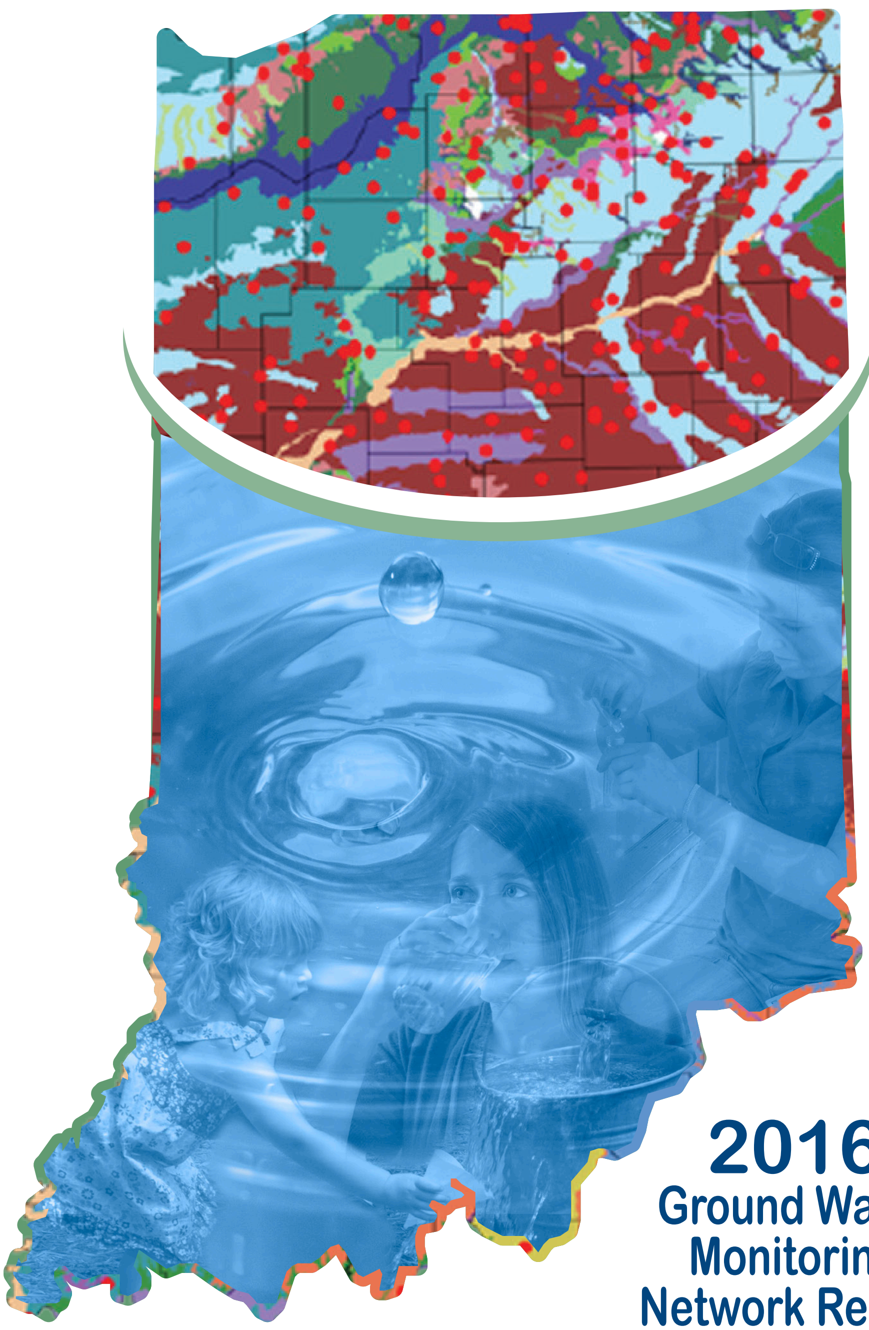
Statewide Ground Water Monitoring Network:

Summary and Results



2016
Ground Water Monitoring Network Report

Indiana Department of Environmental Management

Office of Water Quality

A State that Works

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1.0 Introduction

1.1 Ground Water Usage in Indiana

Ground water is an important resource for Indiana citizens, agriculture and industry. The majority of the population uses ground water for drinking water and other household uses. The National Ground Water Association estimates that 4,454,000 Hoosiers (approximately 67% of the population) rely on ground water as their principle source of drinking water. Of these, around 1,660,000 residents (26% of the population) obtain their water from private domestic wells, which are not required to be tested on a regular basis for quality (Maupin et al., 2014).

1.2 Inception and Project Goals

In 2008, the Ground Water Section of the Drinking Water Branch of the Indiana Department of Environmental Management's (IDEM) Office of Water Quality conducted the inaugural field sampling of the Statewide Ground Water Monitoring Network (GWMN). The overall goals of the project at its inception were to determine:

1) General ground water quality across the state.
2) The effect of ground water on the quality of surface waters.
3) Recharge/discharge relationships of ground water, including surface water/ground water interaction.
4) How source water and drinking water supplies can best be protected by utilizing data derived from a comprehensive approach to assessment and monitoring.

Each of these goals involve first sampling ground water across the state to statistically establish ground water background levels in distinct hydrogeologically defined settings of the state. Once statistically-established ambient ground water conditions have been established for the state, comparison between ground water and surface water data may be made and hypotheses concerning ground water/surface water interactions can be formulated and tested. To reach the goals of the GWMN, the following steps were determined:

1) Collect ground water samples from public water supply wells and private residential wells within distinct hydrogeologic areas of the state with the overall goal to determine the quality of ground water in the state's aquifers.
2) Identify and expand sampling in areas with notable contamination.
3) Practice continual improvement by adjusting the GWMN as necessary to best fit resources (monetary/field support) and data gap needs.

1.3 Historical Summary

IDEM has conducted sampling for the GWMN annually since the inaugural year of 2008. Six complete rounds of sampling have been conducted to date. Although many of the sampling sites were revisited during multiple sampling rounds, the number of sites sampled yearly is not static, and varies based on site suitability, participant interest, availability of resources, and previous sampling results. Table 1 shows the number of sites sampled during each round of sampling with the breakdown between public water supply and private residential sites.

In addition to the number and location of the GWMN sampling sites, the objectives of the network have been modified from year to year during the first five rounds of sampling to better reflect the overall goals of the GWMN. For example, during Sampling Rounds 4 and 5, sub-projects were conducted concurrently with GWMN sampling activities. In Round 4, nine sites were sampled three times during the spring, summer, and autumn, as part of a triannual sampling study. In Round 5, eight sites were also sampled triannually, and nine sites located in the karst regions of Indiana were also sampled biannually during the summer and autumn.

Table 1: Historical Summary of GWMN Sampling Rounds

Sampling Round Number	Start Date	End Date	Total Sites Sampled	Public Water Supply Sites	Private Residential Sites
1	7/2008	10/2009	235	140	95
2	9/2009	12/2009	157	92	65
3	4/2010	12/2010	236	107	129
4	4/2011	11/2011	254	86	168
5	4/2012	10/2012	304	99	205
6	5/2013	8/2014	399	128	271

1.4 Funding

Startup funding, equipment, and vehicle costs for the GWMN were made available by Clean Water Act supplemental Section 106 funding. Staffing costs are provided through a mix of funds from the State of Indiana (60%) and the U.S. Environmental Protection Agency (40%). Laboratory analytical costs are provided through dedicated funds allocated to IDEM from the State of Indiana.

2.0 Ground Water Monitoring Network Sample Round Six Summary

2.1 Identified Issues

In the January 2010 guidance document, *Ground Water Monitoring Network Standard Operating Procedure (S-001-OWQ-D-GW-10-S-R0)* (Appendix A) the objectives of the network were modified to:

- Develop a plan to monitor trends in ground water quality over the next 25 years.
- Establish a network of 200-plus monitoring wells (by hydrogeologic setting).
- Develop a baseline for annual and/or quarterly monitoring.
- Determine real variations in regional ground water quality.
- Evaluate impacts from land use.
- Share data and foster partnerships.

After consultation with scientists from the Center for Geospatial Data Analysis at Indiana Geological Survey (Letsinger et al., 2012), it was determined that the GWMN, as currently designed, was ill-suited for achieving these objectives, and the objectives could not be adequately accomplished by a single monitoring network. Additionally, previous sampling sites were not randomly selected, which resulted in spatial clustering and biased the data. As a result, the design of the GWMN beginning in Round 6, which commenced in May 2013, was modified to focus on the goal of evaluating ambient ground water quality as a function of generalized hydrogeologic setting through random sampling.

2.2 Round Six Network Design

The Indiana Geological Survey (IGS) divided the state into hydrogeologic settings to "provide a conceptual model to help interpret the occurrence, movement, and sensitivity to contamination of ground water in relation to … the surface and subsurface environment" (Fleming, 1995). There are over 240 individual hydrogeologic settings across the state, and the settings are largely based on glacial activity. IGS and IDEM scientists grouped those settings into 20 generalized settings that are common throughout the state (Table 2) and that also were developed as part of the Office of Indiana State Chemist's Pesticide Management Plan. Figure 1 shows these general settings.

A statistically-based approach is needed to select sampling sites in areas that accurately represent ambient ground water quality in each of the 20 generalized hydrogeologic settings. The approach seeks to represent the sampling population of all of the drinking water wells in the Indiana Department of Natural Resources' Water Well Record Database that have an associated well log (approximately 146,500 wells). The number of samples needed to represent that sampling population can be determined from a simplified version of the Cochran formula (Yamane, 1967). From the Yamane formula,

$$n = \frac{N}{(1 + N(e)^2)}$$

n is the number of samples needed, N is the sampling population, and e is the confidence interval (which was selected to be 95%). From this, the required sampling size is 398 samples.

The 398 sampling sites were randomly selected and proportionally distributed throughout the 20 lumped hydrogeologic settings via a weighting procedure (also known as stratified sampling) based on the percentage of located wells in that setting. Table 3 shows how the samples were distributed across the 20 generalized hydrogeologic settings. The weighted number of samples in the generalized settings will range from 1 to 154 samples. As sites were selected within each generalized setting, care was also taken to distribute the samples among the individual hydrogeologic settings that comprise the generalized setting. Figure 2 shows the location of the Round 6 sampling sites.

2.3 Site Selection

Sampling sites must meet certain eligibility requirements before they can be included in the Ground Water Monitoring Network (GWMN). The well log for the well must be on file with the Indiana Department of Natural Resources. An outside spigot that does not go through a water softener or other treatment system is also required for private residential wells. Noncommunity public water supplies could be sampled, provided they have a source water sample tap that allows a sample to be collected directly off the wellhead, in accordance with Indiana's Ground Water Rule.

Sampling sites that were previously sampled as part of the GWMN were screened for suitability and randomly selected to minimize the potential for spatial clustering. 159 sites that were previously sampled as part of the GWMN were retained for Round 6. An additional 58 public water supplies that met the above requirements were added to the GWMN.

The remaining 182 sampling sites that were needed to complete the round of statistically-based sampling (Round 6) were randomly distributed through the generalized settings per Table 3. New residential sampling sites were randomly brought into the GWMN as follows:

- Random nodes were generated by the National Oceanic and Atmospheric Administration Sampling Design Tool for ArcGIS. Residential wells that meet the requirements of the GWMN were identified within a two-mile radius of each node. The identified wells were targeted for either a site visit from GWMN staff or a mailer explaining the GWMN and requesting access for sampling. Through December 2013, an additional 123 sampling sites were added to the GWMN in this manner.
- In May 2014, IDEM issued a press release seeking eligible residential well owners willing to have their water wells sampled as part of the GWMN. Over 1,200 residents from 77 counties in Indiana volunteered to have their well sampled through an online signup form. GWMN staff attempted to locate the well record in the Indiana Department of Natural Resources' Water Well Record Database for each of the submitted addresses. Wells that had suitable well logs and met the requirements of the GWMN were placed in a pool of qualified applicants and randomly selected for sampling based on their location in the generalized hydrogeologic setting. Qualified applicants not chosen for sampling as part of Round 6 were retained for consideration in sampling Round 7.

As indicated above, well depth was considered when selecting sites for Round 6 of the GWMN to ensure that the sampling sites are representative of the principal aquifer units in each setting. Figure 3 shows the 2013 sampling sites as a function of well depth.

Because bedrock aquifers are a significant source of ground water in some areas, many of the wells sampled for the GWMN are installed into bedrock (Figure 4). For Round 6, 118 of the sampling sites were bedrock wells. Because the GWMN sampling sites were randomly selected from the well populations of particular areas, it follows that the bedrock wells in the GWMN are reflective of increased ground water usage from bedrock aquifers in those areas. As Figure 4 shows, principal bedrock aquifers include the Silurian carbonates, Pennsylvanian sandstones, and Mississippian limestones, while the Mississippian and Devonian shales of northern Indiana are not utilized as a ground water resource.

2.4 Protocols and Methods

For Round 6 of the GWMN, IDEM Office of Water Quality Ground Water Section staff conducted activities which included:

a) Statistical analysis of the design of the previous versions of the GWMN.
b) Random selection of sampling sites in each general hydrogeologic setting.
c) Collection of ground water samples from drinking water wells.
d) Shipment of samples for laboratory analysis.
e) Review of analytical sampling results.
f) Distribution of sampling results to GWMN participants.
g) Report generation.

The sampling protocol is outlined in detail in the GWMN Standard Operating Procedure (Appendix A). Ground Water Section staff and summer interns collect samples during the sampling season (primarily April through August), although sampling can continue into autumn. Samples are generally collected from outdoor spigots that have not been treated or from source water sample taps in the case of public water supplies. The well is purged through a flow-cell for several minutes to ensure the sample is representative of ground water conditions in the subsurface. Field parameters (including temperature, specific conductivity, dissolved oxygen, pH, and oxidation reduction potential) are monitored by a YSI Model 650 Water Quality Monitoring System with a 6-series sonde throughout the purging period. Once the field parameters have stabilized, the ground water samples are collected and placed on ice before being sent to a lab for analysis.

Samples are analyzed for over 200 parameters, including alkalinity, anions/cations, metals, nitrate-nitrite, synthetic organic compounds, volatile organic compounds, and pesticide degradates. Refer to Appendix B for a complete list of analytes and Table 4 for the list of analytes detected during sampling Round 6. To assure quality results, all samples are sent to an Indiana State Department of Health certified laboratory. Matrix spike and matrix spike duplicate (MS/MSD) samples are collected and sent with the samples. The results are quality assurance/quality control reviewed by the project chemist.

Table 2: Generalized Hydrogeologic Settings (from Fleming and others, 1995)	
Generalized Hydrogeologic Setting	**Description**
Ablation Sequences	Ablation till is sometimes referred to as melt-out till. It can be massive, densely compacted, and poorly sorted to thin sequences of sandy to loamy ablation sediments that locally contain significant outwash deposits. These sediments are highly sensitive due to a shallow water table and permeable surface sediments.
Alluvial Valley	Alluvial valleys are modern stream valleys and floodplains that consist of fine- to coarse-grained alluvial sediments. Aquifers can be narrow in width and deeply incised in bedrock. The water table is quite shallow (less than 5 feet), and these areas often act as local discharge areas for ground water flow.
Dissected Bedrock	This setting is predominantly a broad upland defined by outcrops of several relatively-resistant rock units. Individual hydrogeologic settings within this general setting generally correspond to the major bedrock units in the area, including the siltstone, shale, and interbedded shale and sandstone. Ground water availability tends to be poor in this setting, and occurs in fractures and along bedding plains.
Dissected Bedrock Thin Till	Unconsolidated deposits in this setting are generally less than 50 feet in thickness over large areas, and laterally extensive sand and gravel units are not common. The unconsolidated deposits overlie moderately to strongly dissected bedrock units, which include interbedded sandstone and mudstone, shale, and karst-forming limestone. Ground water availability in the setting is generally poor, except along bedrock fractures and zones of major solution features.
Fan Head Complex	Fan heads are the near-ice ends of outwash fans, and typically contain a variety of coarse grained sand and gravel deposits. Fan heads consist of massive high-relief terrain composed of both till-capped and exposed sand and gravel deposits. Although ground water is present at considerable depth, the setting has variable sensitivity depending on the thickness of surficial till deposits.
Ice Contact Deposits	Ice contact deposits are those deposits which were deposited on top, beneath, or on the side of glacial ice. Linear ridges chiefly composed of sand and gravel, also known as eskers, were deposited along melt water channels on top of or within glacial ice. Irregular, isolated mounds and hummocky elongated ridges that may or may not be isolated features and can be composed entirely of sand and gravel or a chaotic complex of granular and till-like units have traditionally been known as kames.
Karst Plain and Escarpment	The primary karst plain in Indiana is also known as the Mitchell Plain. This is a classic karst region of south-central Indiana that corresponds to the outcrop of middle Mississippian limestone. The Mitchell Plain is underlain by a sequence of middle Mississippian limestone (unit M2) that is relatively dense and well cemented and thus has little primary porosity. Secondary permeability is spectacularly developed at many places in the form of caverns, caves and enlarged joints. The Mitchell Plain has a well-developed cap of residual soil known as the "terra rossa" which typically measures between 15 and 30 feet thick. Ground water availability is generally good in the Mitchell Plain with yields in the moderate range of 10-50 gallons per minute. Recharge can be quite rapid in areas with numerous sink holes. Ground water and surface water are intimately interrelated, with many sink holes and sinking streams that contribute to subterranean drainages. Ground water beneath large parts of the Mitchell Plain should be regarded as highly sensitive to contamination from agricultural chemicals.
Lake Deposits	Lake deposits formed from sediment-laden meltwater along the margins of glacial ice sheets. Silts and fine sands are the predominant sediment type in this setting. Although the water table is rarely more than a few feet below the ground surface, the fine grain sediments generally have a low permeability.
Meltwater Channels	Meltwater channels are tributary channels that are typically underlain by a mix of granular and till units of widely ranging thicknesses. These channels are sharply entrenched and linear. The channels tend to be poorly drained, and frequently contain wetlands.
Outwash Complex	An outwash complex is comprised of rolling to hummocky landscape and thin units of disconnected sand and gravel. There are discontinuous tills within the sequence. Unconsolidated sediments can be up to 150 feet, but generally range in thickness from 20 to 40 feet. The surface is highly permeable and leads to considerable recharge. The ground water flow is likely to be shallow and has an elevated sensitivity.
Outwash Plains	Outwash plains are typically broad, flat expanses comprised of thick units of highly permeable outwash sand and gravel. Clay lenses and sheets of till may locally divide the outwash into discrete aquifers. A combination of thick outwash sequences and shallow water table make this setting highly vulnerable to surficial contamination.
Sand Plains and Loess Sands	These areas are typified by wind-blown and lake-deposited sand and loess (silt) deposits overlying sand and gravel deposits or bedrock. Both sand and loess deposits may reach thicknesses ranging from 10 to 50 feet and possess surficial topographies ranging from flat to rolling dune topographies. Sand and loess plains are highly permeable and vulnerable to ground water contamination.
Sluiceways and Discrete Channels	Sluiceways are very similar to outwash plains, but differ by being more channelized, narrower, and essentially well-developed troughs that are significantly entrenched into surrounding terrains. Like outwash plains, sluiceways contain abundant sand and gravel deposits reaching significant depths. A combination of thick outwash sequences and shallow water table make this setting highly vulnerable to surficial contamination.
Till Capped Fan	A till capped fan is a thin to thick cap of silt loam till atop thin to very thick sequences of sand and gravel. The principal aquifers in this setting are the various sand and gravel units below the till cap. The depth to water is shallow due to perching on the fine-grained capping units.
Till Cored Moraine	Till cored moraines are morainal ridges typical cored by loam till and till-like sediments. The morainal sediments range between 25 and 75 feet thick and commonly overlie a zone of fairly thick outwash. Aquifers are generally limited to

