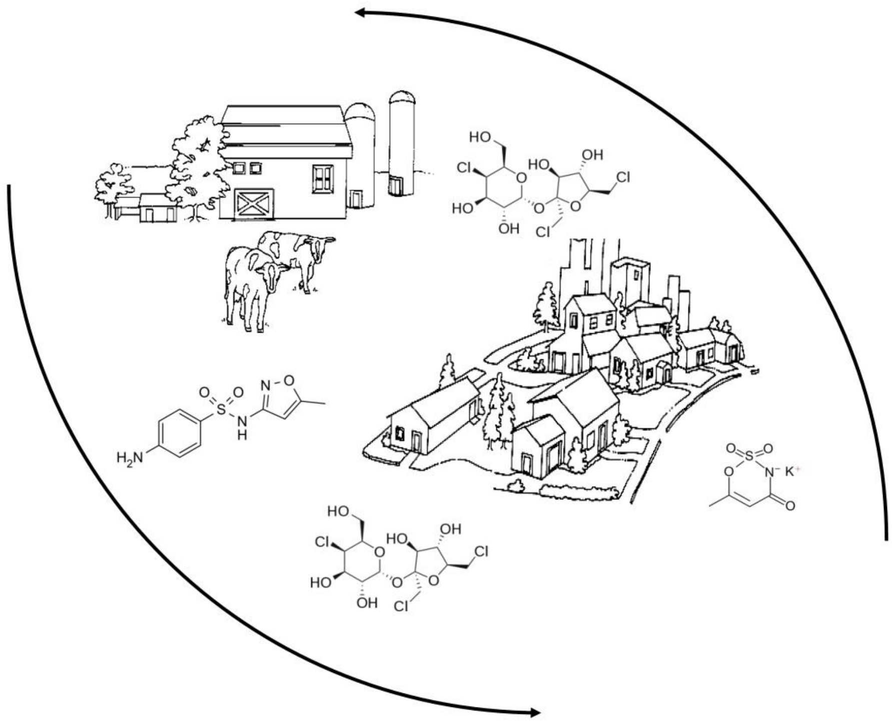
Evaluating Chemical Tracers in Suburban Groundwater as Indicators of Nitrate-Nitrogen Sources



A Final Report Prepared for the Wisconsin Department of Natural Resources

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PROJECT SUMMARY

Title **Evaluating Chemical Tracers in Suburban Groundwater as Indicators of Nitrate-Nitrogen Sources**

Project Identification **Wisconsin DNR Project #219**

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Background & Need Nitrate-nitrogen concentrations exceed the drinking water standard in nine percent of Wisconsin’s private wells and forty-seven community water system wells. It has been estimated that up to ninety percent of the nitrogen that contaminates groundwater is from agricultural sources, but on-site wastewater systems may also be important sources of groundwater nitrate-nitrogen in some areas. It is important that the source of nitrate-nitrogen to an individual well be understood to make appropriate land management and treatment decisions.

Objectives The objective of this study was to develop a chemical method for distinguishing between fertilizer and on-site waste sources of nitrate to a well by analyzing other compounds that are likely present in groundwater recharge from those sources.

Methods A group of likely tracers for on-site waste and agricultural nitrate contamination were identified through literature review and previous research. The ideal tracer is ubiquitous in the source water, mobile in groundwater, resistant to degradation and detectable at environmentally relevant concentrations. Analytical methods were refined to concentrate and analyze the on-site waste indicator compounds. That group included pharmaceuticals, artificial sweeteners and personal care products. Five pesticide metabolites and a bovine antibiotic were included as agricultural source indicators. Water samples were collected five times over two years from eighteen private wells in a suburban area with a history of nitrate-N contamination. Two sets of monitoring wells were installed near the private wells to understand the vertical variation in water quality in the study area.

Results & Discussion

Ninety six percent of the samples from the private wells and all of the monitoring well samples in this suburban study area that had a nitrate-N concentration greater than 3 mg N/L also had at least one of four contaminant source indicators. Those indicators were the artificial sweeteners acesulfame or sucralose, the pharmaceutical sulfamethoxazole or the agricultural pesticide metabolite metolachlor ESA. In the monitoring wells, on-site waste tracers were found in the shallower wells and agricultural tracers were found in the deeper wells. That was consistent with recharging water moving deeper into the aquifer with increasing distance in this suburban area.

Conclusions & Implications

The artificial sweeteners acesulfame and sucralose were consistently found at detectable concentrations in on-site waste contaminated water with a nitrate concentration greater than 3 mg N/L. Because both of these tracers have been registered for use in foods for more than fifteen years, they would appear to be reliable chemical tracers for distinguishing on-site waste nitrate-N contamination.

Related Publications

Nitka, A., W. DeVita, P. McGinley. 2015. Peering in the 21st Century: Chemical Tracers for Nitrate Source Identification. Presented at the Annual Meeting of the Wisconsin Water Association. Wisconsin Dells, WI. September 10, 2015.

Nitka, A. W. DeVita, P. McGinley. 2015. Evaluating Chemical Tracers in Suburban Groundwater as Indicators of Nitrate-Nitrogen Sources. Published abstract and poster presentation at the Wisconsin Section American Water Resources Association Annual Conference. Oconomowoc, WI. March 5 - 6, 2015.

Key Words

Nitrate, On-site waste systems, contaminant source tracking

Funding

This study was funded by the Wisconsin Department of Natural Resources

INTRODUCTION

Groundwater is an important but vulnerable resource. Approximately 30% of Wisconsin residents use private wells for their water supply (Gotkowitz and Liebl, 2013) accounting for more than 750,000 wells. Approximately 70% rely on more than 500 municipal water supplies. Because groundwater is recharged by precipitation passing through the soil and into groundwater aquifers, it is susceptible to contamination. It can acquire contaminants from a variety of land management activities including agricultural land amendments, discharge from municipal and on-site waste systems, and runoff from roadways and other impervious surfaces.

One of the most common groundwater contaminants is nitrate. Nitrate is found naturally in groundwater at low concentrations. Concentrations greater than 3 mg N/L usually indicate contamination (Madison and Brunett, 1985). Nitrate in groundwater is a health concern. The U.S. Environmental Protection Agency has a health standard of 10 mg N/L nitrate (U.S. EPA, 2012). This standard was set to prevent methemaglobinemia in infants. The Wisconsin Division of Public Health also recommends people of all ages avoid long-term consumption of water with nitrate concentrations exceeding this standard (WI DNR, 2010). Since 2000, almost 1 in 6 private water supply wells tested in Portage County, Wisconsin had nitrate-nitrogen concentrations that exceeded the groundwater enforcement standard (Portage County, 2011). Nitrate concentrations were greater than the standard in forty-seven community water systems (WI DNR, WGCC, 2015). Sources of nitrate contamination in groundwater include agricultural activities and septic wastewater discharge. Shaw (1994) estimated that ninety percent of the nitrate entering Wisconsin groundwater was from agricultural fertilizer and manure, and that on-site waste systems account for approximately nine percent of the nitrate. Because private wells are often found near other homes which have on-site waste systems, the source of high nitrate concentrations in an individual well may be more likely to result from on-site waste than the state-wide nitrogen budget would suggest. The source of nitrate cannot be determined through routine nitrate analysis. With nitrate concentrations increasing in groundwater at many locations in Wisconsin (GCC, 2009), it is important to better understand the sources of nitrate-nitrogen to an individual well for developing remedial strategies for improving groundwater quality.

PURPOSE

The objective of this research was to evaluate the relationship between groundwater nitrate and a group of chemical tracers that could be used as indicators of on-site wastewater disposal or agricultural activities. It was the goal of this research to develop a tool to help water resource managers, municipalities, and well owners understand the source of nitrate contamination so they can determine appropriate treatment and remediation options.

METHODS

ANALYTE SELECTION

A variety of nitrate source indicators were chosen for this study. Chemical characteristics, such as mobility in groundwater and water solubility, as well as their common use, were considered when choosing source indicators. A group of fourteen pharmaceuticals and personal care products unique to human use was chosen to identify wells likely impacted by on-site waste systems. A bovine antibiotic, fungicide metabolite, and four chloroacetanilide herbicide metabolites (CAAMs) were used to identify contamination from agricultural sources.

INORGANIC ANALYTES

The inorganic tracer compounds included the major ions chloride, boron and phosphorus. Both on-site waste systems and agricultural activities can increase chloride concentrations in groundwater (Kraft et al., 2008; Hinkle et al., 2009). Boron was also used as an inorganic tracer as previous studies have suggested its use in detergents make it a potential wastewater indicator (EPA, 2008). Phosphorus was also explored as an inorganic tracer. On-site waste systems are a source of phosphorus; however, significant removal can occur (25% to 99%), preventing much of the phosphorus from entering the groundwater (Robertson, 1998).

ORGANIC ANALYTES

Food and consumable products

Several food products were chosen as human waste tracers (Table 1). Caffeine is found in coffee, soft drinks and other products unique to human consumption. It has been detected in surface water samples near wastewater treatment plants (Glassmeyer et al., 2005). Its primary metabolite, paraxanthine, has been detected in untreated groundwater used for public drinking-water supplies in California (Fram et al., 2011). Artificial sweeteners are commonly added to low-calorie foods and beverages. Sucralose has been found in European surface waters (Loos et al., 2009) and Canadian urban areas (Van Stempvoort et al., 2011). Scheurer et al. (2009) evaluated multiple artificial sweeteners in German waste water and surface waters. Acesulfame and sucralose have been detected in previous groundwater samples from the Town of Hull (Nitka, 2014). For this study, the artificial sweetener saccharin was added to the suite of tracers. Sulfanilic acid is a food color additive that was also added for this study. The nicotine metabolite cotinine was also included in the tracer suite.

Pharmaceuticals (human and veterinary)

Pharmaceuticals are another group of compounds used as indicators of human waste impacts. Acetaminophen is an over-the-counter analgesic that has been found in surface water and groundwater samples (Glassmeyer et al., 2005; Fram et al., 2011). Triclosan is an antimicrobial compound found in many sanitizing products. Carbamazepine is a mood stabilizer and anti-seizure medication and is also used to treat attention deficit disorder. While not as widely used as other waste tracers, it does not appear to be removed while passing through soil (Nakada et al., 2008) and is one of the most frequently detected pharmaceuticals in groundwater (Fram et al., 2011). The Minnesota Pollution Control Agency (MPCA) collected surface water samples upstream, at the point of discharge, and downstream from at least 20 wastewater treatment plants (WWTPs) and found carbamazepine, sulfamethoxazole (human antibiotic), and venlafaxine (antidepressant) were the most commonly detected pharmaceuticals in 96 percent of effluent samples and in greater than 40 percent of surface water samples. Trimethoprim was also frequently detected (Ferry, 2011). Carbamazepine was already included in the human waste tracer suite (Nitka, 2014). Sulfamethoxazole, trimethoprim, and the venlafaxine were added for this study. The bovine antibiotic sulfamethazine was added to the suite as an indicator of agricultural contamination.

Pesticides

Pesticide metabolites were used as tracers of agricultural contamination (Table 2). The chloroacetanilide herbicides alachlor and metolachlor are commonly used in Central Wisconsin on corn and soybeans. They metabolize into ethane sulfonic acid and oxanilic acid products. Chlorothalonil is a fungicide commonly used for potatoes and it readily degrades into 4-hydroxy-chlorothalonil. These metabolites were all added to the tracer suite for this study as an indicator of agricultural impacts to groundwater.

Table 1. Nitrate source indicators analyzed by LC/MS/MS. (Log K_{ow} values were obtained from the Hazardous Substances Data Bank, 2006-2012.)

Analyte	Use	~Log K_{ow} (est)
Acesulfame	Artificial sweetener	-1.3
Acetaminophen	Pain reliever	0.5
Caffeine	Stimulant	-0.1
Carbamazepine	Anticonvulsant	2.4
Cotinine	Nicotine metabolite	0.1
Hydroxychlorothalonil	Fungicide metabolite	2.9
Paraxanthine	Caffeine metabolite	-0.4
Saccharin	Artificial sweetener	0.9
Sucralose	Artificial sweetener	-1.0
Sulfamethazine	Livestock antibiotic	0.1
Sulfamethoxazole	Human antibiotic	0.9
Sulfanilic Acid	Dye metabolite	-2.2
Triclosan	Consumer product antibacterial	4.8
Trimethoprim	Human antibiotic	0.9
Venlafaxine	Antidepressant	3.2

Table 2. Pesticide metabolites analyzed by HPLC.

Metolachlor ESA	Metolachlor OA	Alachlor ESA	Alachlor OA

The results of the method detection limit study are shown in Table 3. Water samples from two private wells were sent to the Wisconsin State Lab of Hygiene and results for sucralose and sulfamethoxazole were confirmed via personal communication with Dr. Curtis Hedman.

Table 3. Method detection limit for indicators of septic waste contamination and the fungicide metabolite hydroxychlorothalonil. ^{E} = estimated value

Compound	Limit of Detection (ng/L)
Acesulfame	7.0
Acetaminophen	4.4
Caffeine	5.0
Carbamazepine	2.5
Cotinine	4.3
Hydroxychlorothalonil	25^{E}
Paraxanthine	12
Saccharin	19
Sucralose	25
Sulfamethazine	2.1
Sulfamethoxazole	2.3
Sulfanilic Acid	25^{E}
Triclosan	60
Trimethoprim	2.0
Venlafaxine	2.5

SAMPLE PREPARATION AND ANALYSIS

Pharmaceuticals and personal care products (PPCPs)

Samples analyzed for pharmaceuticals, personal care and food products were filtered through glass fiber filters (Whatman), collected in one-liter amber bottles and stored at 4ºC.

