What's in our Groundwater?

Virus and Other Contaminants in Groundwater: Data from Iowa Groundwater Study

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Outline

- Why Study this Stuff?
- Partnerships and People
- Hydrologic Conditions
- Study Analyte List
- Well Selection Criteria
- Results
- Conclusions

Why Study?

- WI: Viruses frequently present in raw Ground Water PWS source aquifers – including the "geologically "protected".
- WI: Higher frequency in wet periods. Leaking sewer systems implicated.
- EPA & Unregulated Contaminants – USGS Emerging Contaminants, Viruses … Pharmaceuticals?
- Original Source Water Protection - GW Vulnerability concepts based on private wells, geology, and nitrate.

Partnerships

CHEEC
Center for Health Effects of Environmental Contamination

Funding for:
- Sample Collection
- Virus Analysis
- Data management/ interpretation

DNR IOWA
DEPARTMENT OF NATURAL RESOURCES

- Majority funding
- Drinking Water (SWP)
- Public System gpd
- Well (re)selection
- Cold calling of PWS
- Data shares
- Contracts and grants
- Technical Report
- Final State Report

State Hygienic Laboratory at The University of Iowa

- Sampled Wells
- General WQ
- Nutrients
- Metals, Anions
- Pesticides
- Pathogens

USGS
science for a changing world

(*Iowa*)
- Sampled wells
- Shipped Samples

(*Colorado*)
- Pharmaceuticals

EIL – U of Waterloo

USDA United States Department of Agriculture

- Analyzed for Viruses

Participating Community Water Supplies

Thank You!!

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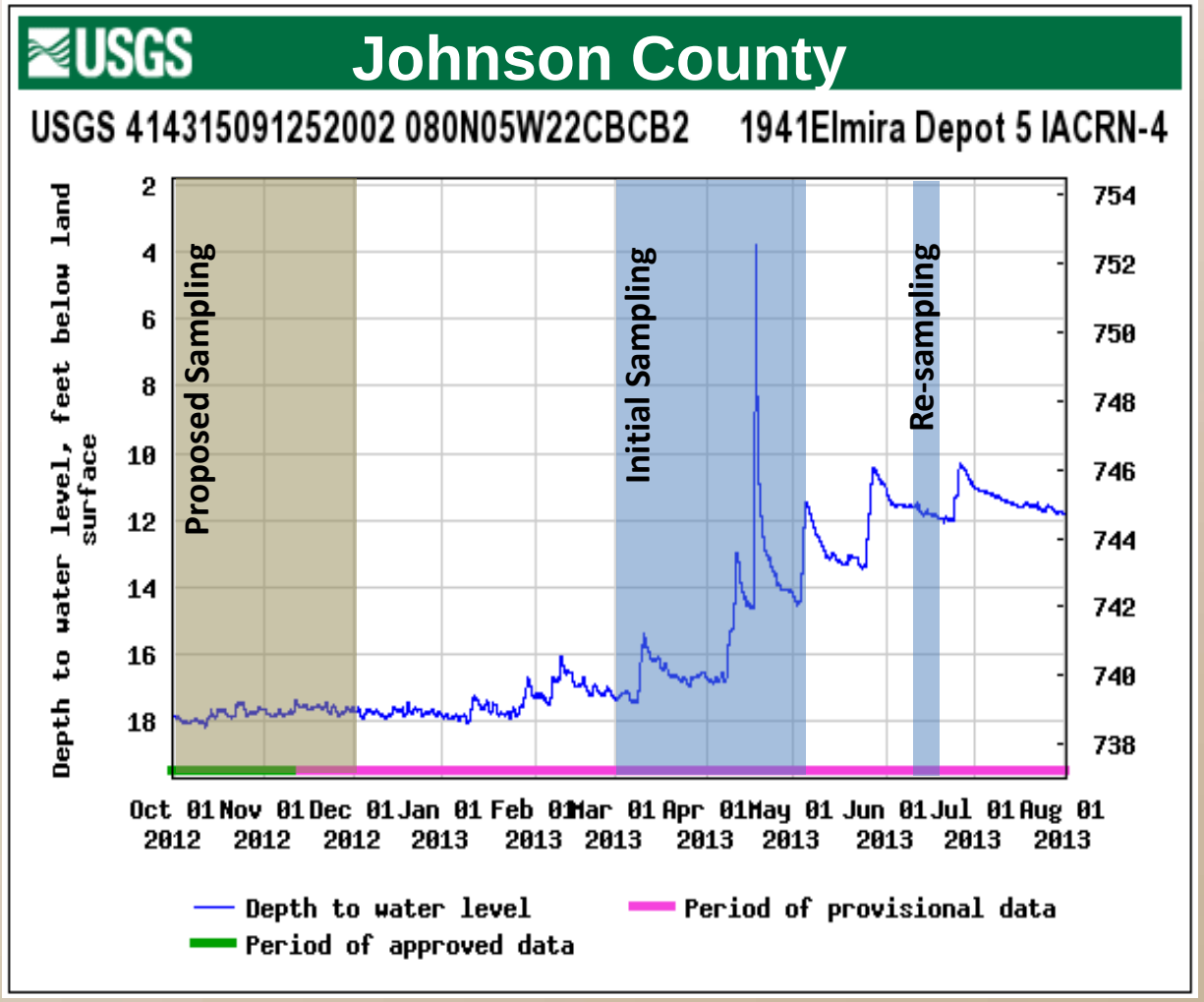
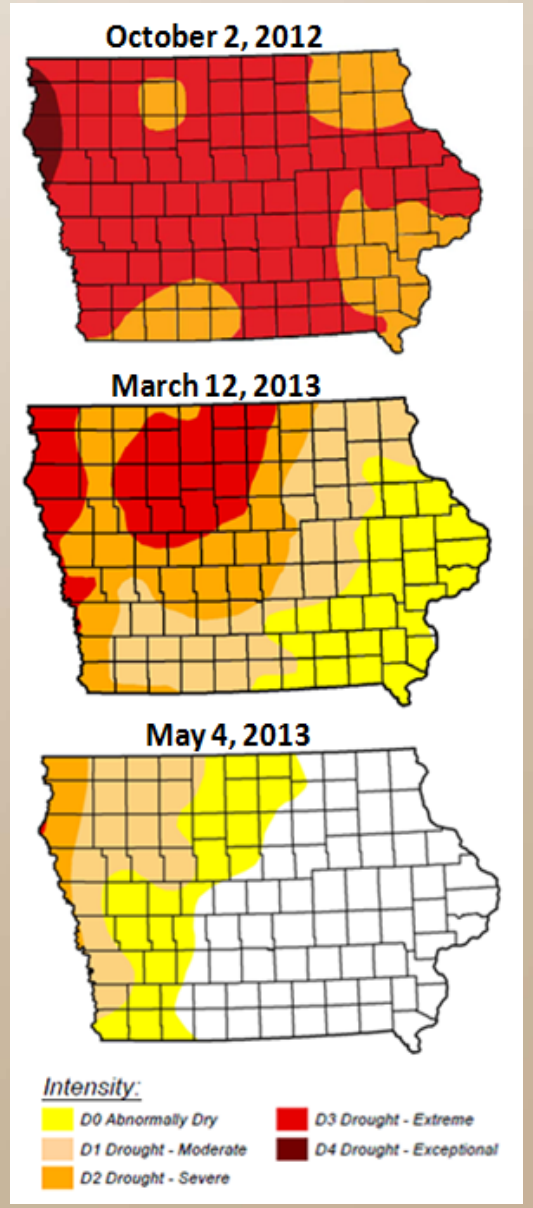
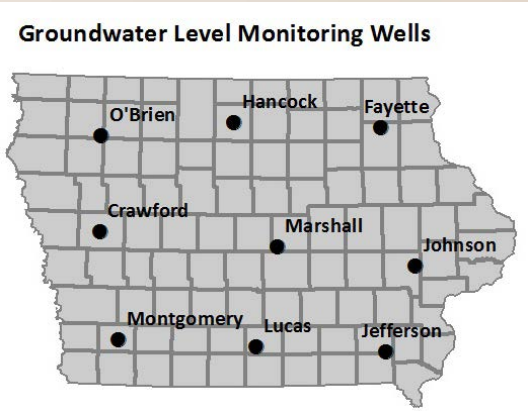
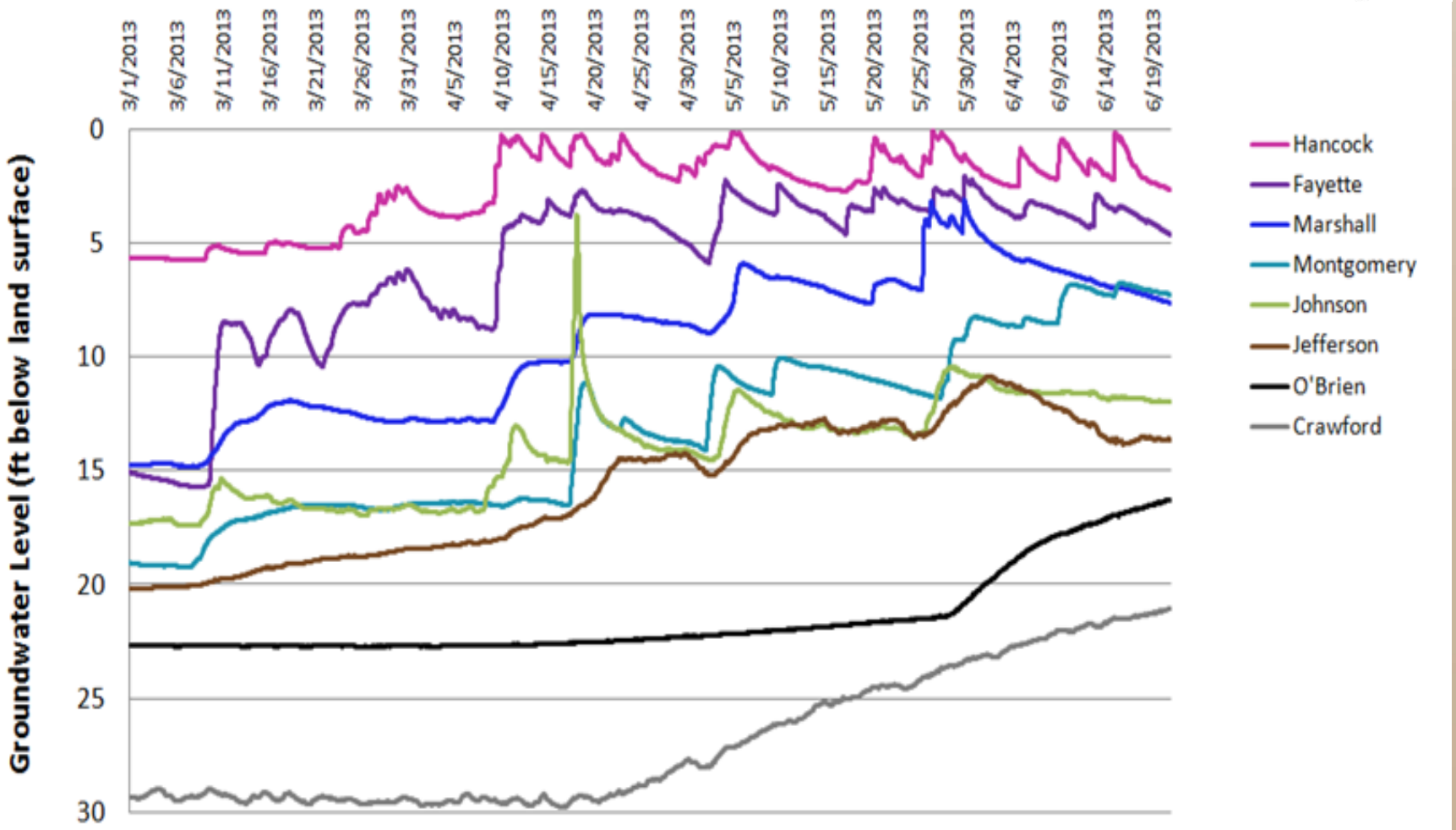
Hydrologic Conditions





