When It Hits The Fan…Pathogens from Human and Swine Sources in the Environment

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Biological Fact #1

Pigs poop

Biological Fact #2

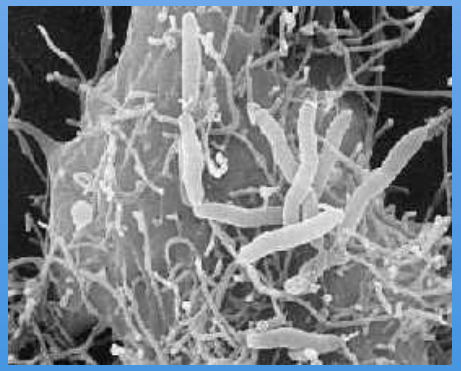
Humans poop, too!

Biological Fact #3

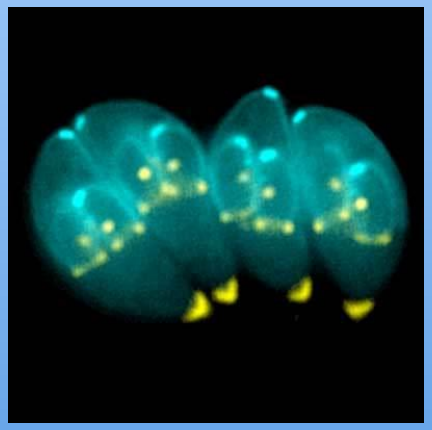
Pathogens are present in poop

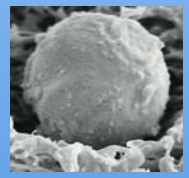
Bacteria (e.g., *Campylobacter*, *Salmonella*, *E. coli* O157:H7, *Aeromonas)*



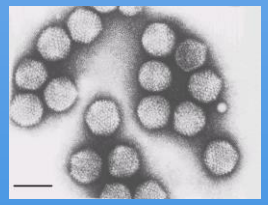


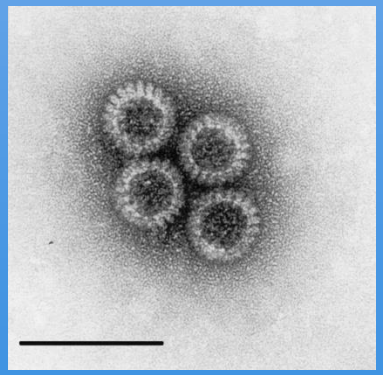

Protozoa, (e.g., *Cryptosporidium*, *Giardia*, *Toxoplasma)*





Viruses (e.g., adenovirus, enterovirus, rotavirus)





Manure's Double-Edged Sword

Manure as Asset

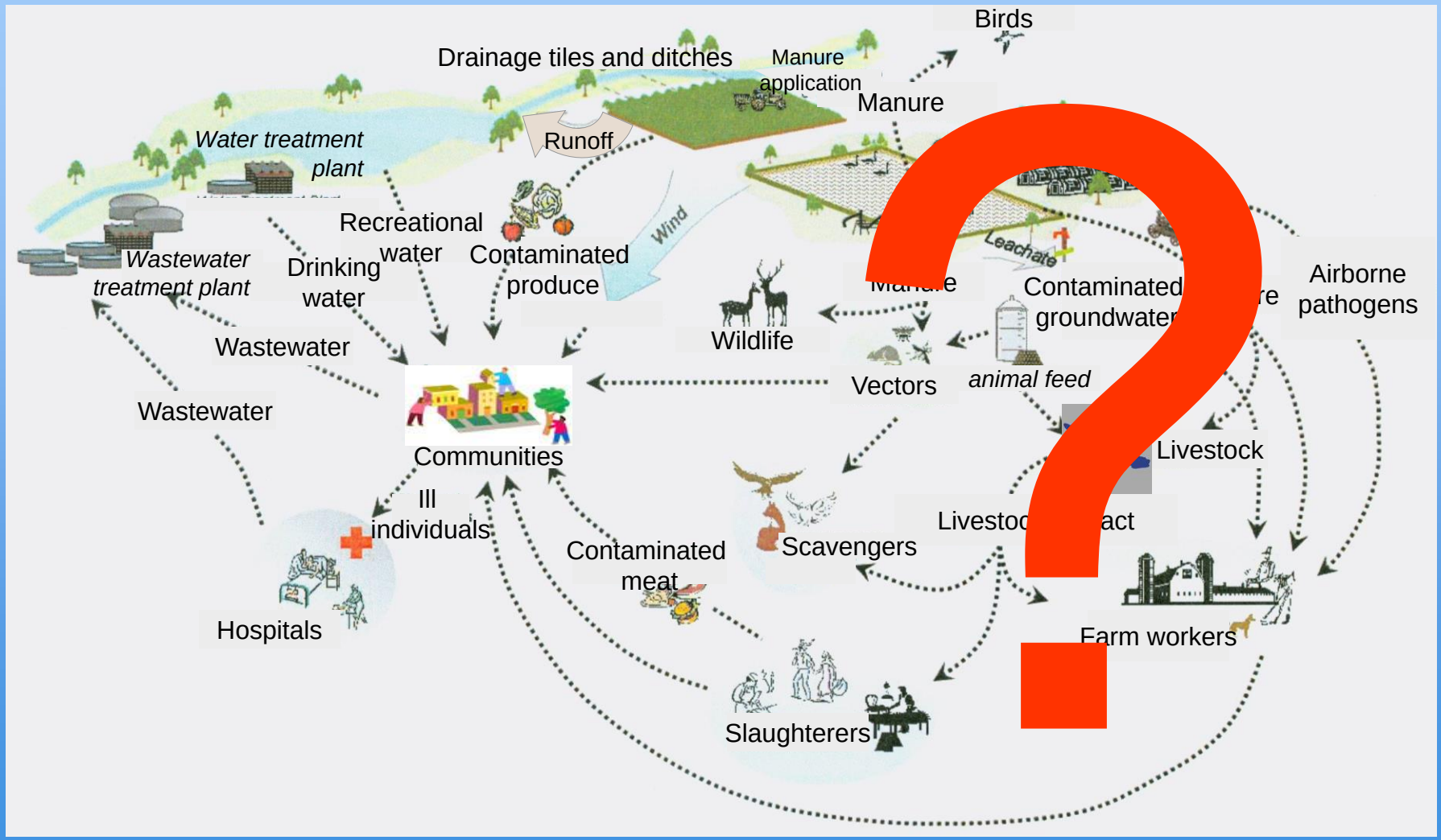
Manure field-application is a cost-effective and sustainable approach for optimal soil tilth and fertility

Manure as Liability

Manure may contain pathogens harmful to both humans and livestock

Societal goal: Maximize the beneficial uses of manure while minimizing environmental pathogen transmission

Human and Livestock Pathogen Movement in the Environment



Rogers and Haines, 2005, EPA/600/R-06/021

Primary Human Pathogens in Swine Manure

- Enterohemorrhagic *E. coli* (e.g., E. coli O157:H7)
- *Salmonella* species
- *Campylobacter* species
- *Yersinia enterocolitica*
- *Listeria* species
- *Giardia lamblia*
- Rotavirus (possible transmission from pigs to humans)
- Norovirus (pigs believed to harbor human strains)
- Hepatitis E virus

