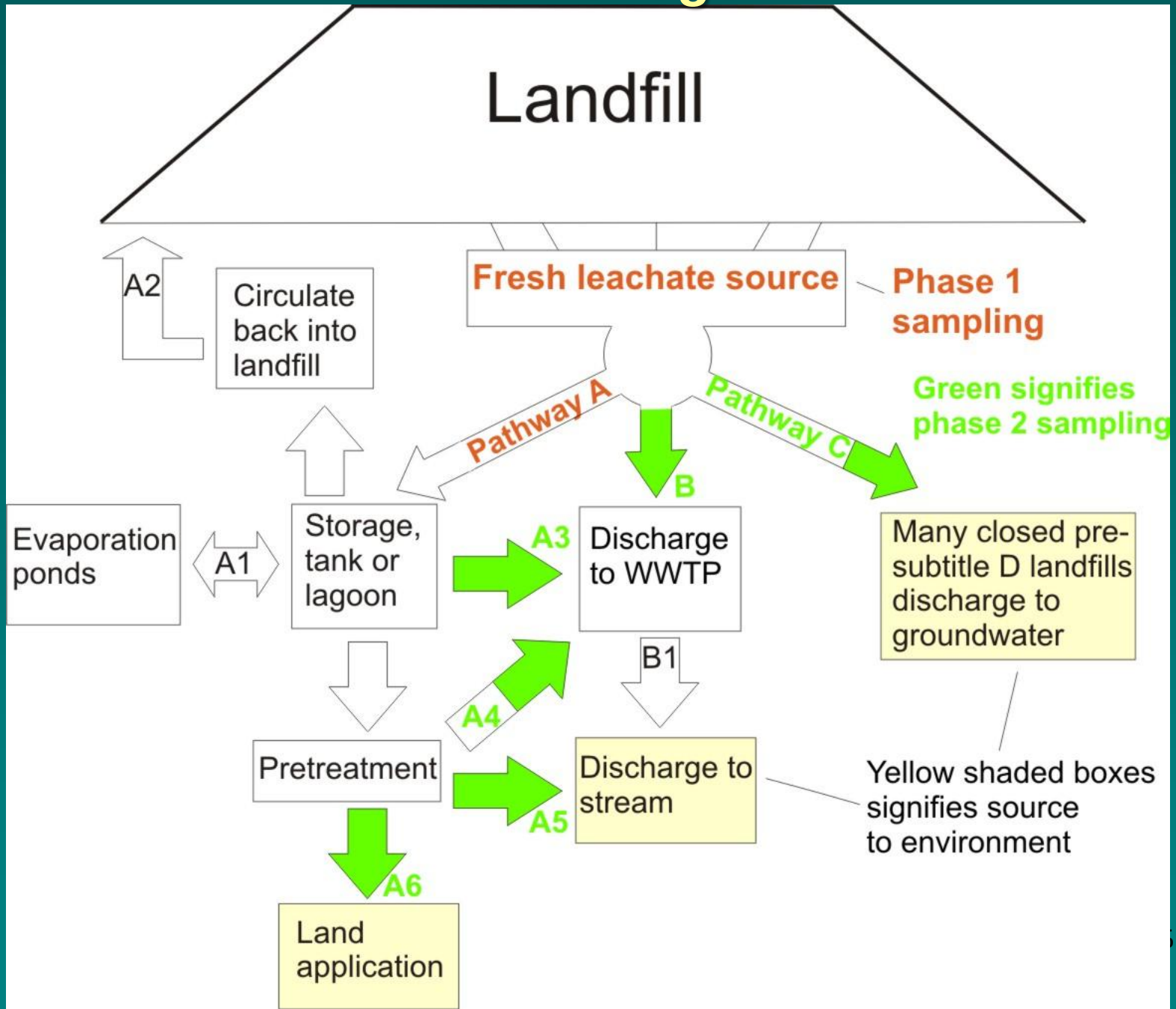
Methodology: Kolok and Schoenfuss, J. Environ. Monitoring, 2012, 14: 202-208