Hydrologic Conditions





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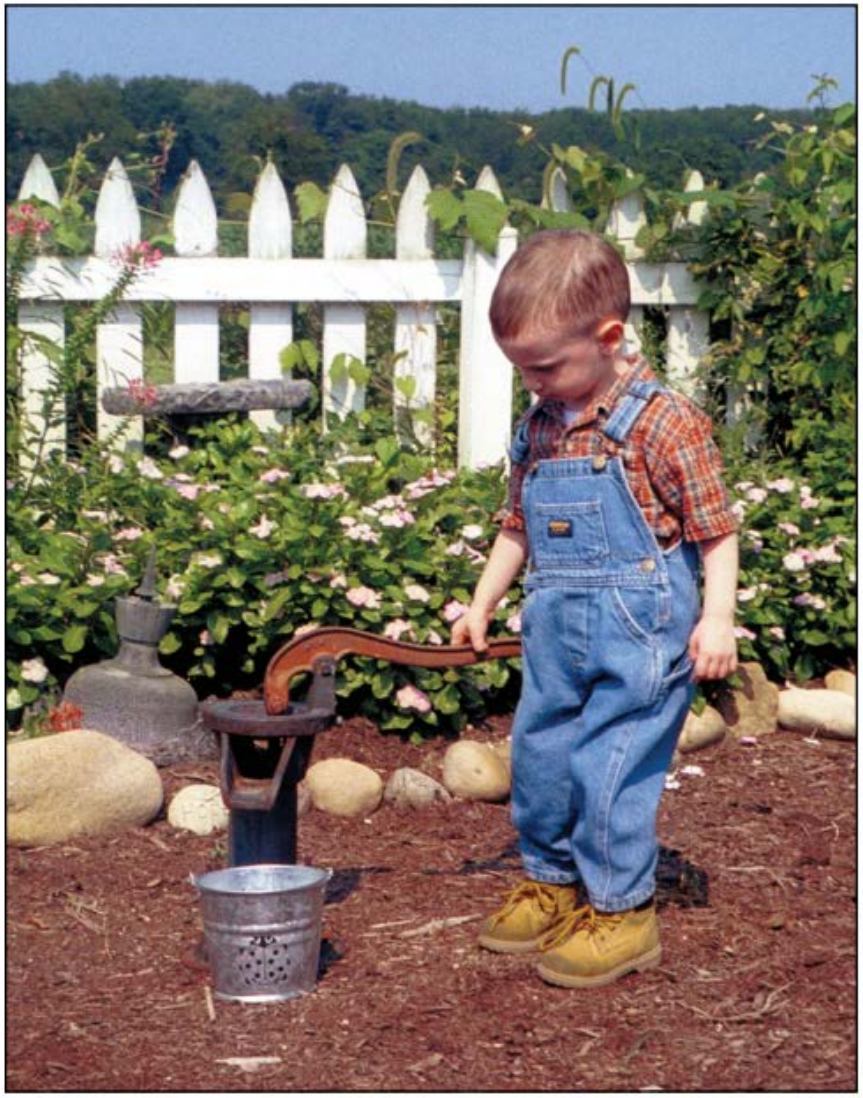
Well Selection

Only enough funding to sample 66 wells (out of ~6,000 public wells: 1%)

Factors

- Pumping Rate
- Well Age
- Land Use
- Geologic Protection



Cover photo courtesy of Charlene E. Shaw, U.S. Environmental Protection Agency

http://water.epa.gov/drink/info/well/upload/2003_06_03_privatewells_pdfs_household_wells.pdf

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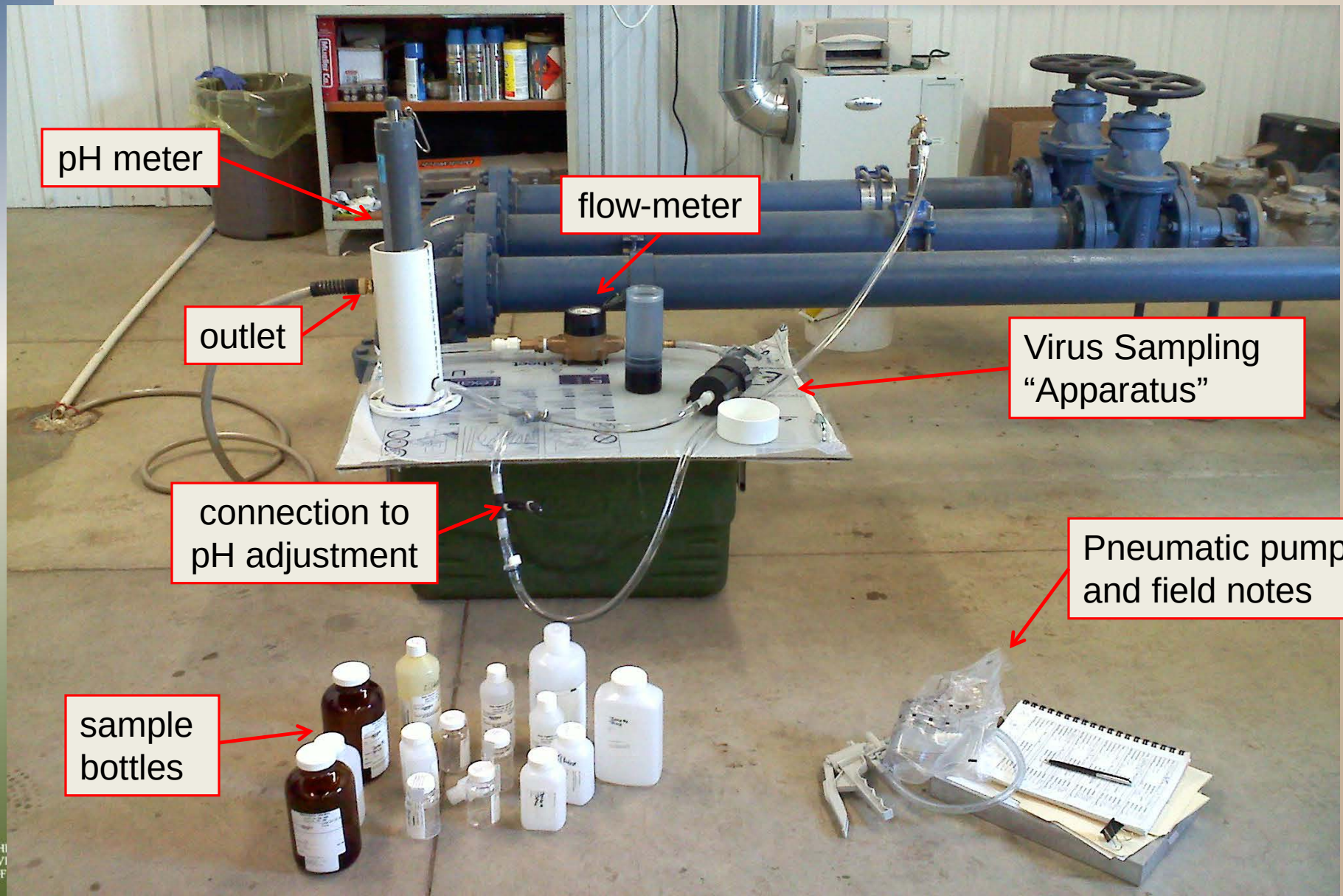
Selected Wells

Well Age			Well Susc.			Well Use			Land Use		
Date			Conf. Layers			Daily Discharge			Majority 1000 ft		
<1980	A	24	0-50 ft.	A	29	<40,000 gpd	A	30	Row Crop	A	12
1980-2000	B	21	50-100 ft.	B	15	>40,000 gpd	B	36	Developed	B	34
>2000	C	21	>100 ft.	C	22				Grasses	C	20

AQUIFER	Aquifer Count	AQUIFER	Aquifer Count
Alluvial	12	Silurian	7
Cambrian-Ordovician	8	Silurian-Devonian	7
Devonian	8	Mississippian	5
Buried Sand and Gravel	7	Cambrian	2
Dakota	7	Ordovician	2
		Devonian, Ordovician	1

Sampling Setup



Pre-sampling Preparation

- Filtering Apparatus Construction
- Water Plant Operator Contacts
  - Approximately 66 well operators
  - Alignment of expectations
- Materials and Equipment Preparation
  - Inventory of Equipment
  - Preparation of Reagents
  - Sterilization of fittings and tubing

Sampling Protocols

- Set-up of Filtering Apparatus
- Flow Rate Adjustment
- pH stabilization
- Virus filter attachment
- Re-adjust flow rate and check pH
- Four hours of pumping
- Supplemental sample collection
- Virus sample shipping

Challenges

- Pumping Rates (well head vs. protocol)
- Timing of sampling
- “Wasting” water and cost
- Connecting to well house spigots
- Effluent rates and drains
- Flooding
- Cold weather sampling