	confined sand and gravel units below the till, or the limestone or sandstone bedrock.
Till Plain	The central till plain is a vast region of predominantly low relief that covers virtually all of central Indiana. Sediments are typified by several till-dominated sequences deposited during numerous glacial events. Ground water is present in unconsolidated or bedrock aquifers at depths ranging from less than 30 feet to hundreds of feet. Most aquifers in the central till plain are confined or semi-confined.
Tunnel Valleys	Tunnel valleys are melt water discharge channels which formed at the base of the ice sheet and carried away melt water and deposits to the front of the glacier. Tunnel valleys may possess a highly variable sequence of deposits ranging from thick sand and gravel at one location and thick till only a short distance away. Vulnerability to ground water contamination can be highly variable within a tunnel valley depending upon the nature of deposits along that length.
Trough System	A trough system is entrenched troughs of various lake sediments within morainal areas that range in width from 500 feet to 2 miles. The depth to water tends to be shallow in these areas (less than 5 feet).
Unconfined Outwash	Unconfined outwash is a generic term referring to surficial sand and gravel outwash deposits which have no limiting clay or till cover restricting infiltration. These deposits are generally found along valley train sluiceways and outwash plain settings and on unconfined fan and fan head settings. Outwash deposits relatively close to the source of the meltwater is commonly quite coarse grained (sand and abundant gravel), whereas outwash deposited farther from the ice source is often fine grained (sand and lesser gravel). All these deposits are highly permeable and are vulnerable to surficial contamination.
Wabash River Valley	The Wabash River valley is the largest and longest glacial sluiceway–outwash plain system within Indiana. The Wabash River Valley has thick deposits of sand and gravel along its length with shallow bedrock outcropping at several areas as well. The Wabash River Valley is a major ground water discharge point for vast areas of Indiana and is a very significant ground water resource.

Figure 1: General Hydrogeologic Settings

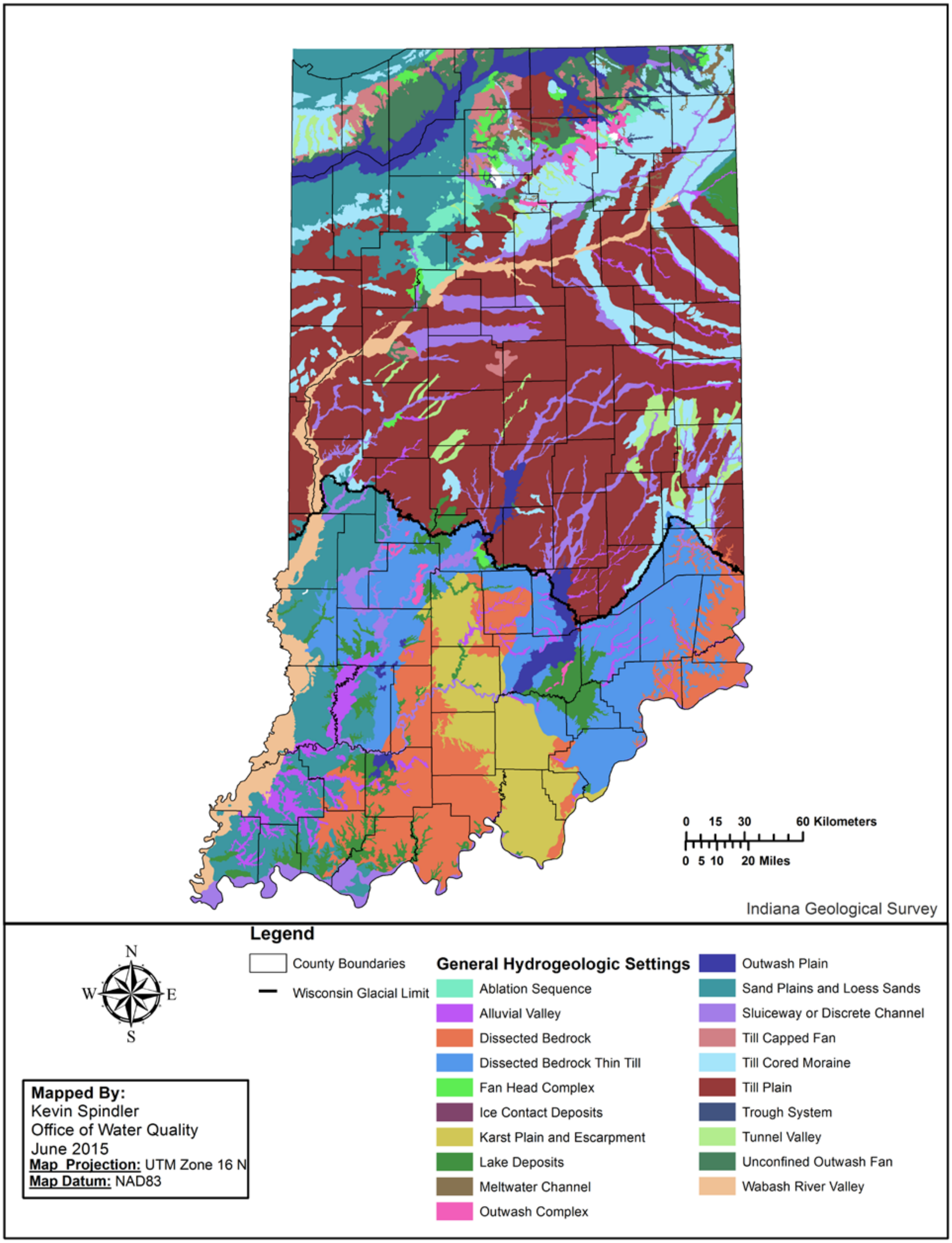


Table 3: Statistical-Based Samples by Generalized Hydrogeologic Setting			
General Setting	**Indiana Department of Natural Resources Located Well Count/Setting**	**Percent of Located**	**Number of Weighted Samples/Setting**
Ablation Sequence	1604	1.09%	4.4
Alluvial Valley	1894	1.29%	5.2
Dissected Bedrock	1945	1.33%	5.3
Dissected Bedrock Thin Till	6397	4.37%	17.4
Fan Head Complex	1859	1.27%	5.1
Ice Contact Deposits	386	0.26%	1.1
Karst Plain and Escarpment	3500	2.39%	9.5
Lake Deposits	2093	1.43%	5.7
Meltwater Channel	380	0.26%	1.0
Outwash Complex	1959	1.34%	5.3
Outwash Plain	8298	5.66%	22.6
Sand Plains and Loess Sands	11732	8.01%	31.9
Sluiceway or Discrete Channel	12723	8.68%	34.6
Till Capped Fan	3271	2.23%	8.9
Till Cored Moraine	16168	11.04%	44.0
Till Plain	56234	38.38%	153.1
Trough System	1549	1.06%	4.2
Tunnel Valley	3682	2.51%	10.0
Unconfined Outwash Fan	6410	4.38%	17.5
Wabash River Valley	4330	2.96%	11.8
Total number of located wells:	146507		
Total number of samples needed (Yamane, 1967)			**398**

Figure 2: Round 6 GWMN Sampling Sites

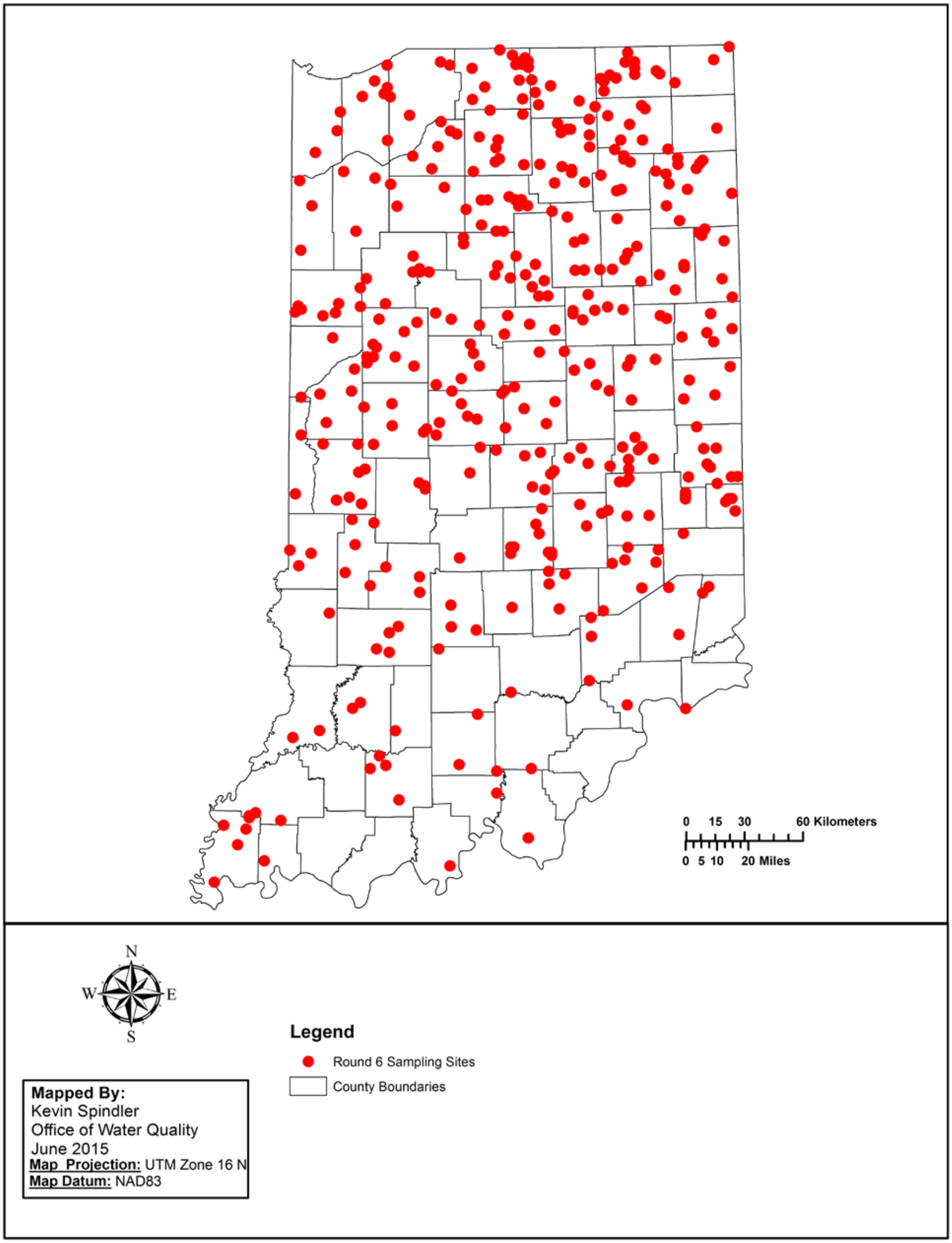


Figure 3: Round 6 GWMN Sampling Site Well Depths

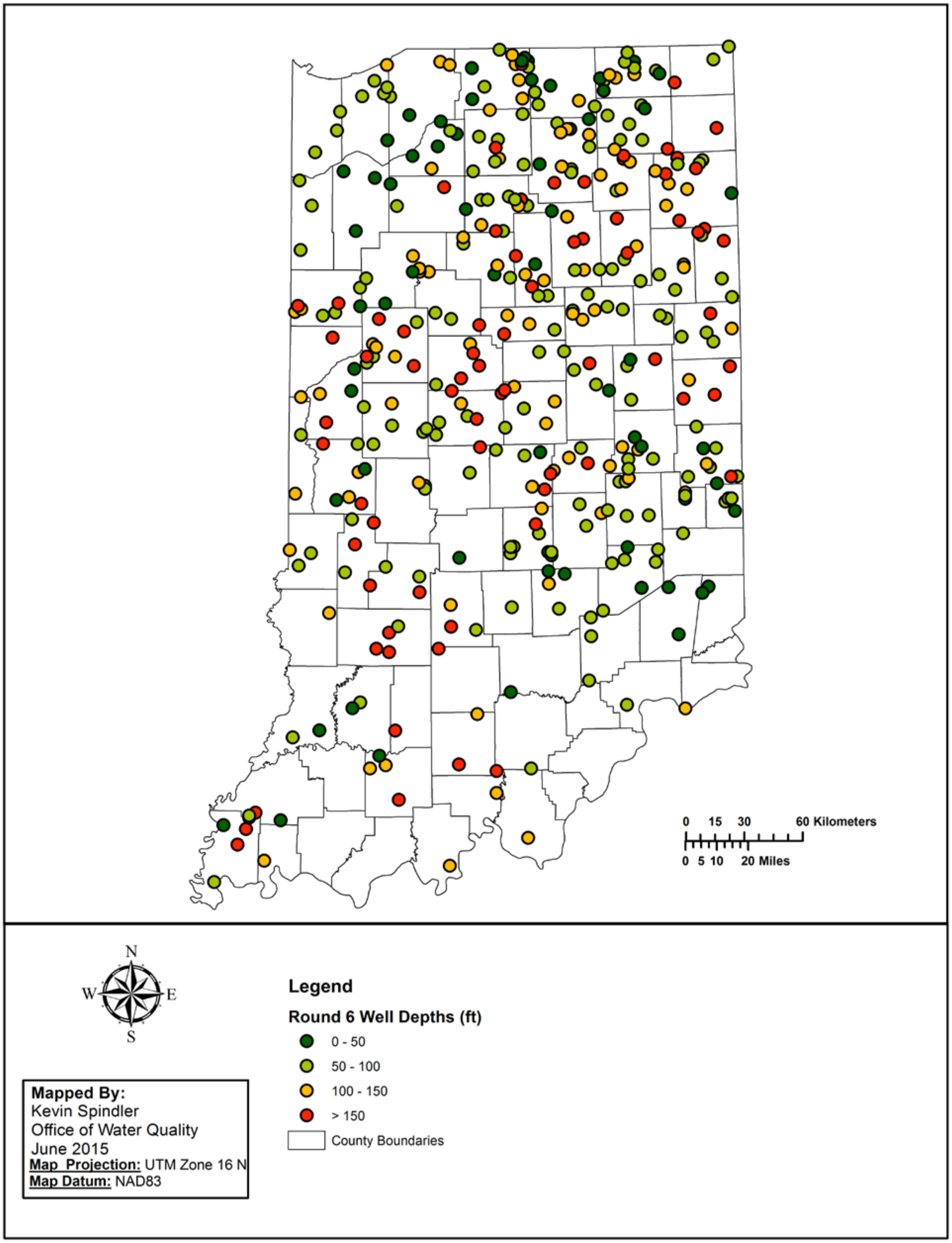
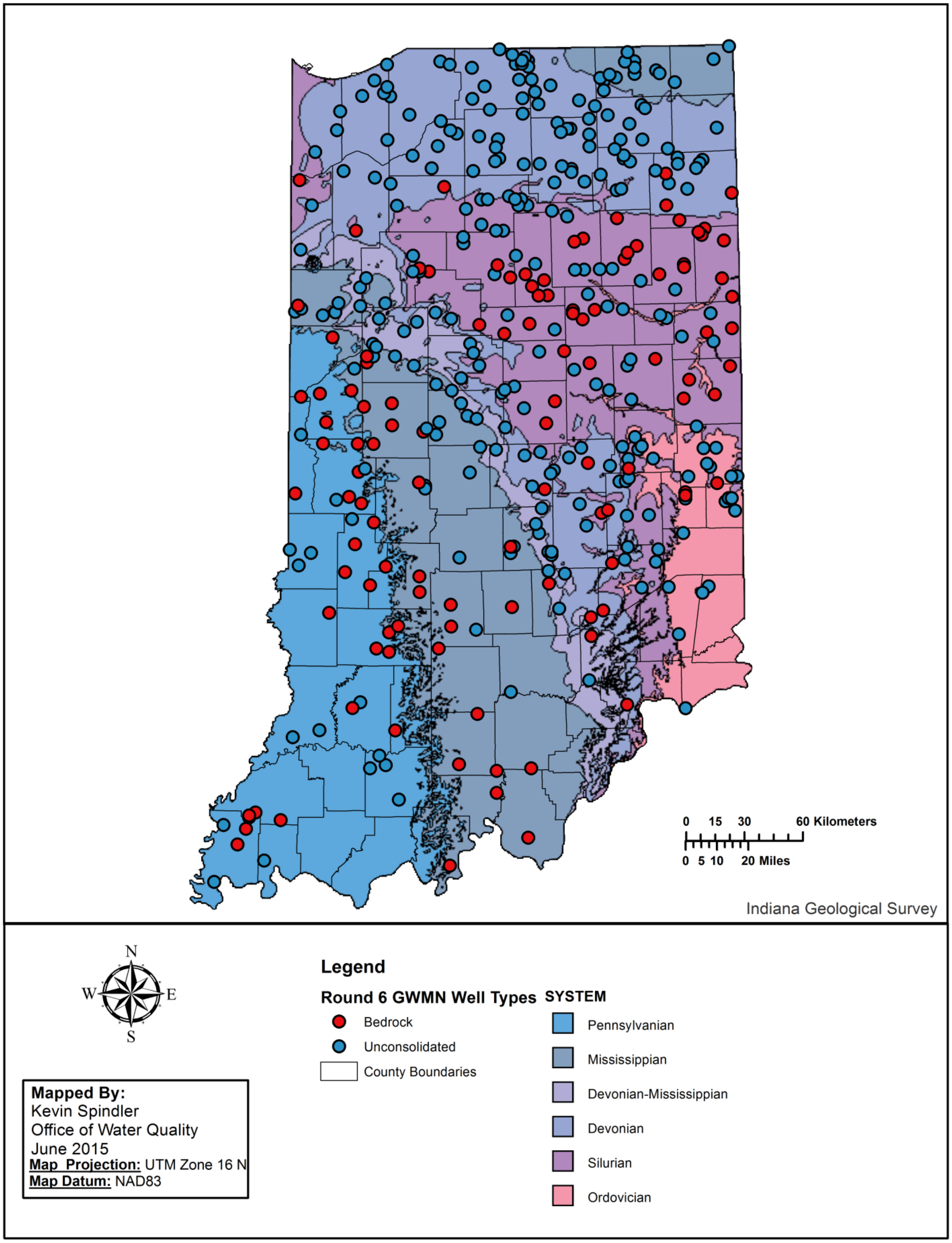


Figure 4: Round 6 GWMN Site Well Types



Section 3.0 Round 6 Results and Analysis

In 2013 and 2014, 398 ground water samples were collected from private residential wells and public water supplies as part of Ground Water Monitoring Network (GWMN) sampling Round 6.

