GROUNDWATER CONDITIONS IN THE CARBONATE BEDROCK AREAS OF WISCONSIN

Aquifer vulnerability to microbial pathogen contamination

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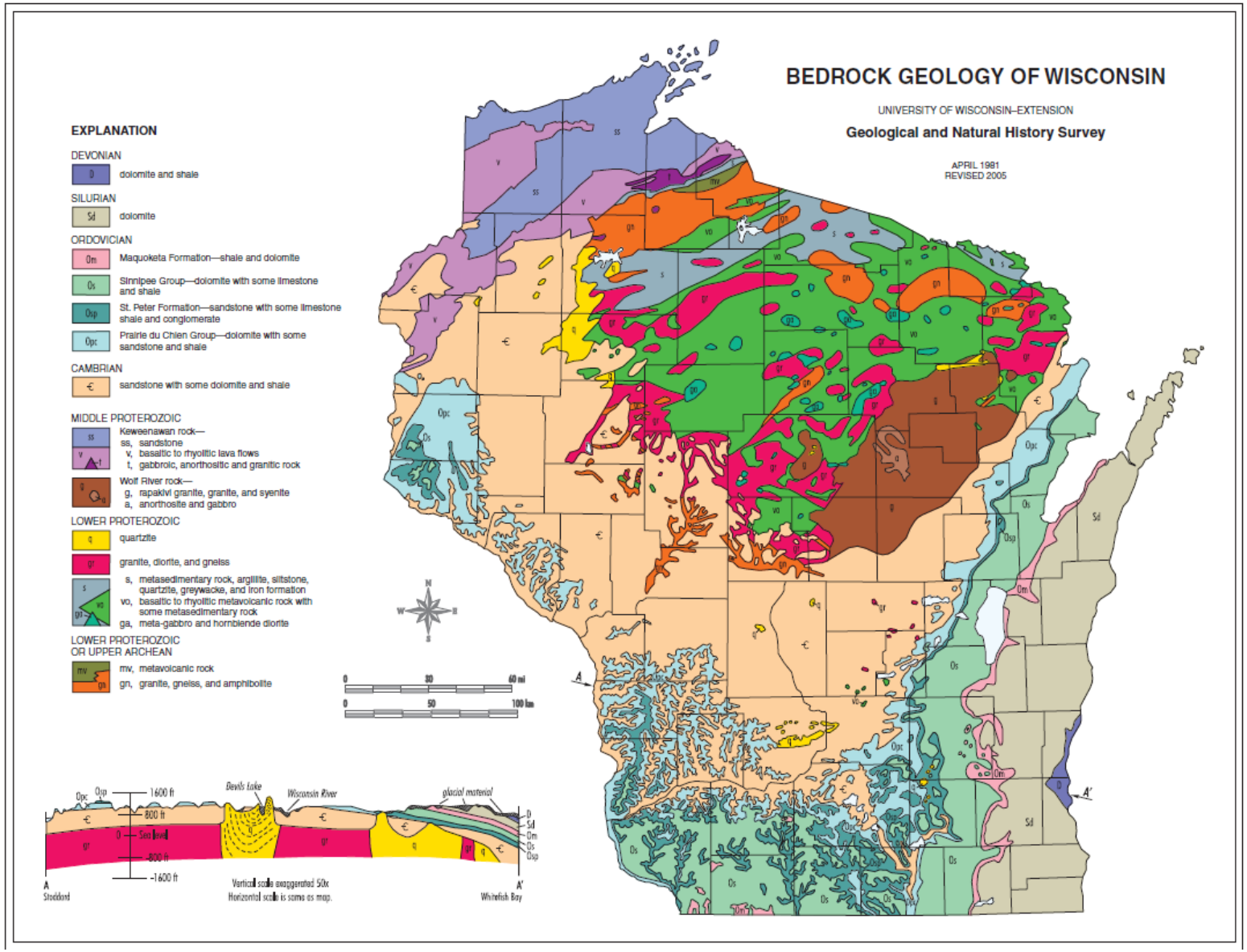
Bedrock Geology of Wisconsin