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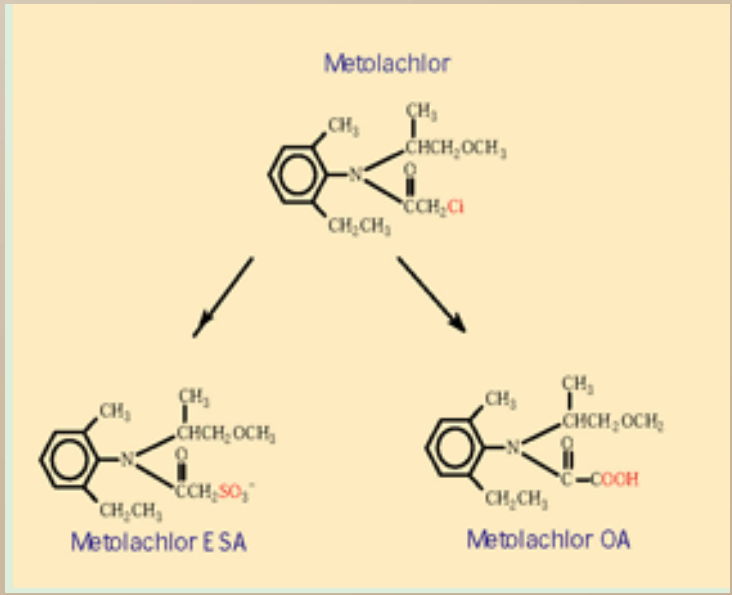
Challenges/Acknowledgements

Study Analytes

- General water quality indicators
- Nutrients
- Metals
- Pesticides/degradates
- Pharmaceuticals
- Pathogens/bacteria
- Viruses



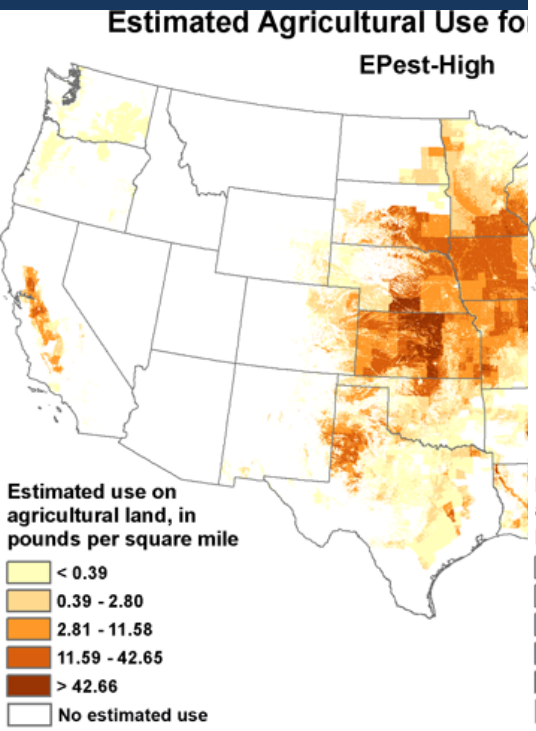
http://pubs.usgs.gov/circ/circ1210/major_findings2.htm

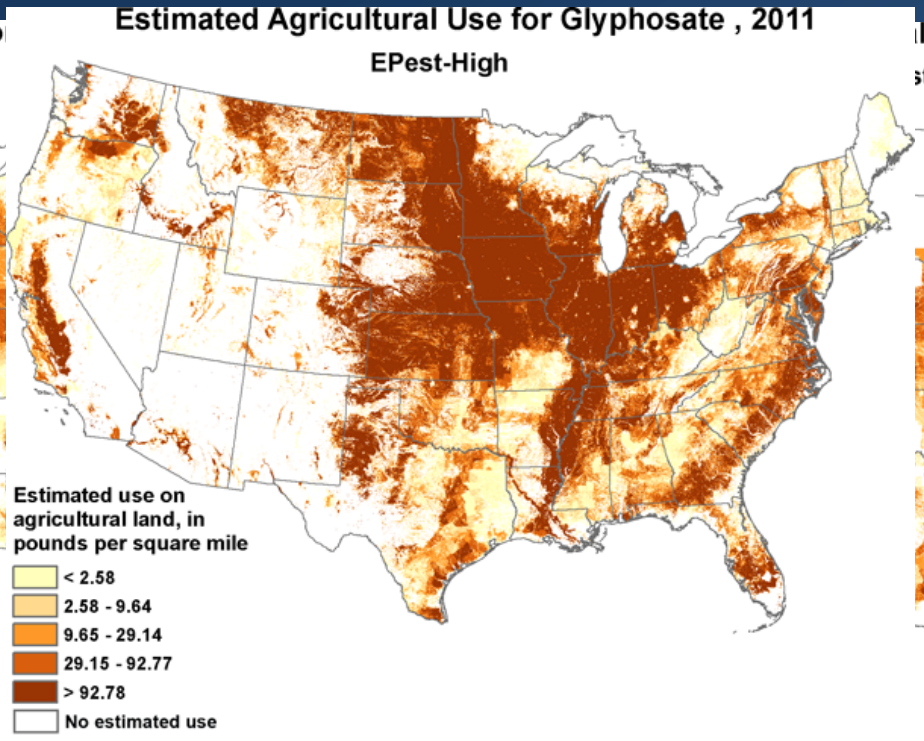
Total Analyte List

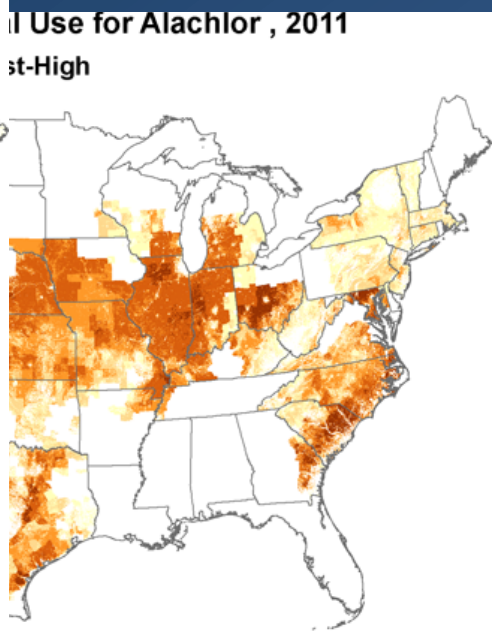
Cations and Anions	Nutrients	Pathogen Indicators	Pesticides and Degradates	Pharmaceuticals		
Fluoride	Nitrate + nitrite as N	Adenovirus A	Alachlor (Lasso)	erythromycin	Fluconazole	penciclovir
Chloride	Ammonia Nitrogen as N	Adenovirus B	Atrazine	norethindrone	fluoxetine	Pentoxifylline
Sulfate	Ortho-Phosphate as P	Adenovirus C	Carbofuran (Furadon)	10-h-amitriptyline	fluticasone	phenazopyridine
Bicarbonate Alkalinity	Total Kjeldahl Nitrogen as N	Adenovirus D	Glyphosate	abacavir	fluvoxamine	Phendimetrizine
Bromide	Total Phosphorus as P	Adenovirus F	Simazine	acetaminophen	glipizide	Phenytoin
Calcium (dissolved)		Total Coliform Bacteria	Acetochlor	acyclovir	glyburide	Piperonyl butoxide
Carbonate Alkalinity		Enterovirus	Metolachlor (Dual)	albuterol	hydrocodone	prednisolone
Magnesium (dissolved)		Norovirus I	Ametryn	alprazolam	hydrocortisone	prednisone
Potassium (dissolved)		Norovirus II	Bromacil	amitriptyline	hydroxyzine	promethazine
Silica as SiO2		Campylobacter	Butachlor	amphetamine	Iminostilbene	propoxyphene
Sodium (dissolved)		Salmonella	Butylate (Sutan)	Antipyrine	ketoconazole	propranolol
General Water Quality		Bovine polyomavirus	Carbaryl (Sevin)	Antipyrine	lamivudine	pseudoephendrine
Turbidity		Coliphage Male Specific	Clomazone	atenolol	Lidocaine	p-xanthine
pH		Coliphage Somatic	Cyanazine (Bladex)	benztropine	loperamide	quinine
Total Dissolved Solids		*E.coli*	Deisopropyl Atrazine	betamethazone	loratadine	raloxifene
Conductivity		Enterococci	Desethyl Atrazine	bupropion	lorazepam	ranitidine
Dissolved Oxygen		Enterohemorrhagic E. coli	Dimethenamid	caffeine	Meprobamate	sertraline
Total Alkalinity		Human polyomavirus	EPTC (Eptam)	Carbamazepine	metformin	sitagliptin
Total Hardness		Pepper mild mottle virus	Metribuzin (Sencor)	Carisoprodol	Methadone	sulfadimethoxine
Total Organic Carbon		Swine Hepatitis E	Pendimethalin (Prowl)	Chlorpheniramine	methocarbamol	sulfamethizole
Total Suspended Solids			Prometon	cimetidine	methotrexate	sulfamethoxazole
Metals			Propachlor	Citalopram	metoprolol	tamoxifen
Copper (dissolved)			Propazine	clonidine	Metoxalone	Temazepam
Antimony (dissolved)			Triallate	codeine	morphine	theophylline
Arsenic (dissolved)			Trifluralin (Treflan)	cotinine	nadalol	thiabendazole
Barium (dissolved)			Acetochlor ESA	dehydronifedipine	nevirapine	tiotropium
Beryllium (dissolved)			Acetochlor OXA	desmethyldiltiazem	nicotine	Tramadol
Chromium (dissolved)			Alachlor ESA	desvenlafaxine	nizatidine	triamterene
Lead (dissolved)			Alachlor OXA	Dextromethorphan	nordiazepam	trimethoprim
Selenium (dissolved)			Metolachlor ESA	Diazepam	norfluoxetine	valacyclovir
Thallium (dissolved)			Metolachlor OXA	Diltiazem	norsertraline	Venalfaxine
Uranium (dissolved)			AMPA	Diphenhydramine	norverapamil	Verapamil
Zinc (dissolved)			Dimethenamid ESA	duloxetine	omeprazole	warfarin
Aluminum (dissolved)			Dimethenamid OXA	ezetimibe	orlistat	
Iron (dissolved)			Glufosinate	fadrozole	oseltamivir	
Manganese (dissolved)			delO/delH	famotidine	oxazepam	
Cobalt (dissolved)				fenofibrate	Oxycodone	
Strontium (dissolved)				fexofenadine	paroxetine	
Vanadium (dissolved)						
Nickel (dissolved)						
Titanium (dissolved)						