Samples were concentrated prior to analysis using methods developed previously (Nitka, 2014). Waters Oasis 6cc (200 mg) HLB cartridges were used with a Dionex Autotrace 280 (Thermo Scientific) unit for automated solid phase extraction (SPE) of samples. Cartridges were conditioned with 5 mL of methanol and 5 mL of reverse osmosis (RO) water. Cartridges were loaded with 100 mL of sample then dried with nitrogen gas for 30 minutes. Cartridges were eluted with 5 mL of methanol and dried to less than 50 µL at 50˚C using a Turbovap Concentration Workstation.

Deuterated analogs of acesulfame, caffeine, carbamazepine, cotinine, sucralose, sulfamethazine, triclosan were used as internal standards for their respective analytes. Deuterated analogs were not available for some analytes. Those analytes were assigned internal standards with similar structures or retention times. Fifty µL of internal standard mix of varying concentrations were added, and samples were brought to a volume of 500 µL in 15 mM acetic acid.

Analysis of the indicators was performed using an Agilent 1200 series high performance liquid chromatograph coupled to an Agilent 6430 triple quadrupole mass spectrometer with an electrospray ionization source. Twenty µL of sample was injected and carried through the LC column (Zorbax Eclipse XDB-C8 column, 4.6 × 50 mm; 1.8 µ) (Scheurer et al., 2009) by a mobile phase of 15 mM acetic acid in reverse osmosis (RO) water (mobile phase A) and 15 mM acetic acid in methanol (mobile phase B). An Agilent 1200 series LC pump was used to provide a pre-programmed gradient at a flow rate of 0.5 mL/minute. Benzoylecgonine-D3 was added to samples prior to extraction for use as a surrogate standard. Recoveries of this compound were used to evaluate the efficiency of the solid phase extraction process.

Chloroacetanilide metabolites (CAAMs)

Filtered (Whatman glass fiber) groundwater samples analyzed for the ethane sulfonic acid (ESA) and oxanilic acid (OA) metabolites of the chloroacetanilide herbicides metolachlor and alachlor were collected in one-liter amber bottles and stored at 4ºC. Extraction for chloroacetanilide herbicide metabolites was performed according to the method of Zimmerman et al. (2000). 125 mL of each sample was processed through the Dionex Autotrace 280 Solid Phase Extraction (SPE) system utilizing Waters SepPak C18 cartridges, which had been conditioned withmethanol, ethyl acetate, again with methanol, and RO water. The C18 cartridge was first eluted with ethyl acetate, to remove the non-polar compounds. Methanol was used to elute the second fraction, containing the polar CAAMs, and was collected in 5 mL glass centrifuge tubes. Samples were concentrated using a Turbovap Concentration Work Station at 50ºC to take the samples to complete dryness. Extracts were reconstituted with 1000 μL 80:20 buffer:acetonitrile. These samples were stored in a freezer until they were analyzed by the Agilent 1100 HPLC, equipped with a UV photodiode array detector (PDA). Analytes were identified and quantified using a Betasil C18 250 x 5 mm column with 5 micron particles, and positive samples confirmed with an Aquasil C18 250 x 5 mm column with 5 micron particles.

Nitrate/chloride

Samples for nitrate and chloride were collected in high-density polyethylene (HDPE) bottles and stored at 4ºC. Samples taken from the monitoring wells were filtered using a 0.45 um membrane filter. A Lachat 8000 flow injection analyzer was used for nitrate (Lachat Method 10-107-04-1-A) and chloride (Lachat Method 10-117-07-1-B) analysis.

Metals

Samples for metal analyses were collected in high-density polyethylene (HDPE) bottles and stored at 4ºC. Samples taken from the monitoring wells were filtered using a 0.45 um membrane filter. All samples were acidified with nitric acid to a pH of less than 2. An Agilent ICP-OES was used to analyze samples according to EPA Method 200.7 for sodium, boron, phosphorus, potassium, calcium, magnesium, manganese, sulfate, and iron. Metals of emerging concern, including vanadium, chromium, cobalt, strontium, molybdenum, uranium were analyzed by an Agilent ICP-MS.

EXPERIMENTAL DESIGN

STUDY SITE

The Town of Hull is located in central Wisconsin (Figure 1). It is the third largest municipality in Portage County. Unlike neighboring Stevens Point and Plover, Hull's 5700 residents rely on private wells for their drinking water. Hull is comprised largely of single-family residential areas with some agricultural land. Its groundwater recharge area extends outside the township boundaries for several miles into land that is largely used for agriculture.

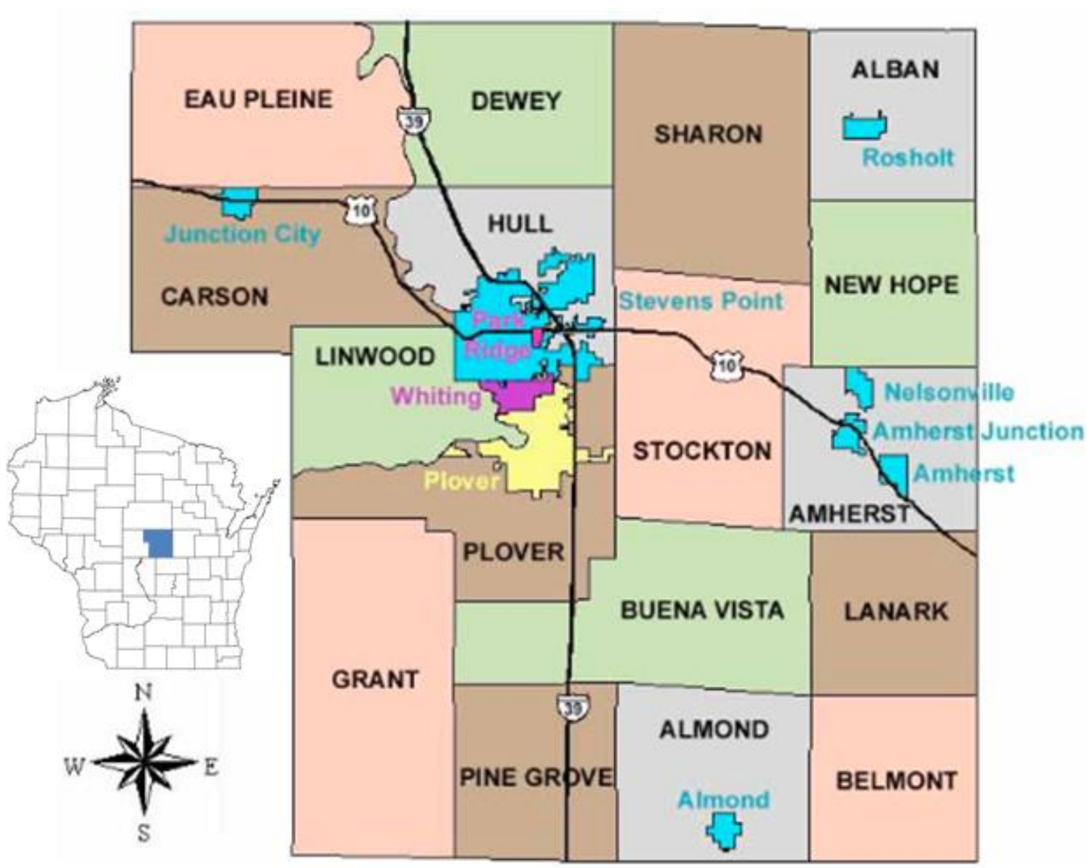

Figure 1. Map indicating the location of the Town of Hull in central Wisconsin (Source: Portage County Planning and Zoning).

SELECTION OF PRIVATE WELLS

Eighteen private wells were chosen for this study. Six wells were selected based on their nitrate results from a drinking water program conducted by UWSP and UW-Extension in October 2013. Twelve more wells were selected in areas that had previously shown high nitrate concentrations. Wells were located in suburban subdivisions with on-site waste systems and nearby agricultural land. Well construction reports were available for four wells (APPENDIX A). Five of the wells were drilled wells and thirteen were driven-point wells.

Well selection was also based on the direction of groundwater flow. Nine wells were located in a northern subdivision, with two addition wells located upgradient (Figure 2). Groundwater in this area flows generally from northwest to southeast. Seven other wells were located in the southern part of the study area (Figure 3), where groundwater flows east to west.

INSTALLATION OF MONITORING WELLS

Monitoring wells were installed to provide a depth profile for nitrate and source indicators (APPENDIX A). Town of Hull officials were consulted to authorize placement of monitoring wells. Two multi-port wells were installed on township right-of-way property. One three-port well was installed downgradient of the northern subdivision at depths of 6.2, 10.8, and 15.4 meters each with 0.9 meter screens. A second three-port well and a deeper drilled well were installed along the flow path of the wells in the southern subdivision. The well ports were at depths of 9.1, 12.0, 15.1, and 21.5 meters, each with 0.9 meter screens.

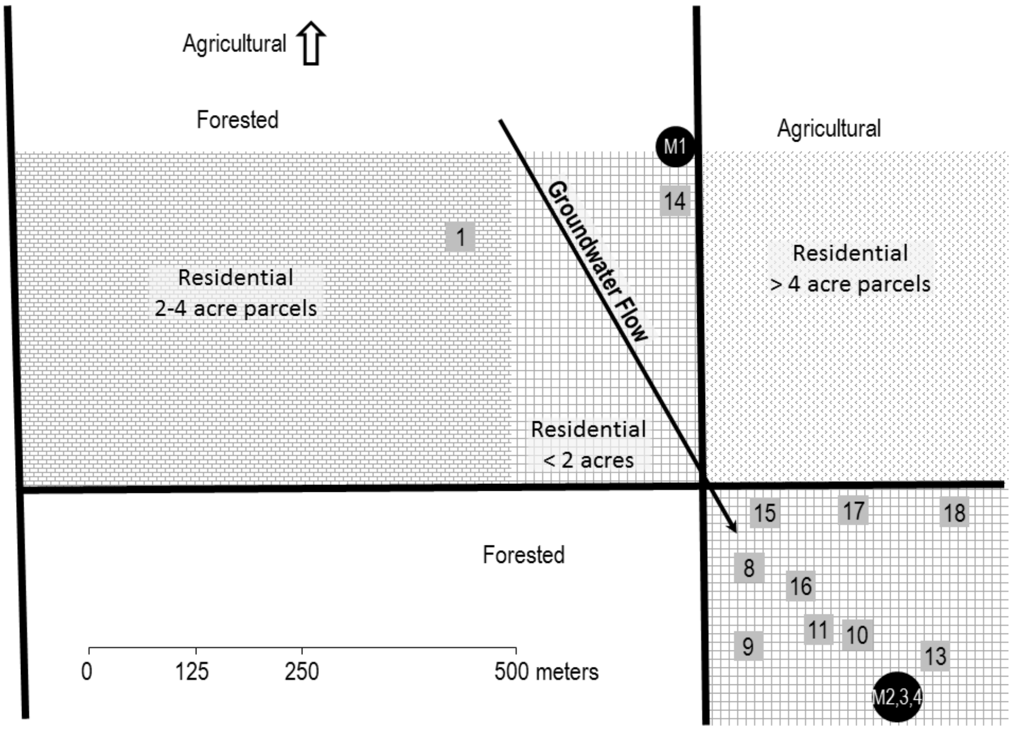

Figure 2. North study area showing land uses and density of homes in the residential areas. Numbered squares show location of private wells sampled and dark circles show the location of the monitoring wells.

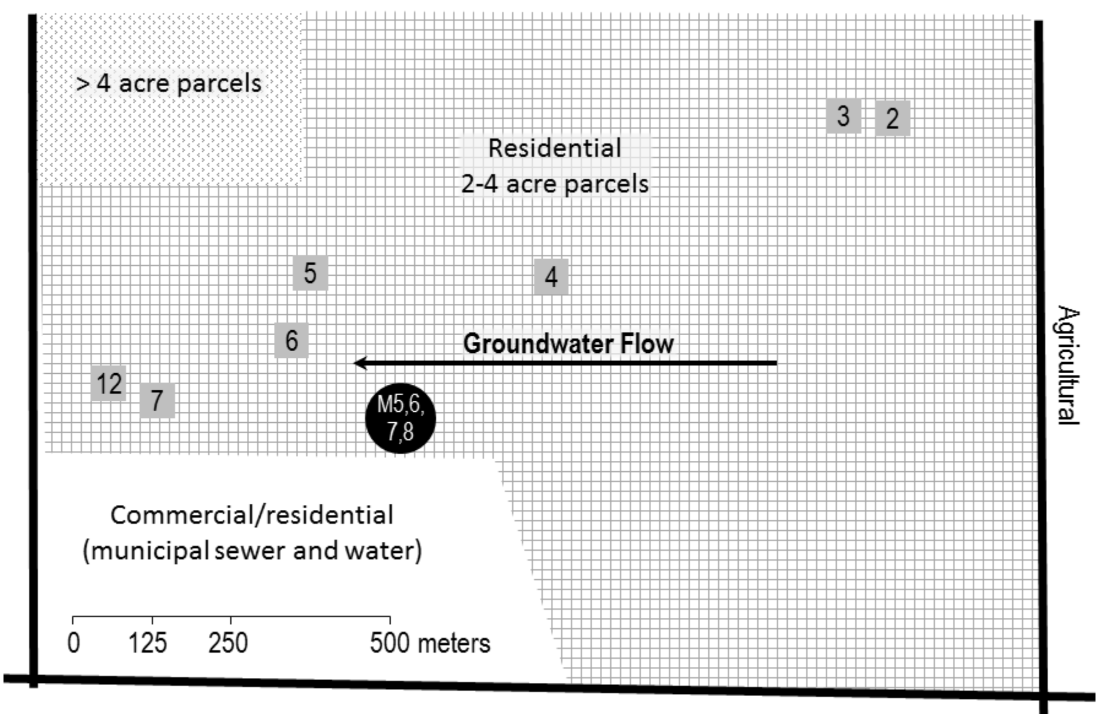

Figure 3. South study area showing land uses and density of homes in the residential areas. Numbered squares show location of private wells sampled and dark circles show the location of the monitoring wells.