3.1 Summary of Results

Table 4 shows summary statistics for the analytical parameters that were detected in the ground water samples collected as part of Round 6 (with the exception of disinfection byproducts and plasticizers, which are not included in this analysis). If an analyte is not present, it was not detected. In addition, the U.S. Environmental Protection Agency (U.S. EPA) maximum contaminant level (MCL), secondary maximum contaminant level (SMCL), or recommended level is provided when applicable.

For all samples collected as part of Round 6, analytes that had the most occurrences above an MCL included Arsenic (43 samples/11%) and Nitrogen, Nitrate-Nitrite (9 samples/2%). Occurrences above an SMCL or U.S. EPA recommended level included Iron (263 samples/67%), Sulfate (20 samples/5.1%), and Strontium (40 samples/10.3%).

Several volatile organic chemicals (VOCs) were detected in the Round 6 GWMN samples, including Methyl tert-butyl ether (MTBE), Tetrachloroethylene (PCE), Toluene, and Atrazine. These VOCs occurred in one sample each, at concentrations that did not exceed or approach an MCL.

Table 4: Summary Statistics of Detected Compounds

Analyte	Number of Samples	Number Above Detection Limit	% Above Detection Limit	Detection Limit	Median	Mean	Min	Max	Standard Dev	U.S. EPA MCL	U.S. EPA SMCL or Recommended Level (rec)	Number of samples > MCL or SMCL	% > MCL or SMCL
Anions/Cations													
Calcium (mg/L)	390	383	98.21	0.1	83	81.76	0.05	320	38.08	--	--		
Chloride (mg/L)	390	389	99.74	0.25	9.05	19.22	0.125	340	34.66	--	--		
Magnesium (mg/L)	390	376	96.41	0.1	30	31.30	0.05	290	23.76	--	--		
Potassium (mg/L)	390	387	99.23	0.1	1.4	1.87	0.05	40	2.51	--	--		
Sodium (mg/L)	390	390	100.00	0.1	14	33.31	1.5	450	51.45	--	200 mg/L (rec)	7	1.79
Sulfate (mg/L)	390	351	90.00	0.25	31	66.68	0.125	1400	155.30	--	250 mg/L	20	5.13
Metals and Minerals													
Antimony (µg/L)	390	11	2.82	0.25	0.125	0.13	0.125	0.74	0.05	--	--		
Arsenic (µg/L)	390	147	37.69	2	1	4.34	1	68	7.91	10 µg/L	--	43	11.03
Barium (µg/L)	390	378	96.92	5	130	193.17	0.25	1700	210.13	2000 µg/L	--	0	0.00
Boron (µg/L)	390	235	60.26	50	52	130.13	9.2	1500	211.81	--	--		
Bromide (mg/L)	390	132	33.85	0.05	0.025	0.07	0.025	2.8	0.18	--	--		
Chromium (µg/L)	390	1	0.26	2	1	1.01	1	5.8	0.24	100 µg/L	--	0	0.00
Copper (µg/L)	390	195	50.00	1	1.05	3.37	0.5	110	8.32	1300 µg/L	--	0	0.00
Iron (mg/L)	390	316	81.03	0.02	1.1	1.27	0.01	14	1.44	0.3 mg/L	--	263	67.44
Lead (µg/L)	390	7	1.79	1	0.5	0.54	0.5	6.9	0.40	15 µg/L	--	0	0.00
Nickel (µg/L)	390	216	55.38	1	1.3	2.76	0.5	160	8.75	--	100 µg/L (rec)	0	0.00
Silicon (mg/L)	390	390	100.00	0.1	8.2	8.14	3.3	20	2.22	--	--		
Strontium (mg/L)	390	375	96.15	0.005	0.44	1.60	0.0025	17	2.98	--	4 mg/L (rec)	40	10.26
Zinc (µg/L)	390	306	78.46	4	10	23.09	2	420	40.56	--	5000 µg/L	0	0.00
Nitrogen, Nitrate-Nitrite													

Table 4: Summary Statistics of Detected Compounds

Analyte	Number of Samples	Number Above Detection Limit	% Above Detection Limit	Detection Limit	Median	Mean	Min	Max	Standard Dev	U.S. EPA MCL	U.S. EPA SMCL or Recommended Level (rec)	Number of samples > MCL or SMCL	% > MCL or SMCL
Nitrogen, Nitrate-Nitrite (mg/L)	390	139	35.64	0.01	0.005	0.89	0.005	22	2.75	10 mg/L	--	9	2.31
Pesticides and Breakdown Products													
Acetochlor ESA (µg/L)	380	8	2.11	0.1	0.05	0.07	0.05	2.1	0.14	--	--		
Acetochlor OA (µg/L)	380	4	1.05	0.1	0.05	0.05	0.05	0.3	0.02	--	--		
Alachlor ESA (µg/L)	380	28	7.37	0.1	0.05	0.11	0.05	6.4	0.39	--	--		
Alachlor OA (µg/L)	380	6	1.58	0.1	0.05	0.07	0.05	4.1	0.24	--	--		
gamma-BHC (Lindane) (µg/L)	389	2	0.51	0.02	0.01	0.01	0.01	0.03	0.00	0.2 µg/L		0	0.00
Metolachlor ESA (µg/L)	380	34	8.95	0.1	0.05	0.16	0.05	7.8	0.67	--	--		
Metolachlor OA (µg/L)	380	15	3.95	0.1	0.05	0.08	0.05	2.9	0.20	--	--		
Volatile Organic Compounds													
Methyl-t-butyl ether (MTBE) (µg/L)	389	1	0.26	0.5	0.25	0.25	0.25	2	0.09	--	20 µg/L	0	0.00
Tetrachloroethylene (µg/L)	389	1	0.26	0.5	0.25	0.25	0.25	0.6	0.02	5 µg/L	--	0	0.00
Toluene (µg/L)	389	1	0.26	0.5	0.25	0.27	0.25	9.1	0.45	1000 µg/L	--	0	0.00

***Disinfection byproducts and plasticizers have been omitted from this list until further analysis and sampling can be conducted to determine the source.

3.2 Nitrogen, Nitrate-Nitrite

For Round 6 of the GWMN, 139 samples contained detectable levels of Nitrogen, Nitrate-Nitrite. Nine of those samples contained Nitrogen, Nitrate-Nitrite above the MCL (10 mg/L), with a highest reported concentration of 22 mg/L. The major sources of nitrates in drinking water are runoff from fertilizer use; leaking from septic tanks, sewage; and erosion of natural deposits (U.S. U.S. EPA, 2015).

The locations of the Nitrogen, Nitrate-Nitrite samples are displayed with hydrogeologic sensitivity developed by Fleming et al. (Figure 5) and with aquifer sensitivity developed by Letsinger (2015) (Figure 6). Fleming's hydrogeologic sensitivity map is qualitative based on typical characteristics for the individual hydrogeologic settings, while the Letsinger aquifer sensitivities were quantitatively calculated from factors including slope, sand thickness, surficial clay thickness, percentage clay in soil, land cover, and vegetation. In highly sensitive areas, ground water can be rapidly recharged by surficial infiltration, allowing potential contaminants (including nitrates and pesticides) found at the ground surface or shallow subsurface to be transported into the aquifer. Summary statistics were calculated on the Nitrogen, Nitrate-Nitrate data as a function of generalized hydrogeologic setting (Table 5) and Fleming's aquifer sensitivity (Table 6). As shown in Table 6, samples collected from highly sensitive aquifers contained the highest number of Nitrogen, Nitrate-Nitrite detections (63 samples or 44%), as well as the highest number of detections above the MCL (6). Samples from highly sensitive aquifers had the highest average Nitrogen, Nitrate-Nitrite concentration (1.495 mg/L) of the five sensitivity types analyzed as part of this project.

Table 7 shows a comparison of Nitrogen, Nitrate-Nitrite levels in bedrock and unconsolidated wells sampled in Round 6. Eight of the nine MCL exceedances for Nitrogen, Nitrate-Nitrite occurred in unconsolidated wells. For the whole dataset, similar percentages of detections (36%) occurred between the bedrock and unconsolidated wells. However, the unconsolidated wells contained a higher average concentration (1.0 mg/L) than the bedrock wells (0.63 mg/L).

Average Nitrogen, Nitrate-Nitrite concentrations were calculated for a number of additional parameters (including well type, aquifer oxidation-reduction conditions, aquifer sensitivity, and well depth) as a function of hydrogeologic setting (Table 8). Oxidizing aquifers (as determined by positive oxidation reduction potential [ORP] values) had higher average Nitrogen, Nitrate-Nitrite concentrations (2.65 µg/L) than reducing aquifers (0.27 µg/L). A Mann-Whitney test indicated that the Nitrogen, Nitrate-Nitrite levels were significantly greater in oxidizing aquifers (n=289) than for reducing aquifers (n=101), $U=5461$, $Z=-9.36$, $p<0.05$. For 14 of the 19 settings considered in this analysis, aquifers under oxidizing conditions contained a higher average Nitrogen, Nitrate-Nitrite concentration than reducing aquifers. Previous studies (Freeze and Cherry, 1979) have shown that the distribution and mobility of nitrogen within aquifers can be influenced by ground water redox conditions.

Additionally, 12 of the 19 general hydrogeologic settings had their highest average Nitrogen, Nitrate-Nitrite concentrations in wells less than 100 feet deep. The averages calculated for this study suggest that Nitrogen, Nitrate-Nitrite concentrations tend to be higher in shallow, unconsolidated wells (less than 100 feet deep) in highly-sensitive, oxidizing aquifers. Additional geochemical and statistical analyses are needed to evaluate the causal relationship between these parameters.

Figure 5: Round 6 Nitrogen, Nitrate-Nitrite Results by Hydrogeologic Sensitivity (Fleming et al., 1995)

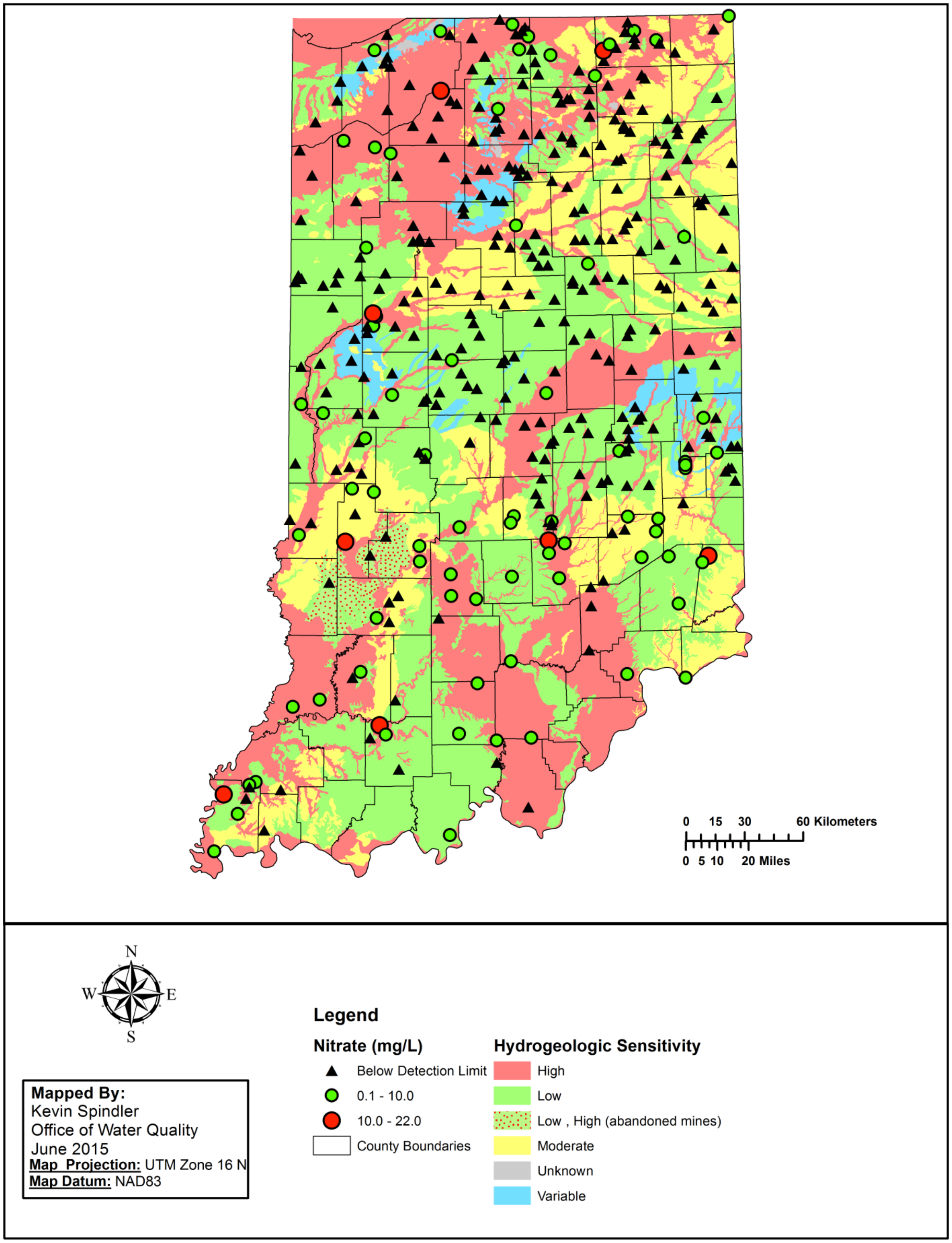


Figure 6: Round 6 Nitrogen, Nitrate-Nitrite Results by Aquifer Sensitivity (Letsinger, 2015)

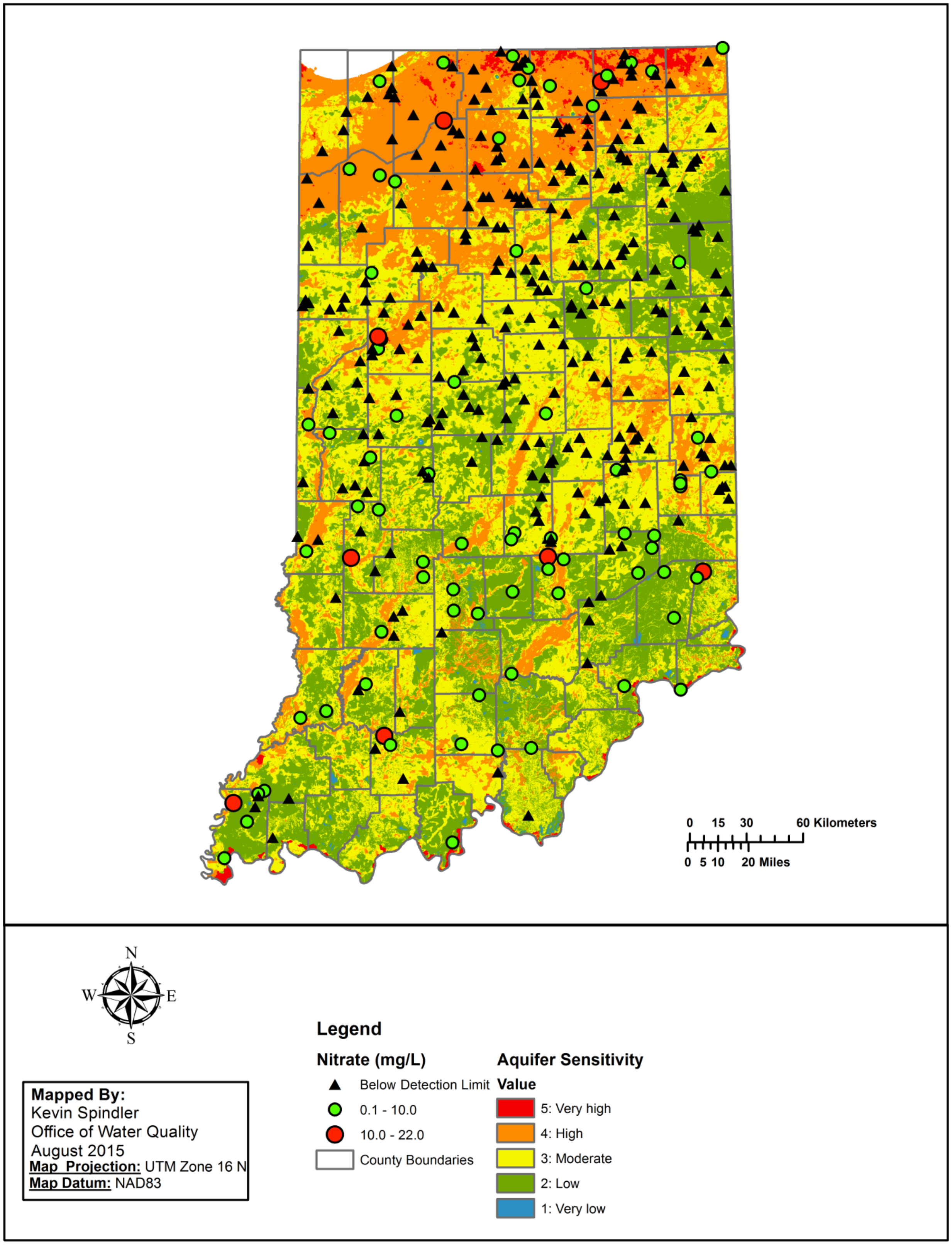


Table 5: Nitrogen, Nitrate-Nitrite Summary Statistics by Generalized Hydrogeologic Setting (mg/L)