Toxin producing *E. coli*

- E. coli O157:H7, the Jack-in-the-Box bug
- Severe diarrhea; 4% of cases develop kidney failure
- 73,000 cases, 60 deaths/year in US
- Walkerton, Ontario outbreak

Salmonella enterica

- In people, diarrhea, cramps, fever
- Can move from the intestine to bloodstream, bone, and urinary tract
- 1.4 million cases, 600 deaths/year in US
- Growing antibiotic resistance

Campylobacter jejuni and C. coli

- Most common cause of bacterial gastrointestinal illness in the US
- Severe diarrhea, potential complications with liver, heart, other organs
- Causes Guillain-Barré syndrome, acute paralysis

Hepatitis E Virus

- HEV is present in approximately
  - 50% of swine herds
  - 70% of storage pits
  - 40% of waste lagoons
- HEV genogroup 3 appears to be shared between swine, humans, and deer
- In developing countries, HEV human mortality rate = 1%, 27% in pregnant women
- However, in developed counties HEV infections are rare
- 45% of samples from the South Fork Iowa River Basin in Iowa were HEV positive

Pathogen traits favoring transmission

- Released to the environment in high numbers in feces
- Long survival times in the environment
- Low dose required for infection
- Capable of multiplying in the environment (i.e., no host required)

Environmental factors favoring pathogen inactivation

- Warm temperatures, greater than 68°F
- Dry desiccating conditions
- Ultraviolet radiation from sunlight
- Freeze-thaw cycles
- Low organic content
- Native microbial communities

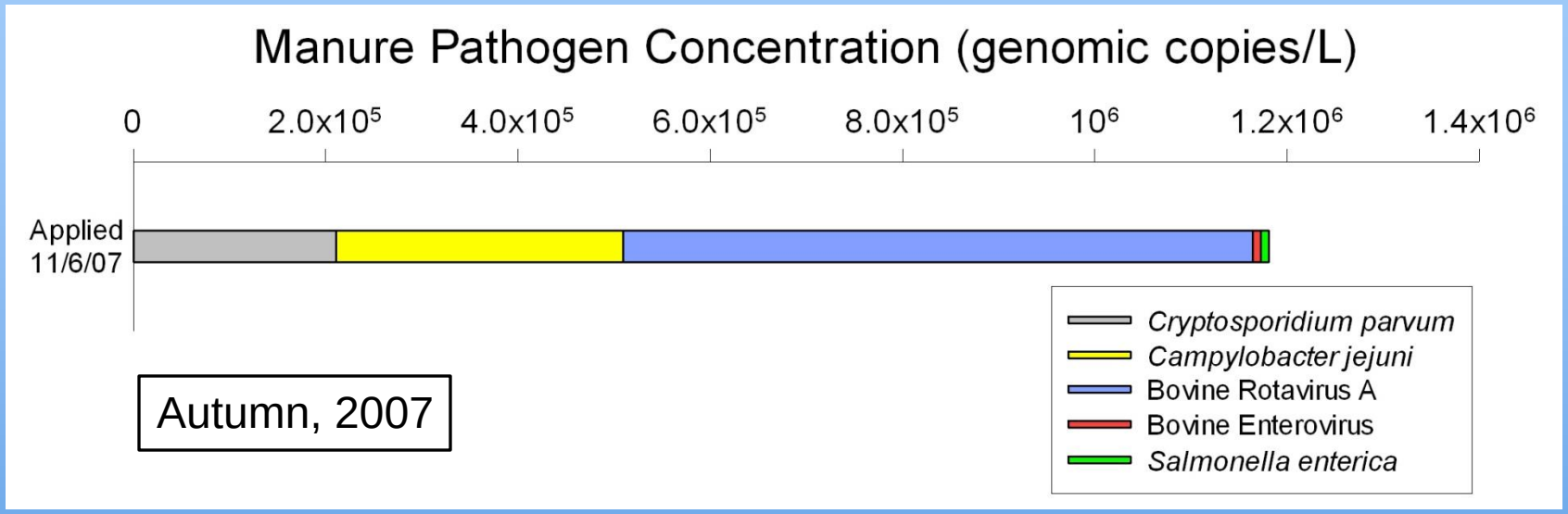
Estimates of Enteric Illness Attributable to Contact with Animals and Their Environments in the United States

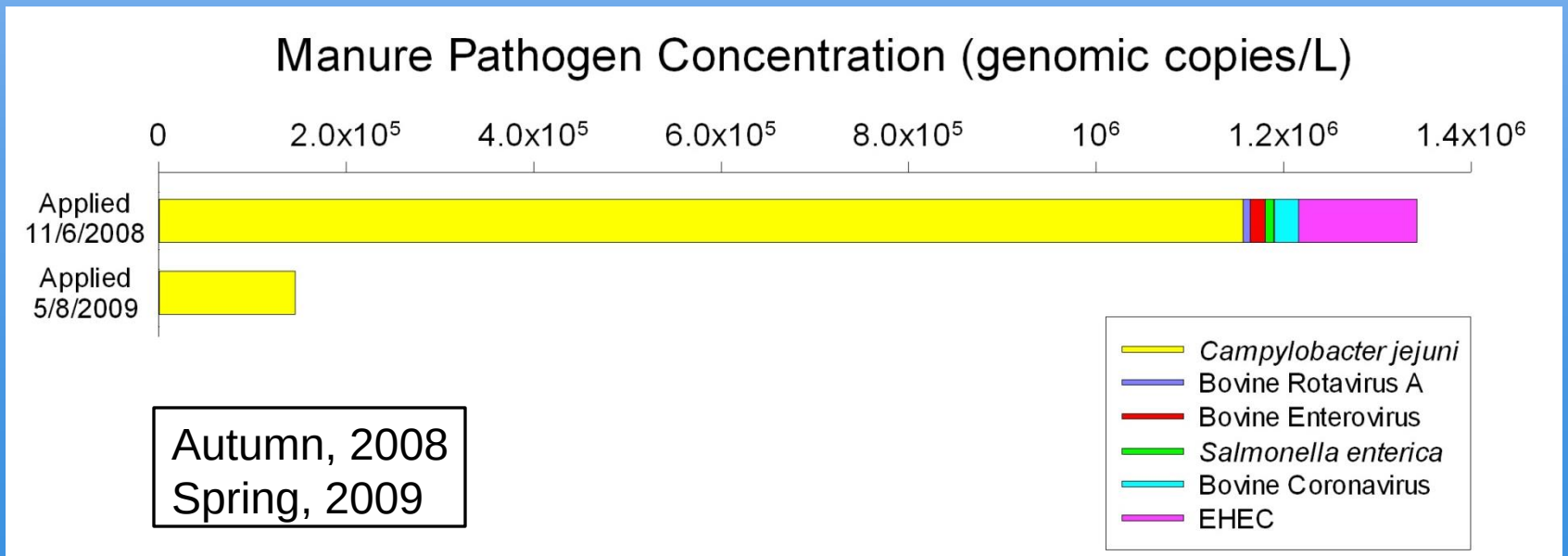
- 445,213 /3.2 million illnesses (14%) from animal contact

Organism	% from animal contact	Annual # illnesses	Annual # hospitalizations	Annual # deaths
Campylobacter species	17%	187,481	1,877	17
ST E. coli	14	16,057	230	2
Non-typhoid Salmonella	11	127,155	2,392	47
Cryptosporidium species	16	113,344	412	7

Centers for Disease Control and Prevention: Hale et al. 2012, CID, 54:S472-79.