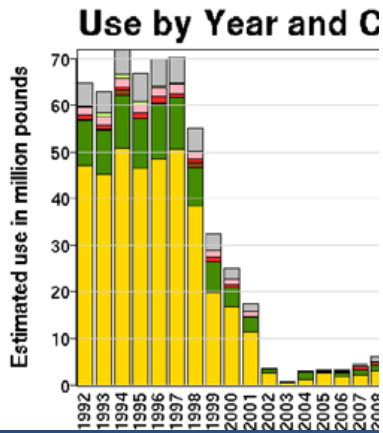
Tritium

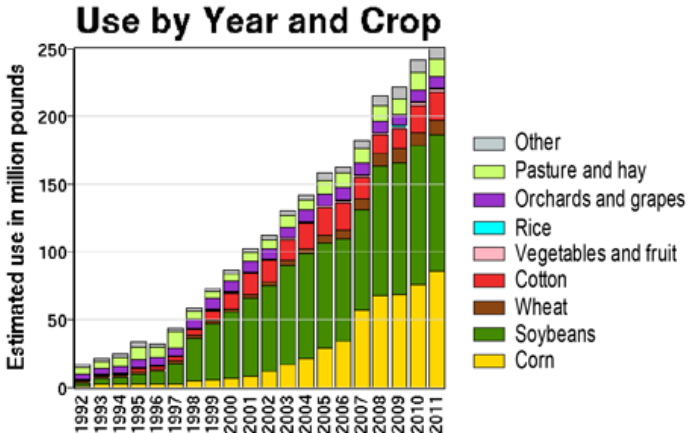
Why Glyphosate?

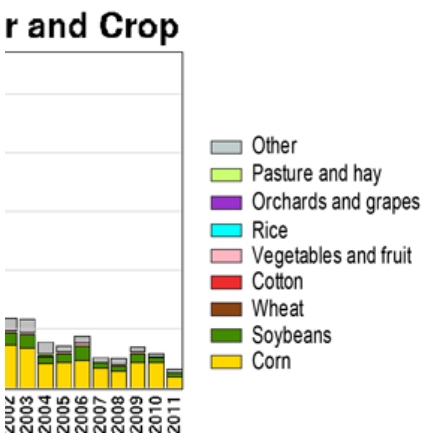












Water Chemistry Results

General Water Quality

	Analyte	N	# of Detect-ions	% Detect-ions	Detection Limit	Units	Minimum	Maximum	Median of Detections	Bench-mark Value	Benchmark Type	% Exceed-ances
General Water Quality	pH	66					6.8	7.7	7.2	6.5 - 8.5	2nd Std	0%
	Conductivity	66	66	100%	1	umho/cm	380	1800	670			
	Total Hardness	64	64	100%	1	mg/L	170	1100	320			
	Total Alkalinity	66	66	100%	1	mg/L	91	1100	280			
	Dissolved Oxygen	66	39	59%	0.1	mg/L	<0.1	7.4	0.5			
	Total Organic Carbon	66	62	94%	0.05	mg/L	<0.5	5.0	1.2			
	Total Dissolved Solids	66	66	100%	1	mg/L	250	1970	420	500	2nd Std	33%
	Total Suspended Solids	66	22	33%	1	mg/L	<1.0	46.0	3.5			
	Turbidity	66	40	61%	1	NTU	<1.0	190.0	12.5	1	MCL[a]	61%
Cations and Anions	Bromide	66	1	2%	0.25/0.5	mg/L	<0.50	0.59	0.47			
	Chloride	66	60	91%	0.5/1.0	mg/L	<1.0	230.0	12.0	250	2nd Std	0%
	Fluoride	66	66	100%	0.1	mg/L	0.12	3.00	0.43	4 2	MCL 2nd Std	0% 5%
	Sulfate	66	64	97%	1	mg/L	1.0	970.0	51.5	250	2nd Std	15%
	Silica as SiO2	66	66	100%	1	mg/L	7.4	37.0	15.5			
	Carbonate Alkalinity	66	0	0%	1	mg/L	<1.0	<1.0				
	Bicarbonate Alkalinity	66	66	100%	1	mg/L	91.0	480.0	280.0			
	Calcium (dissolved)	66	66	100%	0.1	mg/L	34.0	310.0	87.5			
	Magnesium (dissolved)	66	66	100%	0.5	mg/L	13.0	100.0	28.5			
	Potassium (dissolved)	66	64	97%	1	mg/L	<1.0	36.0	2.8			
	Sodium (dissolved)	66	66	100%	0.5	mg/L	2.7	280.0	16.5			
Nutrients	Ammonia Nitrogen as N	66	49	74%	0.05	mg/L	<0.05	6.10	0.64			
	Nitrate + Nitrite as N	65	17	26%	0.1	mg/L	<0.1	12.0	5.4	10.0	MCL	3%
	Total Kjeldahl Nitrogen as N	66	47	71%	0.1	mg/L	<0.1	6.4	0.7			
	Ortho-Phosphate as P	66	32	48%	0.02	mg/L	<0.02	0.78	0.05			
	Total Phosphorus as P	66	56	85%	0.02/0.05/0.1	mg/L	<0.02	1.60	0.06			

Metals

	Analyte	N	# of Detect-ions	% Detect-ions	Detection Limit	Units	Minimum	Maximum	Median of Detections	Bench-mark Value	Benchmark Type	% Exceed-ances
Metals (dissolved)	Aluminum	66	0	0%	0.1	mg/L	<0.1	<0.1		0.05-0.2	2nd Std	0%
	Antimony	66	0	0%	0.005	mg/L	<0.005	<0.005		0.006	MCL	0%
	Arsenic	66	24	36%	0.001	mg/L	<0.001	0.033	0.004	0.010	MCL	8%
	Barium	66	44	67%	0.05	mg/L	<0.05	1.60	0.14	2	MCL	0%
	Beryllium	66	0	0%	0.002	mg/L	<0.002	<0.002		0.004	MCL	0%
	Chromium*†	66	0	0%	0.01	mg/L	<0.01	<0.01		0.1	MCL	0%
	Cobalt*†	66	0	0%	0.05	mg/L	<0.05	<0.05				
	Copper	66	0	0%	0.01	mg/L	<0.01	<0.01		1.3	Action Level	0%
	Iron	66	53	80%	0.02	mg/L	<0.02	16.00	0.50	0.3	2nd Std	47%
	Lead	66	2	3%	0.001	mg/L	<0.001	0.011	0.007	0.015	MCL	0%
	Manganese	66	33	50%	0.02	mg/L	<0.02	1.20	0.09	0.05	2nd Std	41%
	Nickel	66	0	0%	0.05	mg/L	<0.05	<0.05		0.1	HBSL	0%
	Selenium	66	3	5%	0.01	mg/L	<0.01	0.01	0.01	0.05	MCL	0%
	Strontium*†	66	65	98%	0.02	mg/L	<0.02	8.50	0.42	4	HBSL	3%
	Thallium	66	0	0%	0.001	mg/L	<0.001	<0.001		0.002	MCL	0%
	Titanium	66	0	0%	0.05	mg/L	<0.05	<0.05				
	Uranium	66	14	21%	0.001	mg/L	<0.001	0.016	0.003	0.03	MCL	0%
	Vanadium*†	66	0	0%	0.01	mg/L	<0.05	<0.05				
	Zinc	66	6	9%	0.02	mg/L	<0.02	0.07	0.03	5	2nd Std	0%

Pesticides

	Analyte	N	# of Detect-ions	% Detect-ions	Detection Limit	Units	Minimum	Maximum	Median of Detections	Bench-mark Value	Benchmark Type	% Exceed-ances
Pesticides and Pesticide Degradates	Acetochlor*†	66	0	0%	0.025	µg/L	<0.025	<0.025		1	HBSL	0%
	Acetochlor ESA*	66	13	20%	0.025	µg/L	<0.025	0.240	0.058	600	HBSL	0%
	Acetochlor OXA*	66	5	8%	0.025	µg/L	<0.025	0.290	0.082	200	HBSL	0%
	Alachlor (Lasso)	66	0	0%	0.025	µg/L	<0.025	<0.025		2	MCL	0%
	Alachlor ESA*	66	19	29%	0.025	µg/L	<0.025	0.780	0.120	100	HBSL	0%
	Alachlor OXA*	66	3	5%	0.025	µg/L	<0.025	0.110	0.046	100	HBSL	0%
	Ametryn	66	0	0%	0.1	µg/L	<0.1	<0.1				
	Atrazine - SHL	66	0	0%	0.1	µg/L	<0.1	<0.1		3	MCL	0%
	Atrazine - USGS LAB	60	8	13%	0.02	µg/L	<0.02	0.13	0.04	3	MCL	0%
	Desethyl Atrazine	66	0	0%	0.1	µg/L	<0.1	<0.1				
	Deisopropyl Atrazine	66	0	0%	0.1	µg/L	<0.1	<0.1				
	Bromacil	66	0	0%	0.1	µg/L	<0.1	<0.1				
	Butachlor	66	0	0%	0.1	µg/L	<0.1	<0.1				
	Butylate (Sutan)	66	0	0%	0.1	µg/L	<0.1	<0.1				
	Carbaryl (Sevin)	66	0	0%	0.1	µg/L	<0.1	<0.1		40	HBSL	0%
	Carbofuran (Furadon)	66	0	0%	0.1	µg/L	<0.1	<0.1		40	MCL	0%
	Clomazone	66	0	0%	0.1	µg/L	<0.1	<0.1		5880	HHBP	0%
	Cyanazine (Bladex)	66	0	0%	0.1	µg/L	<0.1	<0.1		1	HBSL	0%
	Dimethenamid	66	1	2%	0.025	µg/L	<0.025	0.03	0.03	350	HHBP	0%
	Dimethenamid ESA	66	1	2%	0.025	µg/L	<0.025	0.035	0.035			
	Dimethenamid OXA	66	0	0%	0.025	µg/L	<0.025	<0.025				
	EPTC (Eptam)	66	0	0%	0.1	µg/L	<0.1	<0.1		350	HHBP	0%
	Glyphosate (Round-Up)	50	0	0%	0.02	µg/L	<0.02	<0.02		700	MCL	0%
	Aminomethylphosponic acid (AMPA)	50	2	3%	0.02	µg/L	<0.02	0.02	0.02			
	Glufosinate	60	0	0%	0.02	µg/L	<0.02	<0.02				
	Metolachlor (Dual)*	66	0	0%	0.025	µg/L	<0.025	<0.025		700	HBSL	0%
	Metolachlor ESA*	66	27	41%	0.025	µg/L	<0.025	1.200	0.230			
	Metolachlor OXA*	66	9	14%	0.025	µg/L	<0.025	0.190	0.059			
	Metribuzin (Sencor)	66	0	0%	0.1	µg/L	<0.1	<0.1		90	HBSL	0%
	Pendimethalin (Prowl)	66	0	0%	0.1	µg/L	<0.1	<0.1		210	HHBP	0%
	Prometon	66	0	0%	0.1	µg/L	<0.1	<0.1		400	HBSL	0%
	Propachlor	66	0	0%	0.1	µg/L	<0.1	<0.1				
	Propazine	66	0	0%	0.1	µg/L	<0.1	<0.1				
	Simazine	66	0	0%	0.1	µg/L	<0.1	<0.1		4	MCL	0%
	Triallate	66	0	0%	0.1	µg/L	<0.1	<0.1		175	HHBP	0%
	Trifluralin (Treflan)	66	0	0%	0.1	µg/L	<0.1	<0.1				