SAMPLING

Each private well was sampled and analyzed five times to provide a temporal profile of nitrate and the tracers. Monitoring wells were sampled twice. All samples were analyzed for nitrate and source indicators. Samples were also analyzed for pH, conductivity, alkalinity, total hardness, and major ions. Samples from the last two private well sets and the second monitoring well set were analyzed for elements of emerging concern.

RESULTS

The general water chemistry of groundwater collected from the nitrate-contaminated private wells and monitoring wells is summarized in Tables 4 and 5. A charge balance was calculated for each sampling event of each well (APPENDIX B) to validate the results. All wells had a charge balance error within ±11%.

Table 4. Summary of general water chemistry for the private wells from five sampling events. na = wells with softened water

PW	pH std units		Conductivity µmhos/cm		Alkalinity mg/L as $CaCO_3$		Hardness mg/L as $CaCO_3$		NO_3 mg/L as N	
#	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	8.17	8.40	357	387	40	48	168	184	22.5	24.7
2	7.50	7.82	607	644	152	184	260	288	8.1	20.0
3	7.64	7.90	541	683	140	152	247	308	14.3	17.0
4	7.95	8.02	640	880	174	216	na	na	6.4	15.2
5	8.18	8.25	859	928	116	132	188	204	11.8	13.8
6	7.94	8.08	458	517	112	132	176	192	7.4	12.5
7	8.19	8.36	368	496	104	112	148	191	8.5	11.3
8	8.14	8.31	399	1050	116	172	na	na	7.4	10.4
9	7.78	8.05	372	498	120	132	96	152	3.8	6.8
10	8.27	8.49	271	411	84	100	92	172	4.9	8.0
11	7.58	8.08	364	472	112	140	116	148	4.4	9.7
12	8.24	8.37	313	356	100	136	120	144	5.9	10.2
13	8.19	8.39	297	369	100	116	133	164	4.3	6.2
14	8.29	8.58	138	242	52	88	64	126	2.0	9.4
15	8.30	8.41	172	357	72	112	76	156	3.4	11.7
16	8.02	8.33	340	465	104	124	108	152	2.1	3.1
17	7.69	8.45	251	300	100	108	100	127	1.4	3.3
18	7.53	7.64	231	245	124	132	134	156	<0.1	<0.1

PW	Chloride mg/L		Calcium mg/L		Potassium mg/L		Magnesium mg/L		Sodium mg/L	
#	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	24.0	27.0	40.8	45.5	0.65	0.82	16.5	18.4	2.4	3.0
2	55.1	70.3	60.7	68.4	1.31	1.41	26.0	30.8	17.6	23.4
3	36.3	80.8	56.2	74.6	1.06	1.33	25.7	33.8	9.2	17.2
4	62.9	126.0	na	na	0.26	1.18	na	na	136.3	205.3
5	158.0	180	43.4	50.9	1.89	2.09	18.8	22.2	105.0	120.6
6	50.4	61.1	40.5	44.0	0.01	1.61	18.1	19.7	26.0	37.9
7	32.2	59.4	33.3	42.8	0.90	0.94	15.2	20.4	18.5	21.4
8	32.4	95.2	na	na	0.20	0.32	na	na	98.7	139.8
9	45.7	75.5	24.7	36.4	2.11	2.42	10.1	14.6	40.6	57.9
10	17.2	58.9	23.8	42.1	1.10	1.25	9.0	15.7	12.6	27.4
11	30.7	50.6	28.8	37.8	2.00	2.29	10.6	14.4	29.4	44.2
12	22.5	26.9	31.9	37.7	1.29	1.71	9.8	13.4	16.9	20.7
13	19.2	39.7	31.4	41.4	0.80	1.05	13.1	17.3	10.7	13.3
14	3.5	11.9	22.1	30.3	0.63	0.75	8.8	12.4	2.2	3.7
15	6.2	21.2	19.7	35.6	0.87	1.00	7.4	13.4	9.4	14.6
16	36.2	75.6	27.3	33.7	1.40	1.69	10.0	12.3	33.0	39.9
17	17.3	28.9	24.6	29.3	1.03	1.17	9.9	13.0	13.6	17.5
18	5.3	5.7	28.7	33.1	0.55	0.72	13.2	15.0	1.6	2.1

PW	Phosphorus		Iron		Boron		Manganese		Sulfate	
#	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	<LOD	<LOD	0.019	0.045	0.030	0.051	<LOD	<LOD	23.5	24.8
2	<LOD	<LOD	0.009	0.029	0.016	0.038	<LOD	0.018	27.1	31.5
3	<LOD	<LOD	0.013	0.023	0.010	0.029	<LOD	0.001	24.5	30.5
4	<LOD	0.016	0.006	0.024	0.038	0.061	<LOD	<LOD	15.5	21.6
5	<LOD	0.011	0.014	0.024	0.062	0.098	<LOD	<LOD	28.5	35.7
6	<LOD	<LOD	0.007	0.014	0.045	0.055	<LOD	<LOD	19.3	24.7
7	0.009	0.011	0.008	0.010	0.021	0.065	<LOD	0.002	10.9	14.4
8	<LOD	0.012	0.009	0.061	0.043	0.054	<LOD	<LOD	15.6	16.8
9	0.051	0.070	0.013	0.045	0.017	0.040	<LOD	0.026	10.4	11.1
10	<LOD	0.014	0.007	0.040	0.061	0.081	<LOD	0.003	13.2	18.7
11	<LOD	0.005	0.015	0.030	0.033	0.050	<LOD	0.003	11.2	14.5
12	<LOD	<LOD	0.032	0.571	0.025	0.074	0.002	0.029	10.5	14.1
13	<LOD	0.011	0.011	0.077	0.059	0.071	<LOD	0.011	12.7	15.9
14	0.008	0.016	0.010	0.035	0.100	0.854	<LOD	<LOD	12.5	17.7
15	0.036	0.058	0.004	0.026	0.015	0.031	<LOD	<LOD	10.8	13.4
16	<LOD	0.018	0.011	0.042	0.030	0.039	<LOD	<LOD	9.3	10.6
17	<LOD	0.010	0.015	0.085	0.011	0.028	<LOD	0.001	8.3	10.3
18	<LOD	0.010	1.166	1.700	0.000	0.037	0.375	0.413	7.8	8.8

Table 5. Summary of general water chemistry for the eight monitoring wells from two sampling events.

MW	**pH std units**		**Cond µmhos/cm**		**Alkalinity mg/L as $CaCO_3$**		**Hardness mg/L as $CaCO_3$**		**NO_3 mg/L as N**	
#	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
M1	7.67	8.05	312	389	128	144	157	191	2.7	20.6
M2	7.83	8.26	447	493	96	120	149	167	14.7	23.0
M3	7.50	8.10	393	402	108	108	165	191	4.9	7.0
M4	7.98	8.77	92	103	36	52	43	52	<0.1	<0.1
M5	6.86	7.73	230	275	44	80	79	102	2.7	2.9
M6	8.15	8.30	507	822	96	112	75	129	4.5	10.5
M7	7.86	8.12	579	884	104	120	135	156	11.2	12.2
M8	7.91	8.13	671	764	144	152	291	294	23.6	24.5

MW	**Chloride mg/L**		**Calcium mg/L**		**Potassium mg/L**		**Magnesium mg/L**		**Sodium mg/L**	
#	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
M1	17.2	76.6	36.03	45.56	1.92	2.03	16.177	18.590	11.9	13.8
M2	44.2	69.2	36.91	40.32	2.51	2.68	13.624	15.970	23.2	38.4
M3	19.9	20.2	39.30	46.12	1.03	2.17	16.043	18.210	3.7	6.6
M4	1.1	1.2	10.41	12.49	0.48	0.97	4.114	5.126	0.8	1.1
M5	11.9	13.4	21.22	27.60	0.88	1.35	6.319	8.001	2.5	3.1
M6	78.9	167	17.92	30.95	1.18	2.06	7.298	12.516	74.4	102.2
M7	80.7	148	33.23	38.00	1.86	3.26	12.672	14.692	53.9	113.1
M8	65.3	68.6	64.63	64.84	1.13	1.33	31.295	32.000	22.1	24.6

The nitrate-N concentrations in the private wells ranged from <0.01 mg N/L to 24.7 mg N/L. One of the wells had a nitrate-N concentration below the detection limit (<0.1 mg N/L) for all five sampling events. This well also had high iron and manganese concentrations suggesting that any nitrate in the groundwater may have been removed through denitrification. The other seventeen wells all had detectable nitrate-N on each trip and relatively low iron and manganese concentrations. Figure 4 shows the variation in nitrate concentrations for all sampling events and all wells.

Of the fourteen on-site waste indicators that were analyzed in each of five sampling events at all eighteen private wells, only three compounds were detected. These were acesulfame, sucralose and sulfamethoxazole. They were detected in 66 of the 90 samples. Table 6 shows that the sucralose was found during 85% of samples where at least one on-site waste indicator was detected; acesulfame was detected in 83% and sulfamethoxazole in 79%. Of the nitrate-contaminated private wells that had an on-site waste indicator detected, acesulfame was detected in 76%, sucralose in 82% and sulfamethoxazole in 88% of the wells. Three of the five agricultural contaminants were detected. The herbicide metabolite metolachlor ESA was detected in 50% of the wells. Figures 5 through 8 summarize the analysis of the most commonly detected on-site waste and agricultural tracers.

Monitoring well samples were also analyzed for nitrate and source indicators (Figure 9). In the north study area, nitrate and all contaminant indicator concentrations were below the detection limit in M1, the existing upgradient monitoring well. In the downgradient multi-port wells (M2, M3, and M4) acesulfame and sucralose were detected in the two shallower wells. Very low concentrations (<0.025 ng/L) of sulfamethoxazole were also detected in the shallow wells. Metolachlor ESA was detected in the deepest well. In the south study area, the concentration of nitrate increased with depth. On-site waste tracers were detected in all of the nitrate-contaminated monitoring wells with the highest concentrations at the 14.9 meter depth (M7). Metolachlor ESA was only detected in the deepest well (M8) at 21.3 meters from the surface.

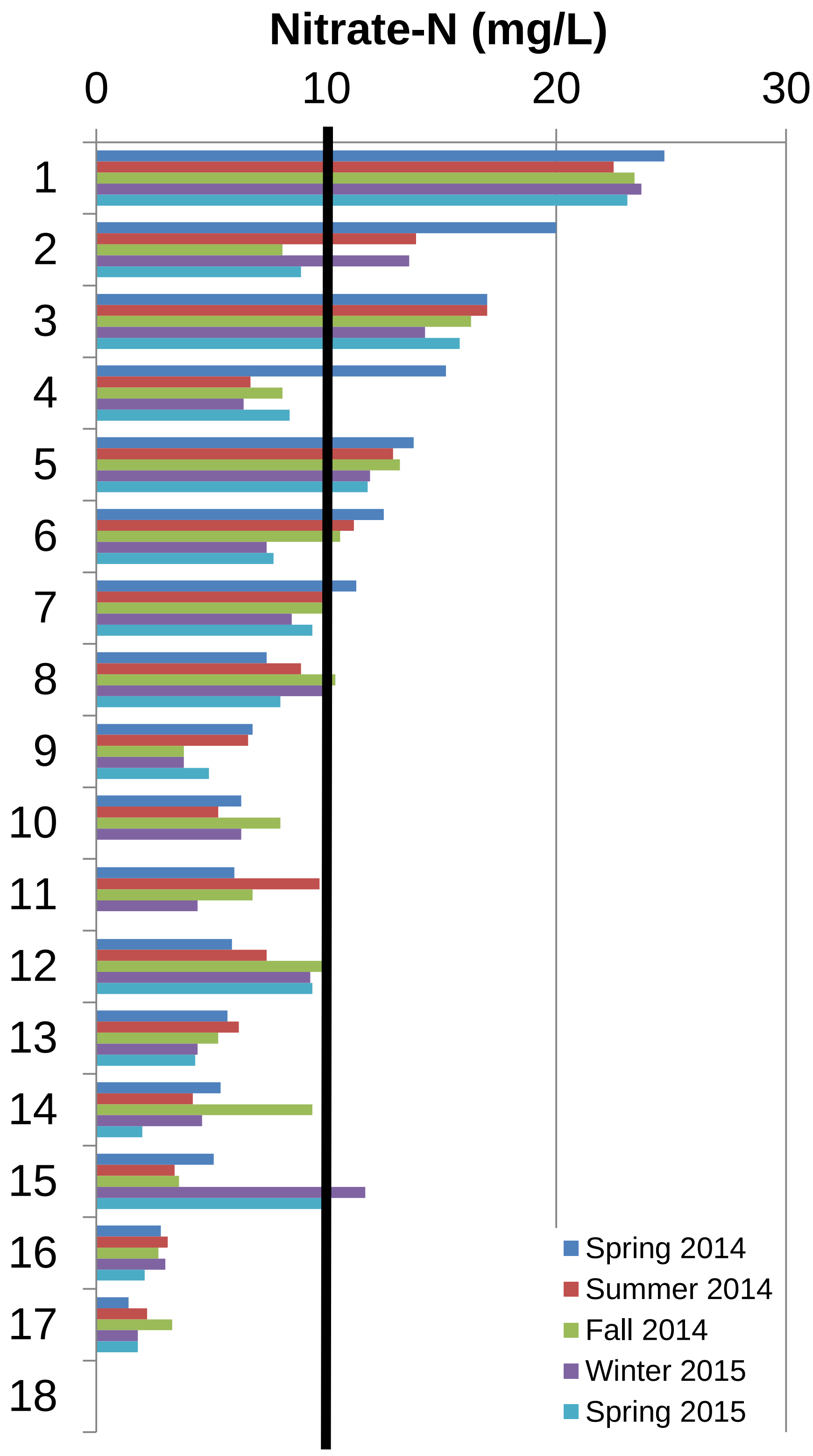

Figure 4. Graph of nitrate concentrations for 18 private wells ranked from highest initial nitrate concentration to lowest. Results are from five sampling events.