Pathogens in manure from a single farm by year and season





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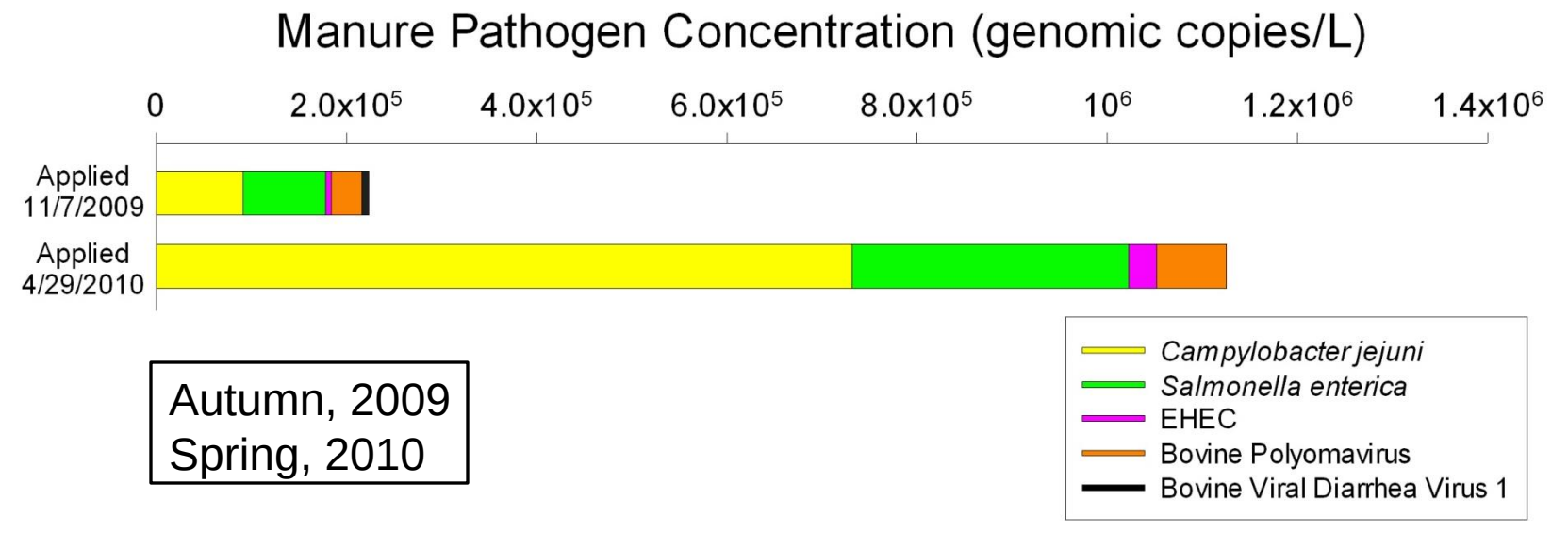
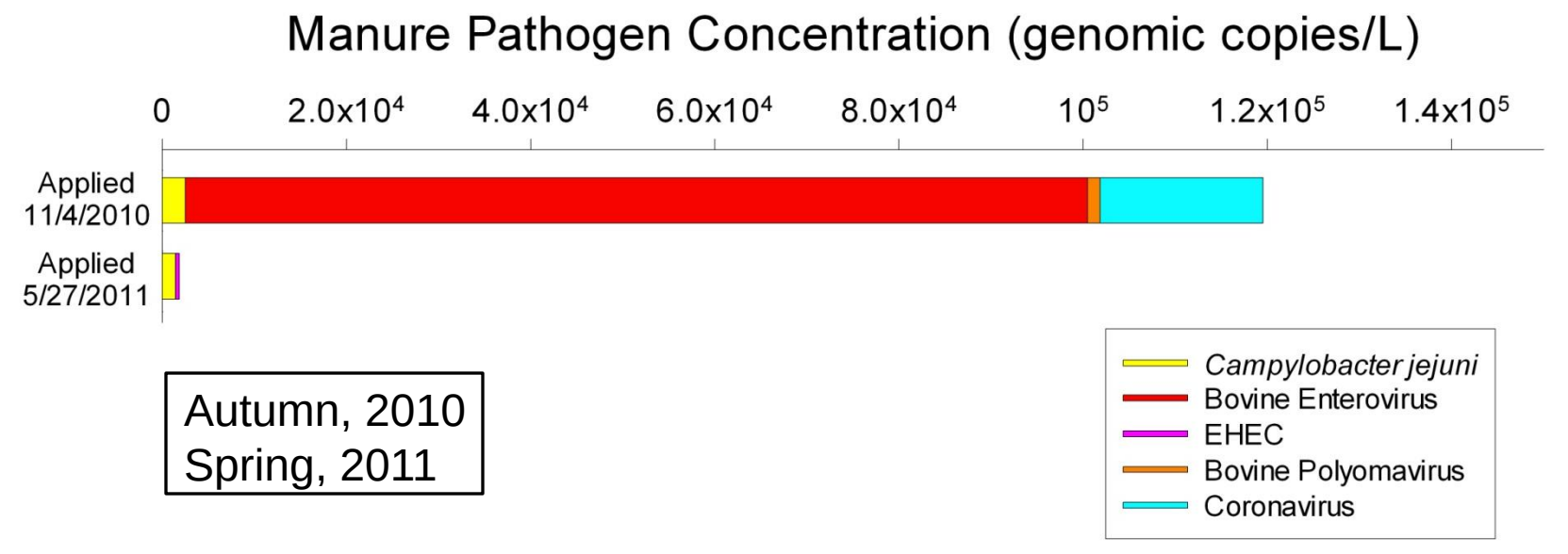




Livestock Pathogens in Groundwater

Sources of Fecal Contamination in Groundwater in Rural Northeastern Wisconsin

Mark Borchardt & Susan Spencer, USDA-Agricultural Research Service, and USGS Wisconsin Water Science Center, Marshfield, WI