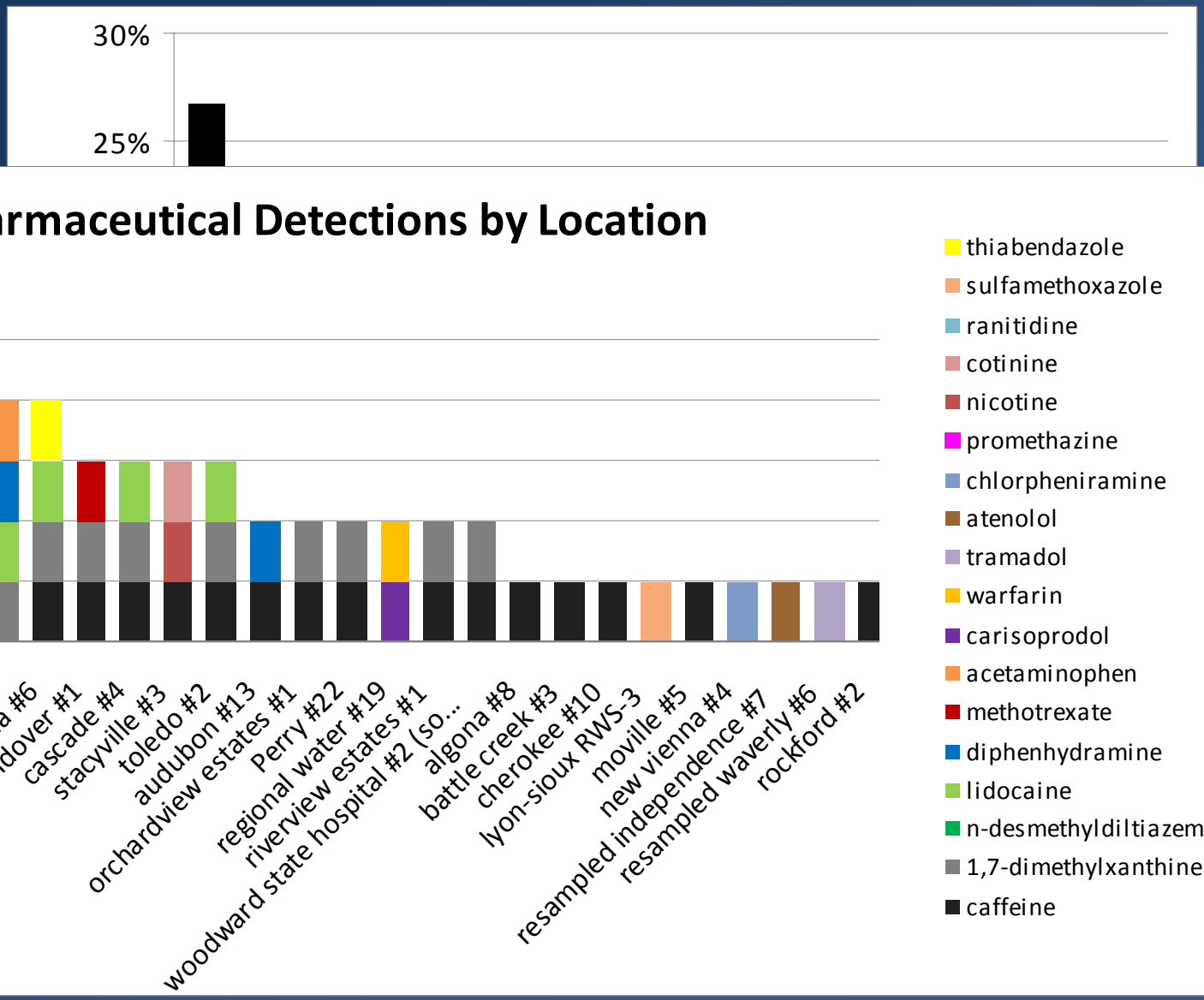
Herbicide Metabolites: 41% ESA's

	Dimethenamid	Acetochlor ESA	Acetochlor OXA	Alachlor ESA	Alachlor OXA	Dimethenamid ESA	Metolachlor ESA	Metolachlor OXA
SUMMARY DATA FOR FIRST 66								
N (number of samples)	66	66	66	66	66	66	66	66
Number of Detections	1	13	5	19	3	1	27	9
Percentage of Detections	2%	20%	8%	29%	5%	2%	41%	14%
Mean	0.013	0.026	0.020	0.087	0.015	0.013	0.134	0.022
Median	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Std. Deviation	0.002	0.036	0.037	0.194	0.013	0.003	0.238	0.031
Minimum	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Maximum	0.030	0.240	0.290	0.780	0.110	0.035	1.200	0.190
Mean of Detections		0.079	0.110	0.273	0.065	0.035	0.309	0.081

Pharmaceuticals

	Analyte	N	# of Detect-ions	% Detect-ions	Detection Limit	Units	Minimum	Maximum	Median of Detections	Use/Common Name
Pharmaceuticals	1,7-dimethylxanthine	64	10	16%	87.7	ng/L	<87.7	det	det	stimulant, caffeine metabolite
	acetaminophen	64	1	2%	7.13	ng/L	<7.13	826	826	analgiesic
	atenolol	64	(1)	2%	13.3	ng/L	<13.3	det	det	hypertension
	caffeine	64	16	25%	90.7	ng/L	<90.7	173	det	stimulant
	carisoprodol	64	1	2%	12.5	ng/L	<12.5	det	det	muscle relaxant
	chlorpheniramine	64	1	2%	4.68	ng/L	<4.68	det	det	antihistamine
	cotinine	64	1	2%	6.37	ng/L	<6.37	det	det	nicotine metabolite
	diphenhydramine	64	2	3%	5.79	ng/L	<5.79	145	84.75	antihistamine
	lidocaine	64	5	8%	15.2	ng/L	<15.2	48.6	det	anesthetic
	methotrexate	64	2	3%	52.4	ng/L	<52.4	det	det	immunosuppressant
	nicotine	64	1	2%	57.8	ng/L	<57.8	det	det	stimulant
	sulfamethoxazole	64	1	2%	26.1	ng/L	<26.1	det	det	antibiotic
	thiabendazole	64	1	2%	4.1	ng/L	<4.1	127	127	fungicide/parasiticide
	tramadol	64	(1)	2%	15.1	ng/L	<15.1	det	det	narcotic
	warfarin	64	1	2%	6.03	ng/L	<6.03	7.78	7.78	anticoagulant

Pharmaceuticals – 33% of wells



Bacteria / Pathogens

	Analyte	N	# of Detect-ions	% Detect-ions	Detection Limit	Units	Minimum	Maximum	Median of Detections
Pathogen Indicators	Coliphage Male Specific	66	1	2%	1	PFU/100mL	<1.0	3.0	3.0
	Coliphage Somatic	66	0	0%	1	PFU/100mL	<1.0	<1.0	
	E.coli	66	0	0%	1	MPN/100	<1.0	<1.0	
	Enterococci	66	1	2%	1 and 10	MPN/100	<1.0	1.0	1.0
	Total Coliform Bacteria	66	2 (1)	3%	1	MPN/100	<1.0	1 (4.1)	1

Viruses

	Analyte	N	# of Detect-ions	% Detect-ions	Detection Limit	Units	Minimum	Maximum
Viruses & Pathogens by qPCR	Adenovirus C,D,F	66	0	0%		copies/L	0	0
	Adenovirus A	66	0	0%		copies/L	0	0
	Adenovirus B	66	0	0%		copies/L	0	0
	Enterovirus*†	66	0	0%		copies/L	0	0
	G1 Norovirus*†	66	0	0%		copies/L	0	0
	G2 Norovirus*†	66	1	2%		copies/L	0	4.23
	Human Polyomavirus	66	1	2%		copies/L	0	3.07
	Hepatitis E Virus	66	0	0%		copies/L	0	0
	Bovine Polyomavirus	66	1	2%		copies/L	0	0.46
	PMMV	66	11	17%		copies/L	0	6.38
	Campylobacter*	66	1	2%		copies/L	0	0.4
	Salmonella*	66	0	0%		copies/L	0	0
	Enterohemorrhagic *E. coli*	66	0	0%		copies/L	0	0