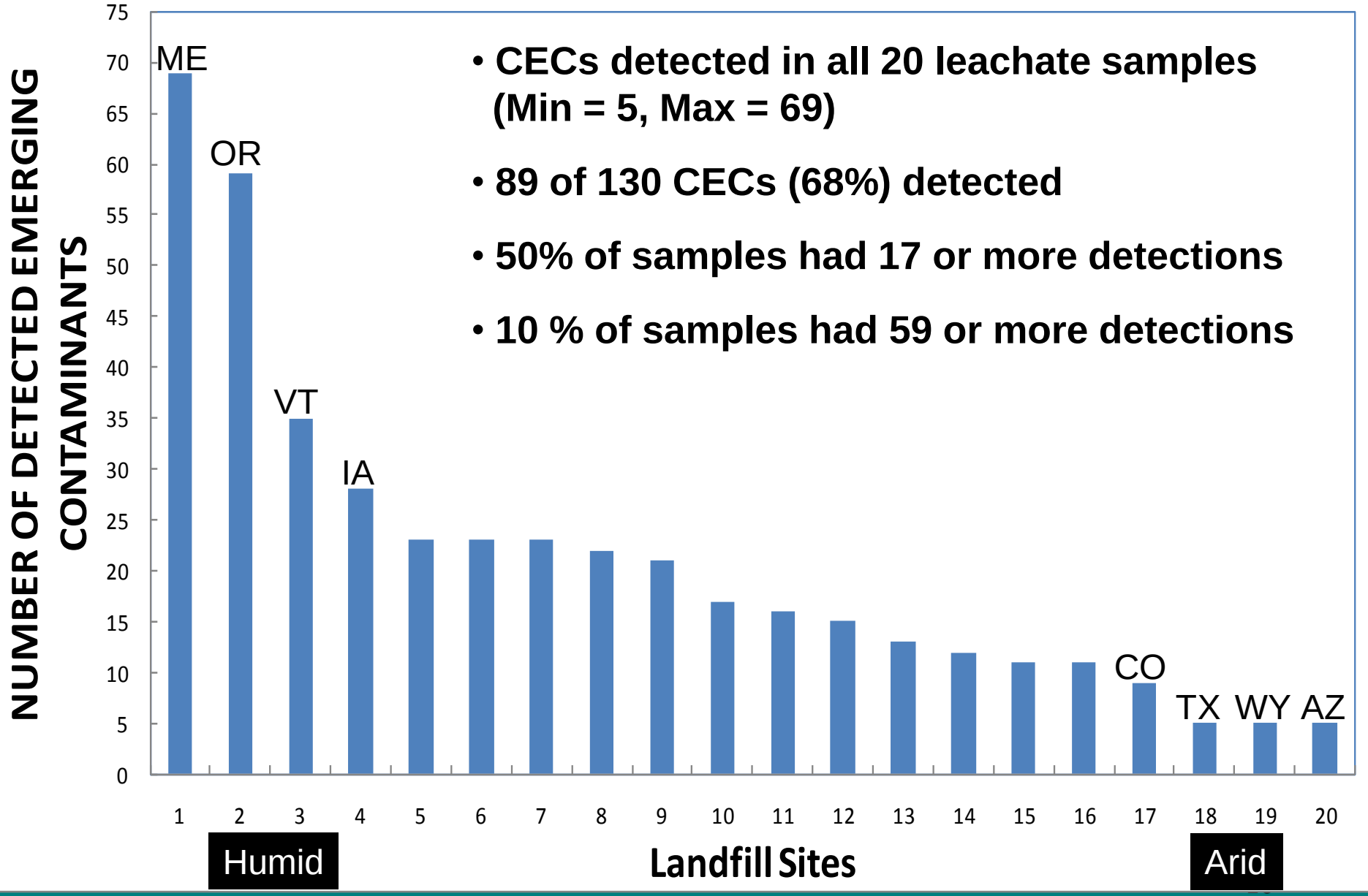
National Landfill Leachate Study



Common Leachate Management Practices

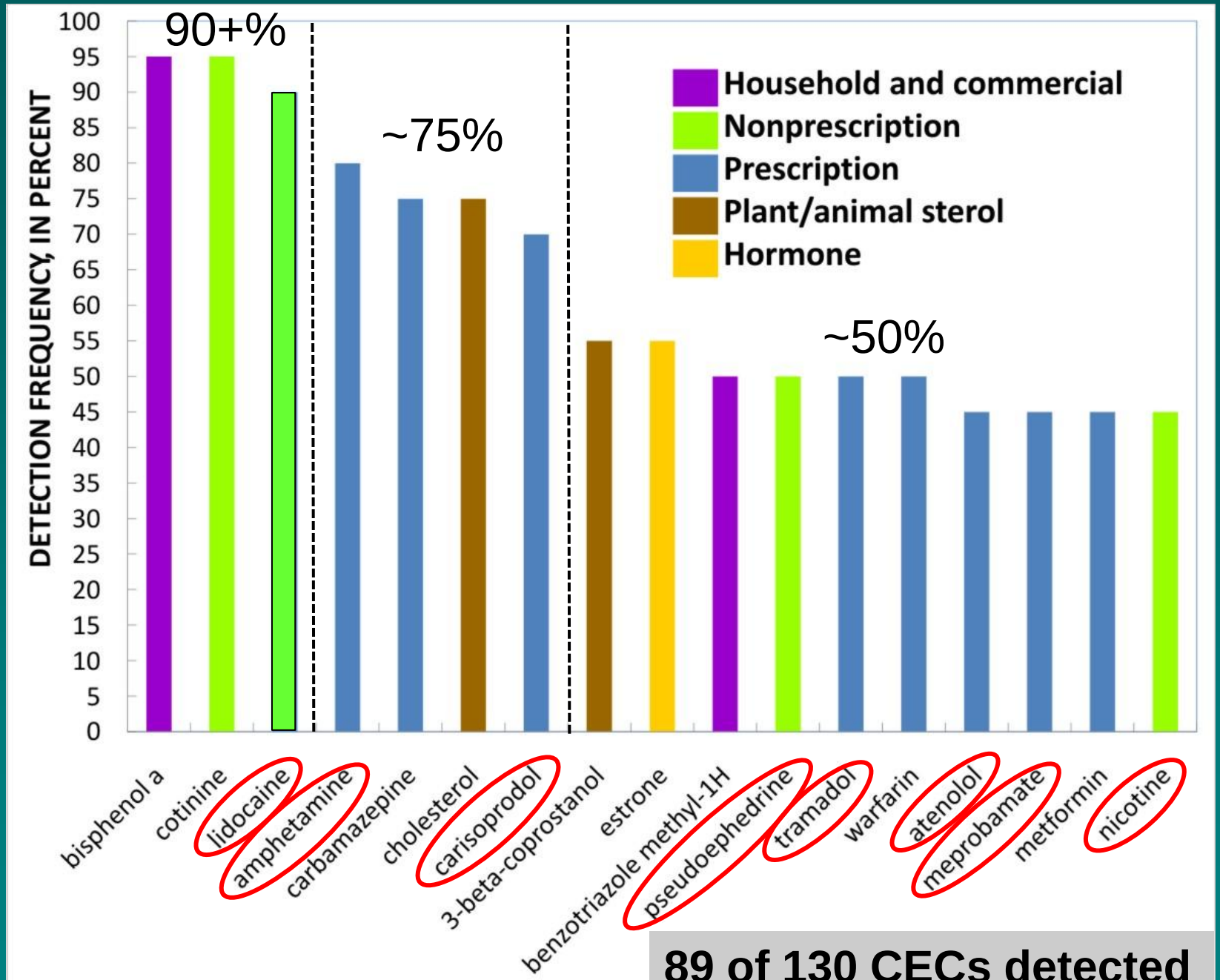


CECs Detected by Landfill Site



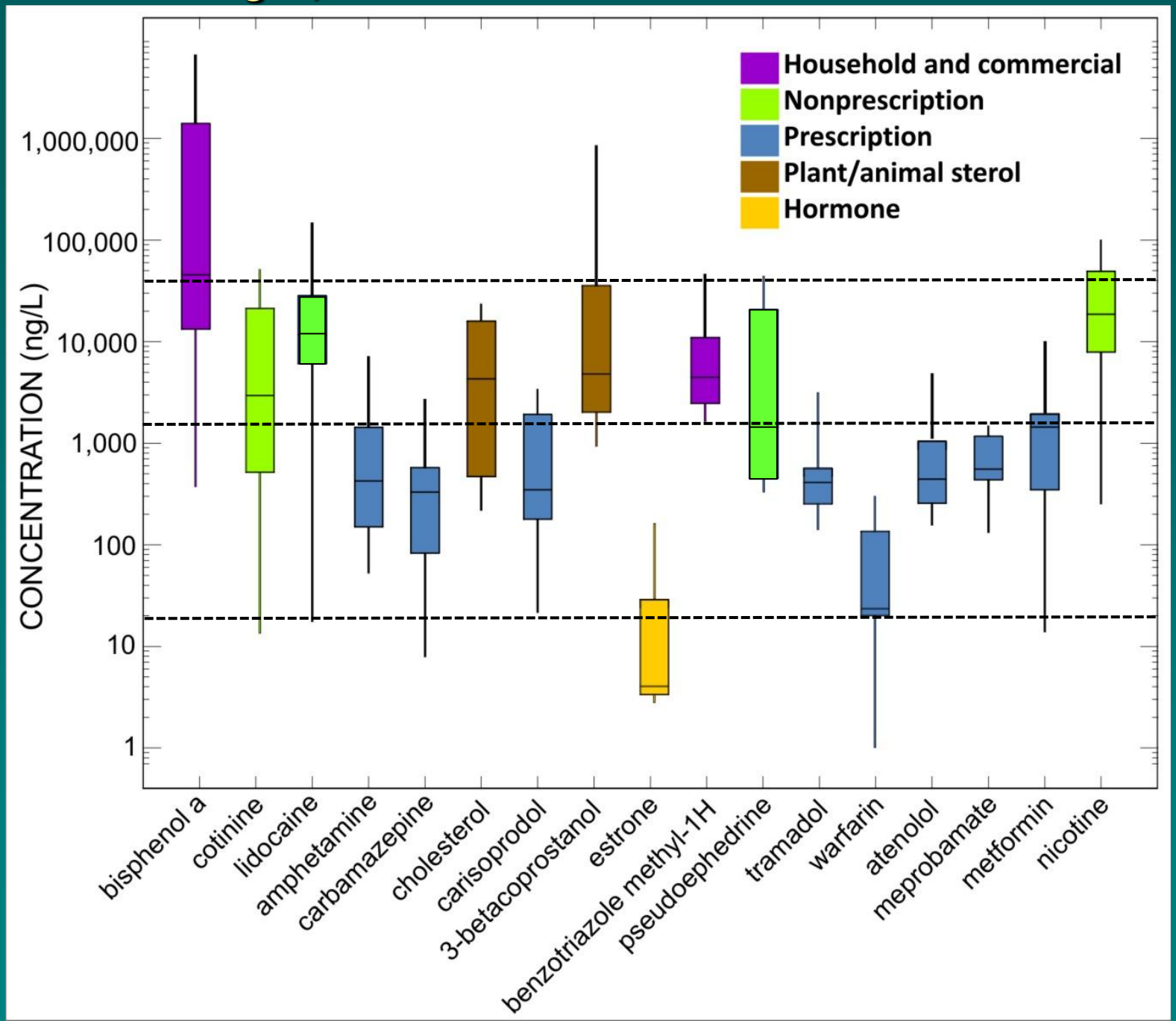
- **CECs detected in all 20 leachate samples (Min = 5, Max = 69)**
- **89 of 130 CECs (68%) detected**
- **50% of samples had 17 or more detections**
- **10 % of samples had 59 or more detections**

CECs Detected in 45% or More in Leachate Samples



89 of 130 CECs detected