Maureen Muldoon, UW-Oshkosh, Dept of Geology

Laura Hubbard & Randall Hunt, USGS Wisconsin Water Science Center, Middleton, WI

Davina Bonness, Kewaunee County Land and Water Conservation Department

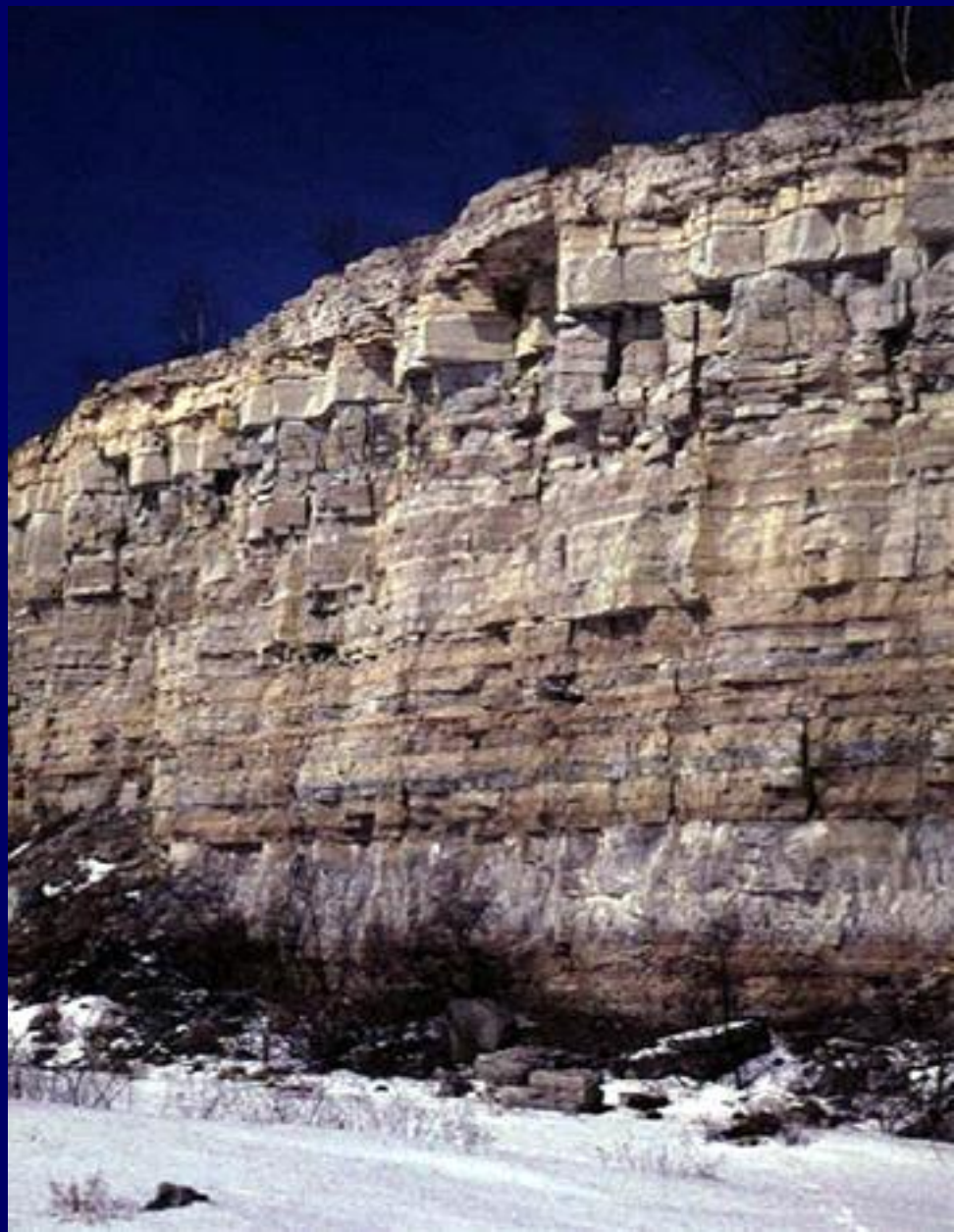
Kevin Masarik, UW-Stevens Point, Center for Watershed Science and Education

Mystery Manure Seep, DePere, WI April 14, 2015

Upper: Manure flowing out of bedrock hole being pumped to storage.