Viruses: 21%, Human 3%

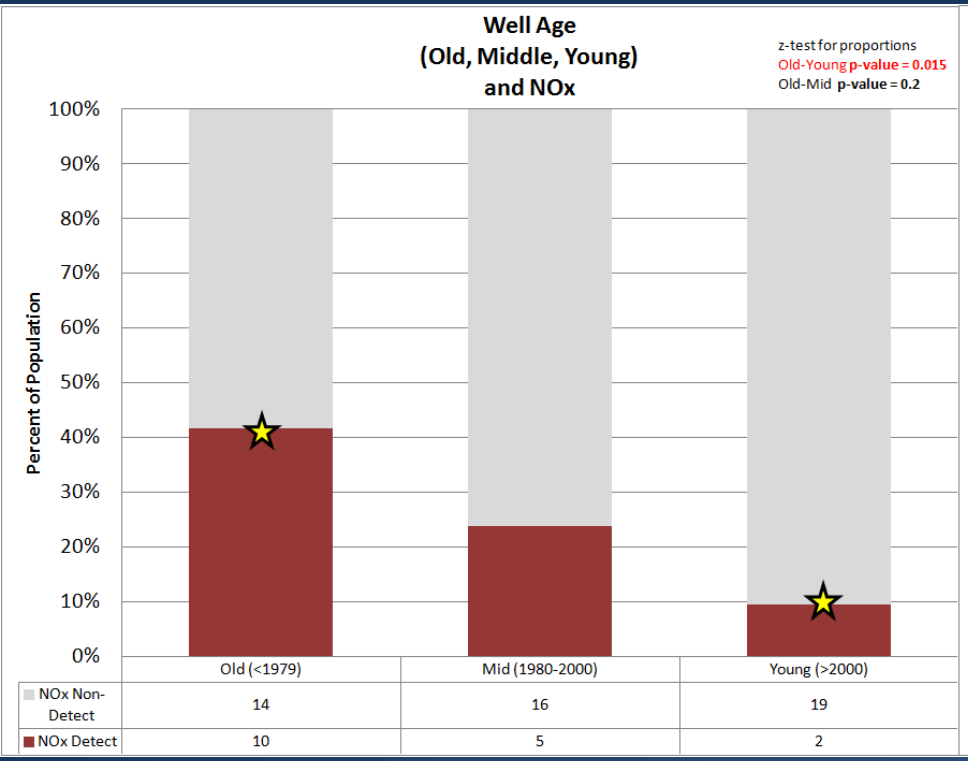
Virus:

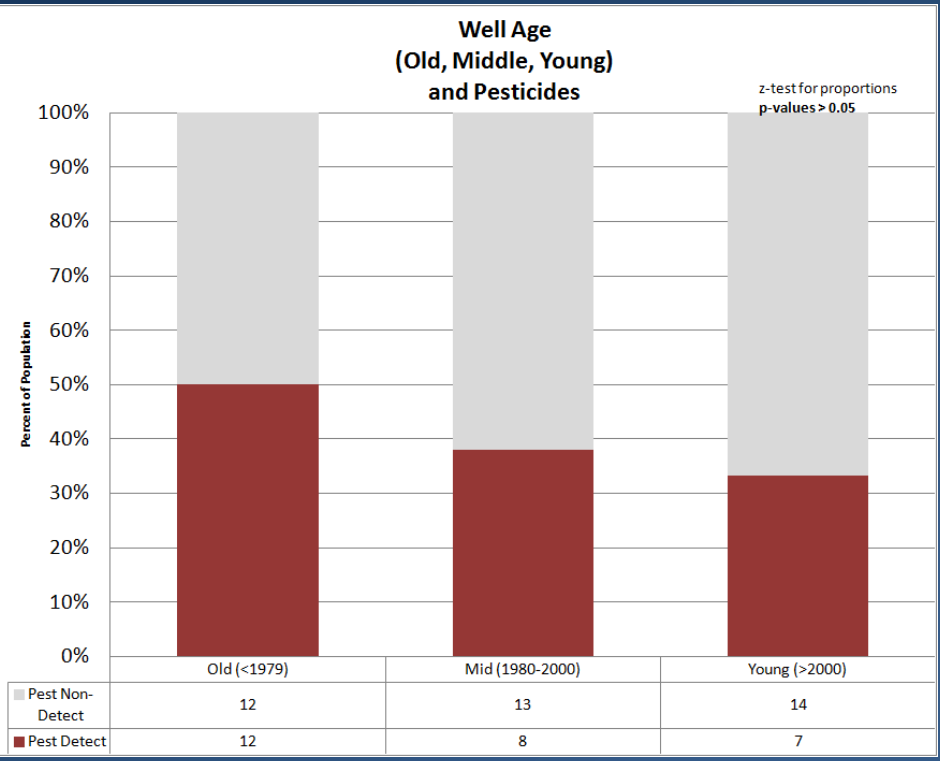
Location (MATRIX) conf	G2 Norovirus	Human PolyomaVirus	Bovine Polyomavirus	PMMV	Campylo-bacter
Perry #22 (BBBA) 77				3.26	
Perry #9R (BABC) 3				4.3	
de witt #7 (CCBC) 200				4.92	
audubon #13 (AAAA) 16				4.28	
massena #6 (CAAA) 12			0.46		
cascade #4 (AABA) 23	4.23				
knierim #1 (ACAA) 125				6.38	
ionia #2 (BCAB) 138		3.7			
joice #1 (CBAC) 93					0.4
algona #8 (CBBB) 73				4.64	
waverly #6 (BABB) 1				4.73	
janesville #3 (BAAA) 0				2.64	
decorah #7 (BABC) 1				3.6	
dumont #2 (BBAB) 50				1.33	
independence #3 (AABB) 20				1.12	

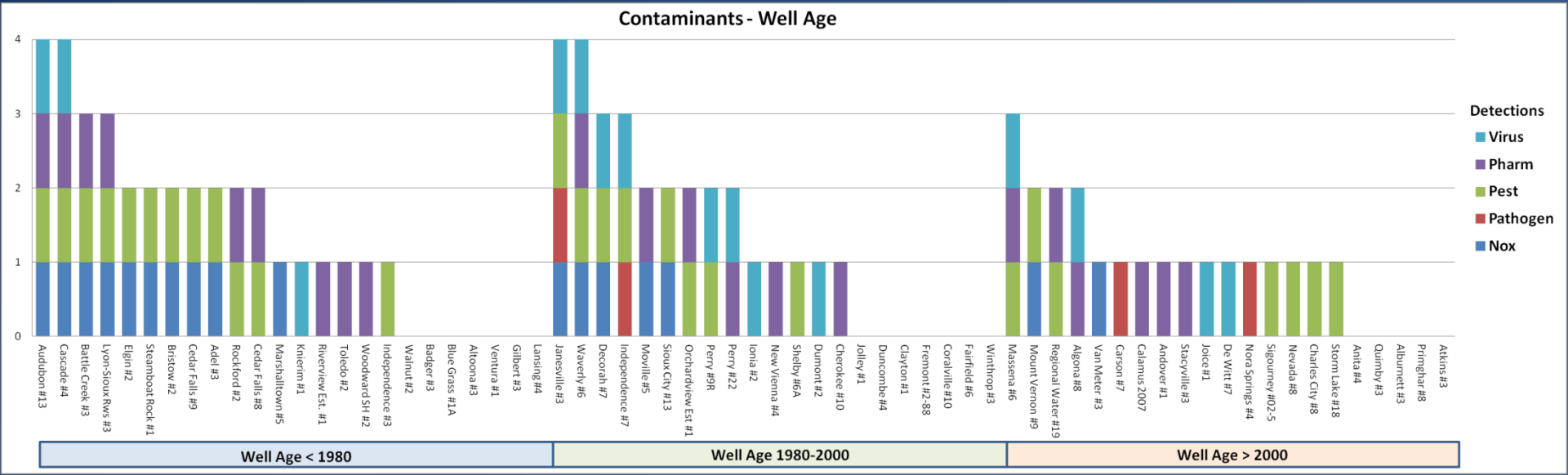
Other Results

- Arsenic: 8% of wells > DWS (10 µg/L)
- Strontium: 3% of wells > suggested DWS
- Atrazine: No detections above 0.1 µg/L (SHL MDL). 13% above 0.02 µg/L (USGS MDL).
- Glyphosate: Not Detected (0.02 µg/L). AMPA in 2 wells (3%).

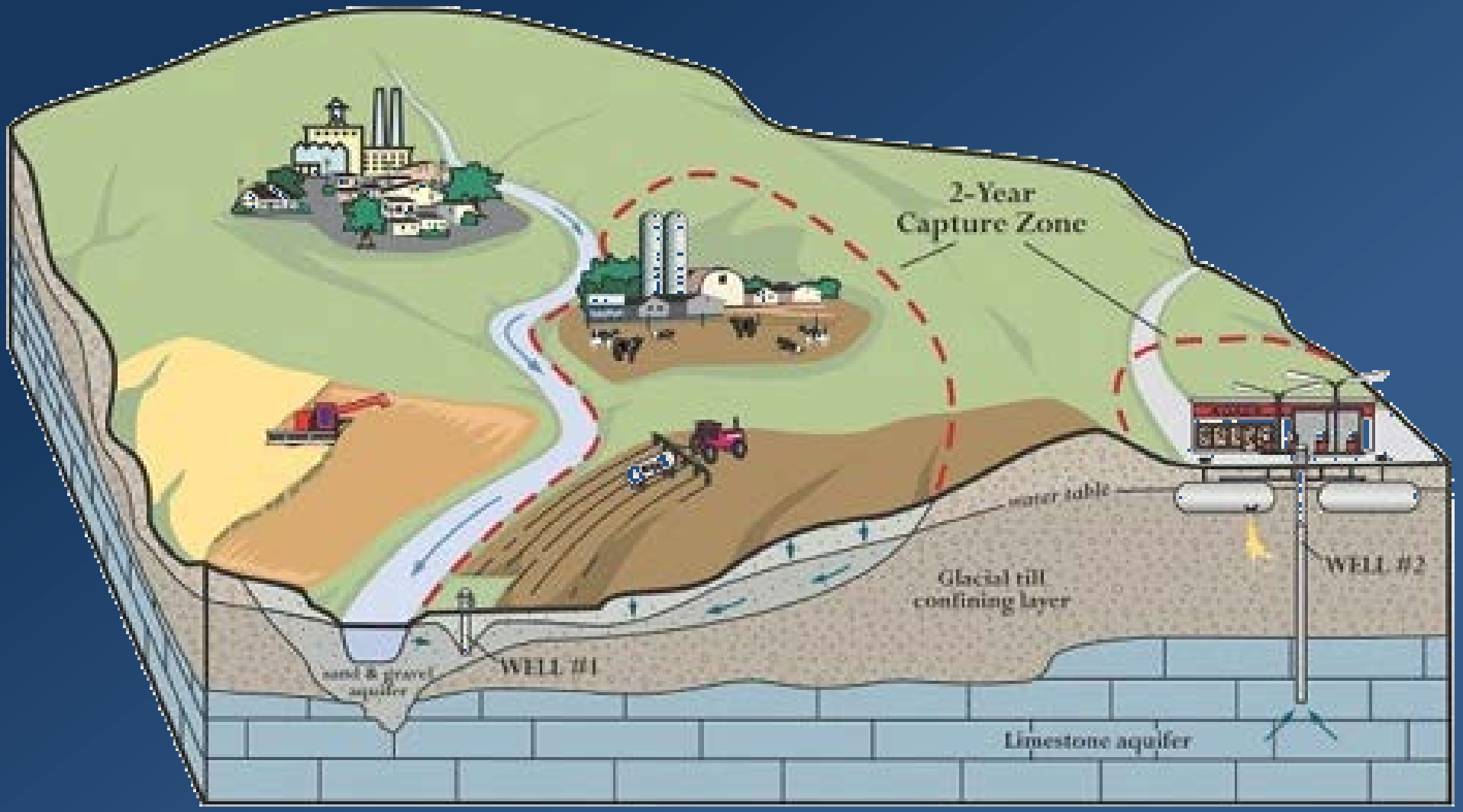
Well Age


Well Age
(Old, Middle, Young)
and NOx
z-test for proportions
Old-Young p-value = 0.015
Old-Mid p-value = 0.2
Percent of Population
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Old (<1979)
Mid (1980-2000)
Young (>2000)
NOx Non-Detect 14 16 19
NOx Detect 10 5 2