	Number of Samples	Number Above Detection Limit	% Above Detection Limit	Number Above MCL	% Above MCL	Median	Mean	Min	Max	Standard Dev
Ablation Sequence	5	0	0	0	0	0.005	0.005	0.005	0.01	0.00
Alluvial Valley	5	2	40	0	0	0.005	0.473	0.005	1.60	0.71
Dissected Bedrock	4	2	50	0	0	0.068	0.070	0.005	0.14	0.08
Dissected Bedrock Thin Till	17	11	65	1	6	0.170	1.736	0.005	13.00	3.28
Fan Head Complex	5	1	20	0	0	0.005	0.080	0.005	0.38	0.17
Ice Contact Deposits	2	1	50	1	50	7.003	7.003	0.005	14.00	9.90
Karst Plain and Escarpment	9	7	78	0	0	0.530	2.235	0.005	7.90	2.92
Lake Deposits	5	3	60	0	0	0.051	1.610	0.005	7.70	3.41
Meltwater Channel	1	0	0	0	0	0.005	0.005	0.005	0.01	--
Outwash Complex	6	2	33	0	0	0.005	0.127	0.005	0.45	0.20
Outwash Plain	22	8	36	2	9	0.005	2.627	0.005	22.00	5.47
Sand Plains and Loess Sands	30	17	57	1	3	0.012	1.638	0.005	16.00	3.54
Sluiceway or Discrete Channel	34	15	44	2	6	0.005	1.802	0.005	15.00	3.69
Till Capped Fan	9	4	44	0	0	0.005	0.467	0.005	4.00	1.33
Till Cored Moraine	44	9	20	0	0	0.005	0.088	0.005	2.80	0.42
Till Plain	151	40	26	0	0	0.005	0.180	0.005	6.40	0.79
Trough System	4	1	25	0	0	0.005	0.379	0.005	1.50	0.75
Tunnel Valley	10	3	30	0	0	0.005	0.532	0.005	4.30	1.35
Unconfined Outwash Fan	16	6	38	0	0	0.005	0.344	0.005	1.90	0.71
Wabash River Valley	11	7	64	2	18	1.100	5.023	0.005	17.00	6.57

Table 6: Nitrogen, Nitrate-Nitrite Summary Statistics by Aquifer Sensitivity (mg/L)

	Number of Samples	Number Above Detection Limit	% Above Detection Limit	Number Above MCL	% Above MCL	Median	Mean	Min	Max	Standard Dev
High	144	63	44	6	4	0.005	1.496	0.005	22.000	2.746
Low	145	48	33	1	1	0.005	0.525	0.005	13.000	1.742
Low , High (abandoned mines)	4	2	50	0	0	0.008	0.280	0.005	1.100	0.547
Moderate	69	20	29	2	3	0.005	0.645	0.005	16.000	2.666
Variable	28	6	21	0	0	0.005	0.336	0.005	4.300	1.091

Table 7: Nitrogen, Nitrate-Nitrite Summary Statistics by Well Type (mg/L)

	Number of Samples	Number Above Detection Limit	% Above Detection Limit	Number Above MCL	% Above MCL	Median	Mean	Min	Max	Standard Dev
Bedrock	118	42	36	1	1	0.01	0.63	0.005	16.000	2.022
Unconsolidated	272	97	36	8	3	0.01	1.00	0.005	22.000	3.003

Table 8: Nitrogen, Nitrate-Nitrite Averages by Category (mg/L)

	Well Type		Aquifer Conditions		Sensitivity					Well Depth			
	Bedrock	Unconsolidated	Oxidizing	Reducing	High	Moderate	Low	Variable	Low , High	0-50	50-100	100-150	>150
Ablation Sequence	Non-Detect (ND)	ND	ND	ND	ND	--	--	--	--	ND	ND	ND	--
Alluvial Valley	0.473	--	1.175	ND	0.473	--	--	--	--	--	0.803	--	0.253
Dissected Bedrock	0.092	0.070	0.092	ND	0.070	--	--	--	--	--	--	0.130	0.050
Dissected Bedrock Thin Till	0.447	3.576	3.130	0.167	0.869	0.038	4.410	--	0.280	4.972	0.045	1.104	0.279
Fan Head Complex	0.193	ND	ND	0.099	0.380	ND	--	ND	--	--	0.130	ND	--
Ice Contact Deposits	--	7.003	--	7.003	ND	14.000	--	--	--	--	14.000	ND	--
Karst Plain and Escarpment	2.472	0.340	2.152	2.900	2.235	--	--	--	--		6.000	1.762	1.770
Lake Deposits	ND	2.012	0.115	3.853	ND	ND	2.680	--	--	ND	7.700	0.115	--
Outwash Complex	0.370	ND	0.370	ND	0.127	--	--	--	--	--	ND	0.148	0.450
Outwash Plain	ND	2.752	9.140	0.712	2.627	--	--	--	--	4.038	1.332	ND	ND
Sand Plains and Loess Sands	3.041	0.825	3.473	0.575	0.485	2.923	6.800	--	--	0.829	1.760	2.683	1.965
Sluiceway or Discrete Channel	0.017	2.184	4.699	0.008	1.856	ND	--	--	--	3.869	1.594	0.610	0.038
Till Capped Fan	--	0.467	1.385	0.008	ND	ND	0.078	0.807	--	--	0.008	1.040	--
Till Cored Moraine	0.050	0.096	0.135	0.082	ND	0.034	0.119	ND	--	1.403	0.036	0.030	0.006
Till Plain	0.139	0.203	0.975	0.037	0.219	0.047	0.244	ND	--	0.595	0.177	0.148	0.085
Trough System	--	0.379	1.500	ND	0.379	--	--	--	--	ND	0.503	--	--
Tunnel Valley	1.735	0.016	1.735	0.016	ND	--	--	0.663	--	0.303	0.873	0.021	--
Unconfined Outwash Fan	--	0.344	0.855	0.271	0.240	1.900	--	--	--	0.006	0.345	0.624	0.011
Wabash River Valley	0.007	6.904	6.368	3.410	5.525	--	--	ND	--	8.515	3.376	6.179	ND

Note: Detailed averages were not compiled for the Meltwater Channel Setting, which consisted on only one sample.

3.3 Arsenic

Arsenic is a naturally occurring element found primarily in rocks, soil, water, and plants in many areas of the United States, including Indiana. Natural events, such as infiltration of water, dissolution of minerals from clay, and erosion of rocks, can release arsenic into water. Arsenic can also be released into the environment as a byproduct of industrial activities, such as wood preservation, mining, and smelting (IDEM, 2013).

For Round 6 of the Ground Water Monitoring Network (GWMN), 147 samples (around 38%) contained detectable levels of Arsenic. Forty-three of those samples (11%) contained Arsenic above the MCL (10 µg/L), with a highest reported concentration of 68 µg/L. Figure 7 shows the location of the Arsenic samples by hydrogeologic setting. Table 9 shows summary statistics for Arsenic samples by hydrogeologic setting. Forty-one of the samples with MCL exceedances for Arsenic occurred north of the Wisconsinan Glacial Boundary, demonstrating the close relationship between Arsenic and glacial sediments. Twenty-five of the samples exceeding the MCL were found in the Till Plain setting. Settings with the highest percentage of samples with detectable levels of Arsenic include the Ablation Sequences (60%), Unconfined Outwash Fans (50%), Till Cored Moraine (45%), Till Plain (45%), and Tunnel Valley (40%).

Tables 10 and 11 show Arsenic summary statistics by aquifer sensitivity and well type, respectively. Around 42% of samples from unconsolidated wells contained detectable levels of Arsenic, compared to 28% of samples from bedrock wells. Approximately 13% of unconsolidated wells contained Arsenic above the MCL, compared to 6% of bedrock samples. Unconsolidated wells had a higher average Arsenic concentration (4.86 µg/L) than bedrock wells (3.12 µg/L). A Mann-Whitney test indicated that the Arsenic levels were significantly greater in unconsolidated wells ($n=272$) than for bedrock wells ($n=118$), $U=13814$, $Z=2.18$, $p<0.05$. As an intra-setting comparison (Table 12), 14 of the 19 hydrogeologic settings had higher average Arsenic concentrations in unconsolidated wells.

Reducing aquifers (as determined by negative oxidation reduction potential values) had higher average Arsenic concentration (5.32 µg/L) than oxidizing aquifers (1.50 µg/L). A Mann-Whitney test indicated that the Arsenic levels were significantly greater in reducing aquifers ($n=289$) than for oxidizing aquifers ($n=101$), $U=8990$, $Z=5.74$, $p<0.05$. For 16 of the 19 hydrogeologic settings considered in this analysis, aquifers under reducing conditions contained a higher average Arsenic concentration than oxidizing aquifers.

Previous studies of glacial aquifers in the northern United States (including Indiana) have shown that Arsenic concentrations are higher in aquifers under reducing conditions (Thomas, 2007). As stated by the California Division of Water Quality's Groundwater Ambient Monitoring and Assessment Program,

> *In water, the most common valence states of arsenic are As(V), or arsenate, which is more prevalent in well oxygenated (aerobic) surface waters, and As(III), or arsenite, which is more likely to occur in anaerobic groundwater or deep lake sediments (reducing environments). The solubility, mobility, and toxicity of As in the environment are dependent upon its oxidation state… Arsenic mobility in groundwater is dependent on the physical and chemical properties of the aquifer, although two types of processes generally control its movement: adsorption/desorption reactions and precipitation/dissolution reactions. During adsorption*

reactions, dissolved arsenic adheres to the surface of solid aquifer materials. Desorption removes the arsenic from aquifer materials and releases it into the surrounding groundwater… Arsenite is more mobile, toxic, and difficult to remove from groundwater than arsenate.

Geochemical modeling is needed to determine the species of Arsenic found in Indiana ground water, and additional geochemical and statistical analyses are needed to evaluate the causal relationship between these parameters.

Figure 7 : Round 6 Ground Water Monitoring Network Arsenic Results

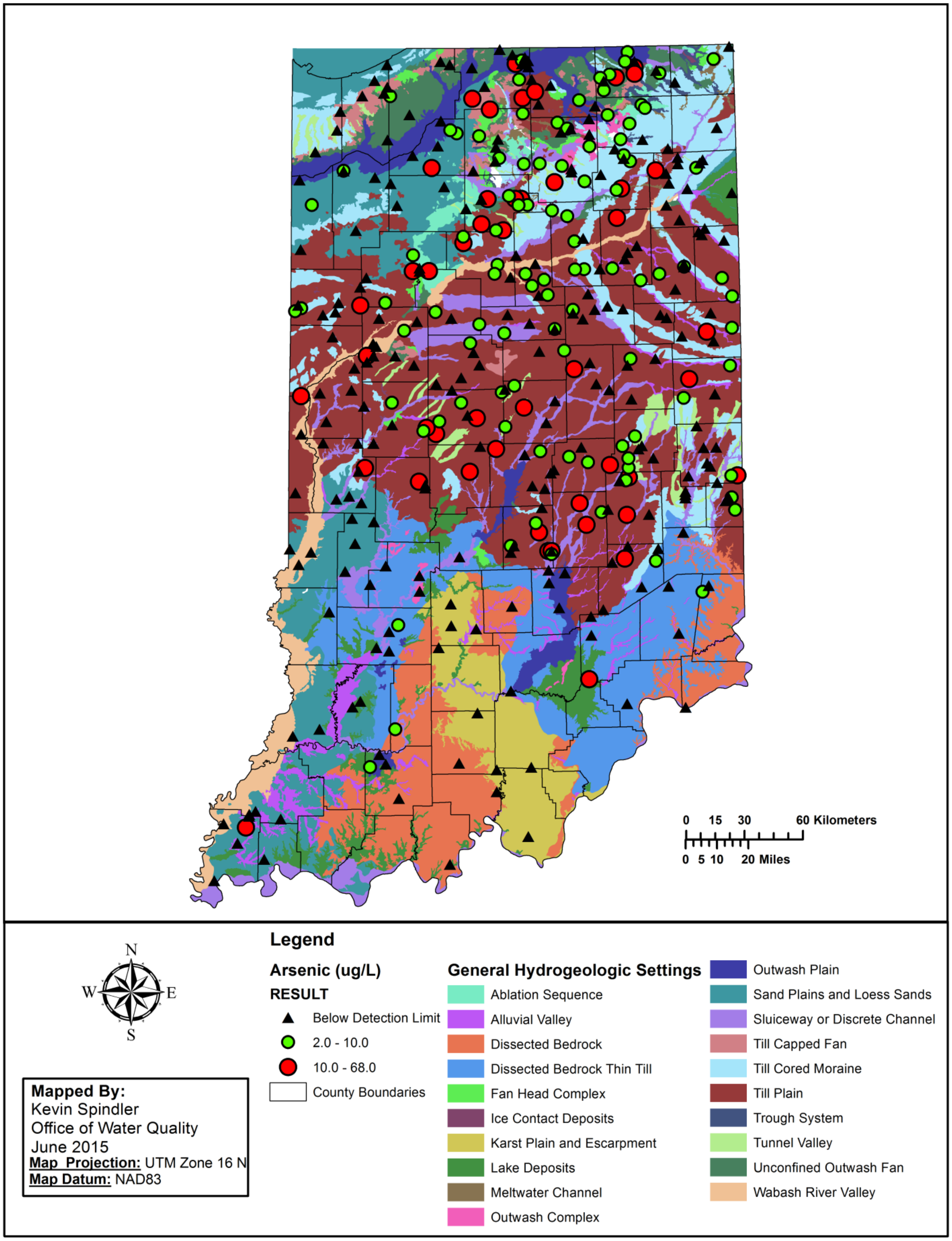


Table 9: Arsenic Summary Statistics by Generalized Hydrogeologic Setting (µg/L)

	Number of Samples	Number Above Detection Limit (ADL)	% ADL	Number Above MCL	% Above MCL	Median	Mean	Min	Max	Standard Dev
Ablation Sequence	5	3	60	1	20	2.5	5.3	1.0	16.0	6.32
Alluvial Valley	5	1	20	1	20	1.0	6.6	1.0	29.0	12.52
Dissected Bedrock	4	1	25	0	0	1.0	1.8	1.0	4.2	1.60
Dissected Bedrock Thin Till	17	3	18	0	0	1.0	1.3	1.0	3.8	0.74
Fan Head Complex	5	1	20	0	0	1.0	1.4	1.0	3.2	0.98
Ice Contact Deposits	2	1	50	1	50	6.5	6.5	1.0	12.0	7.78
Karst Plain and Escarpment	9	0	0	0	0	1.0	1.0	1.0	1.0	0.00
Lake Deposits	5	2	40	1	20	1.0	5.9	1.0	21.0	8.66
Meltwater Channel	1	1	100	0	0	6.1	6.1	6.1	6.1	--
Outwash Complex	6	2	33	0	0	1.0	2.4	1.0	8.0	2.80
Outwash Plain	22	7	32	2	9	1.0	3.1	1.0	19.0	4.51
Sand Plains and Loess Sands	30	7	23	3	10	1.0	4.4	1.0	63.0	11.61
Sluiceway or Discrete Channel	34	13	38	3	9	1.0	5.9	1.0	68.0	13.99
Till Capped Fan	9	3	33	1	11	1.0	4.7	1.0	28.0	8.90
Till Cored Moraine	44	20	45	2	5	1.0	3.2	1.0	16.0	3.44
Till Plain	151	67	44	25	17	1.0	5.2	1.0	65.0	7.81
Trough System	4	1	25	0	0	1.0	1.4	1.0	2.7	0.85
Tunnel Valley	10	4	40	1	10	1.0	4.1	1.0	21.0	6.41
Unconfined Outwash Fan	16	8	50	1	6	1.8	4.5	1.0	17.0	4.64
Wabash River Valley	11	2	18	1	9	1.0	3.6	1.0	27.0	7.80

Table 10: Arsenic Summary Statistics by Aquifer Sensitivity (µg/L)

	Number of Samples	Number Above Detection Limit (ADL)	% ADL	Number Above MCL	% Above MCL	Median	Mean	Min	Max	Standard Dev
High	144	47	33	14	10	1.00	4.33	1.00	68.00	7.906
Low	145	63	43	20	14	1.00	4.87	1.00	65.00	7.913
Low, High (abandoned mines)	4	0	0	0	0	1.00	1.00	1.00	1.00	0.000
Moderate	69	24	35	4	6	1.00	3.08	1.00	14.00	3.629
Variable	28	13	46	5	18	1.00	5.18	1.00	27.00	7.050

Table 11: Arsenic Summary Statistics by Well Type (µg/L)

	Number of Samples	Number Above Detection Limit (ADL)	% ADL	Number Above MCL	% Above MCL	Median	Mean	Min	Max	Standard Dev
Bedrock	118	33	28	7	6	1.00	3.12	1.00	29.00	5.041
Unconsolidated	272	114	42	36	13	1.00	4.86	1.00	68.00	8.823

Table 12: Arsenic Averages by Category (µg/L)

	Well Type		Aquifer Conditions		Hydrogeologic Sensitivity					Well Depth			
	Bedrock	Unconsolidated	Oxidizing	Reducing	High	Moderate	Low	Variable	Low, High	0-50	50-100	100-150	>150
Ablation Sequence	16.00	2.65	6.10	5.13	2.50	--	--	--	--	1.00	3.55	9.25	--
Alluvial Valley	6.60	--	ND	10.33	ND	--	--	--	--	--	ND	--	10.33
Dissected Bedrock	2.07	Non-Detect ND	ND	4.20	1.80	--	--	--	--	--	--	ND	2.07
Dissected Bedrock Thin Till	1.11	1.56	1.12	1.49	ND	1.78	ND	--	ND	1.22	1.78	ND	1.00
Fan Head Complex	ND	1.73	ND	1.55	ND	ND	--	2.10	--	--	1.73	ND	--
Ice Contact Deposits	--	6.50	--	6.50	12.00	ND	--	--	--	--	ND	12.00	--
Karst Plain and Escarpment	ND	ND	ND	ND	ND	--	--	--	--		ND	ND	ND
Lake Deposits	ND	7.18	9.23	ND	21.00	1.00	2.57	--	--	ND	ND	9.23	--
Outwash Complex	ND	3.15	ND	3.15	2.43	--	--	--	--	--	3.87	ND	ND
Outwash Plain	ND	3.23	ND	3.75	3.13	--	--	--	--	1.55	4.73	8.05	ND
Sand Plains and Loess Sands	ND	6.29	1.74	5.86	6.29	ND	ND	--	--	3.06	2.98	11.33	ND
Sluiceway or Discrete Channel	2.10	6.67	ND	8.87	5.85	6.40	--	--	--	1.61	9.68	2.26	2.65
Till Capped Fan	--	4.74	1.43	6.40	ND	ND	15.15	2.08	--	--	2.08	8.08	--
Till Cored Moraine	2.01	3.49	1.58	3.43	2.10	3.25	3.25	3.15	--	3.15	2.66	3.11	4.10
Till Plain	3.93	5.88	1.24	5.89	3.67	3.81	5.63	6.59	--	5.08	4.61	8.49	3.60
Trough System	--	1.43	ND	1.57	1.43	--	--	--	--	2.70	ND	--	--
Tunnel Valley	1.67	5.11	ND	5.40	4.85	--	--	3.89	--	3.57	5.62	ND	--
Unconfined Outwash Fan	--	4.47	ND	4.96	4.32	6.70	--	--	--	2.75	5.66	5.20	ND
Wabash River Valley	10.43	ND	1.38	6.20	1.23	--	--	27.00	--	ND	ND	1.58	1.58

Note: Detailed averages were not compiled for the Meltwater Channel Setting, which consisted on only one sample.