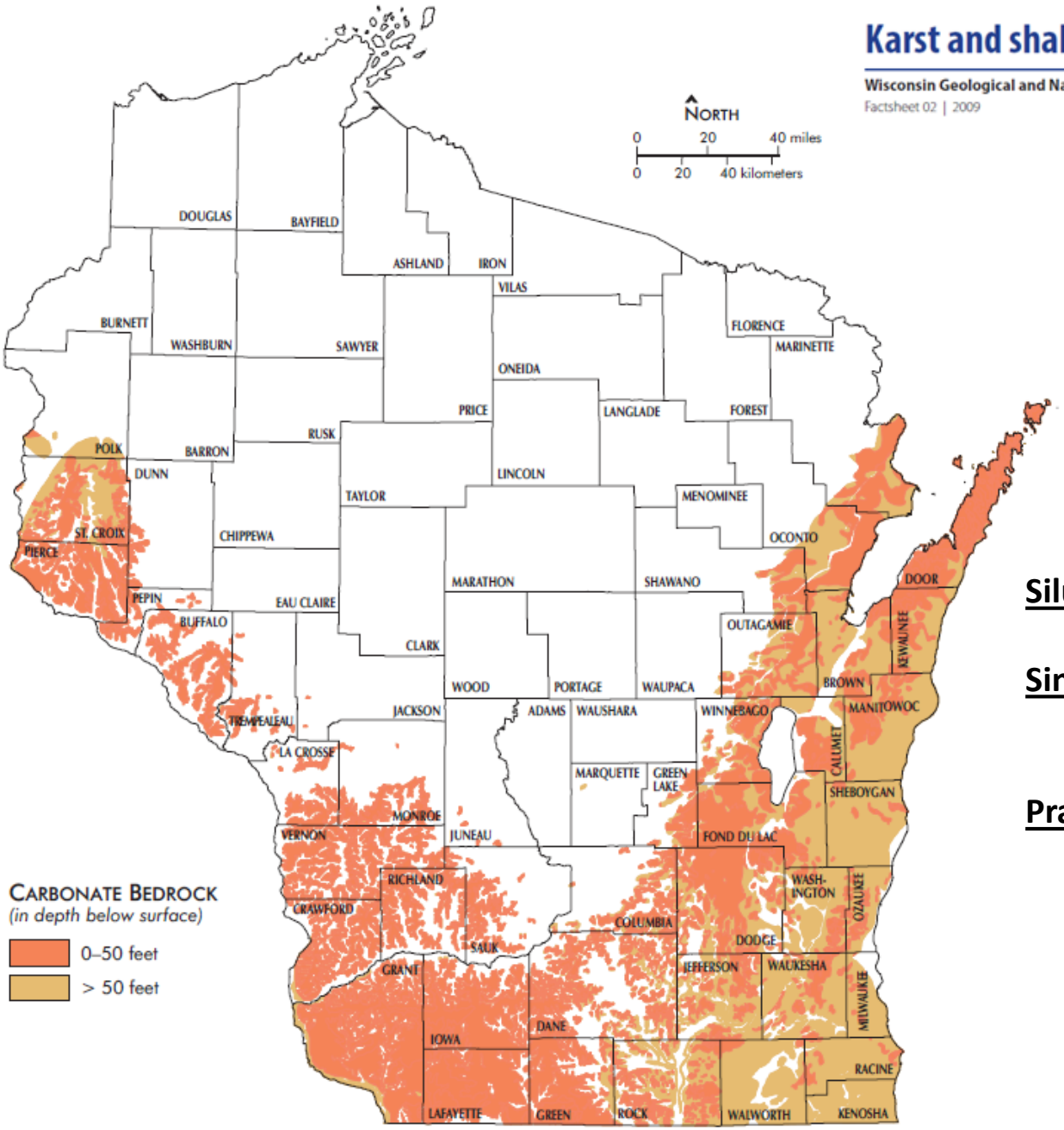


Karst and shallow carbonate bedrock in Wisconsin

Wisconsin Geological and Natural History Survey

Factsheet 02 | 2009

Areas with carbonate bedrock within 50 feet of the land surface are particularly vulnerable to groundwater contamination.



Silurian Dolomite

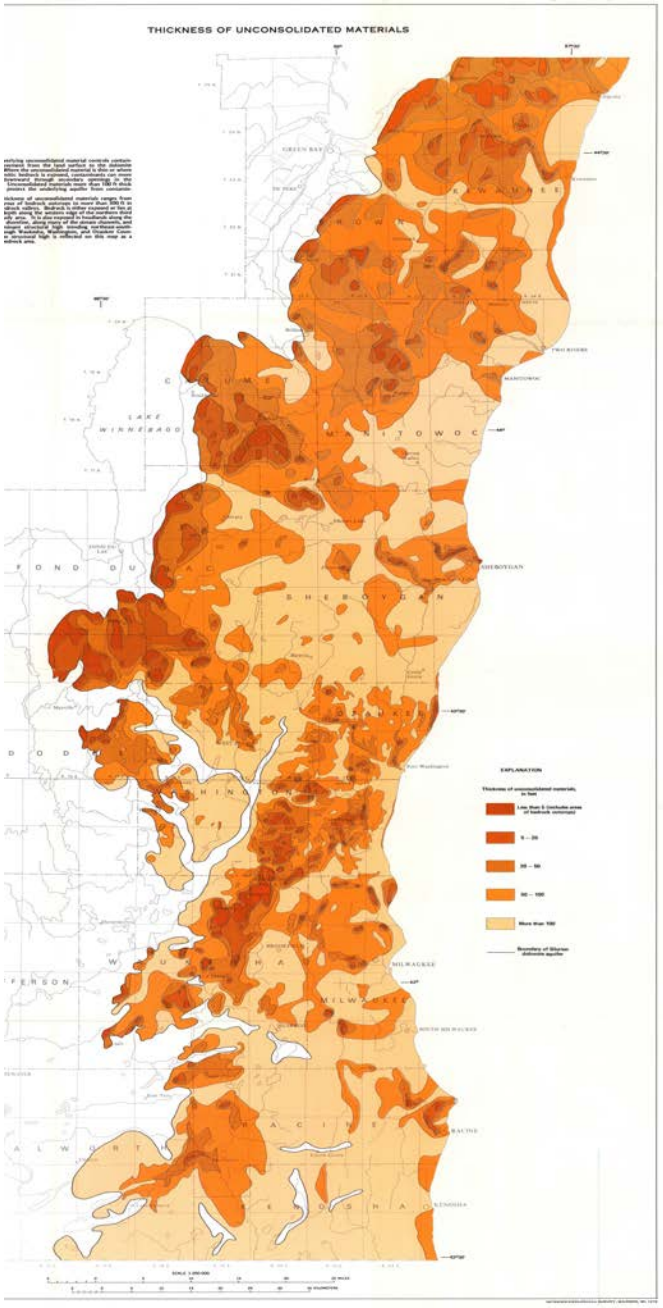
Sinnipee Group Carbonates
(Galena, Platteville formations)

Prairie du Chien Group carbonates
(Shakopee, Oneota formations)