Concentration Ranges, ECs Detected in 45% or More in Leachate Samples



Fourmile and Boulder Creeks: Field labs to conduct hypothesis-driven research

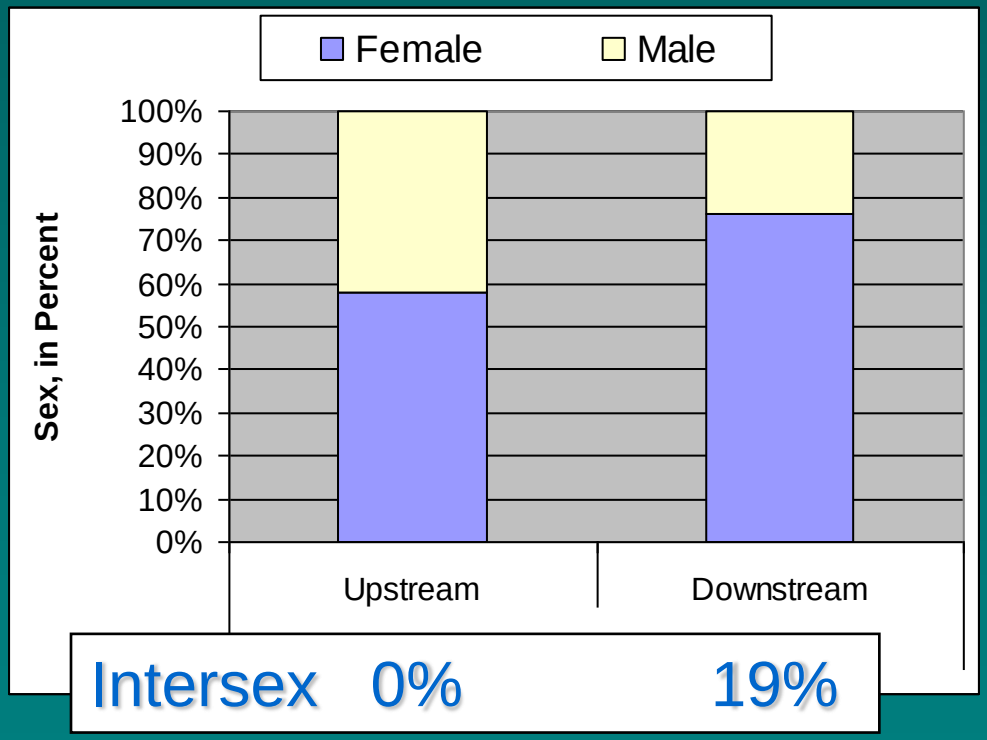
Fourmile Creek (IA)

Boulder Creek (CO)

- Relatively small, headwater basins
- Effluent impacted systems (single WWTP discharge)
  - clear perturbations to the system
- WWTPs undergoing major changes
  - allows unique process-oriented research
- Controls present above WWTPs

Evidence of Endocrine Effects in WWTP Impacted Stream (Boulder Creek)