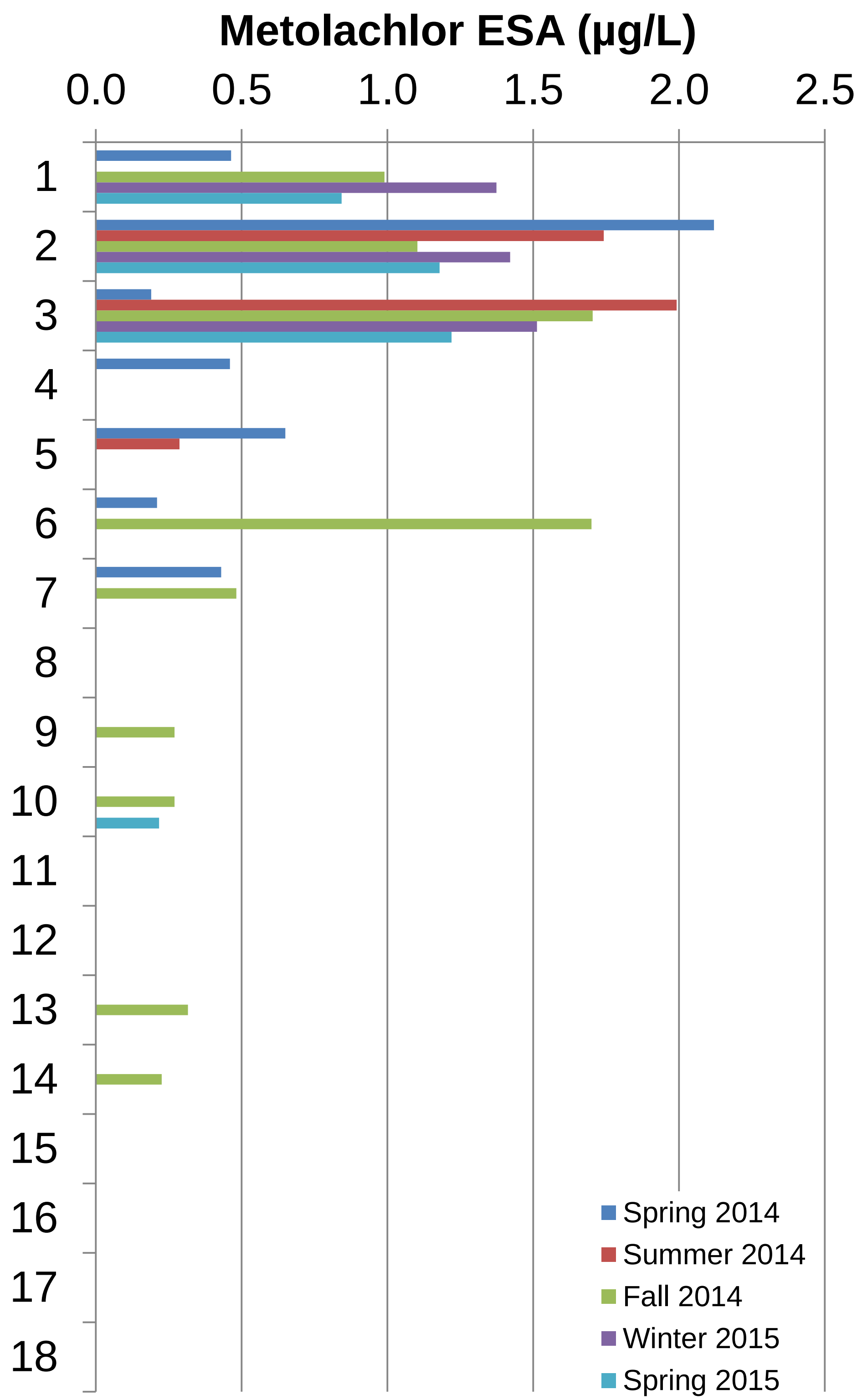

Figure 5. Graph of metolachlor ESA concentrations for 18 private wells ranked from highest initial nitrate concentration to lowest. Metolachlor ESA was used as an indicator of agricultural sources of nitrate in wells.

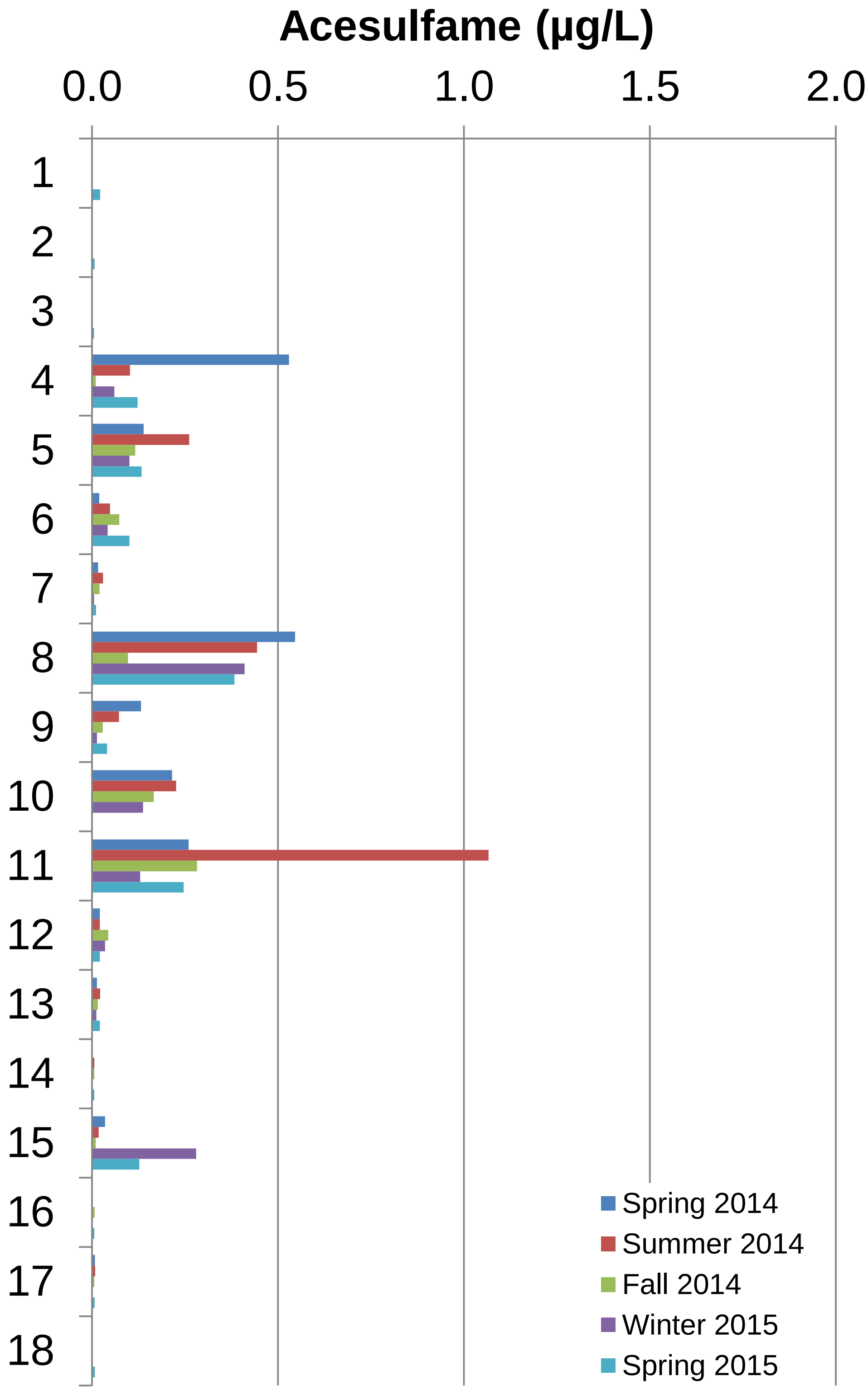

Figure 6. Acesulfame concentrations in private wells ranked from highest initial nitrate concentration to lowest. The presence of this artificial sweetener indicates contamination from septic effluent.

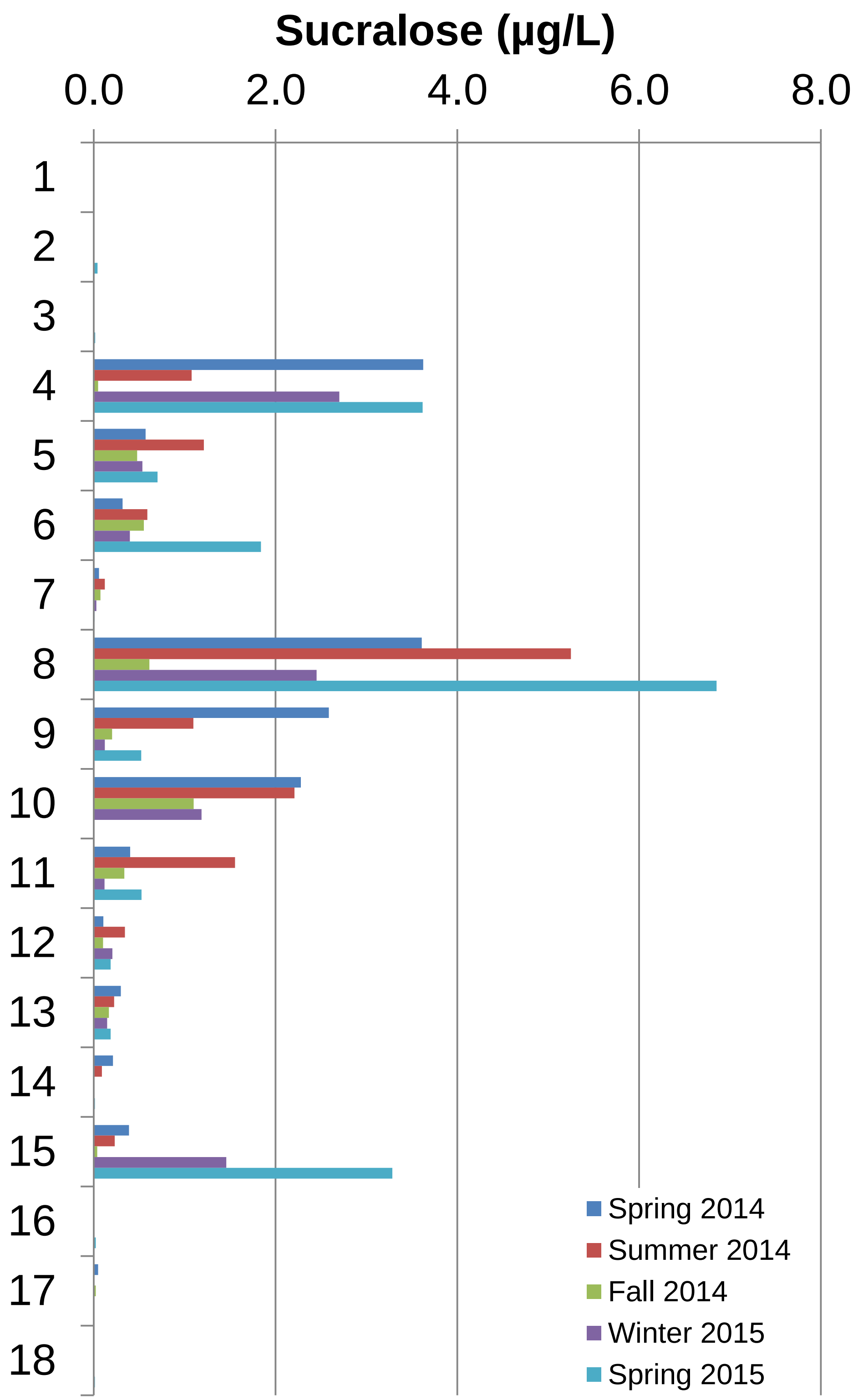

Figure 7. Sucralose concentrations in private wells ranked from highest initial nitrate concentration to lowest. The presence of this artificial sweetener indicates contamination from septic effluent.