Depth to bedrock – Silurian Dolomite

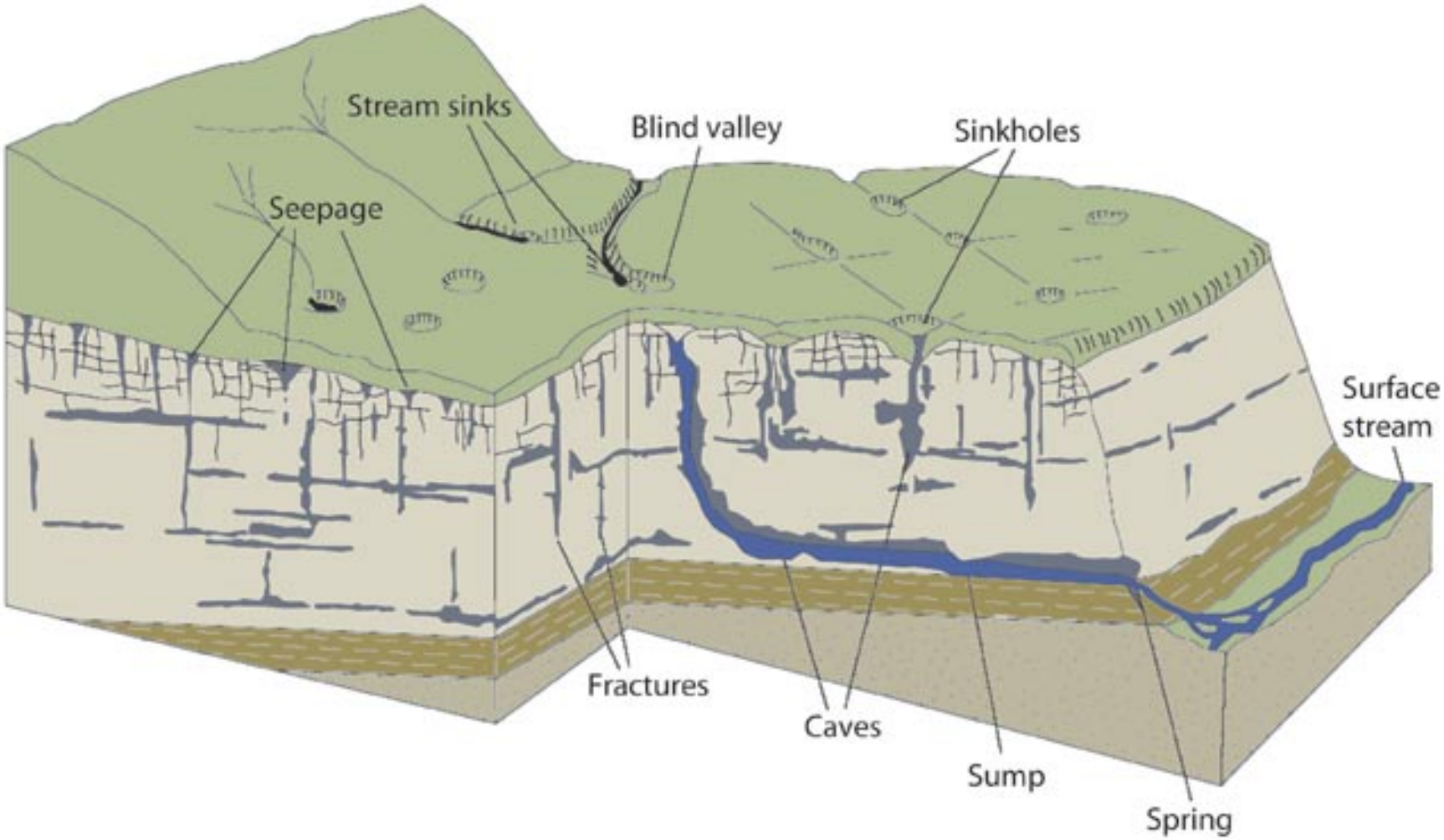
<u>Silurian Dolomite</u>
Thickness of Unconsolidated Material

(From: USGS Water Resources Investigations 78-108
Contamination Potential in the Silurian Dolomite Aquifer, Eastern Wisconsin)



Groundwater flow, karst features, contaminant flow

Typical features of a karst system and landscape: seepages, sinkholes, caves, fractures, springs, and stream sinks



Door County – fractured flow groundwater contaminant study

Tracer Study for Characterization of Groundwater Movement and Contaminant Transport in Fractured Dolomite, 1998, Maureen Muldoon, Ken Bradbury

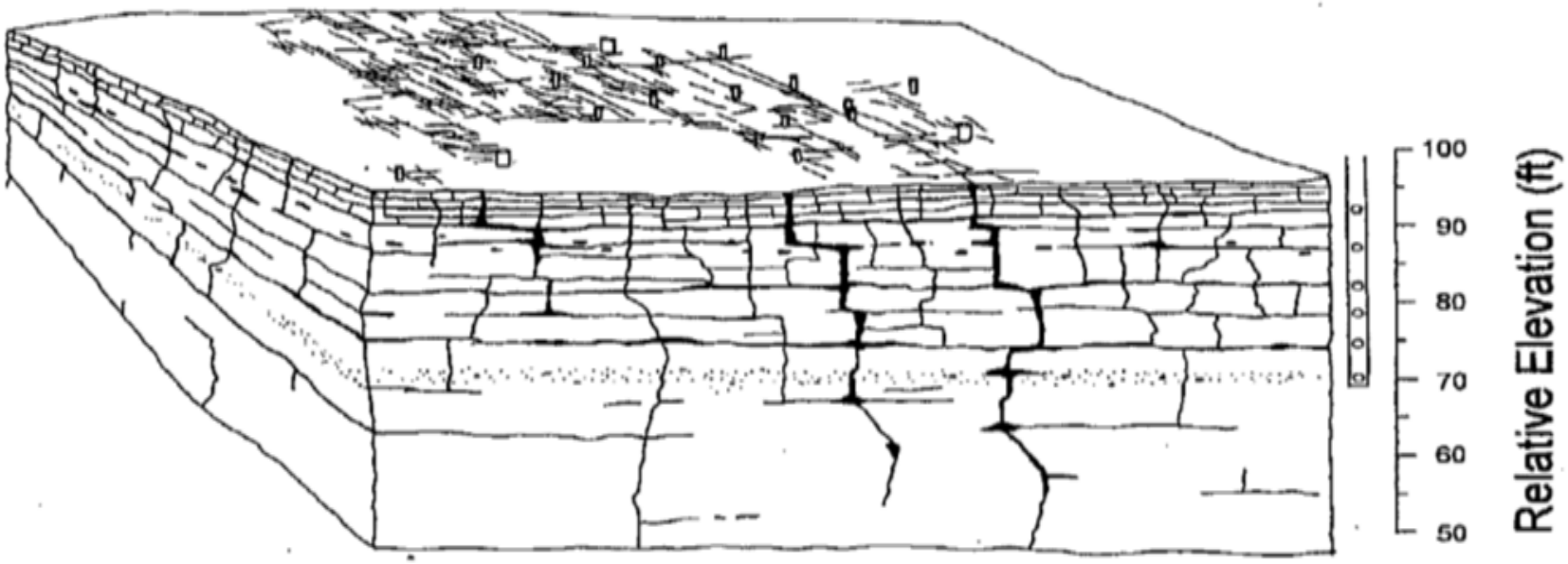


Figure 12. Schematic block diagram of site. Relative elevations are shown on the right along with a schematic multi-port sampler. Ports have been installed in four horizontal fractures (92 ft, 82.5 ft, 79 ft, and 75.5 ft elevation) and two dissolution zones (87.5 and 72 ft elevation). The horizontal fractures appear to be laterally continuous across the site. The upper dissolution zones is characterized by sparse but large vugs; the lower zone is characterized by abundant small vugs.