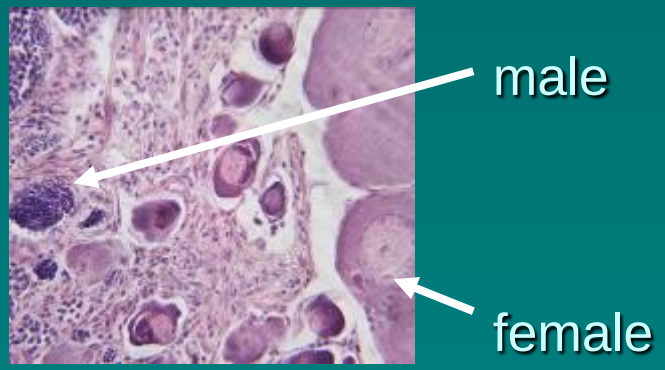
White sucker



Intersex

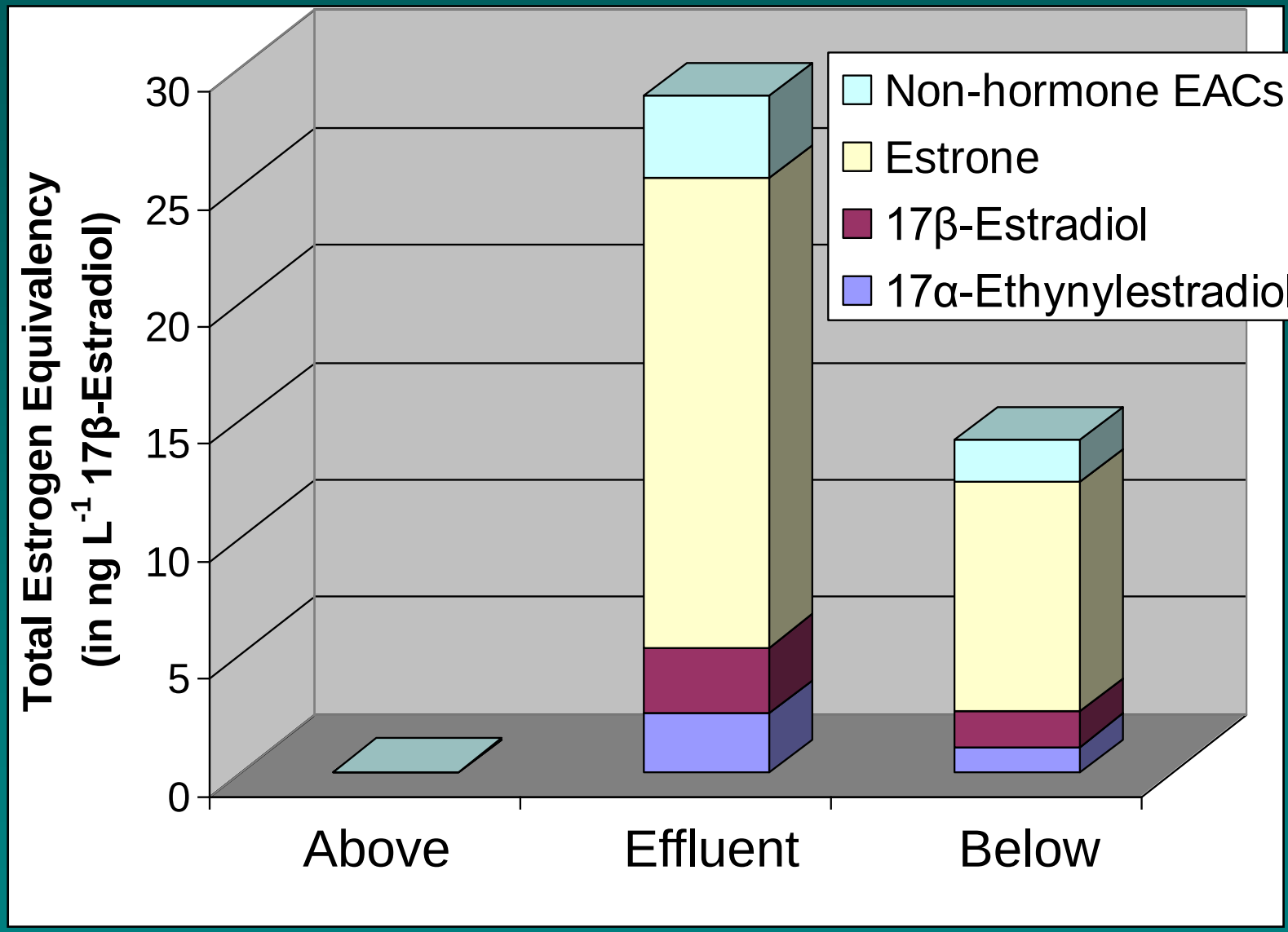
Blood Vitellogenin

Cellular Abnormalities



Vajda et al., 2008

WWTP: dominant source for CECs



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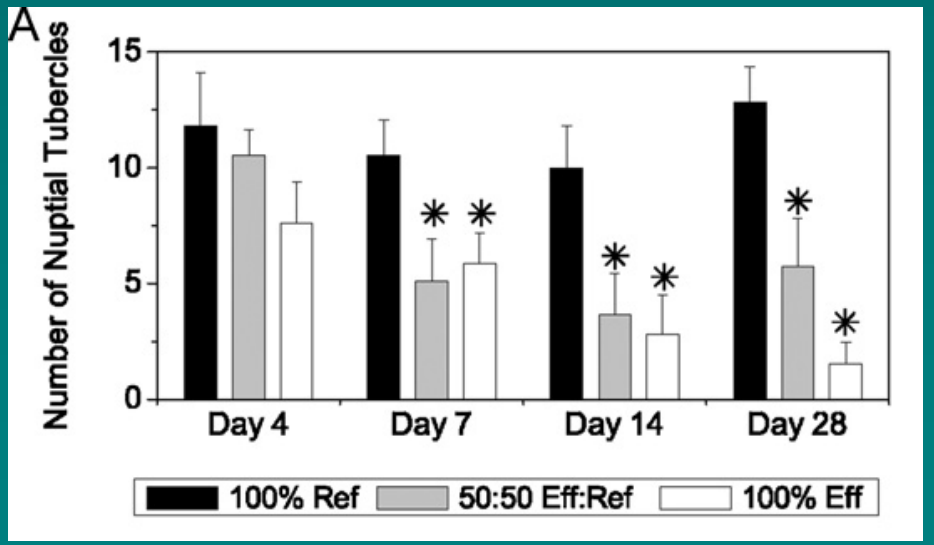
Vajda et al., 2008

Boulder WWTP Effluent Estrogenic (trickling filter treatment process)



Onsite stream waters with controlled photo-period and water temp.