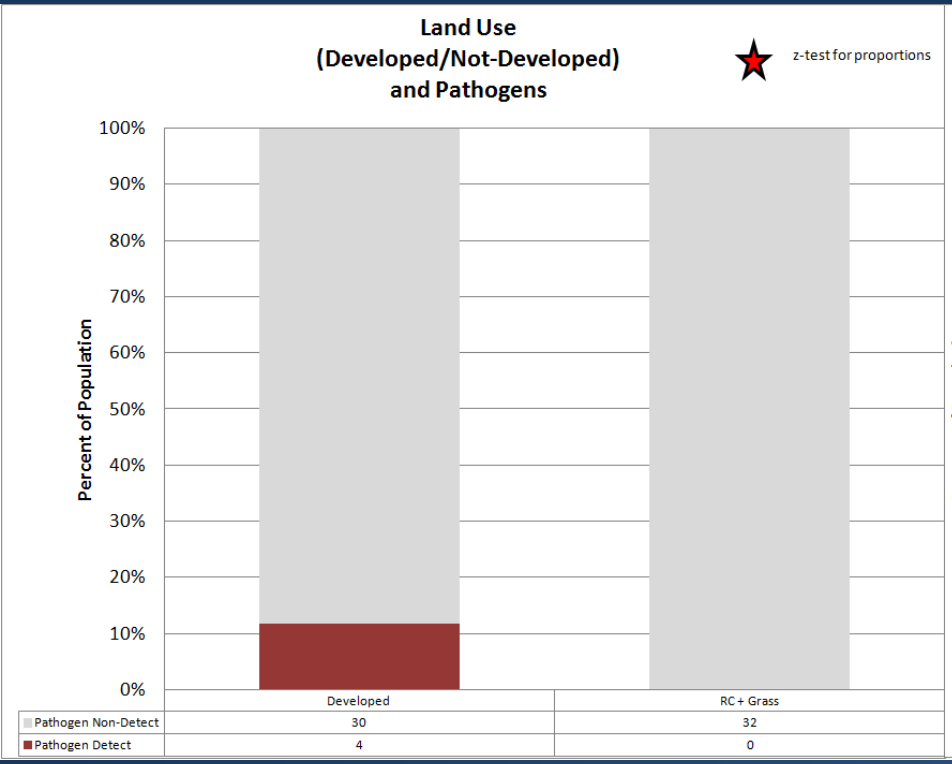

Well Age
(Old, Middle, Young)
and Pesticides
z-test for proportions
p-values > 0.05
Percent of Population
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Old (<1979)
Mid (1980-2000)
Young (>2000)
Pest Non-Detect 12 13 14
Pest Detect 12 8 7

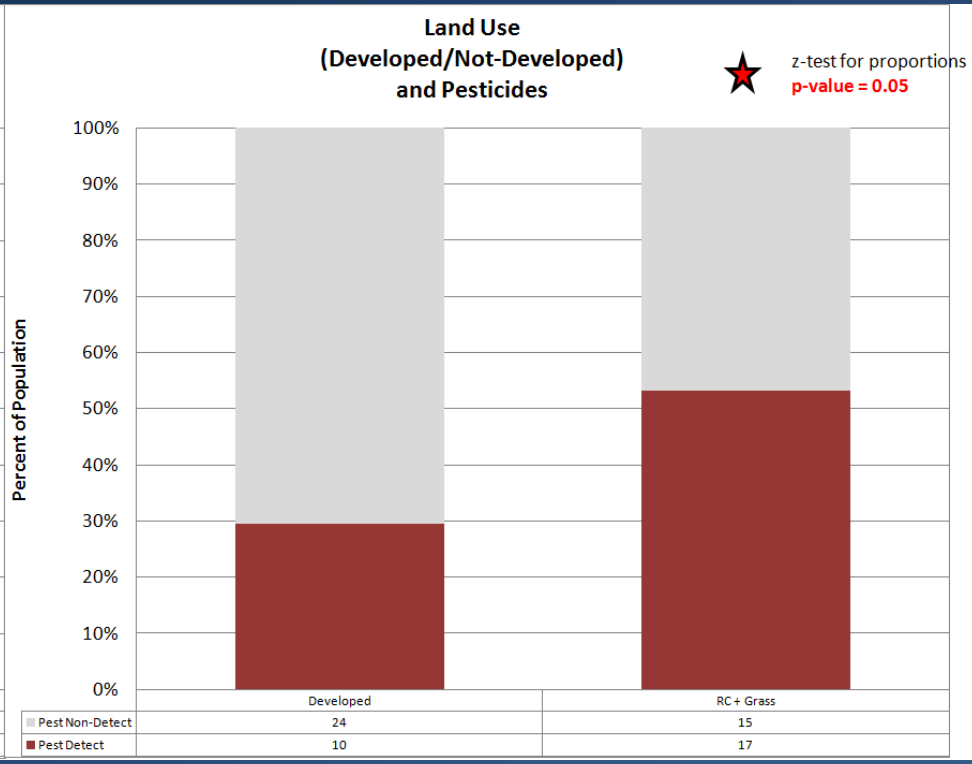

Contaminants - Well Age
Detections
Virus
Pharm
Pest
Pathogen
Nox
Audubon #13
Cascade #4
Battle Creek #3
Lyon-Sioux Rws #3
Elgin #2
Steamboat Rock #1
Bristow #2
Cedar Falls #9
Adel #3
Rockford #2
Cedar Falls #8
Marshalltown #5
Knierim #1
Riverview Est #1
Toledo #2
Woodward SH #2
Independence #3
Walnut #2
Badger #3
Blue Grass #1A
Altoona #3
Ventura #1
Gilbert #3
Lansing #4
Janesville #3
Waverly #6
Decorah #7
Independence #7
Moville #5
Sioux City #13
Orchardview Est #1
Perry #9R
Perry #22
Ionia #2
New Vienna #4
Shelby #6A
Dumont #2
Cherokee #10
Jolley #1
Duncombe #4
Clayton #1
Fremont #2-88
Coralville #10
Fairfield #6
Winthrop #3
Massena #6
Mount Vernon #9
Regional Water #19
Algona #8
Van Meter #3
Carson #7
Calamus 2007
Andover #1
Stacyville #3
Joice #1
De Witt #7
Nora Springs #4
Sigourney #02-5
Nevada #8
Charles City #8
Storm Lake #18
Anita #4
Quimby #3
Albumett #3
Primghar #8
Atkins #3
Well Age < 1980
Well Age 1980-2000
Well Age > 2000

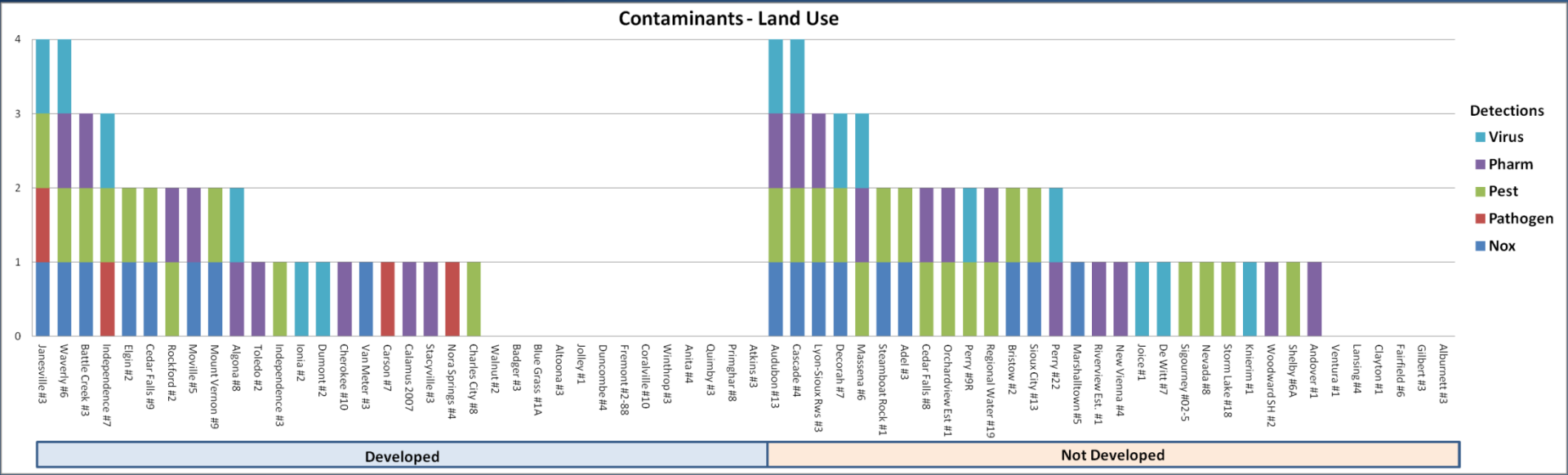
Land Use


2-Year
Capture Zone
water table
Glacial till
confining layer
WELL #1
WELL #2
sand & gravel
aquifer
Limestone aquifer

Land Use


Land Use
(Developed/Not-Developed)
and Pathogens
z-test for proportions
Percent of Population
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Developed
RC+ Grass
Pathogen Non-Detect 30 32
Pathogen Detect 4 0


Land Use
(Developed/Not-Developed)
and Pesticides
z-test for proportions
p-value = 0.05
Percent of Population
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Developed
RC+ Grass
Pest Non-Detect 24 15
Pest Detect 10 17