Walkerton, Ontario case study – public water supply well contamination case

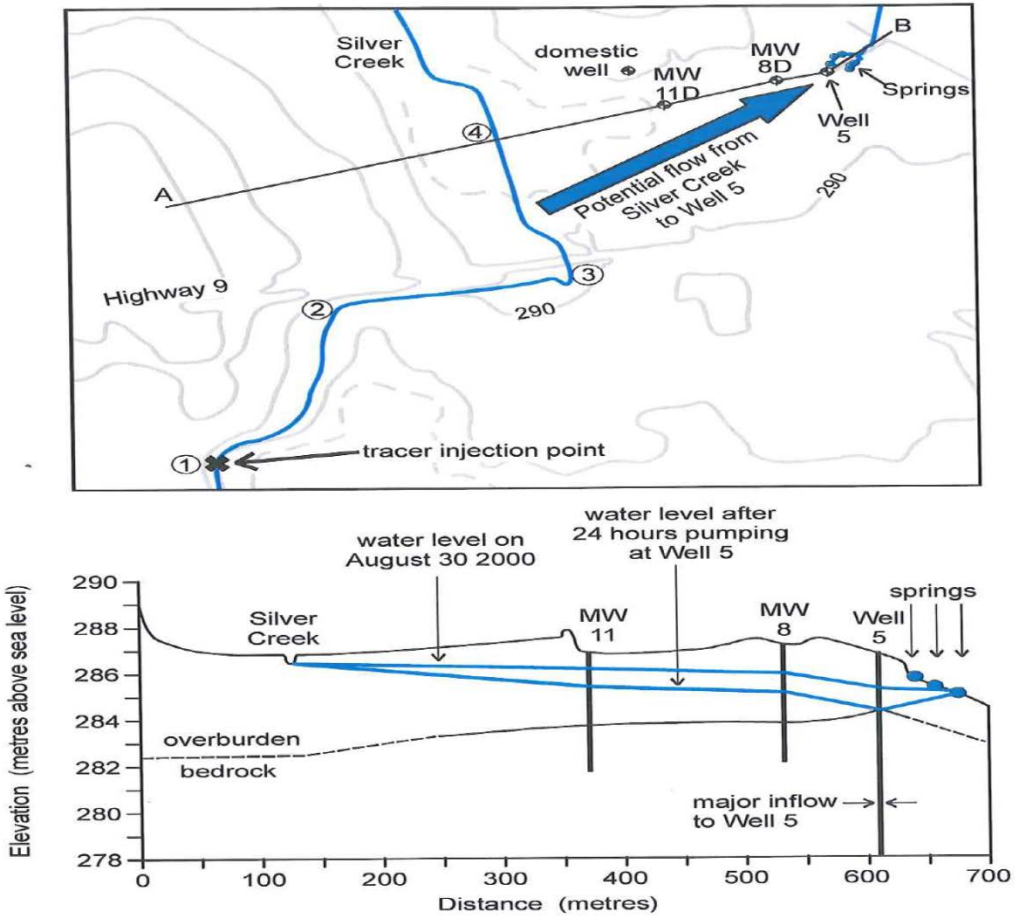


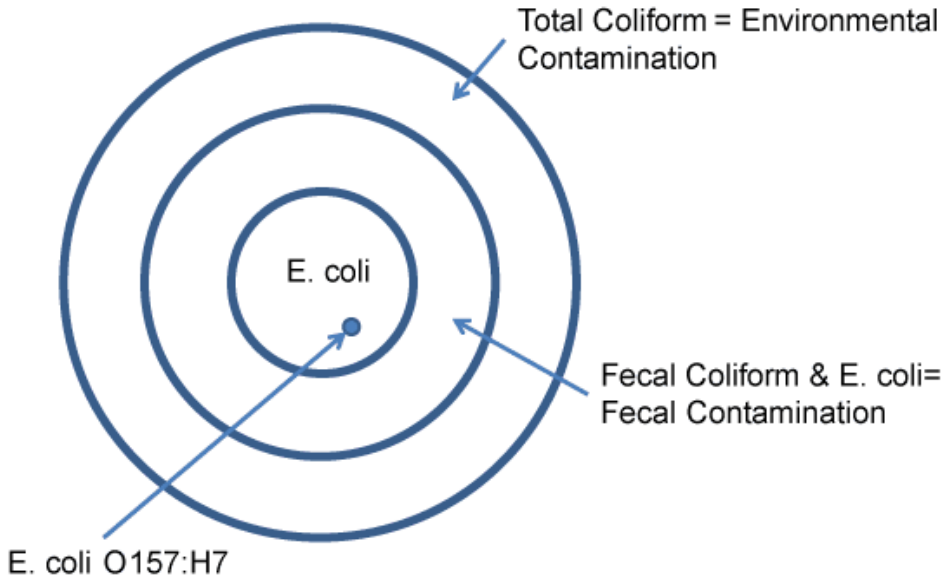
Figure 4 Relationship between Silver Creek and Well 5
a) Plan of the area
b) Profile along line A - B in the plan, showing the potential for water to flow from Silver Creek to the springs at Well 5, and the greater potential when Well 5 was pumping. The vertical exaggeration is 30.

Microbial contamination of water - water born diseases

WATERBORNE DISEASES			
Diseases	Responsible pathogen	Route of	Mode of transmission
Cholera	Vibrio cholerae bacteria	gastro-intestinal	often waterborne
Botulism	Clostridium botulinum bacteria	gastro-intestinal	food/water borne; can grow in food
Typhoid	Salmonella typhi bacteria	gastro-intestinal	water/food borne
Hepatitis A	Hepatitis A virus	gastro-intestinal	water/food borne
Dysentery	Shigella dysenteriae bacteria or Entamoeba histolytica amoeba	gastro-intestinal	food/water
Cryptosporidiosis	Cryptosporidium parvum protozoa	gastro-intestinal	waterborne; resists chlorine
Polio	polioviruses	gastro-intestinal	exposure to untreated sewage; may also be waterborne
Giardia	Giardia lamblia protozoa	gastro-intestinal	waterborne

Pathogen indicators - microbial pathogen indicator organisms:

Total Coliform bacteria, Fecal Coliform bacteria, *E. coli* bacteria



WI Pathogen health based groundwater/drinking water standards:

WI Groundwater Quality Standards (ch. NR 140) – 0 Total Coliform bacteria

WI Public Drinking Water Standards (ch. NR 809) – 0 Total Coliform bacteria

0 *E. coli* bacteria

Pathogen containing waste sources – land application/spreading /treatment sources

Septage - regulated under NR 113
Municipal Wastewater Biosolids (sludge) – regulated under NR 204
Municipal Wastewater – regulated under NR 206/NR 110
Home domestic wastewater (septic system) – regulated under SPS 383
Industrial Wastewater liquid, sludge, bi-product solids – regulated under NR 214
CAFO animal waste and process wastewater – regulated under NR 243
Non-CAFO animal waste and process wastewater – regulated under NR 151