Left: Recovering manure on surface from groundwater seepage

Silurian Dolomite Aquifer



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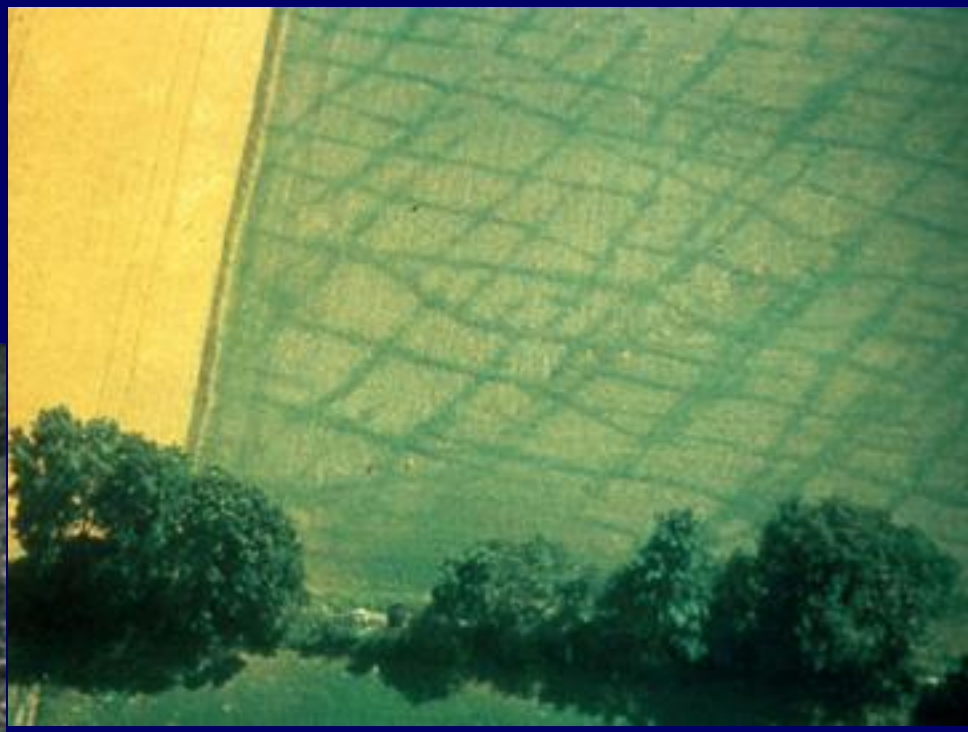
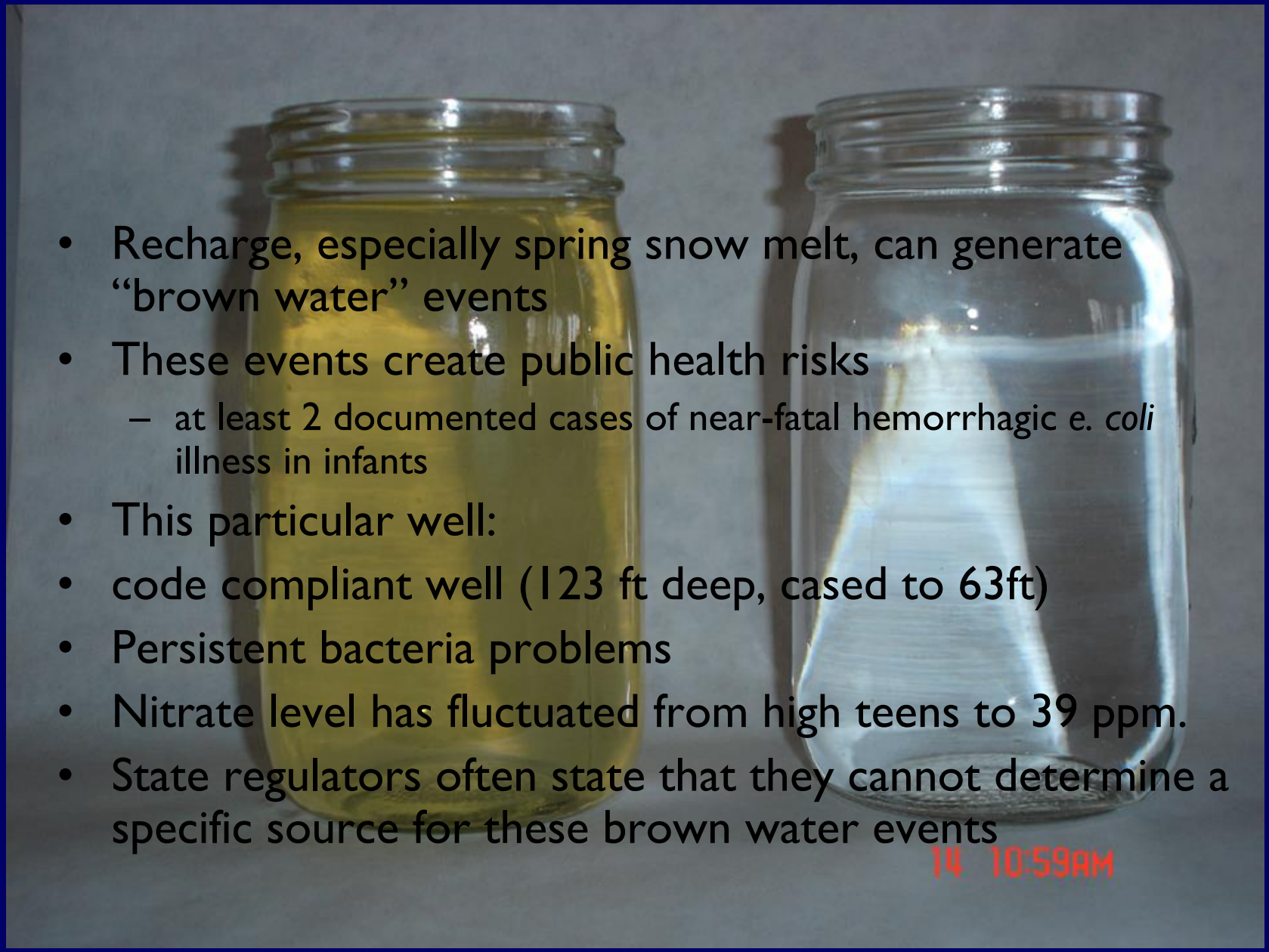


Brown Water



- Recharge, especially spring snow melt, can generate "brown water" events
- These events create public health risks
  - at least 2 documented cases of near-fatal hemorrhagic e. *coli* illness in infants
- This particular well:
- code compliant well (123 ft deep, cased to 63ft)
- Persistent bacteria problems
- Nitrate level has fluctuated from high teens to 39 ppm.
- State regulators often state that they cannot determine a specific source for these brown water events

Pathogen Sampling (May 2014)

- Sampled 10 household wells in Kewaunee County
  - 6 bovine-specific viruses plus bovine bacteroides
  - 7 human-specific viruses plus human bacteroides
  - pepper mild mottled virus
  - zoonotic pathogens
    - enterohemorrhagic *E. coli*
    - *Salmonella* species
    - *Campylobacter jejuni*
    - *Cryptosporidium* species
    - *Giardia lamblia*

- pump ~800 L through hemodialysis filters
- qPCR methods except protozoa by IFA
- Coliforms by Quanti-Tray

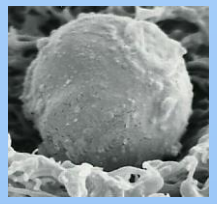
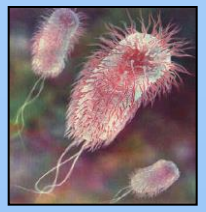
Kewaunee County Results

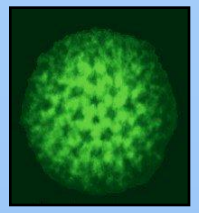
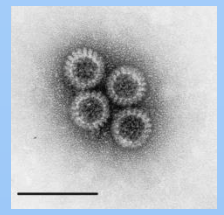
Host	Microbe	No. Wells Detected	Concentration Range (genomic copies/L)
Human-specific	Adenovirus C, D F	1	26
	Adenovirus A	1	3
	Enterovirus	2	21 and 21
	All	3	
Bovine-specific	Polyomavirus	2	16 - 18
	Bacteroides	1	6
	All	3	
Non-defined	Pepper mottle virus	2	22 and 22
	Salmonella spp.	4	2 - 24
	Campylobacter jejuni	1	11
	All	5	
Indicators	Total coliforms	1	3 MPN
	E. coli	1	1 MPN

Kewaunee Results Summary

- 7 of 10 wells were positive for fecal contamination
- Human and bovine fecal sources contaminated 3 wells each; 1 well had both sources
- 6 wells were negative for total coliform or *E. coli* indicators even though pathogens or MST markers were present
- 4 wells had evidence of contamination of *Salmonella* bacteria and one well was positive for the bacterium *Campylobacter jejuni*

Livestock Pathogens in Surface Water

Transport of Bovine Manure-Borne Pathogens in Surface Runoff in a Corn Silage System