3.4 Pesticide Degradates

Acetochlor Ethanesulfonic Acid (ESA), Acetochlor Oxanilic Acid (OA), Alachlor ESA, Alachlor OA, Metolachlor ESA, and Metolachlor OA are among the breakdown products of herbicides that are commonly used in Indiana to control broadleaf and grassy weeds in corn and soybeans. The breakdown products (ESAs and OAs) are generally more water soluble and mobile than the parent herbicide, so there is greater potential for these degradates to be found in ground water or surface water (Shoemaker, 2003). However, there is no established maximum contaminant level or health recommendation for these pesticide degradates.

Detectable levels of these degradates were found in 68 of the Round 6 Ground Water Monitoring Network samples, with a highest reported concentration of 7.8 µg/L of Metolachlor ESA. Figures 8, 9, 10, 11, 12, and 13 show the Round 6 pesticide degradate results for Acetochlor ESA, Acetochlor OA, Alachlor ESA, Alachlor OA, Metolachlor ESA, and Metolachlor OA.

- Thirty-two of the ground water samples that contained detectable levels of pesticide degradates contained more than one type of degradate compound.
- Thirty of the 69 samples that contained detectable levels of pesticide degradates (43%) were located in areas of high hydrogeologic sensitivity, while 25 of the samples (36%) were in low sensitivity areas.
- Settings with the highest number of samples that contained detectable levels of pesticide degradates include the Outwash Plain hydrogeologic setting (13 samples), Sand Plain and Loess Sand setting (12 samples), Till Cored Moraine (7 samples), and Till Plain (18 samples).