Table 1. Pathogen results for two dairy manure treatment systems

	Farm A		Farm P	
	Fecal Coliform CFU/Gram	*Map* CFU/Gram	Fecal Coliform CFU/Gram	*Map* CFU/Gram
Raw Manure	3,836,400	20,640	1,525,700	20,990
Digested Effluent	3,400	136	N/A	N/A
Separated Liquids	1,700	77	2,085,000	1,200
Storage	7,700	6	87,200	880
Separated Solids	620	20	1,126,400	670
Compost	130	0	12,100	0

from: *Reduction of Selected Pathogens in Anaerobic Digestion*, 2003, Wright, Inglis, Stehman, Bonhotal

Regulatory approach – pretreatment/maximize soil treatment/minimize runoff

pretreatment (for pathogen reduction)
- pathogen indicator limit
- acceptable pathogen reduction pretreatment process

minimization of surface runoff (to "direct conduit" features)
- setbacks to water supply wells
- setbacks to “direct conduit” features
- restrictions on frozen or snow covered ground
- restrictions on areas subject to ponding
- slope restrictions
- restrictions on low permeability soil

maximization of soil treatment (for pathogen removal/inactivation)
- separation to bedrock and groundwater
- restrictions on highly permeable soil
- restrictions areas subject to ponding, saturated soils, during rainfall events

“Land Treatment” – soil treatment mechanisms for pathogen reduction/removal

Physical Filtration

factors: soil depth, saturation, flow rate, surface matting, preferential flow paths, biofilm formation, temperature, flow/loading rates, dosing frequency

Adsorption

factors: cation concentrations, microbial flora, surface matting, temperature, pH

Die-off

factors: microbial predation, drying, organic matrix, microbe multiplication, time

Kewaunee County private well sampling results by Town

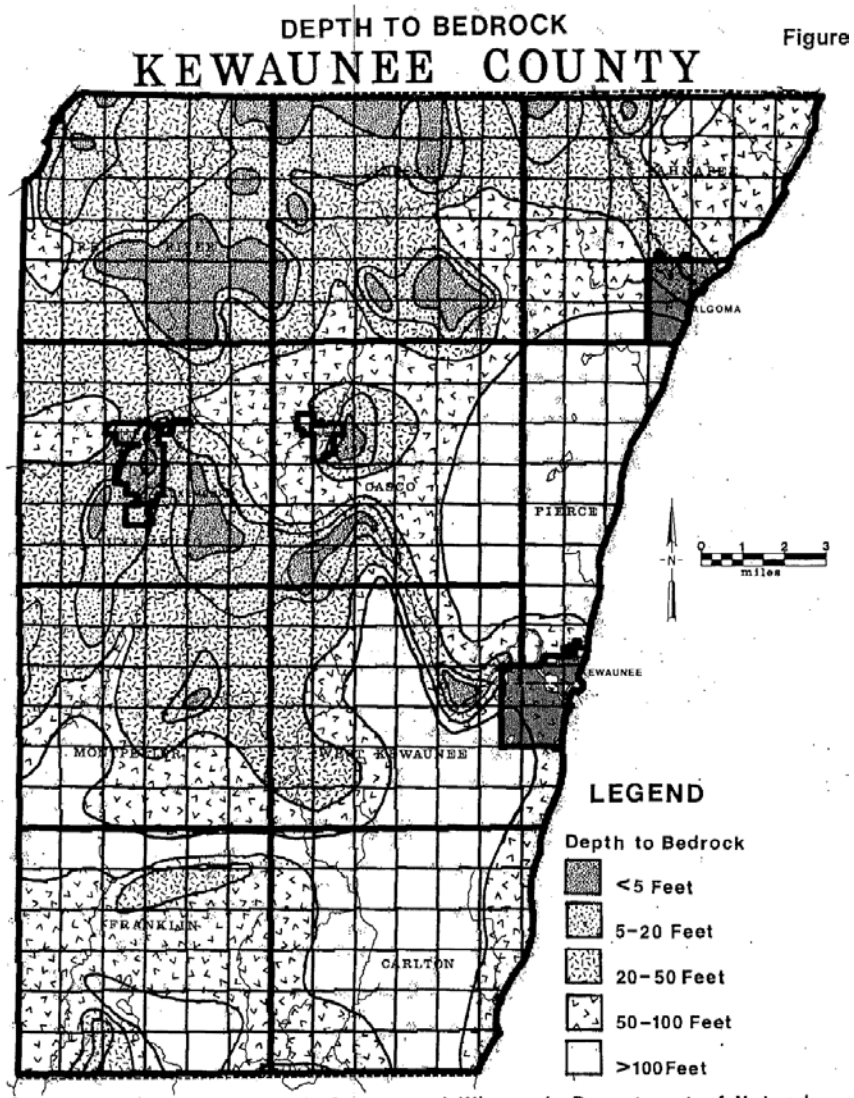
Cumulative Well Testing Data from 2004-2014

	Number of Different Wells Tested	Safe Wells No Bacteria Present Nitrates < 2.0 ppm		Safe Wells w/ Elevated Nitrates No Bacteria Present Nitrates between 2.1 - 9.9 ppm	
		Number	Percent	Number	Percent
Ahnapee	31	27	87.1%	1	3.2%
Carlton	26	20	76.9%	1	3.8%
Casco & Village of Casco	75	57	76.0%	21	28.0%
Franklin	49	39	79.6%	8	16.3%
Lincoln	103	60	58.3%	13	12.6%
Luxemburg	72	50	69.4%	9	12.5%
Montpelier	37	28	75.7%	8	21.6%
Pierce	28	22	78.6%	1	3.6%
Red River	85	49	57.6%	13	15.3%
West Kewaunee	50	39	78.0%	5	10.0%
Kewaunee County Totals:	**556**	391	**70.3%**	80	**14.4%**