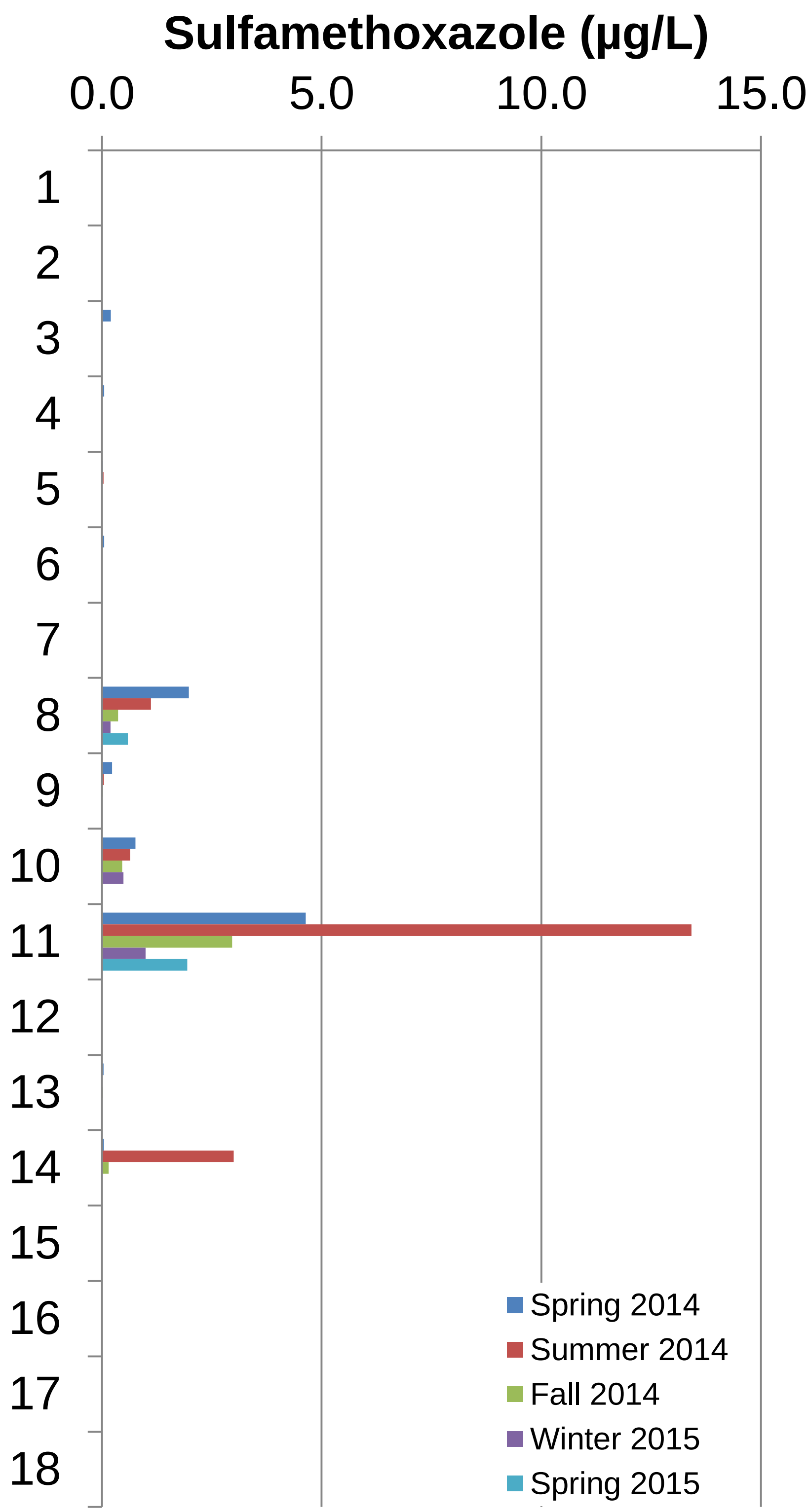

Figure 8. Sulfamethoxazole concentrations in private wells ranked from highest initial nitrate concentration to lowest. The presence of this human antibiotic indicates contamination from septic effluent.

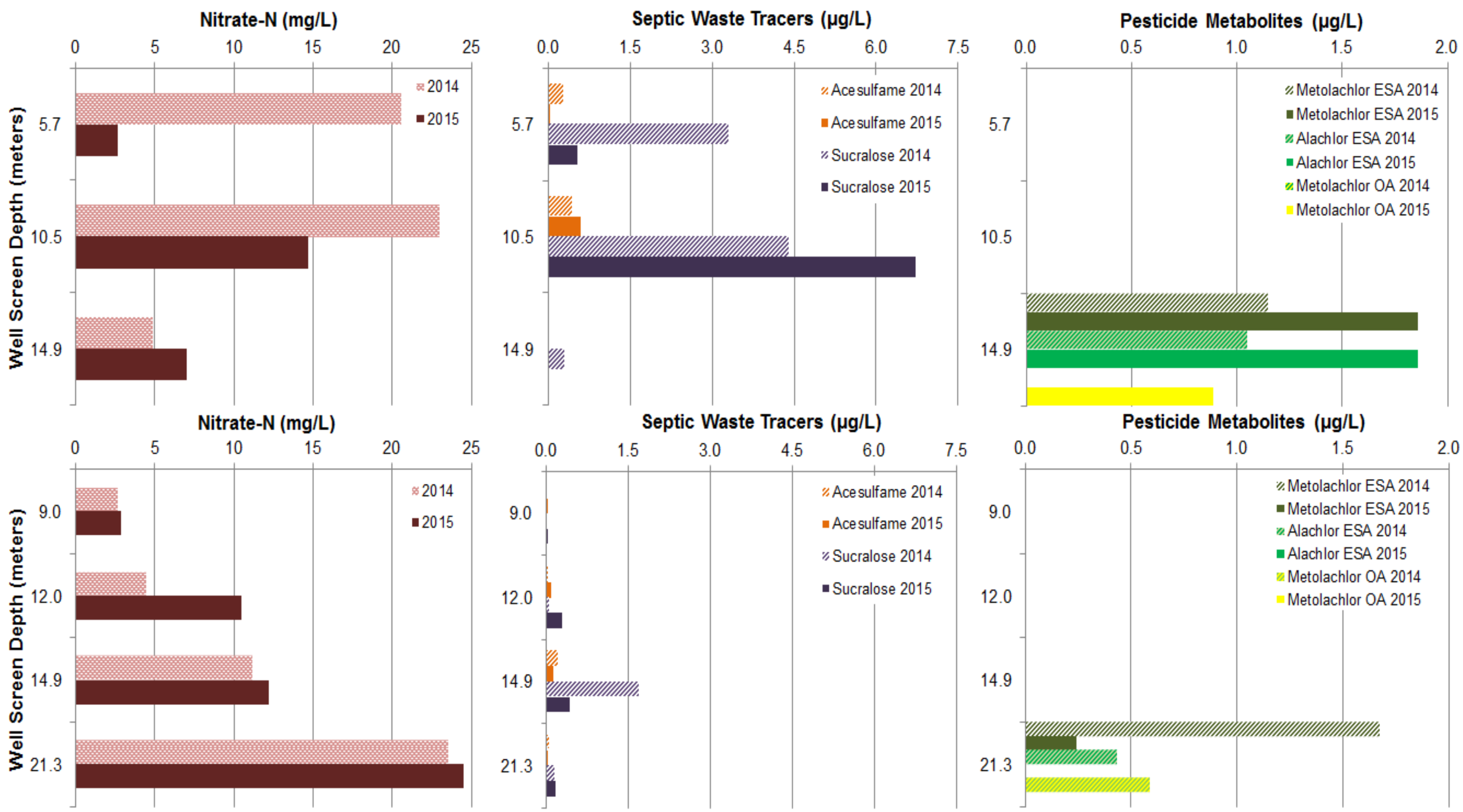

Figure 9. Graphs of nitrate and sources indicator concentrations for the monitoring wells installed for this study. The top set of graphs show results from the wells north subdivision. The bottom set of graphs show results from the wells in the south subdivision. Results are from two sampling events.

A Principal Components Analysis (PCA) of the nitrate and the six most commonly detected indicators in Figure 10 shows that most of the water samples were either agricultural or on-site waste impacted. That is consistent with the relatively narrow source area, both horizontally and vertically in the aquifer that private wells likely access.

Table 6. Occurrence percentage for the sucralose, acesulfame and sulfamethoxazole in on-site waste contaminated wells*

	Percent of Detections in Samples Collected from On-Site Waste Contaminated Wells	Percentage of Detections in Wells with On-Site Waste Contamination
Detection of acesulfame	85%	76%
Detection of sucralose	83%	82%
Detection of sulfamethoxazole	79%	88%

*On-site waste contaminated wells were those wells with one or more detections of an on-site waste contaminant in any sampling visit (each well was sampled five times during the study).

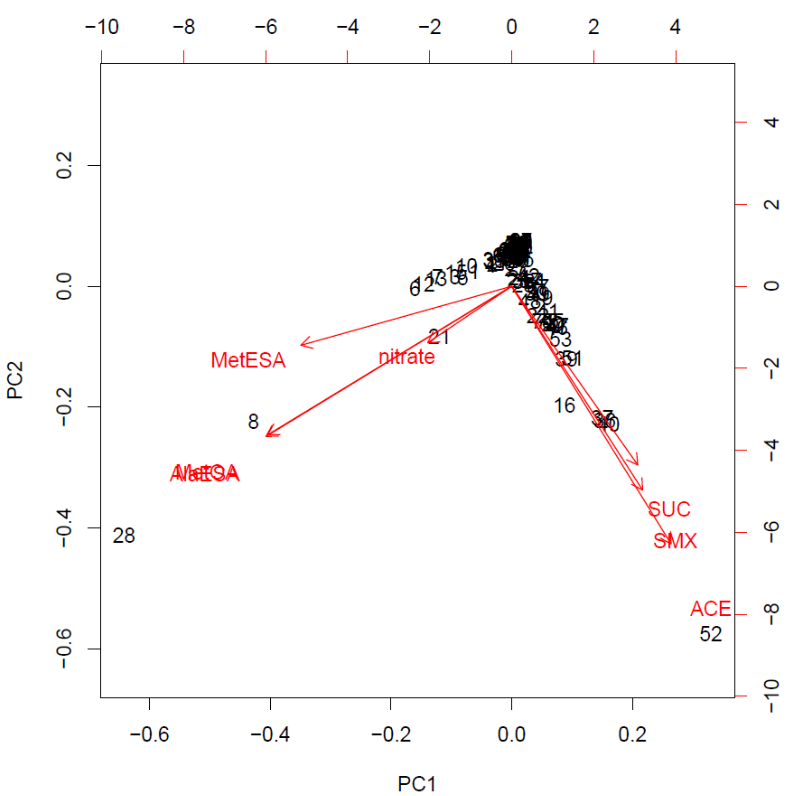

Figure 10. Principal components analysis (PCA) of nitrate and source indicators.

CONCLUSIONS

The results of this study show that chemical tracers can be used to identify sources of nitrate contamination. All of the nitrate-contaminated wells in this suburban study area had detectable concentrations of at least one of the nitrate agriculture and on-site waste indicator compounds. Ninety-six percent of private well samples with nitrate-N concentrations 3.0 mg/L or greater had at least one of four contaminant source indicators. Ninety-nine percent of samples with nitrate-N concentrations 5.0 mg/L or greater had at least one contaminant source indicator. Similar results were found in the monitoring wells used in this study where all of the well samples with nitrate-N concentrations 3.0 mg/L or greater had at least one of four contaminant source indicators. Those four indicators were acesulfame, sucralose, sulfamethoxazole, and metolachlor ESA.

The mixture of both agricultural and on-site waste compounds in the study wells is consistent with the importance of both to groundwater quality in the study area. Agricultural contaminants were found in the deeper monitoring wells consistent with their distance away from the study area. Longer groundwater travel distances lead to contaminants moving deeper in the aquifer. The on-site waste indicators were found in the shallower monitoring wells as expected for contaminant sources that are closer to the monitoring wells.

The results of this study confirm several recent studies suggesting that artificial sweeteners sucralose and acesulfame are useful as indicators of on-site waste contamination of groundwater. These sweeteners have been approved for use in food products for more than fifteen years, are water soluble and relatively recalcitrant in aquifers. Their analysis can be a useful tool for identifying likely on-site waste contamination in many areas. The occurrence of sulfamethoxazole in many of the study wells was not expected because antibiotics are typically prescribed for short-term use. It appears that its use in the study area was common. Combined with its mobility and persistence this suggests it may also be a useful on-site waste indicator. Other on-site waste indicators were not found in groundwater in the study area although previous studies have suggested their presence down-gradient from household systems. Our limited detections of these other compounds may reflect the longer travel distance between on-site waste systems and sampling points in our study. The chloroacetanilide herbicide metabolites were shown to be useful agricultural contamination indicators while the fungicide metabolite and the bovine antibiotic in the indicator group were not found in this study area.

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APPENDIX A– Well Construction Reports

The following are well construction reports for four of the private wells in this study, and the monitoring wells installed for this project. Well construction reports were not available for the other private wells, nor the existing monitoring well (M1).

Well Construction Report For
WISCONSIN UNIQUE WELL NUMBER **XK115**

State of WI - Private Water Systems - DG/2
Department of Natural Resources, Box 7921
Madison, WI 53707
Please type or Print using a black Pen
Please Use Decimals Instead of Fractions.