Figure 8: Round 6 Pesticide Degradate Results – Acetochlor ESA

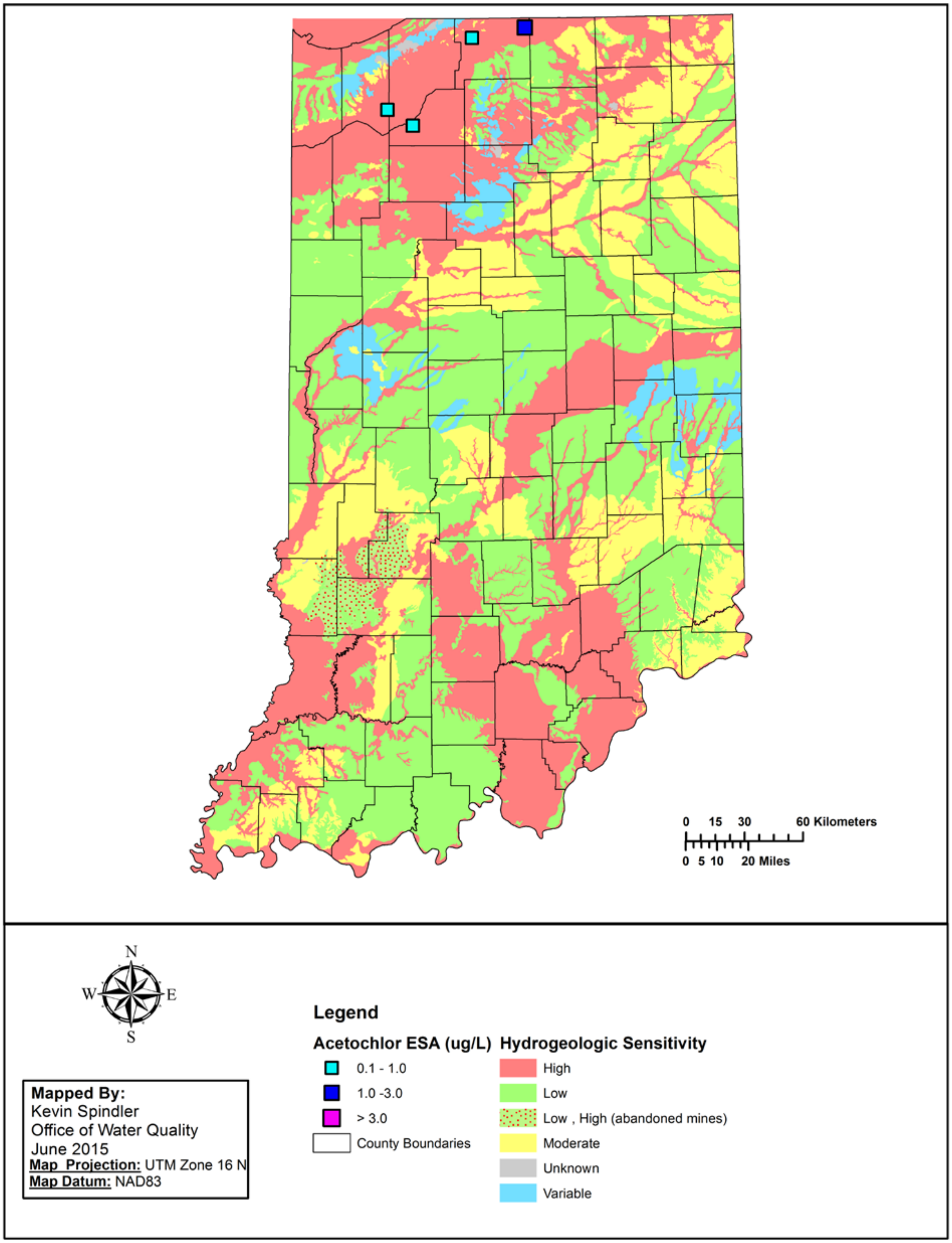


Figure 9: Round 6 Pesticide Degradate Results – Acetochlor OA

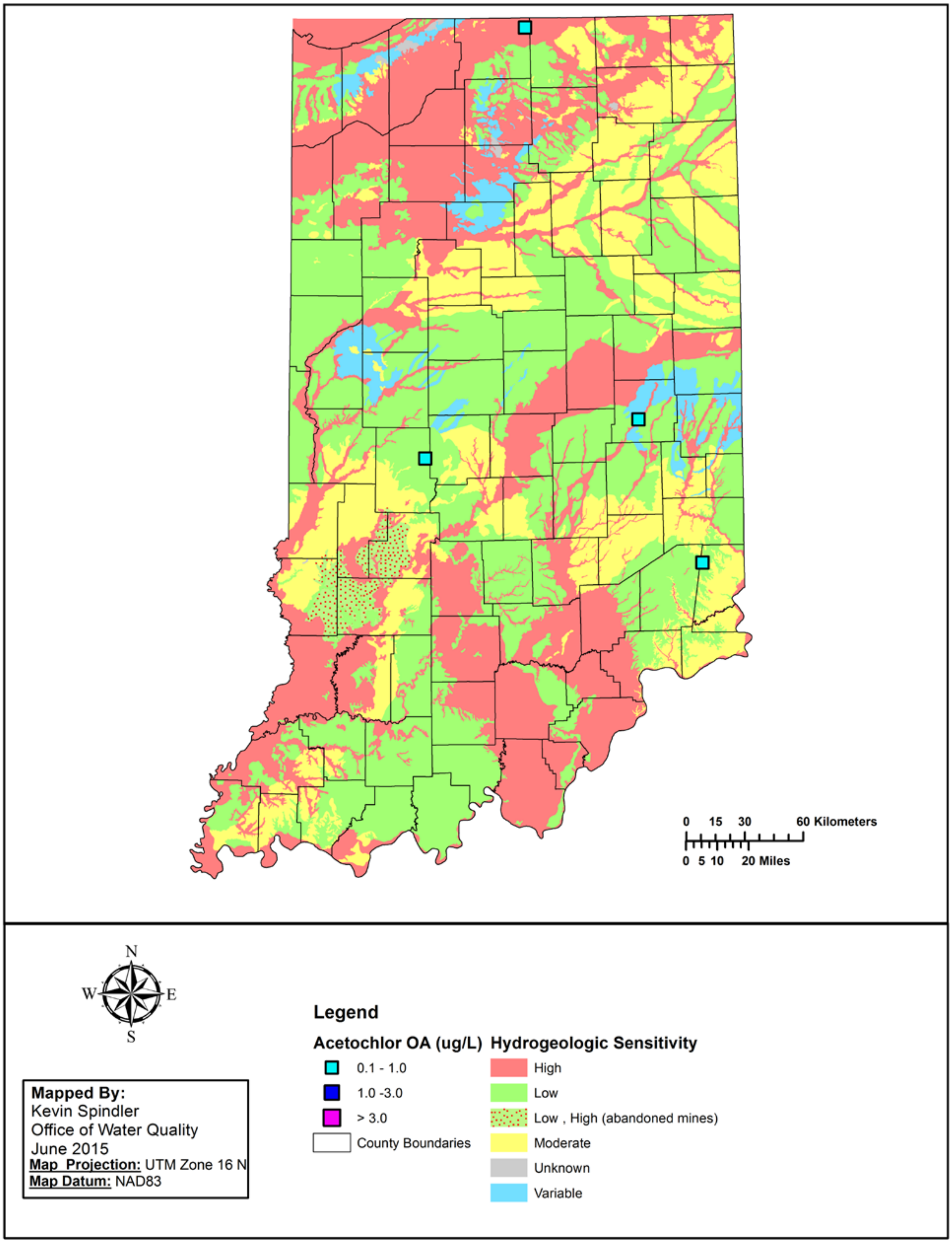


Figure 10: Round 6 Pesticide Degradate Results – Alachlor ESA

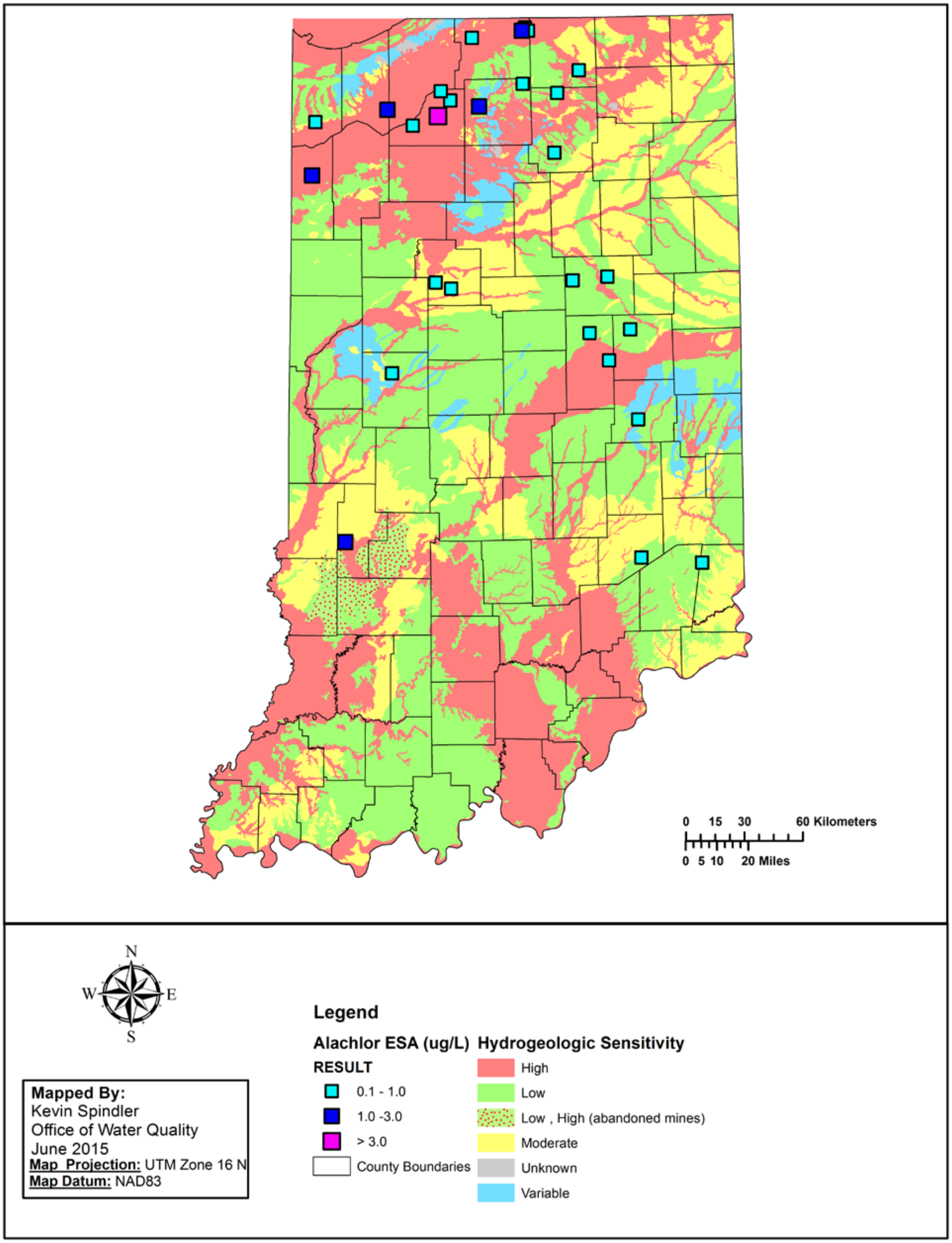


Figure 11: Round 6 Pesticide Degradate Results – Alachlor OA

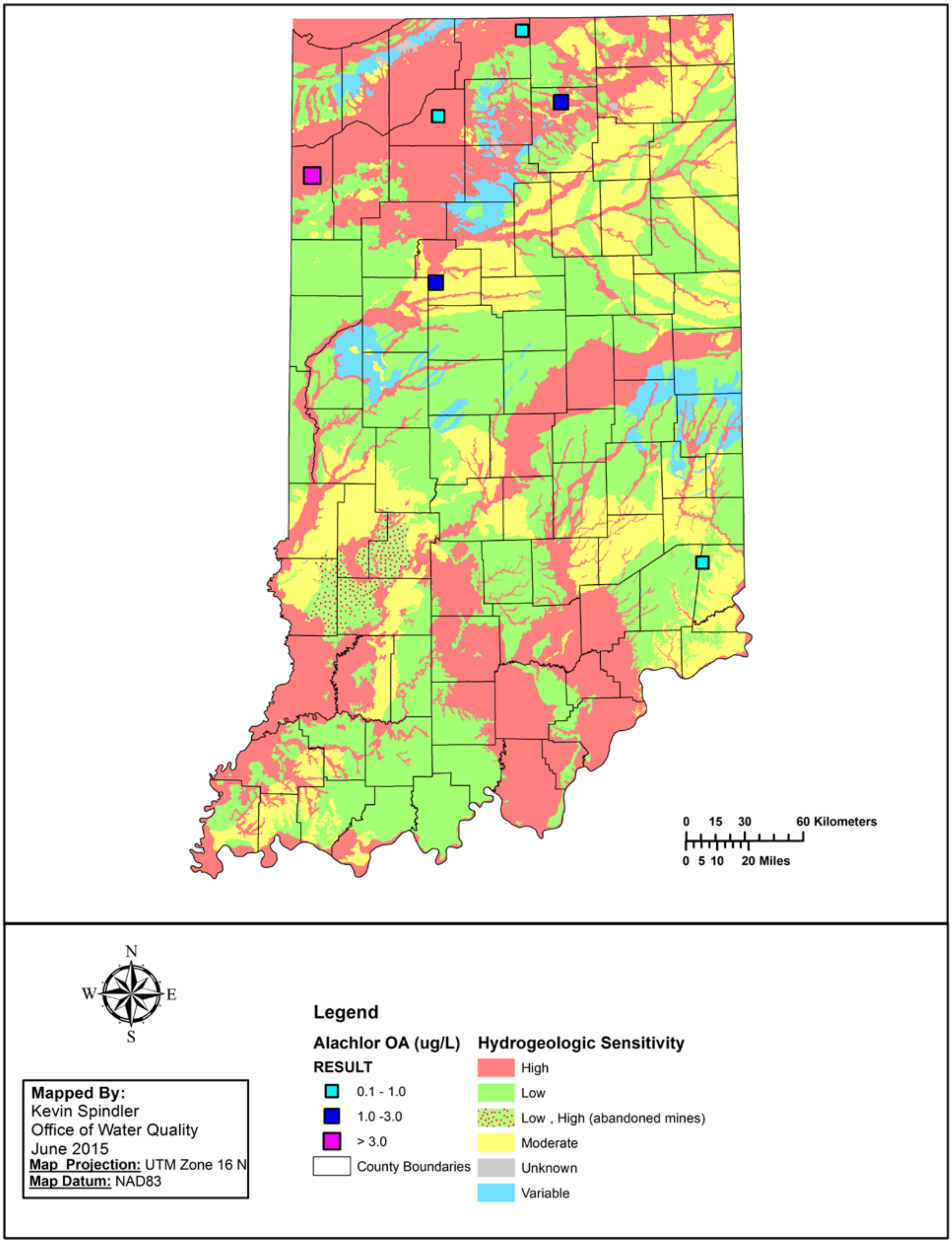


Figure 12: Round 6 Pesticide Degradate Results – Metolachlor ESA

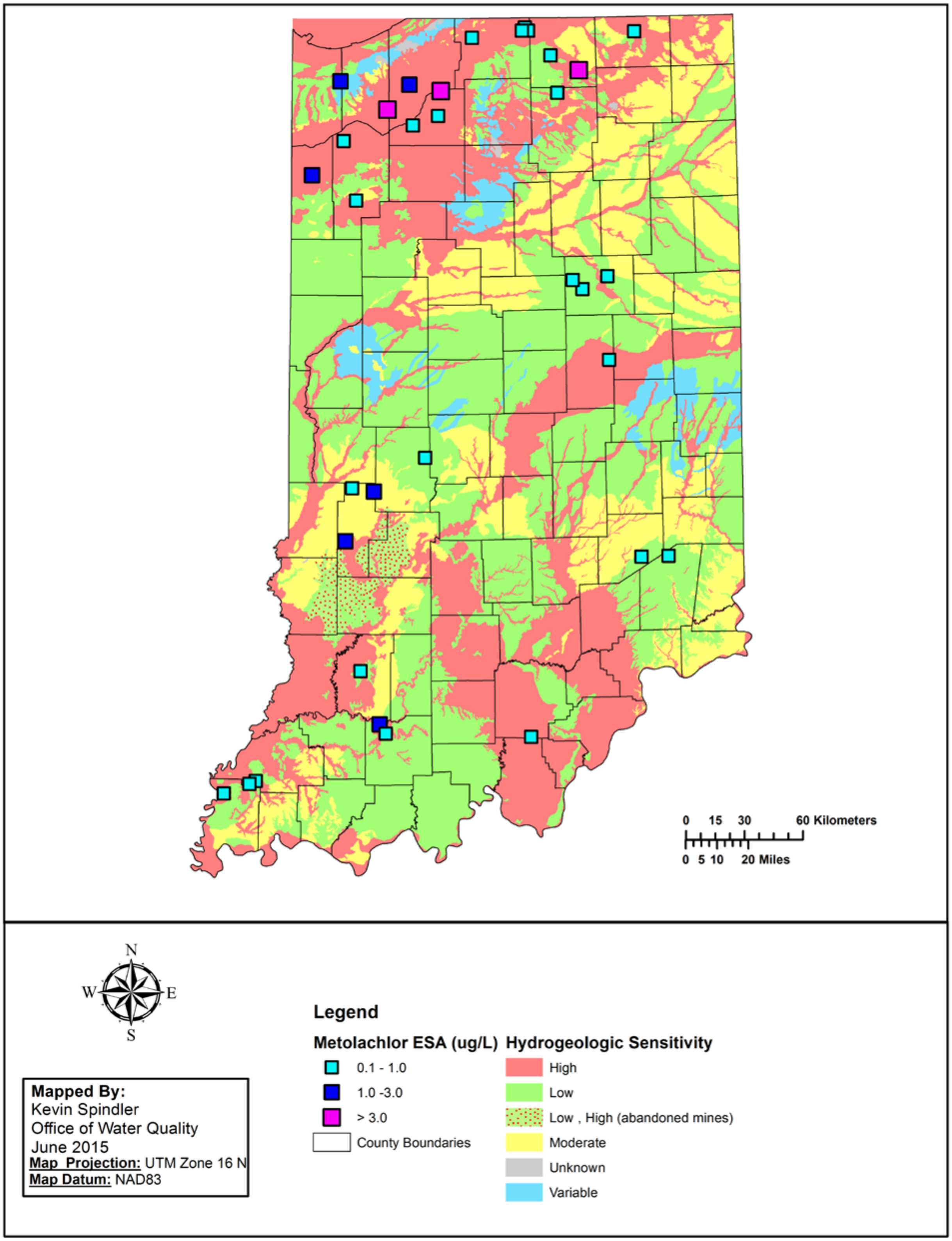
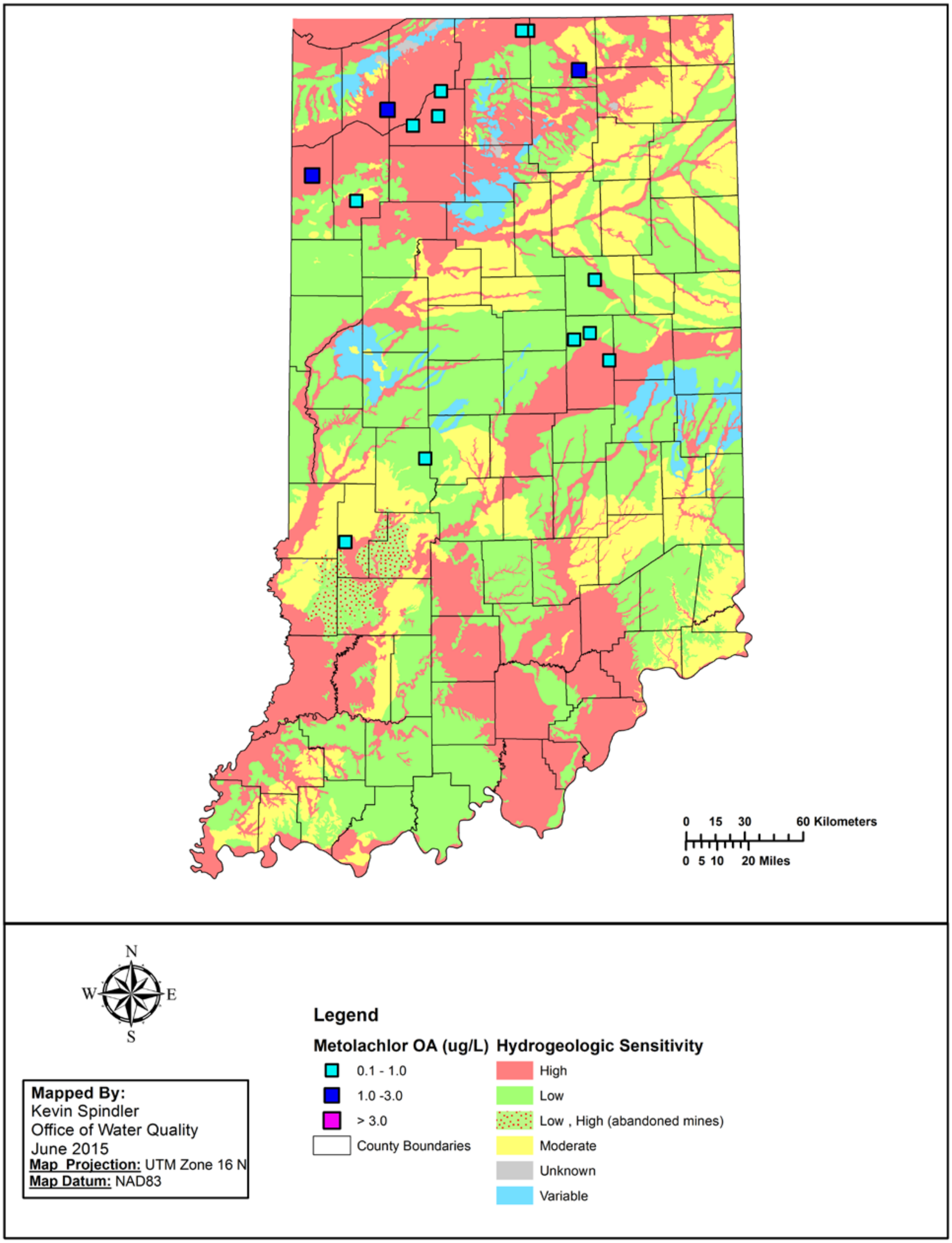


Figure 13: Round 6 Pesticide Degradate Results – Metolachlor OA



3.5 Iron

Three hundred sixteen of the Round 6 Ground Water Monitoring Network (GWMN) samples (81%) contained detectable levels of Iron. Around 263 of the samples (67%) contained Iron concentrations above the U.S. EPA secondary maximum contaminant level (SMCL) (0.3 mg/L), with the highest detected concentration of 14 mg/L. Iron is a naturally-occurring element that is found in ground water under natural conditions (usually) at no more than a few parts per million. When Iron is present in ground water it may also be associated with Iron bacteria that can either fix Iron to the plumbing or dissolve it, producing characteristic rust stains on the plumbing fixtures and toilet bowl and/or laundry. Tables 13 through 15 show summary statistics for Iron samples by hydrogeologic setting, aquifer sensitivity, and well type, respectively.

Hydrogeologic settings with the highest percentage of samples with levels of Iron above the SMCL include the Ablation Sequences (100%), Till Cored Moraine (84%), Till Plain (80%), Tunnel Valley (80%), and Unconfined Outwash Fan (81%) settings. Conversely, the hydrogeologic settings that relied on ground water from bedrock aquifers contained lesser amount of Iron. For the entire data set, around 71% of the Round 6 GWMN samples from unconsolidated wells contained Iron above the SMCL, compared with 59% of bedrock wells.

Settings with low aquifer sensitivities contained levels of Iron above the SMCL in 74% of samples, compared to 60% of samples from highly sensitive settings. The low sensitivity setting samples contained a higher mean Iron concentration (1.47 mg/L) than the high sensitivity settings (1.04 mg/L). Additional geochemical modeling and statistical analysis of Iron in ground water is needed to determine the relationship between Iron and hydrogeological factors in the aquifer.

Table 13: Iron Summary Statistics by Hydrogeologic Setting

	Number of Samples	Number Above Detection Limit (ADL)	% ADL	Number Above MCL	% Above MCL	Median	Mean	Min	Max	Standard Dev
Ablation Sequence	5	5	100	5	100	1.50	2.01	0.37	5.10	1.84
Alluvial Valley	5	3	60	3	60	0.77	0.64	0.01	1.60	0.66
Dissected Bedrock	4	2	50	2	50	2.56	4.78	0.01	14.00	6.60
Dissected Bedrock Thin Till	17	8	47	3	18	0.01	0.16	0.01	1.00	0.28
Fan Head Complex	5	4	80	3	60	0.93	0.86	0.01	2.10	0.87
Ice Contact Deposits	2	1	50	1	50	1.16	1.16	0.01	2.30	1.62
Karst Plain and Escarpment	9	3	33	2	22	0.01	0.11	0.01	0.50	0.18
Lake Deposits	5	4	80	1	20	0.03	0.37	0.01	1.50	0.64
Meltwater Channel	1	1	100	1	100	1.70	1.70	1.70	1.70	--
Outwash Complex	6	4	67	4	67	1.80	1.65	0.01	3.70	1.52
Outwash Plain	22	19	86	13	59	0.65	0.94	0.01	4.00	1.02
Sand Plains and Loess Sands	30	24	80	14	47	0.24	0.79	0.01	6.10	1.37
Sluiceway or Discrete Channel	34	22	65	20	59	0.95	1.23	0.01	4.50	1.31
Till Capped Fan	9	7	78	6	67	2.00	1.60	0.01	4.20	1.46
Till Cored Moraine	44	39	89	37	84	1.75	1.81	0.01	8.00	1.50
Till Plain	151	139	92	121	80	1.30	1.37	0.01	4.60	1.01
Trough System	4	2	50	2	50	0.36	0.46	0.01	1.10	0.54
Tunnel Valley	10	9	90	8	80	1.45	1.40	0.01	3.40	1.06
Unconfined Outwash Fan	16	14	88	13	81	1.25	1.18	0.01	2.30	0.78
Wabash River Valley	11	6	55	4	36	0.04	1.44	0.01	11.00	3.24

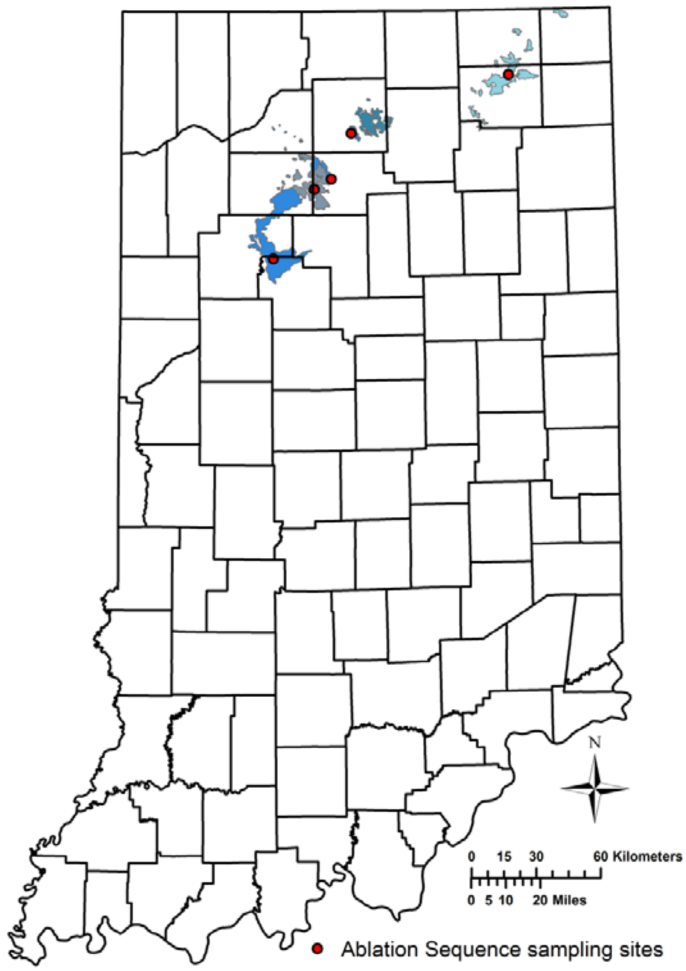
Table 14: Iron Summary Statistics by Aquifer Sensitivity										
	Number of Samples	Number Above Detection Limit (ADL)	% ADL	Number Above MCL	% Above MCL	Median	Mean	Min	Max	Standard Dev
High	144	105	73	87	60	0.71	1.04	0.01	6.100	1.170
Low	145	125	86	107	74	1.30	1.47	0.01	14.00	1.649
Low, High (abandoned mines)	4	3	75	1	25	0.12	0.23	0.01	0.670	0.306
Moderate	69	57	83	47	68	1.10	1.18	0.01	4.500	1.081
Variable	28	26	93	21	75	1.50	1.74	0.01	11.00	2.102

Table 15: Iron Summary Statistics by Well Type (mg/L)										
	Number of Samples	Number Above Detection Limit (ADL)	% ADL	Number Above MCL	% Above MCL	Median	Mean	Min	Max	Standard Dev
Bedrock	118	91	77	70	59	0.55	1.11	0.010	14.000	1.872
Unconsolidated	272	225	83	193	71	1.30	1.34	0.010	8.000	1.209

3.6 Water Quality in Hydrogeologic Settings

3.6.1 Ablation Sequence Setting

Figure 14



Ablation Sequences are composed of various series consisting primarily of ablation till (sometimes referred to as melt-out till). The Ablation Sequences can range from being massive, densely compacted and poorly sorted to thin sequences of sandy to loamy ablation sediments that locally contain significant outwash deposits. These sediments are highly sensitive due to a shallow water table and permeable surface sediments.

For Sampling Round 6 of the Ground Water Monitoring Network, five samples were collected in the Ablation Sequences setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (22.6 mg/L average concentration), Ca (70.0 mg/L), Na (46.9 mg/L), K (1.3 mg/L), SO_4 (48.0 mg/L), and Cl^- (16.8 mg/L).

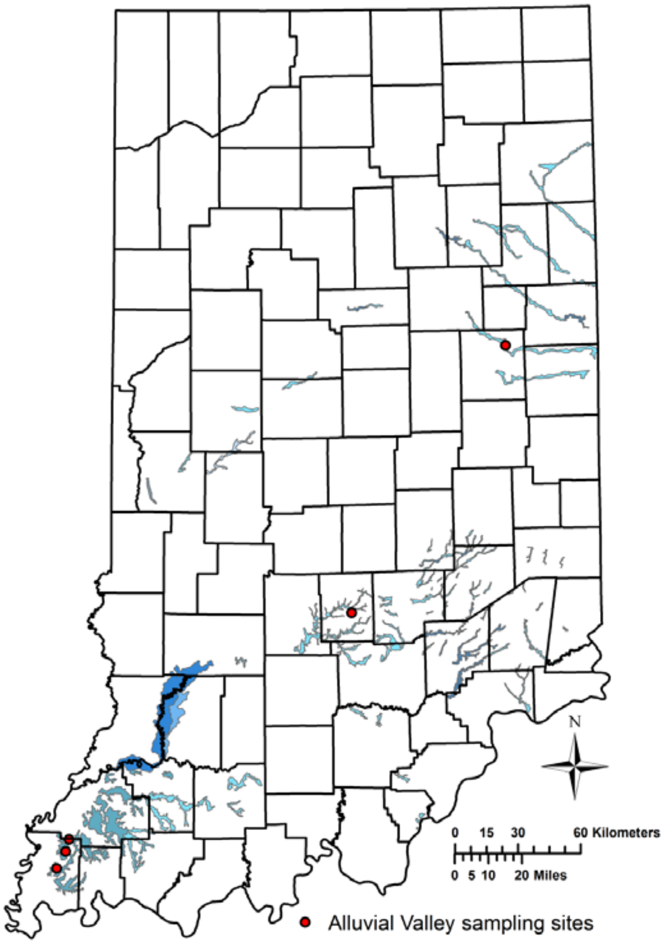
Arsenic was detected in three (60%) of the Round 6 samples from the Ablation Sequences setting, including one sample (20%) that exceeded U.S. EPA's maximum contaminant level (MCL) (10 µg/L). In the Ablation Sequences setting, the highest arsenic concentration was found in the sample from a bedrock well (16 µg/L vs. 2.65 µg/L average for unconsolidated wells). The highest average concentrations were found in wells screened from 100 to 150 feet below the ground surface (9.25 µg/L).

Nitrate was not detected in any of the samples collected from the Ablation Sequences setting.

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in all five of the samples from the Ablation Sequences setting. **Pesticide Degradates** for Acetochlor, Alachlor, or Metolachlor were not detected in these samples.

3.6.2 Alluvial Valley Setting

Figure 15



The **Alluvial Valley** setting is made up of modern stream valleys and floodplains that consist of fine to coarse grained alluvial sediments. Aquifers can be narrow in width and deeply incised in bedrock. The water table is quite shallow (less than 5 feet), and often act as local discharge areas for ground water flow.

For Sampling Round 6 of the Ground Water Monitoring Network, five samples were collected in the Alluvial Valley setting. The water type in this setting is dominated by **calcium** and **sodium/potassium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (24.1 mg/L average concentration), Ca (58.0 mg/L), Na (58.7 mg/L), K (2.1 mg/L), SO_4 (16.8 mg/L), and Cl^- (16.2 mg/L).