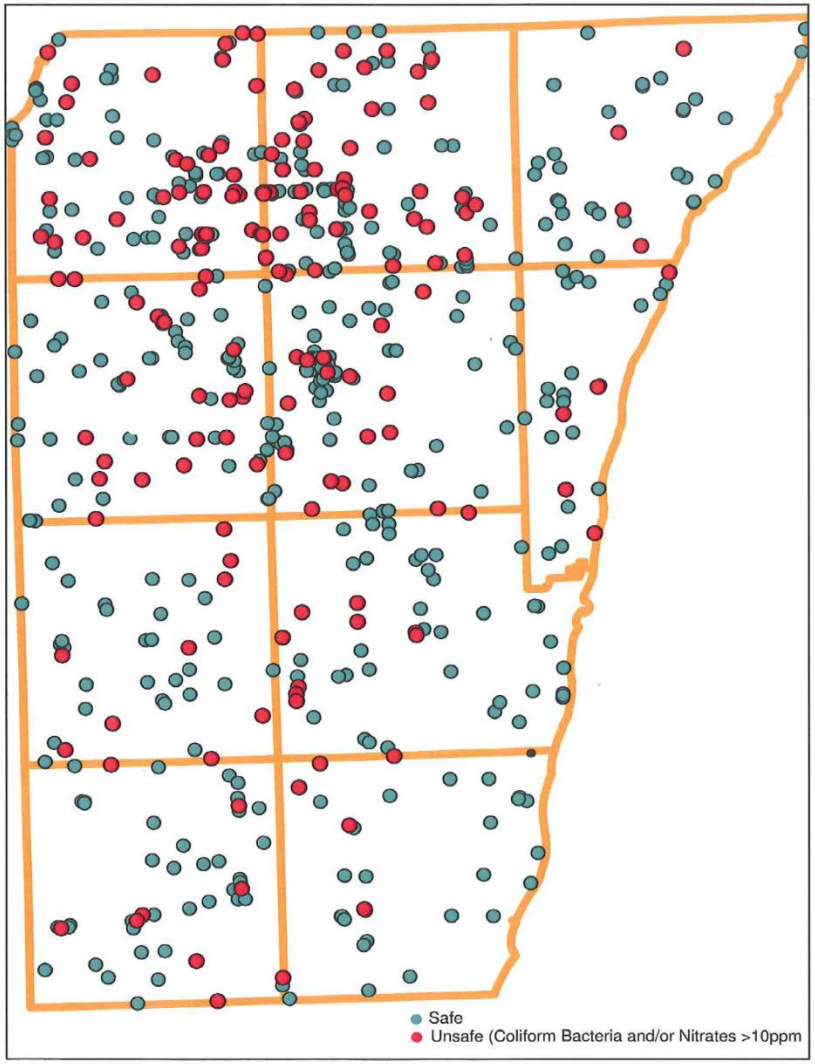
	Unsafe Wells Only Coliform Bacteria Positive		Unsafe Wells **E-coli Positive *All wells also had >10ppm Nitrates		Unsafe Wells Only Nitrates > 10 ppm		Unsafe Wells Bacteria Positive AND Nitrates > 10ppm		Unsafe Wells Bacteria Present AND/OR Nitrates > 10 ppm	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Ahnapee	4	12.9%	0	0.0%	0	0.0%	0	0.0%	4	12.9%
Carlton	6	23.1%	0	0.0%	0	0.0%	0	0.0%	6	23.1%
Casco & Village of Casco	11	14.7%	1	1.3%	5	6.7%	1	1.3%	18	24.0%
Franklin	5	10.2%	0	0.0%	3	6.1%	2	4.1%	10	20.4%
Lincoln	22	21.4%	4	3.9%	8	7.8%	9	8.7%	43	41.7%
Luxemburg	8	11.1%	4	5.6%	5	6.9%	5	6.9%	22	30.6%
Montpelier	4	10.8%	1	2.7%	3	8.1%	1	2.7%	9	24.3%
Pierce	6	21.4%	0	0.0%	0	0.0%	0	0.0%	6	21.4%
Red River	14	16.5%	8	9.4%	11	12.9%	3	3.5%	36	42.4%
West Kewaunee	6	12.0%	2	4.0%	3	6.0%	0	0.0%	11	22.0%
Kewaunee County Totals:	86	**15.47%**	20	**3.60%**	38	**6.8%**	21	**3.8%**	165	**29.68%**

All Ecoli Positive Wells also had nitrates >10ppm

Kewaunee County private well sampling results - maps



Source: United States Geologic Survey and Wisconsin Department of Natural Resources.



Microbial Source Tracking (MST) sampling

Bacteroides spp.
Bacteroides spp. is present in human and animal fecal material. They are strict anaerobes so they do not grow in the environment. The presence of Bacteroides spp. indicates fecal contamination. A series of DNA-based tests can be used to determine whether fecal contamination is present in a source water (surface or well water), and whether that contamination may be of human or bovine (cow) origin.

Sorbitol-fermenting Bifidobacteria
Sorbitol-ferementing Bifidobacteria are present in human fecal material. They are strict anaerobes, so they do not grow in the environment, making them excellent indicators of recent human fecal contamination.

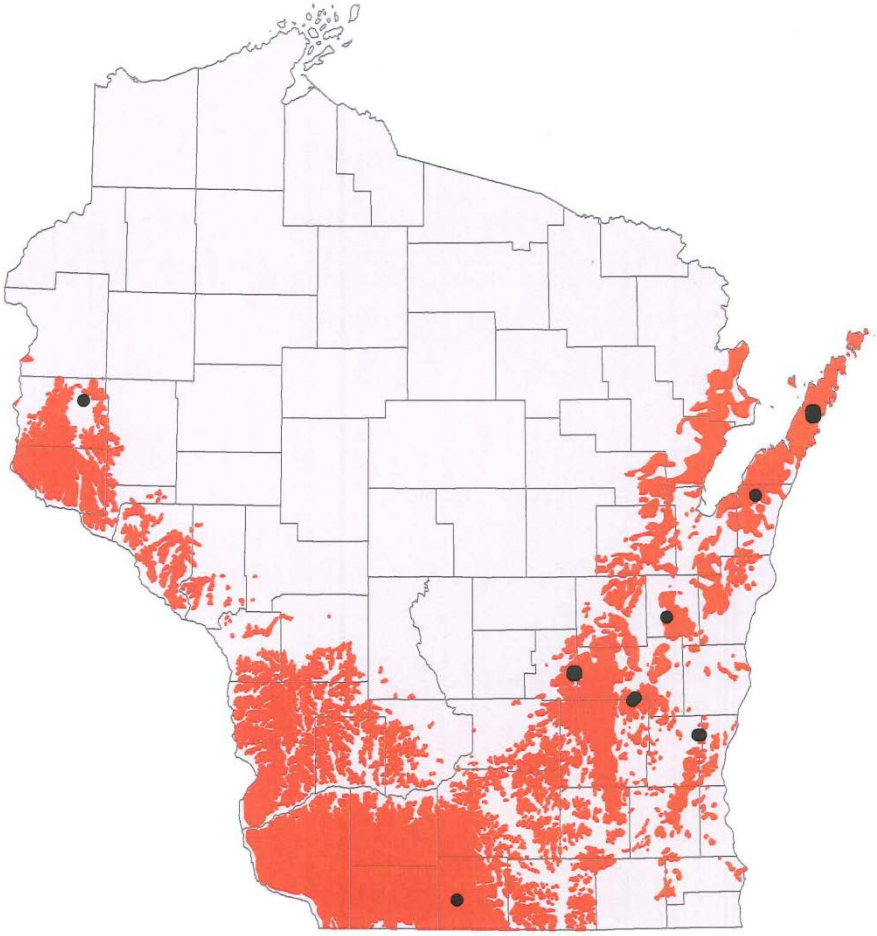
Rhodococcus coprophilus
Rhodococcus coprophilis is found in association with manure of domesticated grazing animals like cows, sheep, horses, goats, etc. To date it has never been isolated from human feces. The presence of Rhodococcus coprophilis indicates grazing animal contamination.