Form 3300-77A (R 8/00)

Property Owner [redacted]
Telephone Number --
Mailing Address [redacted]
City STEVENS POINT State WI Zip Code 54481
County of Well Location Portage
County Well Permit No. W
Well Completion Date 07/14/2014

1. Well Location: [X] Town [ ] City [ ] Village of HULL
Fire # (if available)
Grid or Street Address or Road Name and Number [redacted]
Subdivision Name KIRSCHLING PLEASANT Lot # 11 Block # 2

Well Constructor (Business Name) BERTRAM JUNEMANN WELL DR License # 84
Facility ID Number (Public Wells)
Address 7117 COUNTY ROAD S
Public Well Plan Approval # W--
City RUDOLPH State WI Zip Code 54475
Date of Approval (mm/dd/yyyy)
Hicap Permanent well #
Common Well #
Specific Capacity 5 gpm/ft

Gov't Lot # or SW 1/4 of SW 1/4 of
Section 35 T 24 N; R 8 [X] E [ ] W
Latitude Deg. Min.
Longitude Deg. Min.
Lat/Long Method

2. Well Type [ ] New [X] Replacement [ ] Reconstruction
of previous unique well # constructed in
Reason for replaced or Reconstructed Well? POINT SLOW
[X] Drilled [ ] Driven Point [ ] Jetted [ ] Other:

3. Well serves 1 # of homes and or
(e.g. barn, restaurant, church, school, industry, etc.)
High capacity Well? [ ] Yes [X] No
Property? [ ] Yes [X] No

4. Is the well located upslope or sideslope and not downslope from any contamination source, including those on neighboring properties? [ ] Yes [ ] No
Well located within 1,200 feet of a quarry? [ ] Yes [X] No If yes, distance in feet from quarry:
Well located in floodplain? [ ] Yes [X] No
Distance in Feet from Well to Nearest:

1. Landfill
8 2. Building Overhang
>45 3. Septic [X] Holding Tank [ ]
>51 4. Sewage Absorption Unit
5. Nonconforming Pit
6. Buried Home Heating Oil Tank
7. Buried Petroleum Tank
8. Shoreline [ ] Swimming Pool [ ]
8 9. Downspout/Yard Hydrant
10. Privy
11. Foundation Drain to Clearwater
12. Foundation Drain to Sewer
13. Building Drain [ ] Cast Iron or Plastic [ ] Other
14. Building Sewer [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other
15. Collector or Street Sewer: [ ] Sanitary units in. diam. [ ] Storm [ ] =< 6 [ ] > 6
16. Clearwater Sump
17. Wastewater Sump
18. Paved Animal Barn Pen
19. Animal Yard or Shelter
20. Silo
21. Barn Gutter
22. Manure Pipe [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other
23. Other Manure Storage
24. Ditch
25. Other NR 812 Waste Storage

5. Drillhole Dimensions and Construction Method

Dia (in.)	From (ft.)	To (ft.)
6	0	45

Upper Enlarged Drillhole / Lower Open Bedrock:
[ ] ---1. Rotary - Mud Circulation [ ]
[ ] ---2. Rotary - Air [ ]
[ ] ---3. Rotary - Air and Foam [ ]
[ ] ---4. Drill-Through Casing Hammer
[ ] ---5. Reverse Rotary
[ ] ---6. Cable-tool Bit in. dia [ ]
[ ] 7. Dual Rotary [ ]
[ ] 8. Temp. Outer Casing in. dia. depth (ft)
Removed? [ ] Yes [ ] No
If no, why not?

8. Geology

	Type, Caving/Noncaving, Color, Hardness, etc	From (ft.)	To (ft.)
--S-	SAND	0	45

6. Casing, Liner, Screen

Dia. (in.)	Material, Weight, Specification	From (ft.)	To (ft.)
	6 P.E. A-53 .280 WHEATLAND	0	42
6	Screen type, material & slot size: TELE. JOHNSON SS. 12 SLOT	42	45

9. Static Water Level
ft. above ground surface
28 ft. below ground surface

11. Well is: [X] Above Grade 14 in. [ ] Below Grade
Developed? [X] Yes [ ] No
Disinfected? [X] Yes [ ] No
Capped? [X] Yes [ ] No

10. Pump Test
Pumping Level 34 ft. below surface
Pumping at 30 GPM for 1 hours

7. Grout or Other Sealing Material. Method
Method: MOUNDED

Kind of Sealing Material	From (ft.)	To (ft.)	# Sacks Cement
BENTONITE	0	1	

12. Did you notify the owner of the need to permanently abandon and fill all unused wells on this property? [X] Yes [ ] No If no, explain:

13. Signature of the Well Constructor or Supervisory Driller JJ Date signed 07/17/2014
Signature of Drill Rig Operator (Mandatory unless same as above) JAJ Date signed 07/17/2014

Make additional comments on reverse side about geology, additional screens, water quality, etc.
Variance issued [ ] Yes [X] No

Well Construction Report For
WISCONSIN UNIQUE WELL NUMBER **MC068**

State of WI - Private Water Systems - DG/2
Department of Natural Resources, Box 7921
Madison, WI 53707
Please type or Print using a black Pen
Please Use Decimals Instead of Fractions.

Form 3300-77A (R 8/00)

Property Owner [redacted]
Telephone Number 715-341-9616
Mailing Address [redacted]
City STEVENS POINT | State WI | Zip Code 54481
County of Well Location Portage | County Well Permit No. W | Well Completion Date 07/26/1997

Well Constructor (Business Name) PETER LASKOWSKI | License # 4789 | Facility ID Number (Public Wells)
Address 5009 COYE DR | Public Well Plan Approval # W--
City STEVENS POINT | State WI | Zip Code 54481-5001 | Date of Approval (mm/dd/yyyy)
Hicap Permanent well # | Common Well # | Specific Capacity gpm/ft

1. Well Location
[X] Town [ ] City [ ] Village
of HULL
Fire # (if available)
Grid or Street Address or Road Name and Number [redacted] LOT # 483/190;523/387
Subdivision Name conifer acres | Lot # | Block #
Gov't Lot # or SW 1/4 of NE 1/4 of
Section 35 T 24 N; R 8 [X] E [ ] W
Latitude Deg. Min.
Longitude Deg. Min.
Lat/Long Method GPS008

2. Well Type [ ] New [ ] Replacement [X] Reconstruction
of previous unique well # constructed in
Reason for replaced or Reconstructed Well? PLUGGED POINT
[ ] Drilled [X] Driven Point [ ] Jetted [ ] Other:

3. Well serves 1 # of homes and or
(e.g. barn, restaurant, church, school, industry, etc.)
High capacity Well? [ ] Yes [X] No
Property? [ ] Yes [X] No

4. Is the well located upslope or sideslope and not downslope from any contamination source, including those on neighboring properties? [X] Yes [ ] No
Well located within 1,200 feet of a quarry? [ ] Yes [ ] No If yes, distance in feet from quarry:
Well located in floodplain? [ ] Yes [X] No
Distance in Feet from Well to Nearest:

1. Landfill
2 2. Building Overhang
50 3. Septic [ ] Holding Tank [ ]
75 4. Sewage Absorption Unit
5. Nonconforming Pit
6. Buried Home Heating Oil Tank
7. Buried Petroleum Tank
8. Shoreline [ ] Swimming Pool [ ]
9. Downspout/Yard Hydrant
10. Privy
11. Foundation Drain to Clearwater
12. Foundation Drain to Sewer
40 13. Building Drain
[X] Cast Iron or Plastic [ ] Other
45 14. Building Sewer [X] Gravity [ ] Pressure
[X] Cast Iron or Plastic [ ] Other
15. Collector or Street Sewer:
[ ] Sanitary units in. diam.
[ ] Storm [ ] =< 6 [ ] > 6
16. Clearwater Sump
30 17. Wastewater Sump
18. Paved Animal Barn Pen
19. Animal Yard or Shelter
20. Silo
21. Barn Gutter
22. Manure Pipe [ ] Gravity [ ] Pressure
[ ] Cast Iron or Plastic [ ] Other
23. Other Manure Storage
24. Ditch
25. Other NR 812 Waste Storage

5. Drillhole Dimensions and Construction Method

Dia (in.)	From (ft.)	To (ft.)	Upper Enlarged Drillhole	Lower Open Bedrock
			[ ] ---1. Rotary - Mud Circulation	[ ]
			[ ] ---2. Rotary - Air	[ ]
			[ ] ---3. Rotary - Air and Foam	[ ]
			[ ] ---4. Drill-Through Casing Hammer	
			[ ] ---5. Reverse Rotary	
			[ ] ---6. Cable-tool Bit in. dia	[ ]
			[ ] 7. Dual Rotary	[ ]
			[ ] 8. Temp. Outer Casing in. dia. depth (ft) Removed? [ ] Yes [ ] No If no, why not?	

8. Geology

	Type, Caving/Noncaving, Color, Hardness, etc	From (ft.)	To (ft.)
--S-	SAND	0	43

6. Casing, Liner, Screen

Dia. (in.)	Material, Weight, Specification	From (ft.)	To (ft.)
2	STEEL	0	40

Dia. (in.)	Screen type, material & slot size	From	To
2	STAINLESS	40	43

7. Grout or Other Sealing Material. Method
Method:

Kind of Sealing Material	From (ft.)	To (ft.)	# Sacks Cement

9. Static Water Level
ft. above ground surface
29 ft. below ground surface

10. Pump Test
Pumping Level 5 ft. below surface
Pumping at 10 GPM for 1 hours

11. Well is: [X] Above Grade 18 in. [ ] Below Grade
Developed? [X] Yes [ ] No
Disinfected? [X] Yes [ ] No
Capped? [X] Yes [ ] No

12. Did you notify the owner of the need to permanently abandon and fill all unused wells on this property? [X] Yes [ ] No If no, explain:

13. Signature of the Well Constructor or Supervisory Driller RL | Date signed 03/26/1997
Signature of Drill Rig Operator (Mandatory unless same as above) | Date signed

Make additional comments on reverse side about geology, additional screens, water quality, etc.
Variance issued [ ] Yes [X] No

Well Construction Report For
WISCONSIN UNIQUE WELL NUMBER **MQ937**

State of WI - Private Water Systems - DG/2
Department of Natural Resources, Box 7921
Madison, WI 53707
Please type or Print using a black Pen
Please Use Decimals Instead of Fractions.

Form 3300-77A (R 8/00)

Property Owner [redacted]
Telephone Number 715-344-6638
Mailing Address [redacted]
City STEVENS POINT | State WI | Zip Code 54481
County of Well Location Portage | County Well Permit No. W | Well Completion Date 10/15/1998

1. Well Location: [X] Town [ ] City [ ] Village of HULL
Fire # (if available)
Grid or Street Address or Road Name and Number [redacted]
Subdivision Name | Lot # | Block #

Well Constructor (Business Name) HAUPT WELL & PUMP CO INC | License # 529
Address 5508 MAIN ST
City AUBURNDALE | State WI | Zip Code 54412
Hicap Permanent well # | Common Well #
Facility ID Number (Public Wells)
Public Well Plan Approval # W--
Date of Approval (mm/dd/yyyy)
Specific Capacity 4.3 gpm/ft

Gov't Lot # or NW 1/4 of SW 1/4 of Section 11 T 24 N; R 8 [X] E [ ] W
Latitude Deg. Min.
Longitude Deg. Min.
Lat/Long Method GPS008

2. Well Type [X] New [ ] Replacement [ ] Reconstruction
of previous unique well # constructed in
Reason for replaced or Reconstructed Well?
[X] Drilled [ ] Driven Point [ ] Jetted [ ] Other:

3. Well serves 1 # of homes and or HOME
(e.g. barn, restaurant, church, school, industry, etc.)
High capacity Well? [ ] Yes [X] No
Property? [ ] Yes [X] No

4. Is the well located upslope or sideslope and not downslope from any contamination source, including those on neighboring properties? [X] Yes [ ] No
Well located within 1,200 feet of a quarry? [ ] Yes [ ] No If yes, distance in feet from quarry:
Well located in floodplain? [ ] Yes [X] No
Distance in Feet from Well to Nearest:

1. Landfill
3 2. Building Overhang
42 3. Septic [ ] Holding Tank [ ]
53 4. Sewage Absorption Unit
5. Nonconforming Pit
6. Buried Home Heating Oil Tank
7. Buried Petroleum Tank
8. Shoreline [ ] Swimming Pool [ ]

9. Downspout/Yard Hydrant
10. Privy
11. Foundation Drain to Clearwater
12. Foundation Drain to Sewer
13. Building Drain [ ] Cast Iron or Plastic [ ] Other
14. Building Sewer [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other
15. Collector or Street Sewer: [ ] Sanitary units in. diam. [ ] Storm [ ] =< 6 [ ] > 6
16. Clearwater Sump

17. Wastewater Sump
18. Paved Animal Barn Pen
19. Animal Yard or Shelter
20. Silo
21. Barn Gutter
22. Manure Pipe [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other
23. Other Manure Storage
24. Ditch
25. Other NR 812 Waste Storage

5. Drillhole Dimensions and Construction Method

Dia (in.)	From (ft.)	To (ft.)
6	0	52.6

Upper Enlarged Drillhole / Lower Open Bedrock
[ ] ---1. Rotary - Mud Circulation--------- [ ]
[ ] ---2. Rotary - Air--------- [ ]
[ ] ---3. Rotary - Air and Foam--------- [ ]
[ ] ---4. Drill-Through Casing Hammer
[ ] ---5. Reverse Rotary
[ ] ---6. Cable-tool Bit in. dia------ [ ]
[ ] 7. Dual Rotary [ ]
[ ] 8. Temp. Outer Casing in. dia. depth (ft)
Removed? [ ] Yes [ ] No
If no, why not?

8. Geology

	Type, Caving/Noncaving, Color, Hardness, etc	From (ft.)	To (ft.)
-MS-	SAND MED	0	49
-NS-	SAND FINER	49	52.6

6. Casing, Liner, Screen

Dia. (in.)	Material, Weight, Specification	From (ft.)	To (ft.)
6	STEEL 18.97 A53 SAWHILL P.E. WELDED	0	49.6

Dia. (in.)	Screen type, material & slot size	From	To
5	UOP SS #12	49.6	52.6

9. Static Water Level
ft. above ground surface
18 ft. below ground surface

10. Pump Test
Pumping Level 25 ft. below surface
Pumping at 30 GPM for 1 hours

11. Well is: [X] Above Grade 15 in. [ ] Below Grade
Developed? [X] Yes [ ] No
Disinfected? [X] Yes [ ] No
Capped? [X] Yes [ ] No

7. Grout or Other Sealing Material. Method
Method: GRAVITY

Kind of Sealing Material	From (ft.)	To (ft.)	# Sacks Cement
#9	0	2	

12. Did you notify the owner of the need to permanently abandon and fill all unused wells on this property? [ ] Yes [ ] No If no, explain:

13. Signature of the Well Constructor or Supervisory Driller DH | Date signed 02/08/1999
Signature of Drill Rig Operator (Mandatory unless same as above) AH | Date signed 02/08/1999

Make additional comments on reverse side about geology, additional screens, water quality, etc.
Variance issued [ ] Yes [X] No

Well Construction Report For WISCONSIN UNIQUE WELL NUMBER **CI191**

State of WI - Private Water Systems - DG/2
Department of Natural Resources, Box 7921
Madison, WI 53707
Please type or Print using a black Pen
Please Use Decimals Instead of Fractions.