Contaminants - Land Use
Detections
Virus
Pharm
Pest
Pathogen
Nox
Janesville #3
Waverly #6
Battle Creek #3
Independence #7
Elgin #2
Cedar Falls #9
Rockford #2
Moville #5
Mount Vernon #9
Algona #8
Toledo #2
Independence #3
Ionia #2
Dumont #2
Cherokee #10
Van Meter #3
Carson #7
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Primghar #8
Atkins #3
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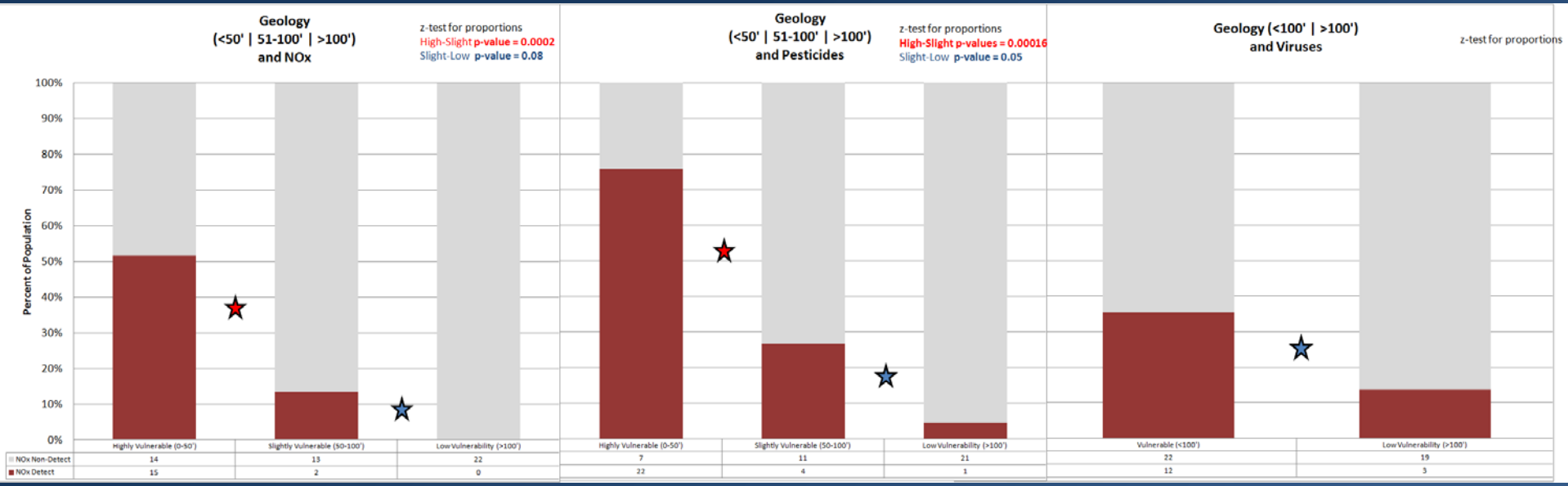
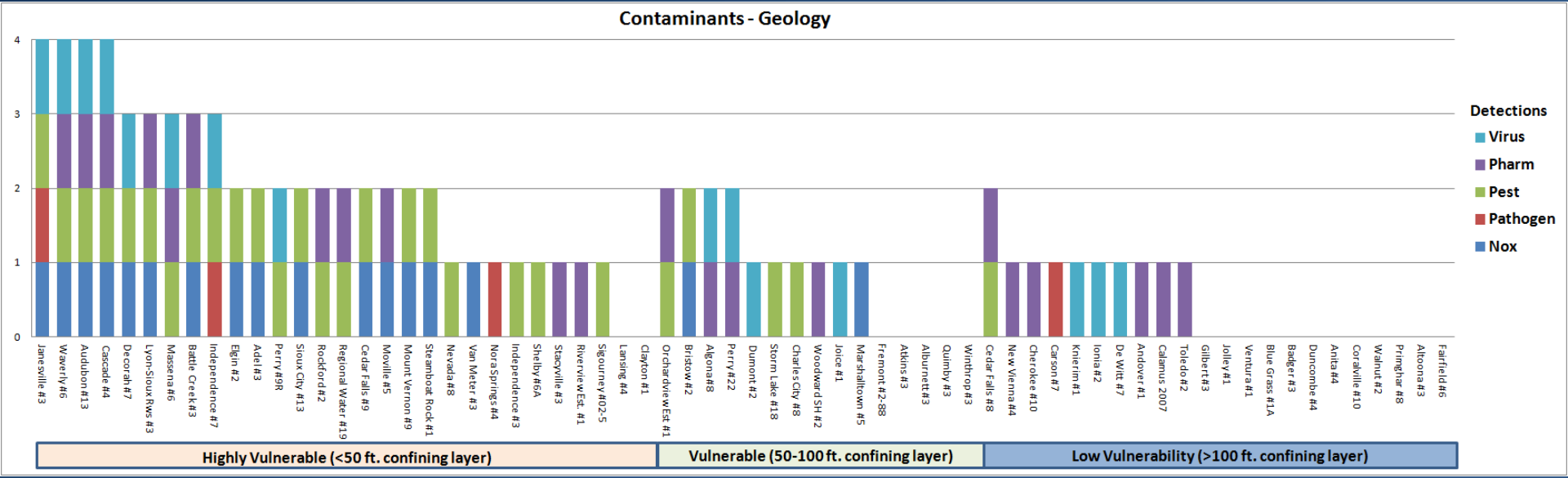
Woodward SH #2
Shelby #6A
Andover #1
Ventura #1
Lansing #4
Clayton #1
Fairfield #6
Gilbert #3
Albumett #3
Developed
Not Developed

Geology – Well Depth





Conclusions

- Trace levels of pharmaceuticals and herbicide metabolites commonly occur in raw PWS groundwater.
- Human viruses detected less frequently, but a wastewater indicator virus occurred more commonly.
- Wastewater constituents present in over half the wells tested.

Conclusions (continued)

- Younger wells have significantly lower nitrates on average. Non-significant relationships also occur with pesticides
- “Developed” areas had the only pathogens. Ag- and Native-land had significantly higher pesticides.
- Significant correlations exist between ‘contaminants’ and well age, area land use, and geologic confining layers.

Conclusions (continued)

- We didn't find an inexpensive indicator of Virus potential. Pharmaceuticals, bacteria, coliphage did not indicate virus occurrence.
- Drought conditions may have significantly affected our results – including identification of indicators.
- After years of extensive application, we did not detect Glyphosate in groundwater.

Future Studies

- Repeat a similar study under normal-to-wet conditions.
- Repeat sampling at a selected subset of the wells for temporal relationships.
- Occurrence of viruses in small PWS and private wells.
- Occurrence of other contaminants in small PWS and private wells.

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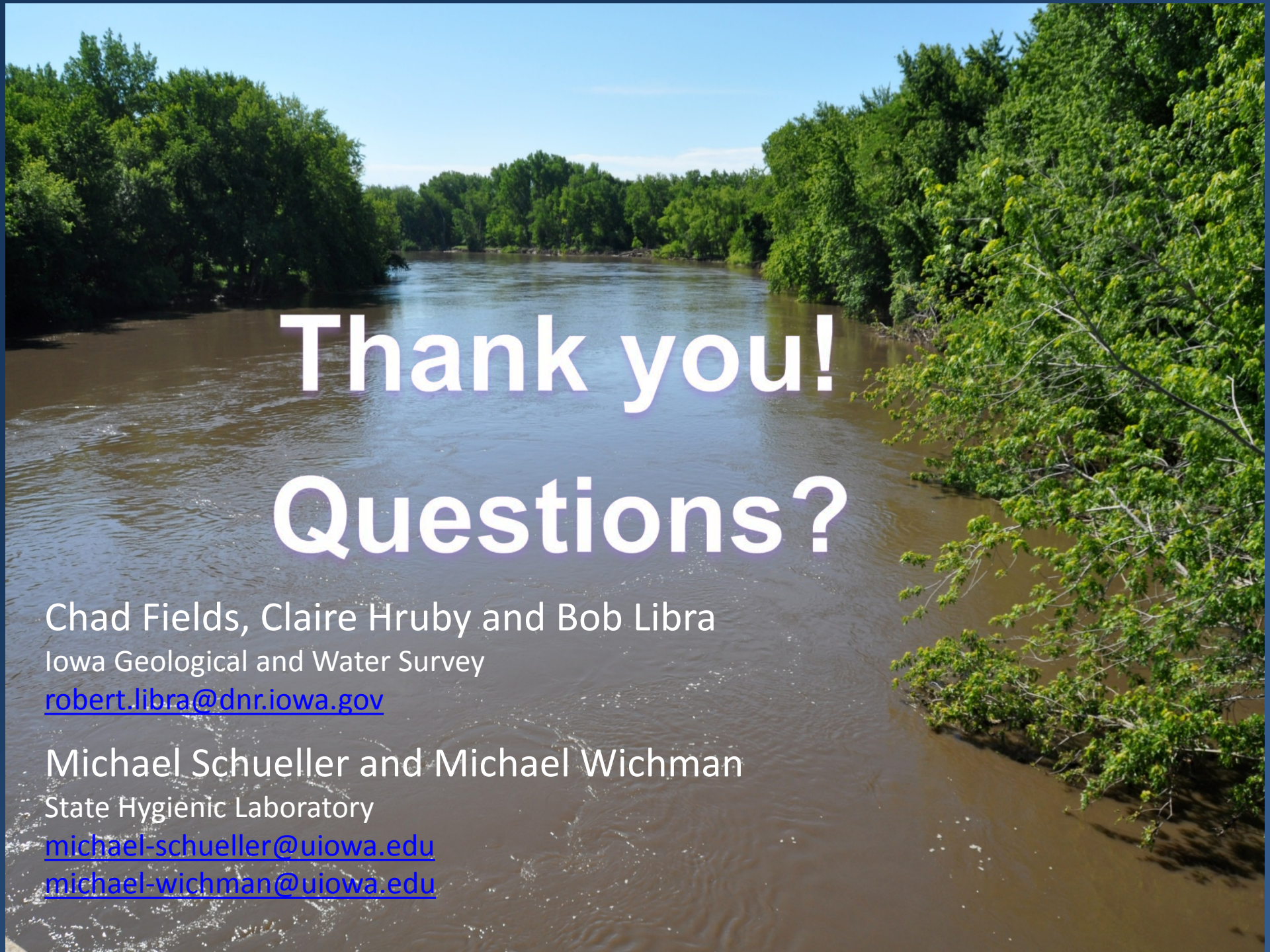

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