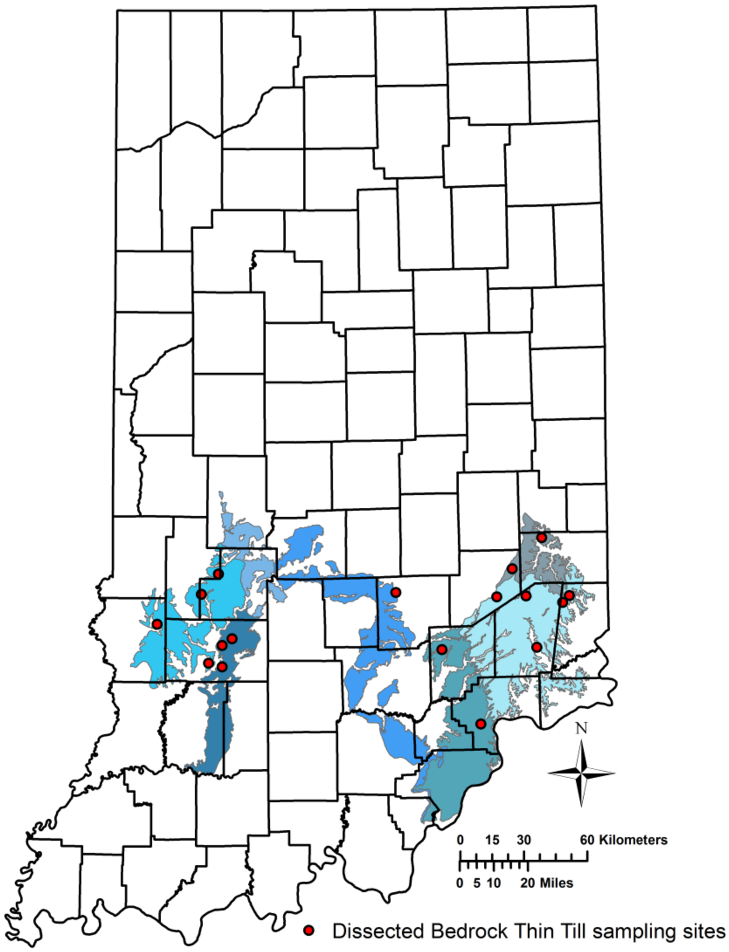
Arsenic was detected in one of the Round 6 samples from the Alluvial Valley setting (20%), which exceeded U.S. EPA's maximum contaminant level (10 µg/L). The arsenic detection occurred in a bedrock well that had a depth of greater than 150 feet below the ground surface.

Nitrate was detected in two of the Round 6 samples from the Alluvial Valley setting; none exceeded U.S. EPA's MCL (10 µg/L). In the Alluvial Valley setting, the samples that contained detectable levels of nitrate were found in oxidizing aquifers, with no nitrate detected in aquifers showing reducing conditions.

Iron was also found above U.S. EPA's secondary maximum contaminant level (0.3 mg/L) in three of the five samples (60%). **Pesticide Degradates** for Acetochlor, Alachlor, and Metolachlor were not detected in these samples.

3.6.3 Dissected Bedrock Thin Till Setting

Figure 16



Unconsolidated deposits in the **Dissected Bedrock Thin Till** setting are generally less than 50 feet in thickness over large areas; and laterally extensive sand and gravel units are not common. The unconsolidated deposits overlie moderately to strongly dissected bedrock units, which include interbedded sandstone and mudstone, shale, and karst-forming limestone. Ground water availability in the setting is generally poor, except along bedrock fractures and zones of major solution features.

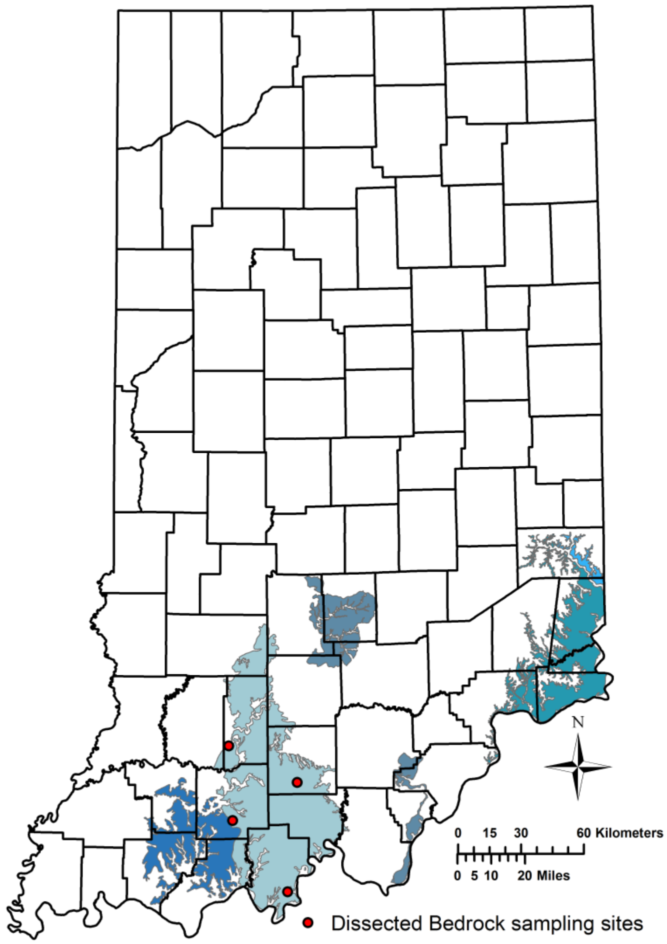
For Sampling Round 6 of the Ground Water Monitoring Network, 17 samples were collected in the Dissected Bedrock Thin Till setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**, with some sodium/potassium types. Major anions and cations detected in this setting include: Mg (20.5 mg/L average concentration), Ca (66.3 mg/L), Na (61.8 mg/L), K (1.1 mg/L), SO_4 (47.9 mg/L), and Cl^- (19.4 mg/L).

Arsenic was detected in three (around 18%) of the Round 6 samples from the Dissected Bedrock Thin Till setting; none of the samples exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Dissected Bedrock Thin Till setting, the highest average arsenic concentrations were found in samples from unconsolidated wells (1.5 µg/L average vs. 1.1 µg/L average for bedrock wells). The highest average concentrations were found in wells screened from 50 to 100 feet below the ground surface (1.78 µg/L). Aquifers that were under reducing conditions had a higher average arsenic concentration (1.14 µg/L) than aquifers under oxidizing conditions (1.12 µg/L).

Nitrate was detected in 11 (around 65%) of the Round 6 samples from the Dissected Bedrock Thin Till setting, and one of those samples exceeded U.S. EPA's MCL (10 µg/L). In the Dissected Bedrock Thin Till setting, the highest average nitrate concentrations were found in samples from unconsolidated wells (3.58 mg/L average vs. 0.45 mg/L average for bedrock wells), and in wells screened less than 50 feet below the ground surface (4.97 mg/L average). Aquifers that were under oxidizing conditions had a higher average nitrate concentration (3.13 mg/L) than aquifers under reducing conditions (0.17 mg/L).

3.6.4 Dissected Bedrock Setting

Figure 17



The **Dissected Bedrock** setting is predominantly a broad upland defined by outcrops of several relatively-resistant rock units. Individual hydrogeologic settings within this general setting generally correspond to the major bedrock units in the area, including the siltstone, shale, and interbedded shale and sandstone. Ground water availability tends to be poor in this setting, and occurs in fractures and along bedding plains.

For Sampling Round 6 of the Ground Water Monitoring Network, four samples were collected in the Dissected Bedrock setting. The water type in this setting is dominated by **sodium/potassium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (27.0 mg/L average concentration), Ca (65.3 mg/L), Na (154.6 mg/L), K (2.7 mg/L), SO_4 (194.6 mg/L), and Cl^- (90.1 mg/L).

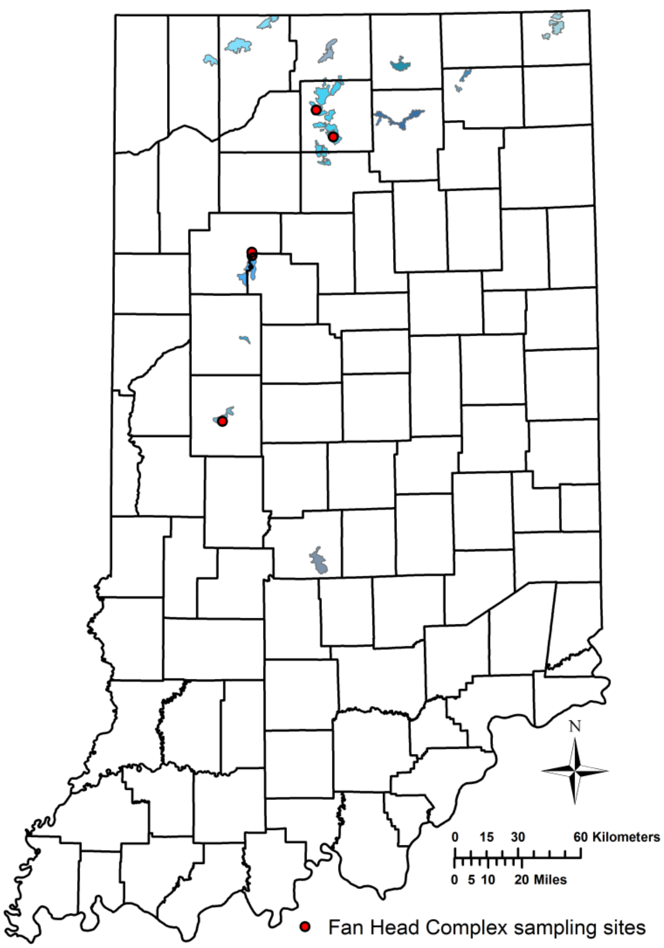
Arsenic was detected in one (25%) of the Round 6 samples from the Dissected Bedrock setting; none of the samples exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Dissected Bedrock setting, the highest average arsenic concentrations were found in samples from bedrock wells (2.0 µg/L average vs. 1 µg/L average for bedrock wells). The highest average concentrations were found in wells screened greater than 150 feet below the ground surface (2.0 µg/L).

Nitrate was detected in two (50%) of the Round 6 Samples from the Dissected Bedrock setting; none exceeded U.S. EPA's MCL (10 µg/L).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in two of the samples from the Dissected Bedrock setting (50%). **Pesticide Degradates** for Acetochlor, Alachlor, and Metolachlor were not detected in these samples.

3.6.5 Fan Head Complex Setting

Figure 18



Fan Head Complexes are the near-ice ends of outwash fans, and typically contain a variety of coarse grained sand and gravel deposits. Fan Heads consist of massive high relief terrain composed of both till capped and exposed sand and gravel deposits. Although ground water is present at considerable depth, the setting has variable sensitivity depending on the thickness of surficial till deposits.

For Sampling Round 6 of the Ground Water Monitoring Network, five samples were collected in the Fan Head Complex setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**, with some sodium/potassium types. Major anions and cations detected in this setting include: Mg (26.2 mg/L average concentration), Ca (75.8 mg/L), Na (53.6 mg/L), K (1.1 mg/L), SO_4 (47.9 mg/L), and Cl^- (39.8 mg/L).

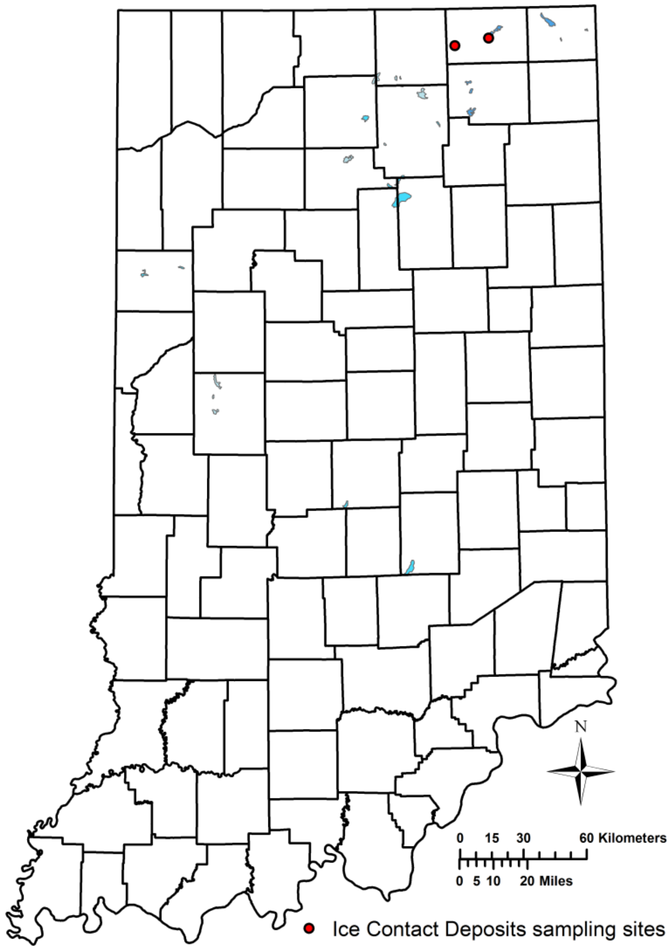
Arsenic was detected in one of the Round 6 samples from the Fan Head Complex setting at 3.2 µg/L, and did not exceed U.S. EPA's maximum contaminant level (10 µg/L).

Nitrate was also detected in one of the Round 6 samples from the Fan Head Complex setting at 0.38 mg/L, and did not exceed U.S. EPA's MCL (10 µg/L).

Iron was found above U.S. EPA's secondary MCL (0.3 mg/L) in three of the samples from the Fan Head Complex setting (60%). The **Pesticide Degradate Alachlor ESA** was found in one sample at a concentration of 1.4 µg/L.

3.6.6 Ice Contact Deposits Setting

Figure 19



Ice Contact Deposits are those deposits which were deposited on top, beneath, or on the side of glacial ice. Linear ridges chiefly composed of sand and gravel, also known as eskers, were deposited along melt water channels on top or within glacial ice. Irregular, isolated mounds and hummocky elongated ridges that may or may not be isolated features and can be composed entirely of sand and gravel or a chaotic complex of granular and till-like units have traditionally been known as kames.

For Sampling Round 6 of the Ground Water Monitoring Network, two samples were collected in the Ice Contact Deposits setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (26.0 mg/L average concentration), Ca (87.0 mg/L), Na (6.7 mg/L), K (3.4 mg/L), SO_4 (16.8 mg/L), and Cl^- (10.8 mg/L).

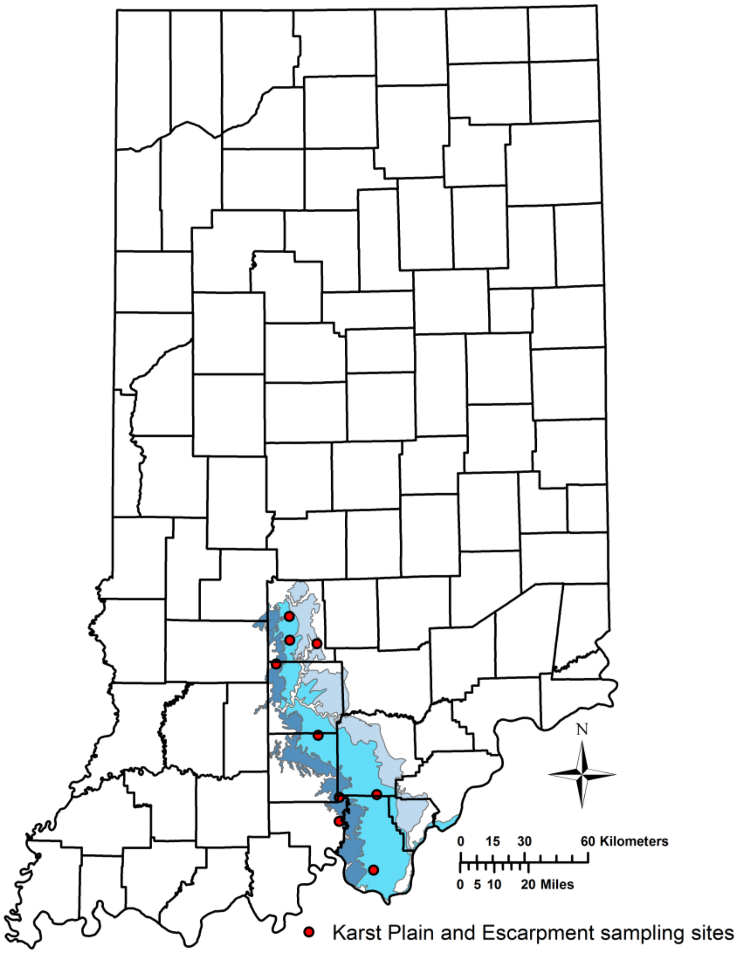
Arsenic was detected in one of the Round 6 samples from the Ice Contact Deposits setting (50%), which exceeded U.S. EPA's maximum contaminant level (10 µg/L) at 12 µg /L.

Nitrate was detected in one of the Round 6 samples from the Ice Contact Deposits setting, which exceeded U.S. EPA's MCL (10 µg/L) at 14 mg/L.

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in one of the samples from the Ice Contact Deposits setting (50%). **Pesticide Degradates** for Acetochlor, Alachlor, and Metolachlor were not detected in this sample.

3.6.7 Karst Plain and Escarpment Setting

Figure 20



The primary **Karst Plain** in Indiana is also known as the Mitchell Plain. This is a classic karst region of south-central Indiana that corresponds to the outcrop of middle Mississippian limestone. Secondary permeability is spectacularly developed at many places in the form of caverns, caves and enlarged joints. The Mitchell Plain has a well-developed cap of residual soil known as the "terra rossa" which typically measures between 15 and 30 feet thick. Recharge can be quite rapid in areas with numerous sink holes. Ground water and surface water are intimately interrelated, with many sink holes and sinking streams that contribute to subterranean drainages. Ground water beneath large parts of the Mitchell Plain should be regarded as highly sensitive to contamination from agricultural chemicals.

For Sampling Round 6 of the Ground Water Monitoring Network, nine samples were collected in the Karst Plain and Escarpment setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**, with some sulfate and sodium/potassium types. Major anions and cations detected in this setting include: Mg (40.7 mg/L average concentration), Ca (109.1 mg/L), Na (31.8 mg/L), K (1.9 mg/L), SO_4 (195.4 mg/L), and Cl^- (25.1 mg/L).