Form 3300-77A
(R 8/00)

Property Owner [redacted]		Telephone -- Number	
Mailing Address [redacted]			
City STEVENS POINT		State WI	Zip Code 54481
County of Well Location Portage	County Well Permit No. W	Well Completion Date 01/29/1990	

1. Well Location X Town ☐ City ☐ Village of HULL — Fire # (if available)

Grid or Street Address or Road Name and Number [redacted]

Subdivision Name — Lot # — Block #

Well Constructor (Business Name) CHETS PLBG AND HTG INC	License # 4832	Facility ID Number (Public Wells)
Address 2511 N TORUN ROAD		Public Well Plan Approval # W--
City STEVENS POINT State WI Zip Code 54481		Date of Approval (mm/dd/yyyy)
Hicap Permanent well #	Common Well #	Specific Capacity 3.3 gpm/ft

Gov't Lot # or SE 1/4 of NE 1/4 of
Section 10 T 24 N; R 8 x E ☐ W
Latitude Deg. Min.
Longitude Deg. Min.

2. Well Type X New ☐ Replacement ☐ Reconstruction — Lat/Long Method GPS008
of previous unique well # constructed in 90
Reason for replaced or Reconstructed Well? NEW HOME
☐ Drilled X Driven Point ☐ Jetted ☐ Other:

3. Well serves 1 # of homes and or (e.g. barn, restaurant, church, school, industry, etc.)
High capacity Well? ☐ Yes X No
Property? ☐ Yes X No

4. Is the well located upslope or sideslope and not downslope from any contamination source, including those on neighboring properties? X Yes ☐ No
Well located within 1,200 feet of a quarry? ☐ Yes ☐ No If yes, distance in feet from quarry:
Well located in floodplain? ☐ Yes X No
Distance in Feet from Well to Nearest:

1. Landfill
2 2. Building Overhang
30 3. Septic ☐ Holding Tank ☐
55 4. Sewage Absorption Unit
5. Nonconforming Pit
6. Buried Home Heating Oil Tank
7. Buried Petroleum Tank
8. Shoreline ☐ Swimming Pool ☐

10 9. Downspout/Yard Hydrant
10. Privy
11. Foundation Drain to Clearwater
12. Foundation Drain to Sewer
10 13. Building Drain ☐ Cast Iron or Plastic ☐ Other
14. Building Sewer ☐ Gravity ☐ Pressure ☐ Cast Iron or Plastic ☐ Other
15. Collector or Street Sewer: ☐ Sanitary units in. diam. ☐ Storm ☐ =< 6 ☐ > 6
30 16. Clearwater Sump

17. Wastewater Sump
18. Paved Animal Barn Pen
19. Animal Yard or Shelter
20. Silo
21. Barn Gutter
22. Manure Pipe ☐ Gravity ☐ Pressure ☐ Cast Iron or Plastic ☐ Other
23. Other Manure Storage
24. Ditch
25. Other NR 812 Waste Storage

5. Drillhole Dimensions and Construction Method

Dia (in.)	From (ft.)	To (ft.)	Upper Enlarged Drillhole	Lower Open Bedrock
			☐ ---1. Rotary - Mud Circulation	☐
			☐ ---2. Rotary - Air	☐
			☐ ---3. Rotary - Air and Foam	☐
			☐ ---4. Drill-Through Casing Hammer	
			☐ ---5. Reverse Rotary	
			☐ ---6. Cable-tool Bit in. dia	☐
			☐ 7. Dual Rotary	☐
			☐ 8. Temp. Outer Casing in. dia. depth (ft) Removed? ☐ Yes ☐ No If no, why not?	

8. Geology

	Type, Caving/Noncaving, Color, Hardness, etc	From (ft.)	To (ft.)
--S-	SAND	0	24

6. Casing, Liner, Screen

Dia. (in.)	Material, Weight, Specification	From (ft.)	To (ft.)
2	STEEL	0	21

Dia. (in.)	Screen type, material & slot size	From	To
2	STAINLESS POINT	21	24

9. Static Water Level
ft. above ground surface
ft. below ground surface

11. Well is: X Above Grade 30 in. ☐ Below Grade
Developed? X Yes ☐ No
Disinfected? X Yes ☐ No
Capped? X Yes ☐ No

10. Pump Test
Pumping Level 3 ft. below surface
Pumping at 10 GPM for 1 hours

7. Grout or Other Sealing Material. Method

Method: Kind of Sealing Material	From (ft.)	To (ft.)	# Sacks Cement

12. Did you notify the owner of the need to permanently abandon and fill all unused wells on this property? X Yes ☐ No If no, explain:

13. Signature of the Well Constructor or Supervisory Driller PL — Date signed 01/30/1990
Signature of Drill Rig Operator (Mandatory unless same as above) Date signed

Make additional comments on reverse side about geology, additional screens, water quality, etc.
Variance issued ☐ Yes X No

State of Wisconsin
Department of Natural Resources

Route to: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐

MONITORING WELL CONSTRUCTION
Form 4400-113A Rev. 7-98

Facility/Project Name: UWSTEVENS POINT

Local Grid Location of Well: ___ ft. ☐N ☐S ___ ft. ☐E ☐W

Well Name: ANN MARIE CT

Facility License, Permit or Monitoring No.

Local Grid Origin ☐ (estimated: ☐) or Well Location ☐ Lat. ___ Long. ___ or

Wis. Unique Well No. DNR Well ID No.

Facility ID

St. Plane ___ ft. N, ___ ft. E. S/C/N

Date Well Installed 06/30/2014 (m m d d y y y y)

Section Location of Waste/Source: ___ 1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐E ☐W

Type of Well: MULTI PORT

Well Code: 11 / MW

Well Installed By: Name (first, last) and Firm: RICHARD STEPHENS UWSP

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Gov. Lot Number

Distance from Waste/Source ___ ft. Enf. Stds. Apply ☐

A. Protective pipe, top elevation ___ ft. MSL

B. Well casing, top elevation ___ ft. MSL

C. Land surface elevation ___ ft. MSL

D. Surface seal, bottom ___ ft. MSL or ___ ft.

12. USCS classification of soil near screen: GP ☐ GM ☐ GC ☐ GW ☐ SW ☒ SP ☐ SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐ Bedrock ☐

13. Sieve analysis performed? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐ 5 0; Hollow Stem Auger ☒ 4 1; Other ☐

15. Drilling fluid used: Water ☐ 0 2; Air ☐ 0 1; Drilling Mud ☐ 0 3; None ☐ 9 9

16. Drilling additives used? ☐ Yes ☒ No

Describe ___

17. Source of water (attach analysis, if required): CITY STEVENS POINT

E. Bentonite seal, top ___ ft. MSL or ___ ft.

F. Fine sand, top ___ ft. MSL or ___ ft.

G. Filter pack, top ___ ft. MSL or ___ ft.

H. Screen joint, top 17,1247 ft. MSL or ___ ft.

I. Well bottom 20,3550 ft. MSL or ___ ft.

J. Filter pack, bottom ___ ft. MSL or ___ ft.

K. Borehole, bottom ___ ft. MSL or ___ ft.

L. Borehole, diameter 8.0 in.

M. O.D. well casing 1.06 in.

N. I.D. well casing 0.75 in.

1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 3.75 in.
b. Length: 5.0 ft.
c. Material: Steel ☒ 0 4; Other ☐
d. Additional protection? ☐ Yes ☒ No
If yes, describe: ___

3. Surface seal: Bentonite ☒ 3 0; Concrete ☐ 0 1; Other ☐

4. Material between well casing and protective pipe: Bentonite ☒ 3 0; Other ☐

5. Annular space seal: a. Granular/Chipped Bentonite ☐ 3 3
b. ___ Lbs/gal mud weight ... Bentonite-sand slurry ☐ 3 5
c. ___ Lbs/gal mud weight ...... Bentonite slurry ☐ 3 1
d. ___ % Bentonite ...... Bentonite-cement grout ☐ 5 0
e. ___ Ft^3 volume added for any of the above
f. How installed: NATIVE SAND — Tremie ☐ 0 1; Tremie pumped ☐ 0 2; Gravity ☒ 0 8

6. Bentonite seal: NONE a. Bentonite granules ☐ 3 3
b. ☐1/4 in. ☐3/8 in. ☐1/2 in. Bentonite chips ☐ 3 2
c. ___ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
a. NONE
b. Volume added ___ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
a. NONE
b. Volume added ___ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☐ 2 3; Flush threaded PVC schedule 80 ☐ 2 4; NPT PVC SCH 40 Other ☐

10. Screen material: PVC SCH 40
a. Screen type: Factory cut ☒ 1 1; Continuous slot ☐ 0 1; Other ☐
b. Manufacturer TIMCO
c. Slot size: 0.020 in.
d. Slotted length: 30 ft.

11. Backfill material (below filter pack): None ☒ 1 4; Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature | Firm

Please complete both Forms 4400-113A and 4400-113B and return them to the appropriate DNR office and bureau. Completion of these reports is required by chs. 160, 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with chs. 281, 289, 291, 292, 293, 295, and 299, Wis. Stats., failure to file these forms may result in a forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on these forms is not intended to be used for any other purpose. NOTE: See the instructions for more information, including where the completed forms should be sent.

State of Wisconsin
Department of Natural Resources

Route to: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

MONITORING WELL CONSTRUCTION
Form 4400-113A Rev. 7-98

Facility/Project Name: UW-STEVENS POINT	Local Grid Location of Well ___ ft. ☐N ☐S ___ ft. ☐E ☐W	Well Name: KIRSHLING PARK
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☐ Lat. ___ Long. ___ or	Wis. Unique Well No. / DNR Well ID No.
Facility ID	St. Plane ___ ft. N, ___ ft. E. S/C/N	Date Well Installed 06/26/2014 (m m d d y y y y)
Type of Well: MULTIPORT; Well Code 11 / MW	Section Location of Waste/Source ___ 1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐E ☐W	Well Installed By: Name (first, last) and Firm: RICHARD STEPHENS, UW SP
Distance from Waste/Source ___ ft.; Enf. Stds. Apply ☐	Location of Well Relative to Waste/Source: u ☐ Upgradient; s ☐ Sidegradient; d ☐ Downgradient; n ☐ Not Known; Gov. Lot Number	

A. Protective pipe, top elevation ___ ft. MSL
B. Well casing, top elevation ___ ft. MSL
C. Land surface elevation ___ ft. MSL
D. Surface seal, bottom ___ ft. MSL or ___ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☒ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis performed? ☐ Yes ☒ No

14. Drilling method used: Rotary ☐ 5 0; Hollow Stem Auger ☒ 4 1; Other ☐

15. Drilling fluid used: Water ☐ 0 2; Air ☐ 0 1; Drilling Mud ☐ 0 3; None ☐ 9 9

16. Drilling additives used? ☐ Yes ☒ No

Describe ___

17. Source of water (attach analysis, if required):
STEVENS POINT CITY WATER

E. Bentonite seal, top ___ ft. MSL or ___ ft.
F. Fine sand, top ___ ft. MSL or ___ ft.
G. Filter pack, top ___ ft. MSL or ___ ft.
H. Screen joint, top 26.5, 36, 46 ft. MSL or ___ ft.
I. Well bottom 29.5, 39, 49 ft. MSL or ___ ft.
J. Filter pack, bottom ___ ft. MSL or ___ ft.
K. Borehole, bottom ___ ft. MSL or ___ ft.
L. Borehole, diameter 8.0 in.
M. O.D. well casing 1.06 in.
N. I.D. well casing 0.75 in.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
a. Inside diameter: 3.75 in.
b. Length: 5.0 ft.
c. Material: Steel ☒ 0 4; Other ☐
d. Additional protection? ☐ Yes ☒ No
If yes, describe: ___
3. Surface seal: Bentonite ☒ 3 0; Concrete ☐ 0 1; Other ☐
4. Material between well casing and protective pipe: Bentonite ☒ 3 0; Other ☐
5. Annular space seal: a. Granular/Chipped Bentonite ☐ 3 3
b. ___ Lbs/gal mud weight . . . Bentonite-sand slurry ☐ 3 5
c. ___ Lbs/gal mud weight . . . . . Bentonite slurry ☐ 3 1
d. ___ % Bentonite . . . . . . Bentonite-cement grout ☐ 5 0
e. ___ Ft^3 volume added for any of the above
f. How installed: NATIVE SAND; Tremie ☐ 0 1; Tremie pumped ☐ 0 2; Gravity ☒ 0 8
6. Bentonite seal: NONE a. Bentonite granules ☐ 3 3
b. ☐1/4 in. ☐3/8 in. ☐1/2 in. Bentonite chips ☐ 3 2
c. ___ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
a. NONE
b. Volume added ___ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
a. NONE
b. Volume added ___ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☐ 2 3; Flush threaded PVC schedule 80 ☐ 2 4
NPT PVC SCH 40 Other ☒
10. Screen material: SCH 40 PVC
a. Screen type: Factory cut ☒ 1 1; Continuous slot ☐ 0 1; Other ☐
b. Manufacturer TIMCO
c. Slot size: 0.020 in.
d. Slotted length: 3.0 ft.
11. Backfill material (below filter pack): None ☒ 1 4; Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm

Please complete both Forms 4400-113A and 4400-113B and return them to the appropriate DNR office and bureau. Completion of these reports is required by chs. 160, 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with chs. 281, 289, 291, 292, 293, 295, and 299, Wis. Stats., failure to file these forms may result in a forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on these forms is not intended to be used for any other purpose. NOTE: See the instructions for more information, including where the completed forms should be sent.