Vajda et al., 2011

Boulder WWTP Post-Upgrade Results

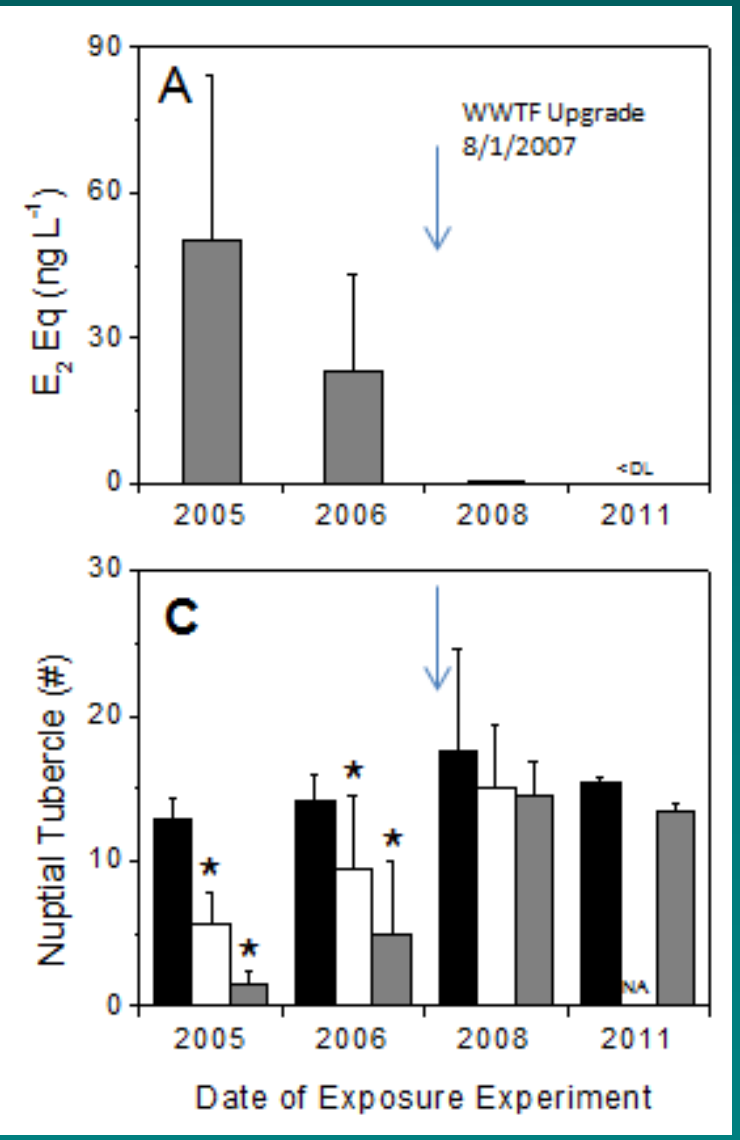
Switch from trickling filter to an activated sludge process:

- Improved the removal efficiencies of many CECs

- Decreased the estrogenicity of discharged effluent

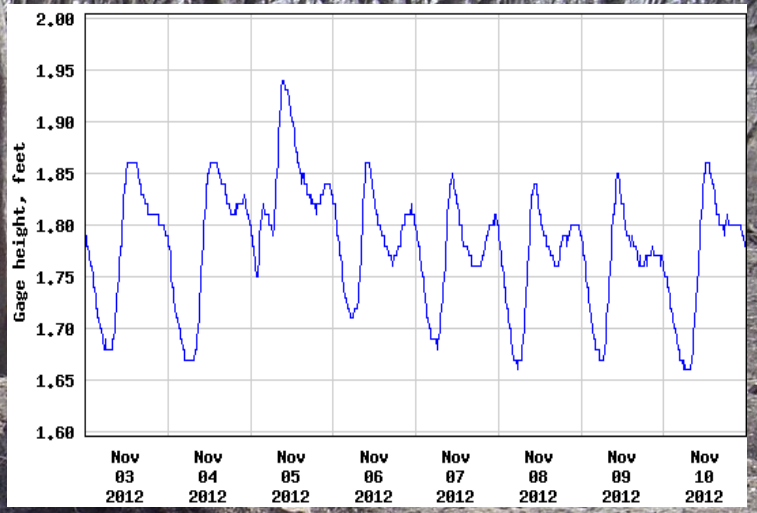
- Reduced endocrine disruption relative to pre-upgrade conditions

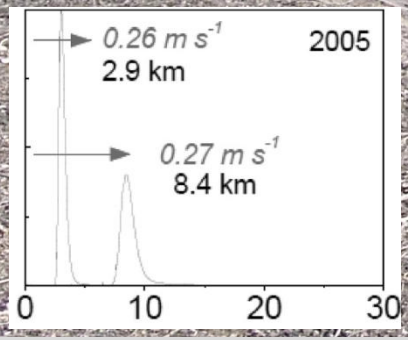
Field survey of fish populations and endocrine disruption in white suckers (Oct. 2011)



Barber et al., 2012, ES&T

Fourmile Creek: Understanding the Hydrology





Barber et al., 2011

Unexpected Phenomena (eddy effect above outfall)

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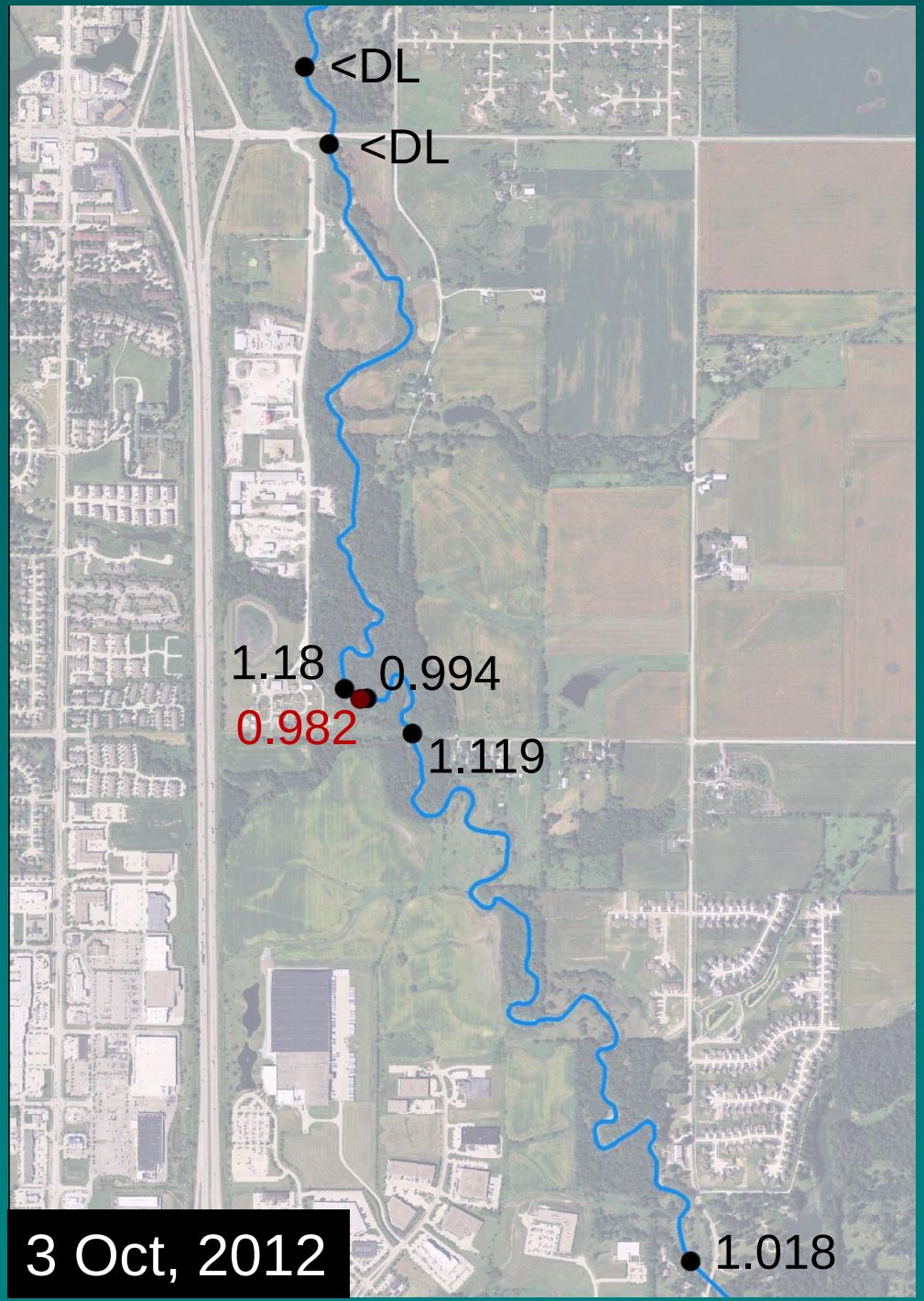
Carbamazepine by ELISA (µg/L)