Mark Borchardt, Susan Spencer,

Matt Volenec, Sherif Nagi

Craig Simson and Bill Jokela

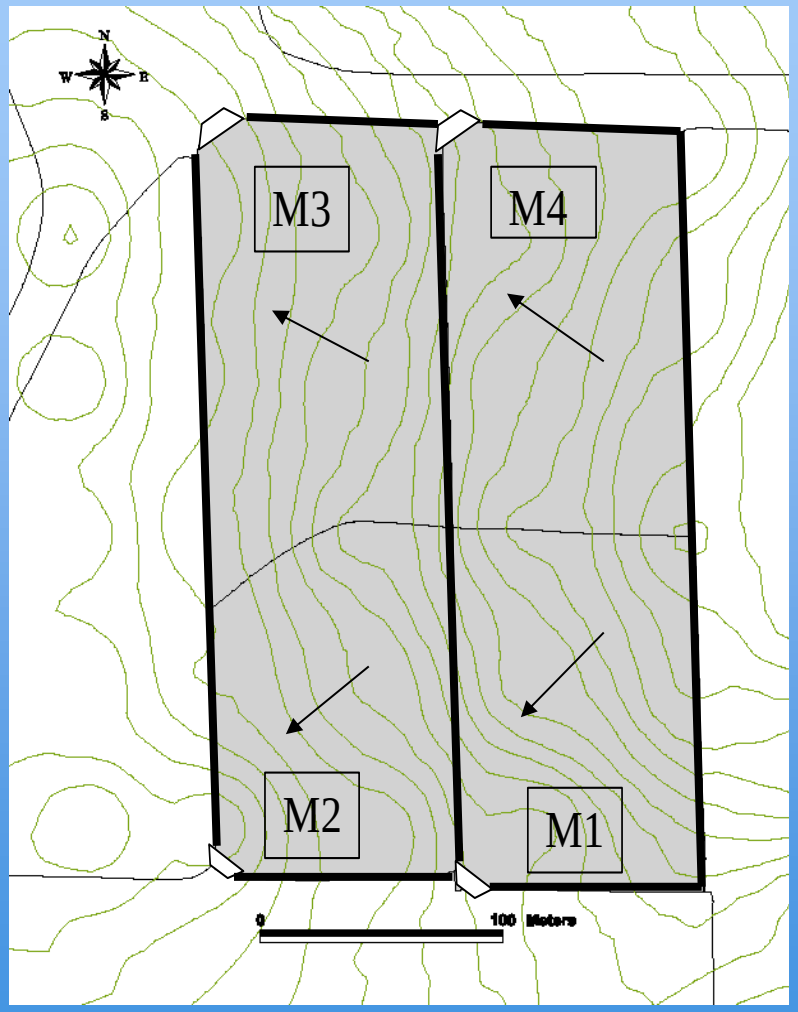
USDA-ARS Institute for Environmentally Integrated Dairy Management

Study Objectives

1. Quantify bovine pathogens in runoff from manure-applied fields
2. Use paired-watershed design to identify cropping, tillage, and manure application practices that minimize pathogen runoff

Objective 2 is only in the early phases of experimentation

Field Site



Located at the North farm of the UW/USDA-ARS Research Station in Marshfield, WI

Withee silt loam with 1-3% slope

Fields divided by drainage ditches and berms into four drainage areas

Each field about 4 acres, cropped in corn

Manure application once per year, about 5,800 gallons/acre

Runoff Monitoring Stations

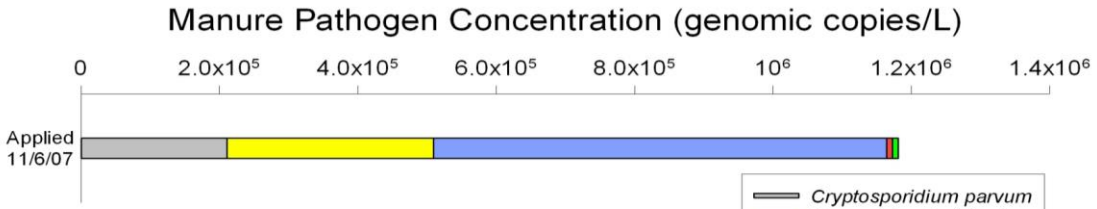
H-flume: stage measured using bubble-pressure transducer

Pathogens: refrigerated glass wool filtration; event-based sampling, not flow-weighted

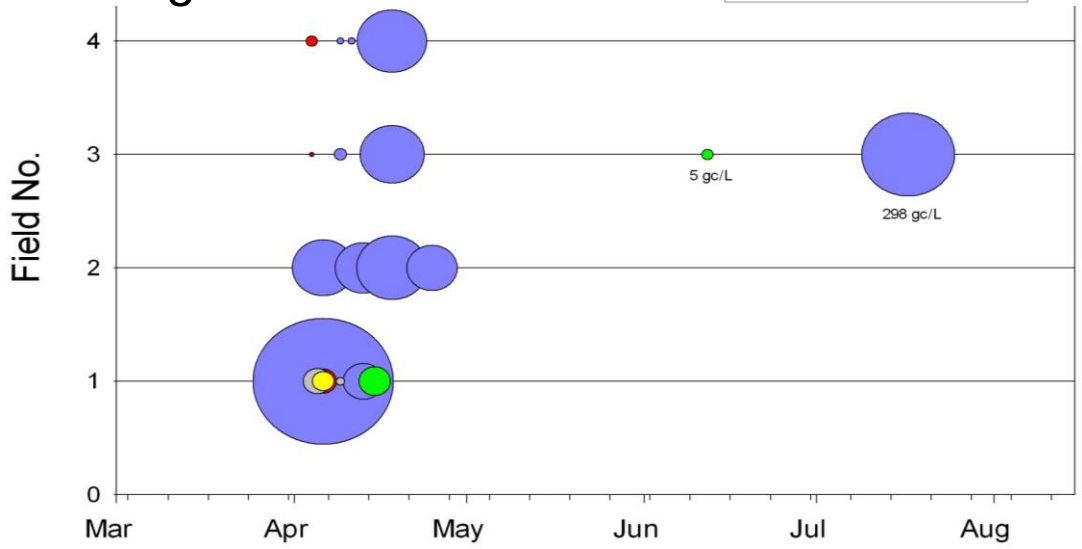
Nutrients, sediment, and indicator *E.coli*: automated refrigerated sampler with time-based sampling