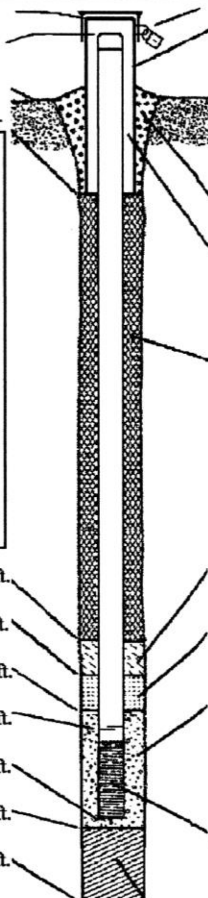
State of Wisconsin
Department of Natural Resources

Route to: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐ ____

MONITORING WELL CONSTRUCTION

Form 4400-113A Rev. 7-98

Facility/Project Name	Local Grid Location of Well	Well Name
UW-STEVENS POINT	____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	KIRSHLING PARK 70-FOOT
Facility License, Permit or Monitoring No.	Local Grid Origin ☐ (estimated: ☐) or Well Location ☐ Lat. ___ ° ___ ' ___ " Long. ___ ° ___ ' ___ " or	Wis. Unique Well No. ______ DNR Well ID No. ___
Facility ID ________	St. Plane ____ ft. N, ____ ft. E. S/C/N	Date Well Installed 09/18/2014 (m m d d y y y y)
Type of Well — Well Code 11 / MW	Section Location of Waste/Source ___ 1/4 of ___ 1/4 of Sec. ___, T. ___ N, R. ___ ☐ E ☐ W	Well Installed By: Name (first, last) and Firm W.M. DEVITA UW-STEVENS POINT
Distance from Waste/ Source ____ ft. Enf. Stds. Apply ☐	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known	Gov. Lot Number ____



A. Protective pipe, top elevation _ _ _ _ _ _ _ ft. MSL

B. Well casing, top elevation _ _ _ _ _ _ ft. MSL

C. Land surface elevation _ _ _ _ _ _ ft. MSL

D. Surface seal, bottom _ _ _ _ _ _ ft. MSL or _ _ _ _ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☑ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis performed? ☐ Yes ☑ No

14. Drilling method used: Rotary ☐ 5 0
Hollow Stem Auger ☐ 4 1
POUNDED Other ☑

15. Drilling fluid used: Water ☐ 0 2 Air ☐ 0 1
Drilling Mud ☐ 0 3 None ☑ 9 9

16. Drilling additives used? ☐ Yes ☑ No

Describe ________

17. Source of water (attach analysis, if required):
____

E. Bentonite seal, top _ _ _ _ _ _ ft. MSL or _ _ _ _ _ ft.

F. Fine sand, top _ _ _ _ _ _ ft. MSL or _ _ _ _ _ ft.

G. Filter pack, top _ _ _ _ _ _ ft. MSL or _ _ _ _ _ ft.

H. Screen joint, top _ _ 67 _ ft. MSL or _ _ _ _ _ ft.

I. Well bottom _ _ 70 _ ft. MSL or _ _ _ _ _ ft.

J. Filter pack, bottom _ _ _ _ _ _ ft. MSL or _ _ _ _ _ ft.

K. Borehole, bottom _ _ _ _ _ _ ft. MSL or _ _ _ _ _ ft.

L. Borehole, diameter _ _ _ _ in.

M. O.D. well casing _ _ _ _ in.

N. I.D. well casing _ _ _ _ in.

1. Cap and lock? ☑ Yes ☐ No
2. Protective cover pipe:
a. Inside diameter: 3.75 in.
b. Length: 3.0 ft.
c. Material: Steel ☑ 0 4
Other ☐
d. Additional protection? ☐ Yes ☐ No
If yes, describe: ________
3. Surface seal: Bentonite ☑ 3 0
Concrete ☐ 0 1
Other ☐
4. Material between well casing and protective pipe:
Bentonite ☑ 3 0
Other ☐
5. Annular space seal: a. Granular/Chipped Bentonite ☐ 3 3
b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐ 3 5
c. ____ Lbs/gal mud weight . . . . . Bentonite slurry ☐ 3 1
d. ____ % Bentonite . . . . . . Bentonite-cement grout ☐ 5 0
e. ____ Ft^3 volume added for any of the above
f. How installed: Tremie ☐ 0 1
NATIVE SAND Tremie pumped ☐ 0 2
Gravity ☑ 0 8
6. Bentonite seal: a. Bentonite granules ☐ 3 3
b. ☐ 1/4 in. ☐ 3/8 in. ☐ 1/2 in. Bentonite chips ☐ 3 2
c. ________ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
a. NONE
b. Volume added ____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
a. NONE
b. Volume added ____ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☐ 2 3
Flush threaded PVC schedule 80 ☐ 2 4
1.25" GALVANIZED STEEL Other ☑
10. Screen material: ________
a. Screen type: Factory cut ☑ 1 1
Continuous slot ☐ 0 1
Other ☐
b. Manufacturer ________
c. Slot size: 0. ___ in.
d. Slotted length: 3.0 ft.
11. Backfill material (below filter pack): None ☐ 1 4
Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
William M DeVita	UW-STEVENS POINT

Please complete both Forms 4400-113A and 4400-113B and return them to the appropriate DNR office and bureau. Completion of these reports is required by chs. 160, 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with chs. 281, 289, 291, 292, 293, 295, and 299, Wis. Stats., failure to file these forms may result in a forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on these forms is not intended to be used for any other purpose. NOTE: See the instructions for more information, including where the completed forms should be sent.

APPENDIX B – Charge Balance Calculations

Private Wells

Well	Trip	Anions	Cations	CBE	Well	Trip	Anions	Cations	CBE
1	1	3.8	3.8	0%	10	1	3.5	3.4	2%
1	2	3.7	3.9	-3%	10	2	4.2	4.3	0%
1	3	3.9	3.9	0%	10	3	3.1	3.1	0%
1	4	3.7	3.5	2%	10	4	3.1	3.0	2%
1	5	3.6	3.5	1%	10	5	4.1	4.2	-1%
2	1	6.8	6.5	2%	11	1	4.9	4.7	2%
2	2	6.3	6.7	-3%	11	2	4.8	5.1	-2%
2	3	6.8	7.0	-1%	11	3	4.2	4.0	2%
2	4	6.1	6.1	0%	11	4	3.8	3.6	1%
2	5	6.7	6.4	2%	11	5	4.0	3.9	2%
3	1	5.5	5.4	2%	12	1	3.4	3.2	4%
3	2	6.1	6.3	-2%	12	2	4.4	3.5	11%
3	3	7.0	7.3	-2%	12	3	3.9	3.9	0%
3	4	6.2	6.3	-1%	12	4	3.6	3.4	2%
3	5	5.7	5.7	0%	12	5	3.5	3.8	-4%
4	1	8.6	8.9	-2%	13	1	3.2	3.1	1%
4	2	7.3	7.6	-2%	13	2	3.9	4.0	-2%
4	3	6.6	5.9	5%	13	3	3.4	3.4	1%
4	4	6.9	7.1	-1%	13	4	3.6	3.4	4%
4	5	7.0	6.8	1%	13	5	3.8	3.7	2%
5	1	8.8	8.5	2%	14	1	2.7	2.7	0%
5	2	8.9	9.0	-1%	14	2	2.0	2.1	-2%
5	3	8.7	9.3	-3%	14	3	2.6	2.6	-1%
5	4	8.8	8.7	1%	14	4	2.1	2.0	2%
5	5	9.0	8.7	2%	14	5	1.5	1.5	-1%
6	1	5.4	5.0	4%	15	1	2.7	2.6	2%
6	2	5.4	5.5	-1%	15	2	2.8	2.6	4%
6	3	5.2	5.3	0%	15	3	2.1	2.1	1%
6	4	4.7	4.7	0%	15	4	3.7	3.4	4%
6	5	5.1	4.8	2%	15	5	3.9	3.7	2%
7	1	5.0	4.7	3%	16	1	4.6	4.3	3%
7	2	4.3	4.5	-2%	16	2	3.9	4.0	0%
7	3	4.5	4.5	-1%	16	3	3.9	3.8	1%
7	4	3.9	3.7	3%	16	4	4.6	4.2	5%
7	5	4.0	3.4	9%	16	5	4.9	4.8	1%
8	1	6.0	6.0	1%	17	1	3.3	3.2	2%
8	2	4.2	4.3	-1%	17	2	3.1	3.1	0%
8	3	4.7	4.3	4%	17	3	3.0	2.7	5%
8	4	6.5	6.1	3%	17	4	3.0	2.8	3%
8	5	6.6	6.6	0%	17	5	2.9	2.8	1%
9	1	5.0	4.7	3%	18	1	2.8	2.8	1%
9	2	4.9	4.8	1%	18	2	2.8	2.9	-1%
9	3	4.4	4.4	-1%	18	3	3.0	3.0	0%
9	4	5.0	4.8	2%	18	4	2.9	2.6	5%
9	5	5.1	4.6	6%	18	5	2.8	2.8	-1%

Monitoring Wells

Well	Trip	Anions	Cations	CBE
M1	1	5.3	4.5	9%
M2	1	5.1	4.4	7%
M3	1	3.3	3.6	-4%
M4	1	1.2	1.1	6%
M5	1	2.2	2.2	1%
M6	1	4.8	4.8	0%
M7	1	5.2	5.5	-3%
M8	1	5.8	6.9	-9%
M1	2	3.6	3.7	-2%
M2	2	3.9	4.7	-10%
M3	2	3.6	4.0	-6%
M4	2	0.9	0.9	0%
M5	2	1.5	1.7	-6%
M6	2	7.1	7.1	0%
M7	2	6.8	7.7	-6%
M8	2	5.6	6.9	-10%

APPENDIX C – Elements of Emerging Concern

Six elements of emerging concern were analyzed for, including: vanadium, chromium, cobalt, strontium, molybdenum, and uranium. Private well samples from trips four and five and monitoring well samples from trip two were analyzed for these elements. Results below are reported in µg/L (ppb).

Private Wells

WELL	TRIP	V	Cr	Co	Sr	Mo	U
1	4	0.3	7	0.09	35.36	0.11	0.045
1	5	0.3	2	0.12	36.14	0.11	0.051
2	4	0.3	3	0.28	104.01	0.33	19.144
2	5	0.7	3	0.18	109.43	0.34	23.810
3	4	0.3	4	0.15	86.20	0.20	10.532
3	5	0.6	3	0.16	76.49	0.21	12.070
4	4	0.5	2	0.04	0.13	0.05	1.731
4	5	1.0	4	0.15	0.37	0.08	3.882
5	4	0.3	5	0.17	69.19	0.25	0.384
5	5	0.5	3	0.18	67.38	0.27	0.411
6	4	0.3	2	0.19	67.47	0.08	0.058
6	5	0.3	2	0.19	71.93	0.09	0.061
7	4	1.0	2	0.08	34.36	0.09	0.445
7	5	1.0	3	0.09	34.27	0.10	0.465
8	4	0.3	6	0.17	0.32	0.32	0.156
8	5	0.6	3	0.19	0.53	0.75	0.162
9	4	0.3	3	0.12	84.90	0.34	0.090
9	5	0.3	3	0.15	76.88	0.39	0.078
10	4	0.3	7	0.17	33.22	0.17	0.113
10	5	0.3	9	0.2	47.15	0.31	0.121
11	4	0.3	2	0.14	66.23	0.25	0.082
11	5	0.5	6	0.17	69.58	0.27	0.075
12	4	0.3	2	0.18	57.37	0.19	0.074
12	5	0.3	4	0.34	53.68	0.20	0.076
13	4	0.3	3	0.10	68.45	0.16	0.127
13	5	0.6	3	0.11	74.27	0.13	0.099
14	4	0.7	5	0.09	28.37	0.10	0.043
14	5	0.5	2	0.06	22.33	0.11	0.039
15	4	0.3	2	0.23	56.83	0.16	0.125
15	5	0.3	9	0.35	60.04	0.38	0.139

16	4	0.3	2	0.08	104.85	0.30	0.111
16	5	0.5	3	0.11	107.19	0.32	0.122
17	4	0.7	4	0.08	48.20	0.15	0.088
17	5	0.5	4	0.09	48.74	0.13	0.073
18	4	0.7	1	0.14	26.56	0.90	0.073
18	5	0.9	2	0.14	26.81	0.79	0.062

Monitoring Wells

WELL	TRIP	V	Cr	Co	Sr	Mo	U
M1	2	0.6	3	0.24	84.66	0.34	0.127
M2	2	0.8	2	0.2	70.07	0.21	0.115
M3	2	1.0	2	0.16	39.72	0.19	0.267
M4	2	0.25	2	0.05	20.3	0.09	0.016
M5	2	0.25	2	0.15	44.58	0.13	0.018
M6	2	0.25	2	0.15	79.95	0.48	0.038
M7	2	0.25	2	0.19	92.96	0.18	0.049
M8	2	0.25	3	0.18	52.8	0.26	1.547