- No detections at upstream most sites
- Eddy effect causing detection proximal above outfall
- Conservative transport



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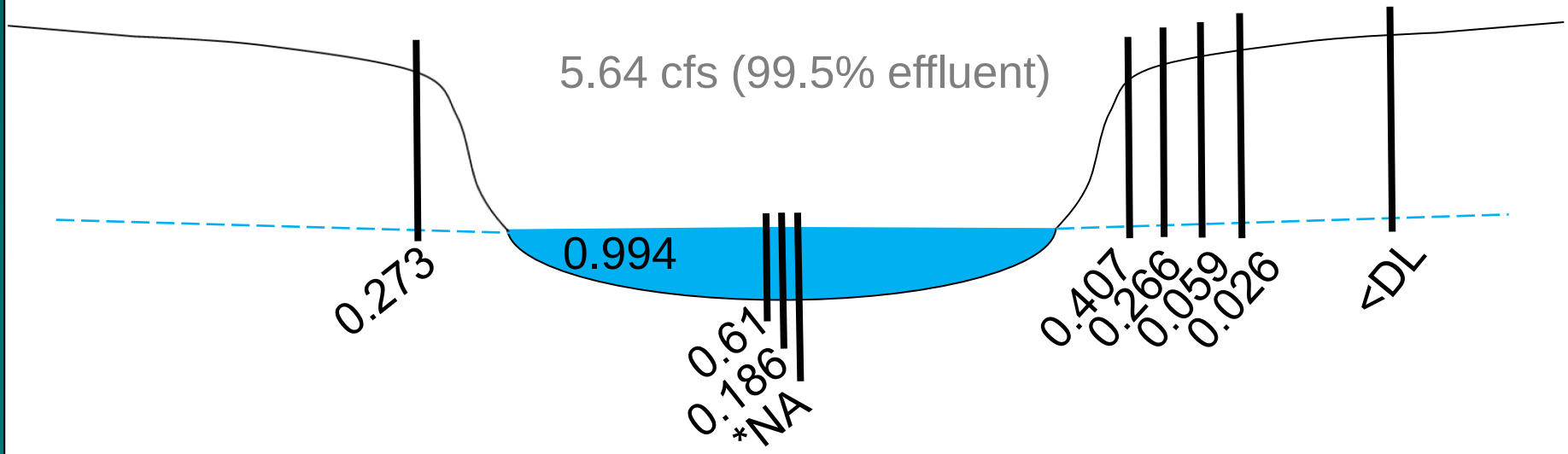
Fourmile Creek below WWTP outfall

3 October, 2012

ELISA Carbamazepine (µg/L)



Bed = sand + gravel, some biofilm

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Swine Hepatitis E in Streams

- HEV important pathogen
- High prevalence of sHEV in swine herds worldwide
- Cross species infection of HEV demonstrated

USGS USDA ARS

Iowa River South Fork Watershed

Iowa Location Map

Wright
Franklin
Alden
Iowa Falls
Williams
Blairsburg
Beaver Creek
South Fork Iowa River
IASF400
Buckeye
Owasa
IATCD
Tipton Creek
Eldora
IABC350
IATC323
IASF450
Hubbard

- Sampling locations
- Swine feeding operations
- Towns
- Basin boundary
- County boundary
- Streams

Source: USDA ARS, Iowa DNR

0 2.5 5 10 Kilometers

N

Swine Hepatitis E

- Large sHEV in manure from 2 hog facilities
- sHEV related to manure applications
  - Aug → (fall manure) → Oct
  - March → (spring manure) → April
    20% 70%
- Results confirmed by sequencing
- No sHEV in out-of-basin reference