Male-specific coliphage genotypes
Male-specific coliphages are viruses that infect coliforms. As such, their presence indicates the presence of fecal contamination in a water source. These viruses can be enumerated and genotyped. Group I and IV coliphages are associated with non-human fecal sources, while Group II and III are associated with human fecal sources.

Examples of sites in WI with MST confirmed animal waste contamination, with established Special Area of Well Compensation Eligibility (SAWCE)

County	Town	T	R	Section(s)	Pathogen(s) detected	Bedrock	Depth to bedrock
Dodge	Lomira	13N	17 E	6	*E. coli,* bovine bacteriodes	limestone, limestone/dolomite	4' to 71'
Fond du Lac	Byron	14N	17 E	32	*E. coli,* bacteriodes, rhodococcus	limestone	17' to 47'
St. Croix	Emerald	30N	16W	10	*E. coli,* bacteriodes, rhodococcus	limerock, sandrock limestone/dolomite	12' to 85'
Green	Monroe	2N	7E	18	*E. coli,* bovine bacteriodes	limerock	4' to 10'
Green Lake	Green Lake	15N	13E	13, 14, 23, 24	"bacteria indicative of livestock waste"	limestone, limerock	7' to 35'
Door	Jacksonport, Bailys Harbor, Egg Harbor	29N, 30N	27E	3, 4, 9, 10, 33 , 34	*E. coli,* bovine bacteriodes	limestone, limestone/dolomite, limerock	6' to 26'
Kewaunee	Lincoln	25N	24E	19	*E. coli,* bovine bacteriodes, rhodococcus	limestone	1' to 21'
Washington	Trenton	11N	20E	1, 2	bovine bacteriodes	dolomite, limestone	8' to 155'
Calumet	Stockbridge	18N	19E	Gov. Lots: 213, 245, 246, 258	*E. coli,* bovine bacteriodes	limestone	6' to 26'

Sites in WI with MST confirmed animal waste contamination, with established Special Area of Well Compensation Eligibility - map



● = site with established SAWCE

SAWCE site with MST confirmed animal waste contamination – Brownsville (Dodge Co.)

TOWN OF LOMIRA, DODGE COUNTY
Special Well Casing Pipe Depth Area & Area of Well Compensation Eligibility
W 1/2 of SE 1/4 of Section 6, T13N, R17E

April 3, 2014

Special Casing Area Boundary

Refer to the attached document:

Well Construction Specifications, Town of Lomira, Dodge County Special Well Casing Pipe Depth Area & Area of Well Compensation Eligibility

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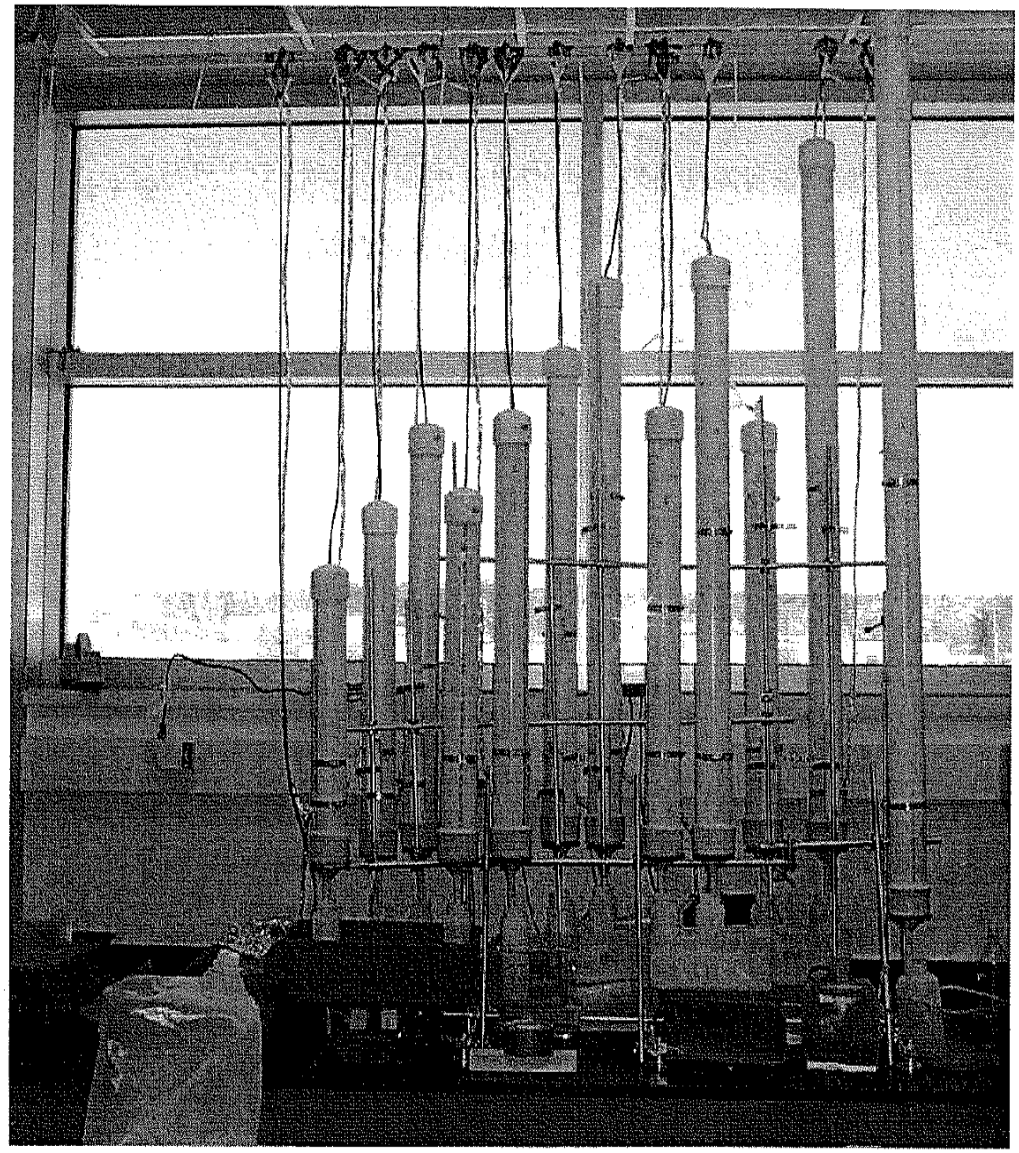
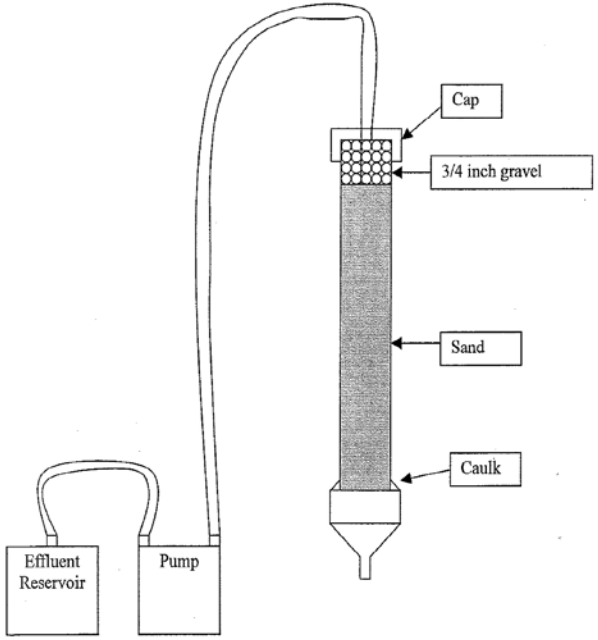
The information shown on these maps has been obtained from various sources, and are of varying age, reliability and resolution. These maps are not intended to be used for navigation, nor are these maps an authoritative source of information about legal land ownership or public access. Users of these maps should confirm the ownership of land through other means in order to avoid trespassing. No warranty, expressed or implied, is made regarding accuracy, applicability for a particular use, completeness or legality of the information depicted on this map.