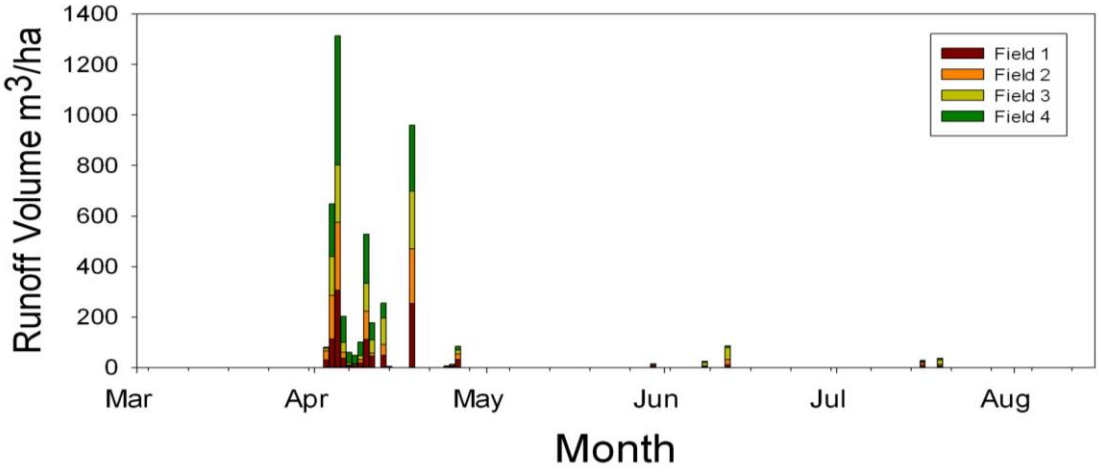
Controlled remotely by radio telemetry

Year 2008



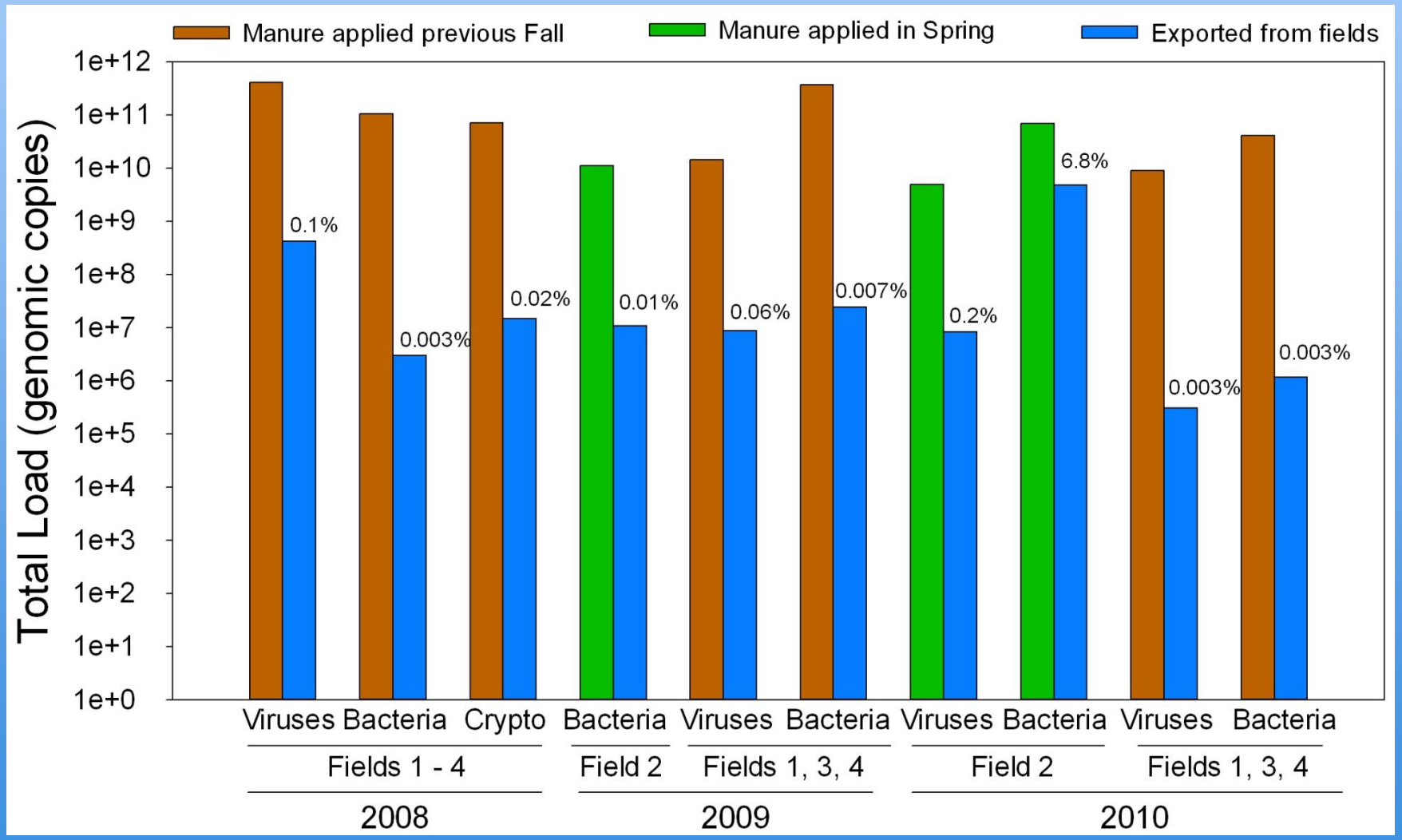
Pathogen Concentrations



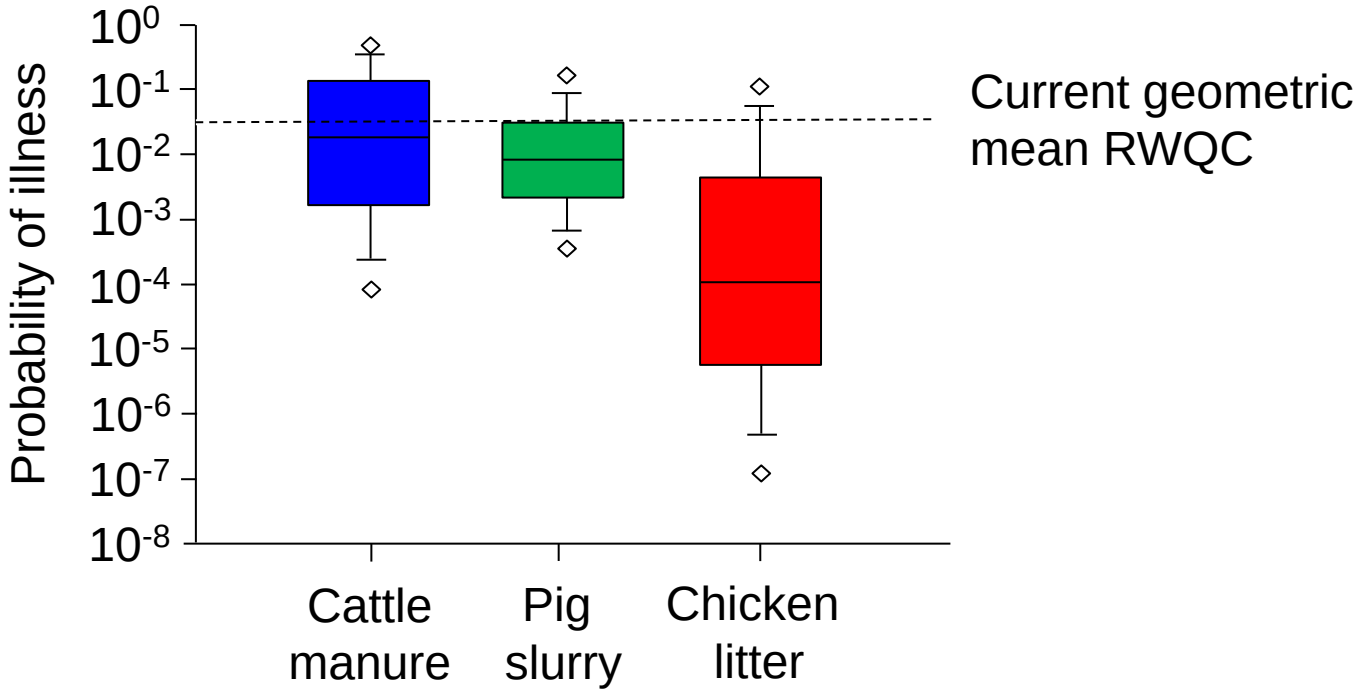


Pathogen Cumulative Export

Caveat: Export values are not-flow-weighted



Risk of Illness from Swimming in Freshwater Impacted by Livestock and Poultry Manure