USGS USDA ARS

J. Schenzel et al.| © Agroscope
Reckenholz-Tänikon Research Station ART

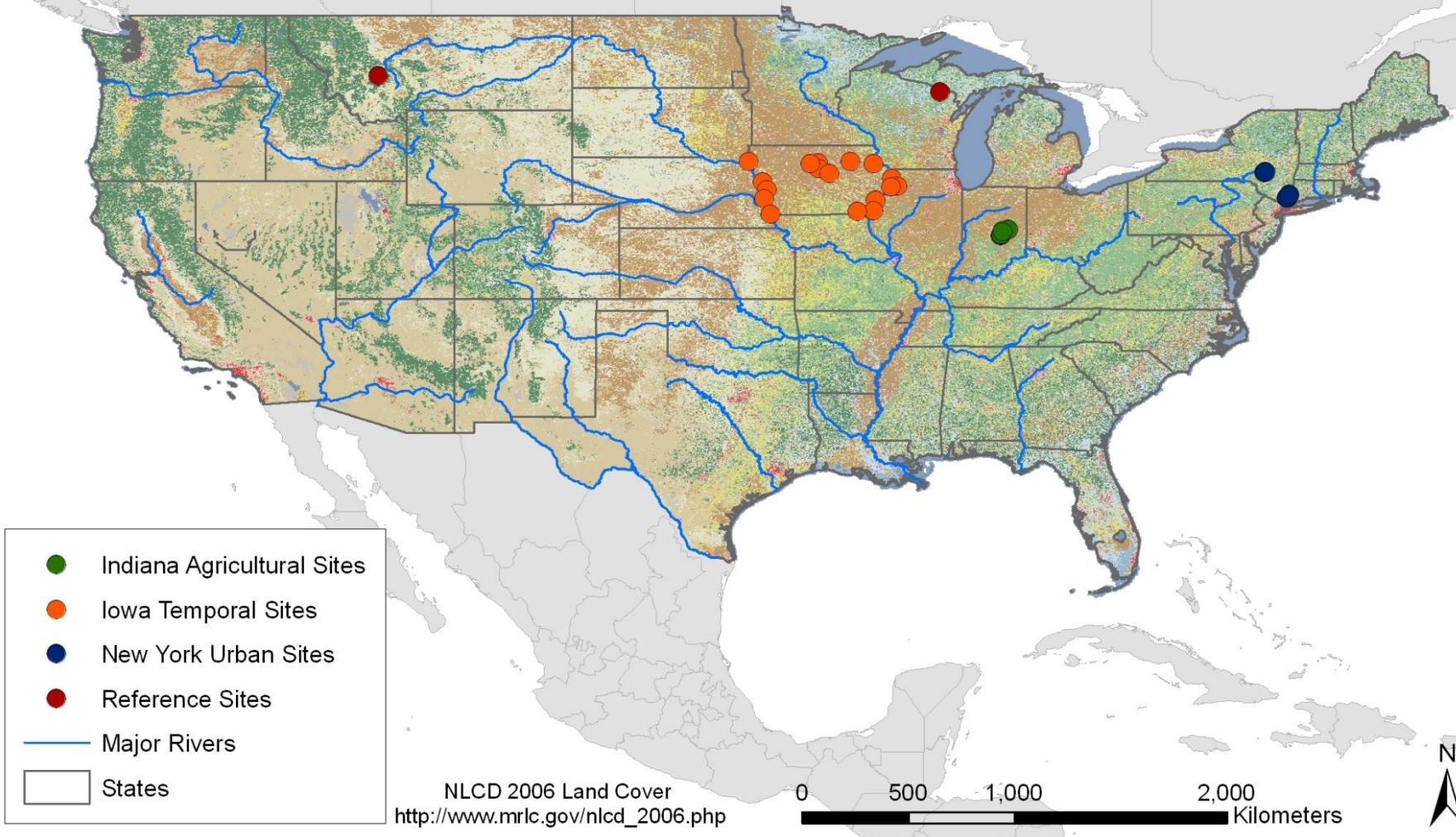
Mycotoxins

Naturally occurring toxic secondary metabolites of fungal species (e.g. *Fusarium spp*.)

Principal sources

- infected crops
- livestock manure
- WWTP effluent

Sampling Network
(116 samples from 35 sites)



Overall Summary

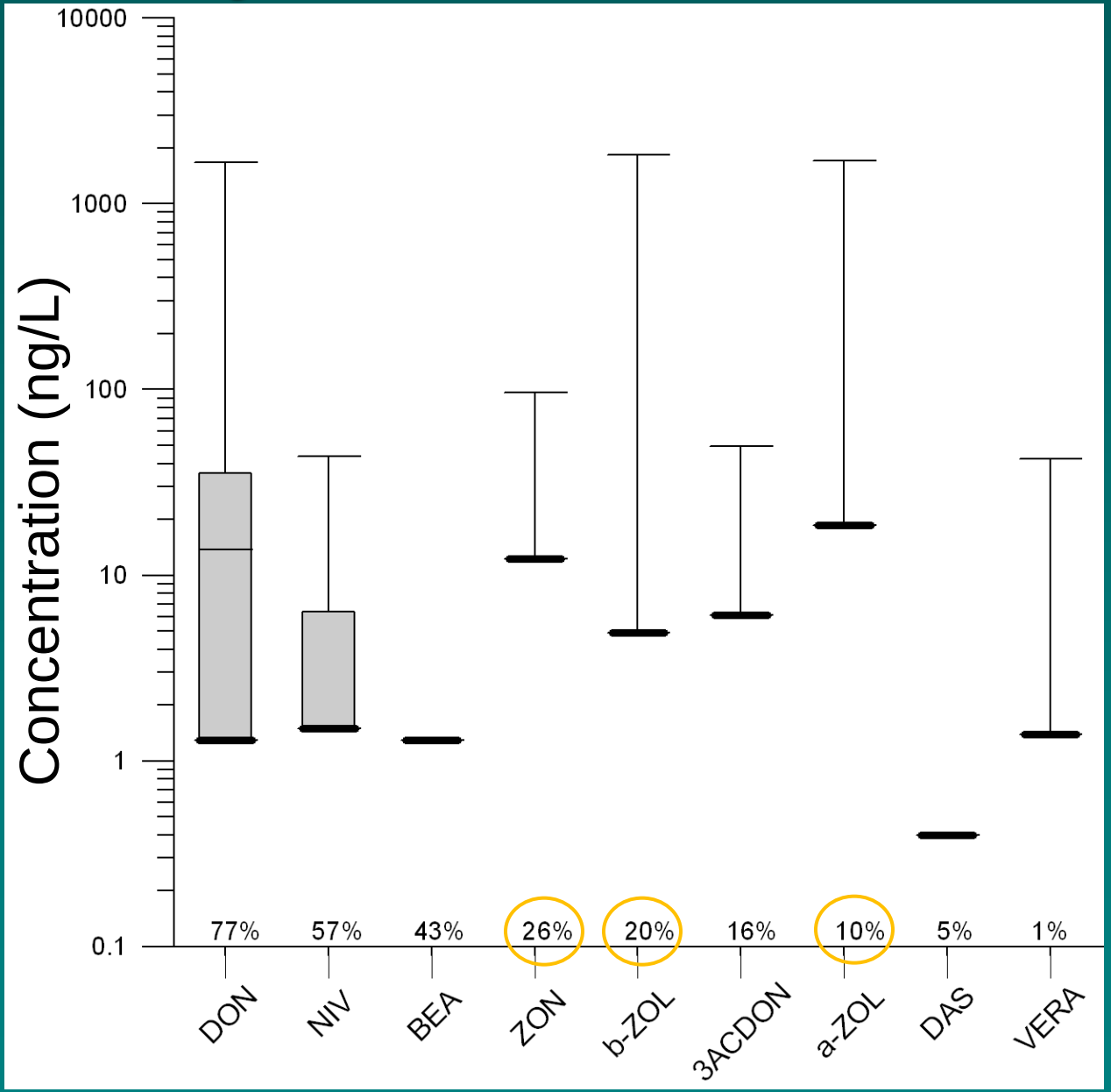
-At least one mycotoxin detection in 94% of 116 samples