Soil treatment for pathogen reduction/removal – WI State Lab of Hygiene study





Soil treatment for pathogen reduction/removal – WI State Lab of Hygiene study

Table 17. Fecal coliform levels/100 mLs for columns dosed with low quality septic system effluent.

Column number	*8*	*9*	*11*	*12*
Column Length	24 inch	36 inch	48 inch	60 inch
Dosing Rate	1 gpd/ft^2	1 gpd/ft^2	1 gpd/ft^2	1 gpd/ft^2
Dosing volume	37 mLs	37 mLs	37 mLs	37 mLs
Doses per day	5/day	5/day	5/day	5/day
Average microbe dose level/100mL	530,000	530,000	530,000	530,000
Week 3 12/15/00	0	0	0	0
Week 6 1/04/01	0	0	0	0
Week 9 1/25/01	0	0	0	0
Week 12 2/15/01	0	0	0	0
Week 15 3/7/01	0	0	0	0
Week 18 3/28/01	0	0	0	0
Week 21 4/19/01*	0	0	0	0
Dosing volume	74mLs	74mLs	74mLs	74mLs
Week 23 5/3/01	0			
Week 24 5/9/01	0	0	0	0
Week 27 6/1/01	0	0	15,000	0
Week 29 6/14/01**	2500	20	biofouled	800
Dosing volume	148mLs	148mLs	148mLs	148mLs
Week 30 6/19/01	470	190,000		190,000
Week 30 6/21/01	90	500		270,000
Week 30 6/22/01	330	18,000		220,000
Week 31 6/26/01	4700	120,000		0
Week 31 6/28/01	5100	238,000		8,600

*Flow rate doubled at end of week 19

**Flow rate quadrupled at end of week 28

Table 27. Column 8 - 24 inches, low quality effluent, 1,000,000 FC/100mL dose rate, dosed 5 times per day, 1gpd/ft^2

	total coliform /gm	*E. coli* /gm	Enterococci /gm	fecal coliform /gm	male-specific coliphage /gm
0-1 inches	>2419.6	488.4	70.8	10,000	<300
1-2 inches	>2419.6	435.2	98.7	9000	<300
2 - 4 inches	>2419.6	260.3	24.3	12,000	<300
4 - 6 inches	>2419.6	72.3	52.1	2000	<300
6 - 8 inches	>2419.6	40.4	24.6	1000	<300
8 - 10 inches	>2419.6	4.1	5.2	240	<300
10 - 12 inches	>2419.6	5.2	4.1	170	<300
12-14 inches	>2419.6	12.1	7.4	150	<300
14-16 inches	>2419.6	4.1	1	100	<300
16-18 inches	>2419.6	9.7	2	20	<300
18-20 inches	2419.6	9.6	4.1	70	<300
20-22 inches	1119.9	7.4	1	40	<300
22-24 inches	>2419.6	12.1	3.1	20	<300
Residual	325.5	4.1	2	10	<300

Current requirments for soil treatment (vertical setback)

NR 243 – land application of manure and process wastewater at CAFO facilities
min. of 2' to groundwater or bedrock [s. NR 243.14 (2) (b) 7.]

NR 204 – landspreading of municipal wastewater biosolids/sludge
min. of 3' separation to bedrock and high groundwater [s. NR 204.07(3)(c)]
(* pretreatment for pathogen reduction required prior to landspreading)

NR 113 – landspreading of septage
min. of 3' separation to bedrock and groundwater [s. NR 113.07(3)(b)]

NR 214 – landspreading of industrial liquid wastes/by-product solids
min. of 3' separation to bedrock or groundwater [s. NR 214.17(2)(f)]

SPS 383 – private onsite wastewater treatment system (septic systems)
min. of 3' separation to bedrock and groundwater [Table 383.44-3]
min. of 5' separation to bedrock and groundwater - sand soils
(* min. of 2' separation to bedrock and groundwater – allowed w/advanced treatment for pathogen reduction)

NR 110/NR 206 – land treatment of municipal wastewater
min. of 5' separation to highest anticipated/seasonal groundwater elevation
min. of 5'-10' separation to bedrock

Sources of fertilizer - based on 2009 harvested cropland (just less than 9 million acres)

< 0.8% Septage (NR 113)

< 0.8% Biosolids (NR 204)

< 3.8% Industrial Wastes - liquid wastes, sludges, by-product solids (NR 214)

50-60% Animal Wastes including CAFO wastes

10-12% CAFO Animal Wastes (NR 243)