Source: US EPA, 2010, Quantitative Microbial Risk Assessment to Estimate Illness in Freshwater Impacted by Agricultural Animal Sources of Fecal Contamination

Livestock Pathogens in Air

Quantitative Microbial Risk Assessment for Estimating Setback Distance from Spray Irrigation of Dairy Manure

Tucker Burch[1,3], Susan Spencer[2,3], Joel Stokdyk[1,3], Aaron Firnstahl[1,3], Becky Larson[4], and Mark Borchardt[2,3]

[1]US Geological Survey, Wisconsin Water Science Center
[2]US Department of Agriculture – Agricultural Research Service
[3]Laboratory for Infectious Disease and the Environment
[4]UW-Madison, Department of Biological Systems Engineering

Manure Irrigation Workgroup Meeting
April 29, 2015

Up close, it’s not pretty

Study Objectives

1. Develop statistical model from field data to predict airborne pathogen transport
2. Use quantitative microbial risk assessment to establish safe setback distance
3. Identify variables that control airborne pathogen transport during manure irrigation
   - Wind speed
   - Solar irradiance
   - Relative humidity
   - Temperature

Measurements During Irrigation Trials

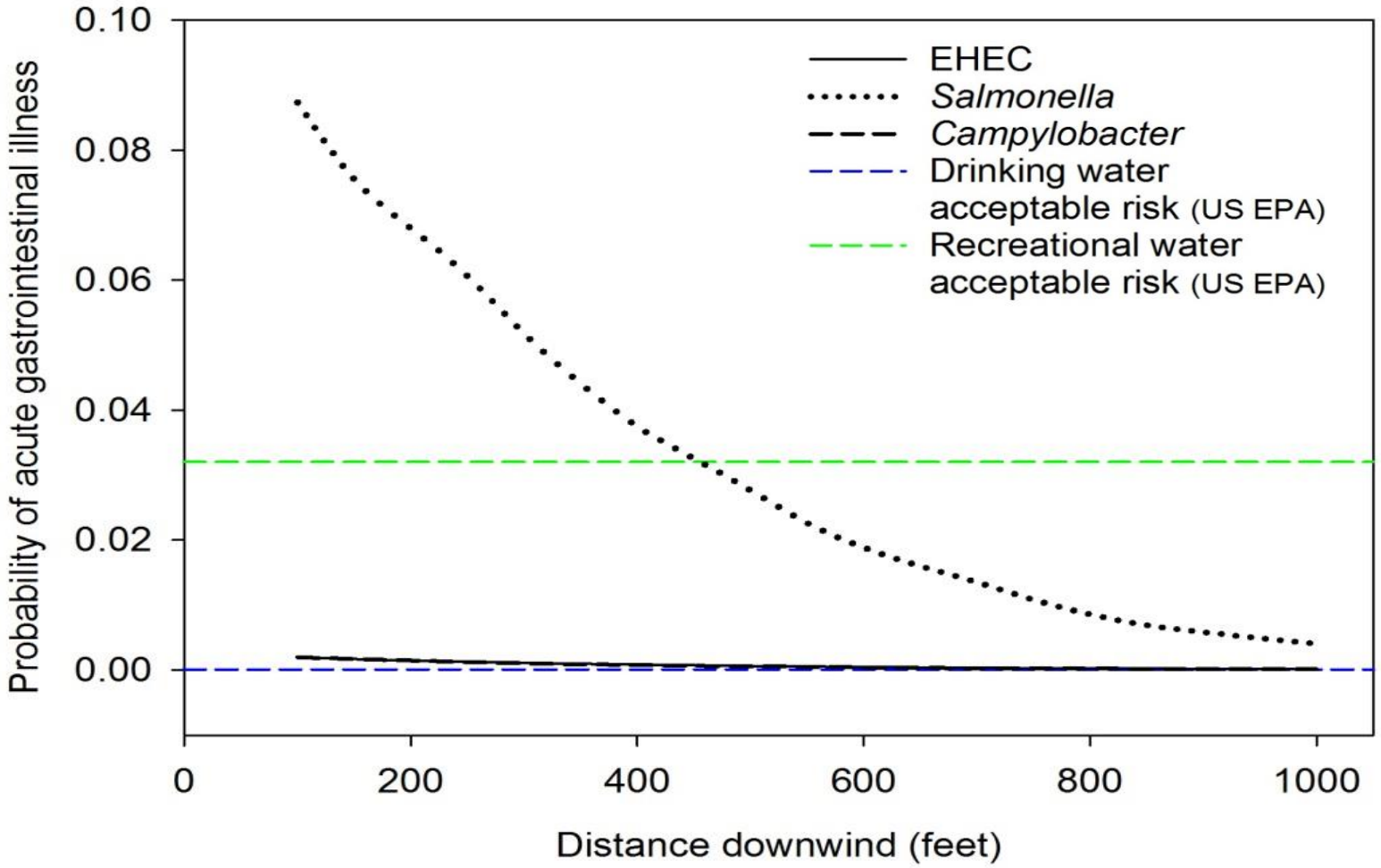
Commensal Microbes and Pathogens
- qPCR
- conventional culture

Portable Weather Station
- wind direction and speed
- air temperature
- solar radiation
- relative humidity

Summary of Experimental Trials

- 3 farms
- 25 trials conducted 2012 - 2014
  - 8 center pivot trials
  - 15 traveling gun trials
  - 2 tanker trials
  - 3 nighttime trials
  - 15 trials with bacterial culture data
  - 25 trials with qPCR (i.e., genetic marker) data

Risk of airborne disease transmission over distance from manure irrigation equipment



Antimicrobial Resistance

- 85% of swine operations use antimicrobials in feed for nursery pigs (USDA 2008)
- Resistance to two or more antimicrobials found in 74% of *Salmonella* and 62% of *Campylobacter* isolates from swine manure (US EPA 2013)
- The linkage between antimicrobial usage in swine operations and antimicrobial resistant infections in humans is under-researched
- An exception: Johns Hopkins study found 38% increase in methicillin-resistant *Staphylococcus aureus* (MRSA) infections in people living near crop fields with land-applied swine manure (Casey et al. 2013, JAMA Intern Med)

Healthy Humans
Healthy Livestock
Solutions for Preventing Exposure to Pathogens in the Environment

Sanitation in the Middle Ages, from an old wood cut

Solutions ?

Solutions for Preventing Exposure to Manure-borne Pathogens in the Environment

Practices to Minimize Transport	Practices to Maximize Inactivation
Distance between livestock and waterways	Storage time
Vegetated treatment areas	Chemical treatment (e.g., lime)
Settling basins and wetlands	Thermophilic processes (e.g., aerated composting)
Manure storage and treatment lagoons	Anaerobic digestion

From: Atwill et al. 2011 An Introduction to Waterborne Pathogens in Agricultural Watersheds, NRCS Draft document

Preventing It from Hitting the Fan…

Working together the agricultural industry, researchers, and policymakers can:

- Identify research priorities
- Generate ideas
- Test potential solutions

Contact Information
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Questions?

Comments?