- 9 compounds detected

- 80% of samples >1 mycotoxins

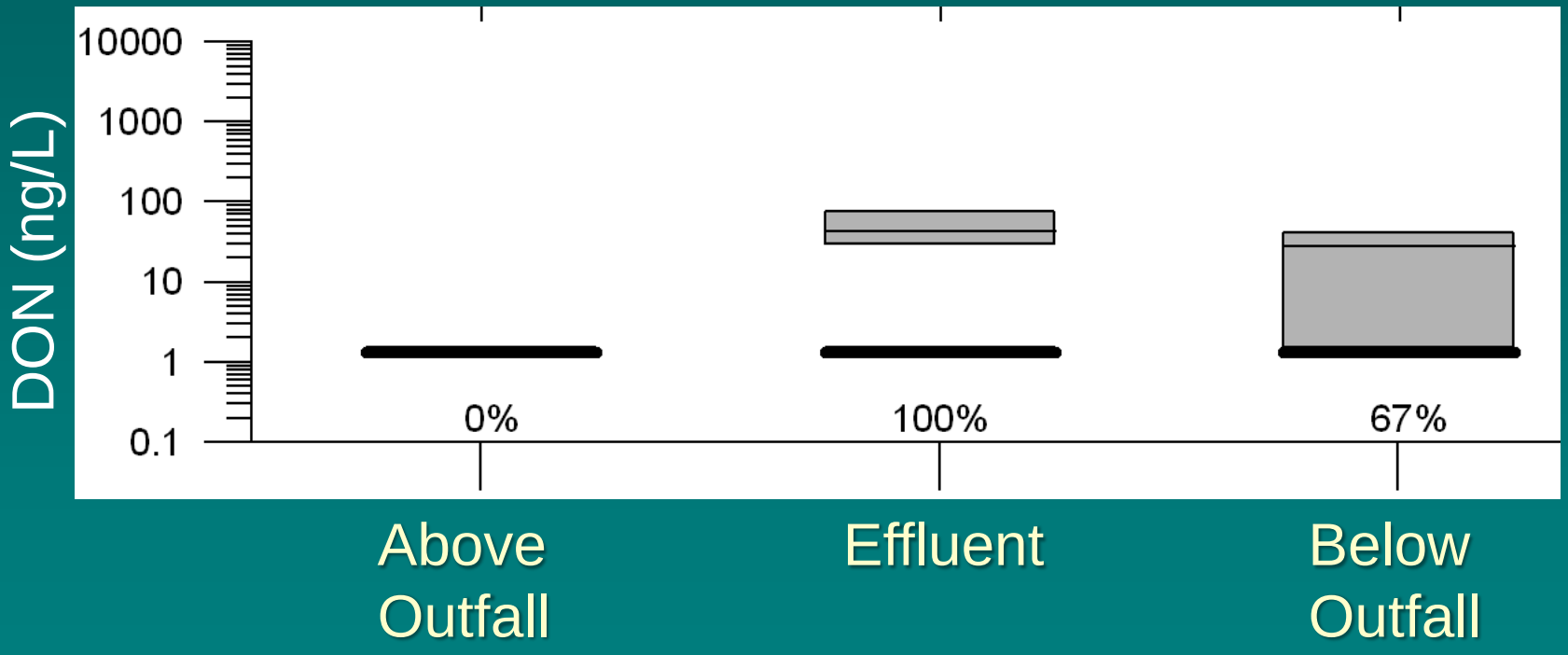
- 42% had >1 estrogenic myco

- 3 concentrations exceeded 1000 ng/L



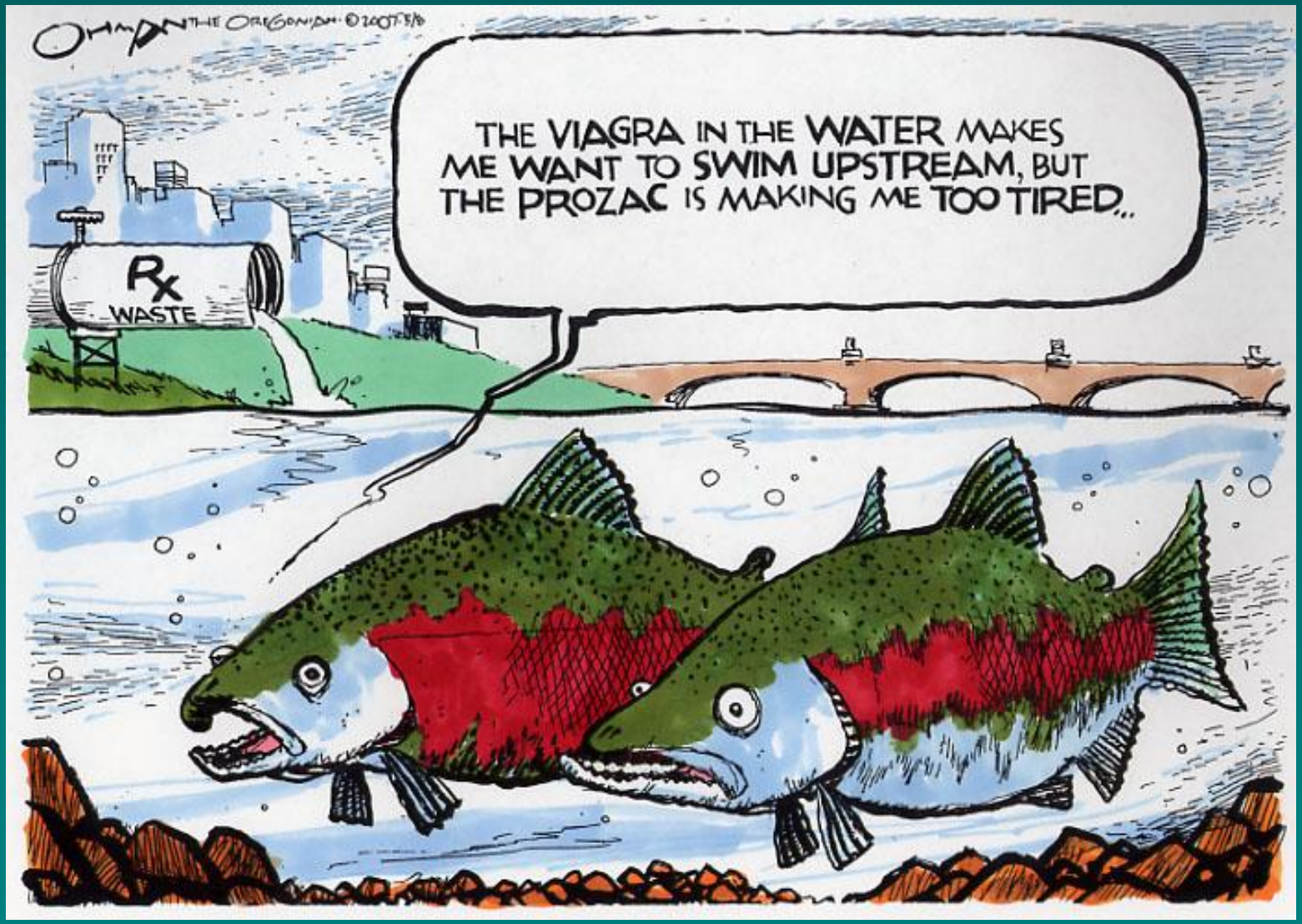
WWTP Effluent a Source of Mycotoxins to streams

- 3ACDON, DON, α-ZOL, β-ZOL



Max effluent concentrations exceeded 1000 ng/L for α-ZOL, β-ZOL

Questions?



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