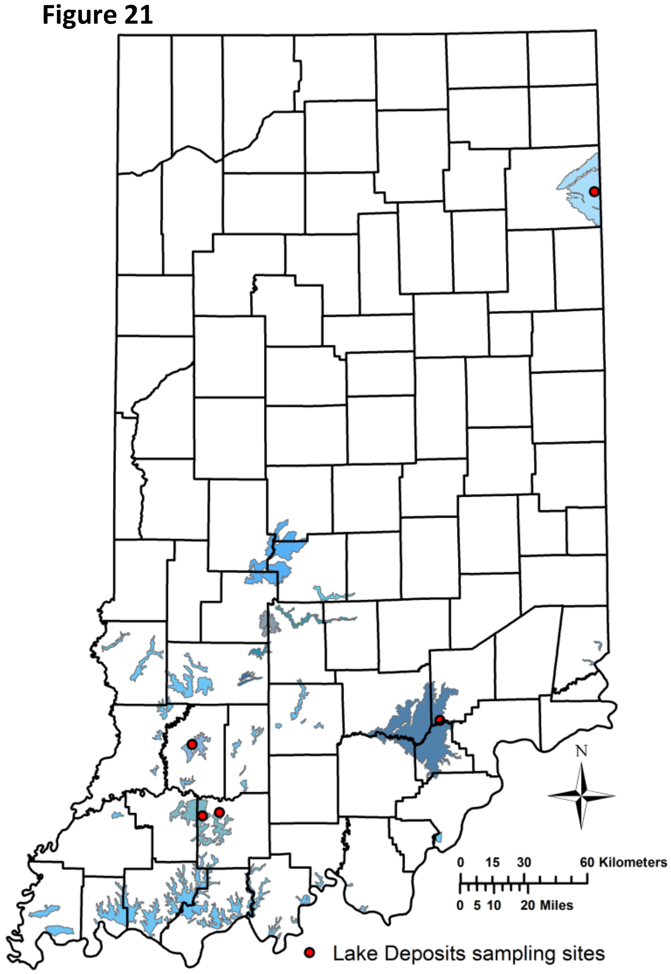
Arsenic was not detected in any of the Round 6 samples from the Karst Plain and Escarpment setting.

Nitrate was detected in seven (around 78%) of the Round 6 samples from the Karst Plain and Escarpment setting; none exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Karst Plain and Escarpment setting, the highest average nitrate concentrations were found in samples from areas with a cultivated crops land use (7.9 mg/L average), and in wells screened less than 50 feet below the ground surface (6.0 mg/L average).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in two of the samples from the Karst Plain and Escarpment setting (22%). The **Pesticide Degradate Metolachlor ESA** was found in one sample at a concentration of 0.9 µg/L.

3.6.8 Lake Deposits Setting

Figure 21



Lake Deposits are formed from sediment-laden meltwater along the margins of glacial ice sheets. Silts and fine sands are the predominant sediment type in this setting. Although the water table is rarely more than a few feet below the ground surface, the fine grain sediments generally have a low-permeability.

For Sampling Round 6 of the Ground Water Monitoring Network, five samples were collected in the Lake Deposits setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**, with some sulfate types. Major anions and cations detected in this setting include: Mg (26.3 mg/L average concentration), Ca (70.8 mg/L), Na (42.6 mg/L), K (1.2 mg/L), SO_4 (61.1 mg/L), and Cl^- (18.4 mg/L).

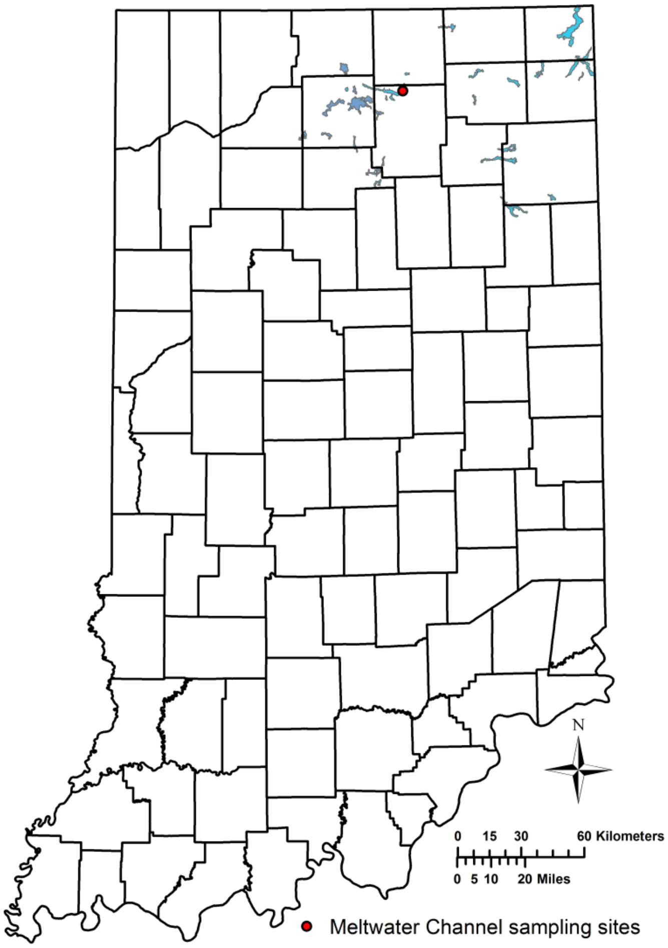
Arsenic was detected in two (40%) of the Round 6 samples from the Lake Deposits setting, including one sample that exceeded U.S. EPA's maximum contaminant level (10 µg/L) at 21 µg/L. In the Lake Deposits setting, the arsenic detections were found in bedrock wells screened more than 100 feet below the ground surface.

Nitrate was detected in three (60%) of the Round 6 samples from the Lake Deposits setting; none exceeded U.S. EPA's MCL (10 µg/L). In the Lake Deposits setting, the highest average nitrate concentrations were found in samples from unconsolidated wells (2.0 mg/L average vs. 0.005 mg/L average for bedrock wells). Aquifers that were under reducing conditions had a higher average nitrate concentration (3.85 mg/L) than aquifers under oxidizing conditions (0.12 mg/L).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in one of the samples from the Lake Deposits setting at 1.5 mg/L. The **Pesticide Degradate Metolachlor ESA** was found in one sample at a concentration of 0.7 µg/L.

3.6.9 Meltwater Channel Setting

Figure 22



Meltwater Channels are tributary channels that are typically underlain by a mix of granular and till units of widely ranging thicknesses. These channels are sharply entrenched and linear. The channels tend to be poorly drained, and frequently contain wetlands.

For Sampling Round 6 of the Ground Water Monitoring Network, one sample was collected in the Meltwater Channel setting. The water type in this sample consists of **calcium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (44 mg/L), Ca (100 mg/L), Na (8.3 mg/L), K (1.6 mg/L), SO_4 (75 mg/L), and Cl^- (28 mg/L).

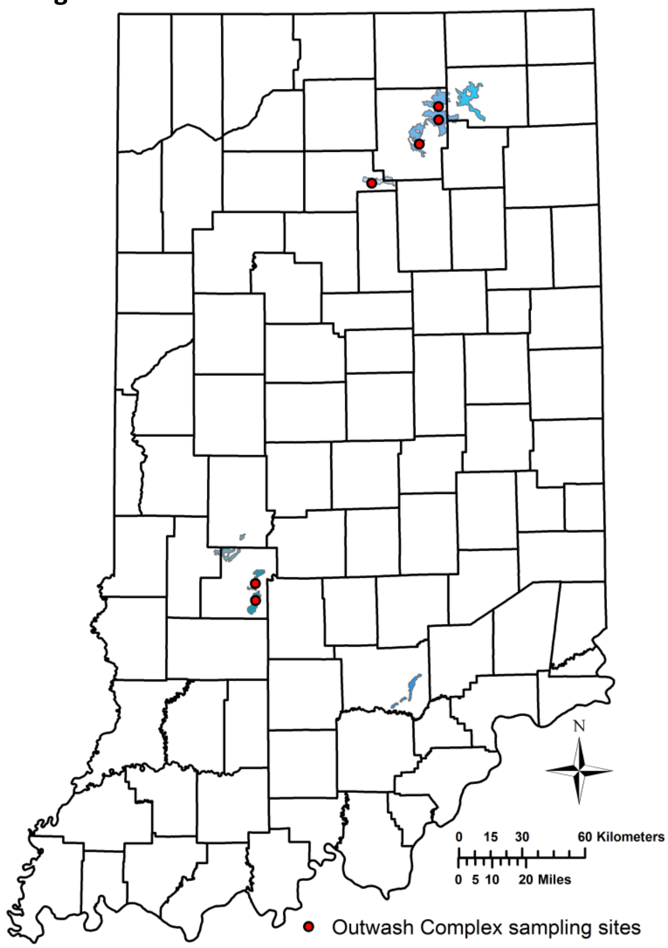
Arsenic was detected in the Round 6 sample from the Meltwater Channel setting at a concentration of 6. µg/L, which does not exceed U.S. EPA's maximum contaminant level (10 µg/L).

Nitrate was not detected in the Round 6 sample from the Meltwater Channel setting.

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in the sample from the Meltwater Channel setting at 1.7 mg/L. Several **Pesticide Degradates** were found in the sample, including: **Acetochlor ESA** (0.3 µg/L), **Alachlor ESA** (0.3 µg/L), and **Metolachlor ESA** (0.3 µg/L).

3.6.10 Outwash Complex Setting

Figure 23



The **Outwash Complex** setting is comprised of rolling to hummocky landscape and thin units of disconnected sand and gravel. There are discontinuous tills within the sequence. Unconsolidated sediments can be up to 150 feet, but generally range in thickness from 20 to 40 feet. The surface is highly permeable and leads to considerable recharge. The ground water flow is likely to be shallow and has an elevated sensitivity.

For Sampling Round 6 of the Ground Water Monitoring Network, six samples were collected in the Outwash Complex setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (29.3 mg/L average concentration), Ca (100.5 mg/L), Na (7.6 mg/L), K (1.0 mg/L), SO_4 (56.2 mg/L), and Cl^- (14.5 mg/L).

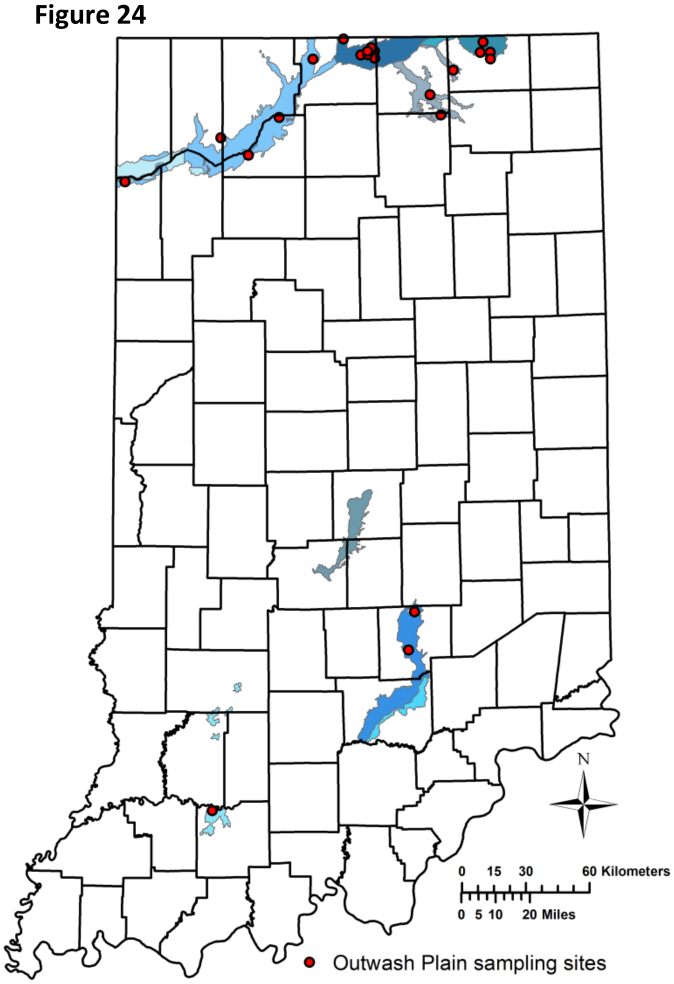
Arsenic was detected in two (around 33%) of the Round 6 samples from the Outwash Complex setting; none of them exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Outwash Complex setting, the highest average arsenic concentrations were found in samples from unconsolidated wells (3.15 µg/L average vs. non-detect for bedrock wells). The highest average concentrations were found in wells screened from 100 to 150 feet below the ground surface (3.87 µg/L). Aquifers that were under reducing conditions had a higher average arsenic concentration (3.15 µg/L) than aquifers under oxidizing conditions (non-detect).

Nitrate was detected in two (around 33%) of the Round 6 samples from the Outwash Complex setting; none exceeded U.S. EPA's MCL (10 µg/L). In the Outwash Complex setting, the highest average nitrate concentrations were found in samples from bedrock wells (0.37 mg/L average vs. non-detect for unconsolidated wells), and in wells screened more than 100 feet below the ground surface. Aquifers that were under oxidizing conditions had a higher average nitrate concentration (0.29 mg/L) than aquifers under reducing conditions (non-detect).

Iron was also found above U.S. EPA's Secondary MCL (0.3 mg/L) in four of the samples from the Outwash Complex setting (67%). None of the samples contained **Pesticide Degradates** for Acetochlor, Alachlor, or Metolachlor.

3.6.11 Outwash Plain Setting

Figure 24



Outwash Plains are typically broad flat expanses and comprised of thick units of highly permeable outwash sand and gravel. Clay lenses and sheets of till may locally divide the outwash into discrete aquifers. A combination of thick outwash sequences and shallow water table make this setting highly vulnerable to surficial contamination.

For Sampling Round 6 of the Ground Water Monitoring Network, 22 samples were collected in the Outwash Plain setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (22.4 mg/L average concentration), Ca (73.5 mg/L), Na (13.6 mg/L), K (1.5 mg/L), SO_4 (42.4 mg/L), and Cl^- (23.5 mg/L).

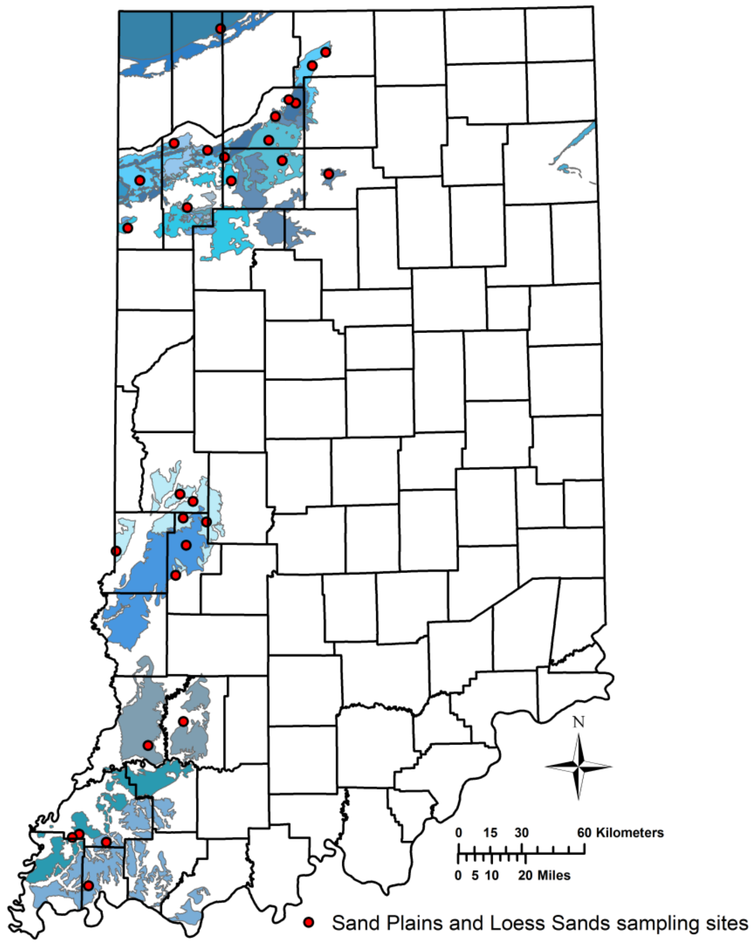
Arsenic was detected in seven (around 32%) of the Round 6 samples from the Outwash Plain setting, including two samples (9%) that exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Outwash Plain setting, the highest average arsenic concentrations were found in samples from unconsolidated wells (3.22 µg/L average vs. non-detect for bedrock wells). The highest average concentrations were found in wells screened from 50 to 150 feet below the ground surface. Aquifers that were under reducing conditions had a higher average arsenic concentration (3.75 µg/L) than aquifers under oxidizing conditions (non-detect).

Nitrate was detected in eight (around 36%) of the Round 6 samples from the Outwash Plain setting, including two samples (9%) that exceeded the MCL (10 µg/L). In the Outwash Plain setting, the highest average nitrate concentrations were found in samples from the cultivated crops land use area (4.0 mg/L), and in wells screened less than 50 feet below the ground surface (4.04 mg/L average). Aquifers that were under oxidizing conditions had a higher average nitrate concentration (9.14 mg/L) than aquifers under reducing conditions (0.71 mg/L).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in 13 of the samples from the Outwash Plain setting (59%). **Pesticide Degradates** were found in several samples, including: **Acetochlor ESA** (5 samples, 2.1 µg/L max), **Acetochlor OA** (1 sample, 0.3 µg/L max), **Alachlor ESA** (8 samples, 2.2 µg/L max), **Alachlor OA** (1 sample, 0.2 µg/L max), **Metolachlor ESA** (10 samples, 7.8 µg/L max), and **Metolachlor OA** (6 samples, 2.9 µg/L max).

3.6.12 Sand Plains and Loess Sands Setting

Figure 25



The **Sand Plains and Loess Sands** setting is typified by wind-blown and lake deposited sand and loess (silt) deposits overlying sand and gravel deposits or bedrock. Both sand and loess deposits may reach thicknesses ranging from 10 to 50 feet and possess surficial topographies ranging from flat to rolling dune topographies. Sand and Loess Plains are highly permeable and vulnerable to ground water contamination.

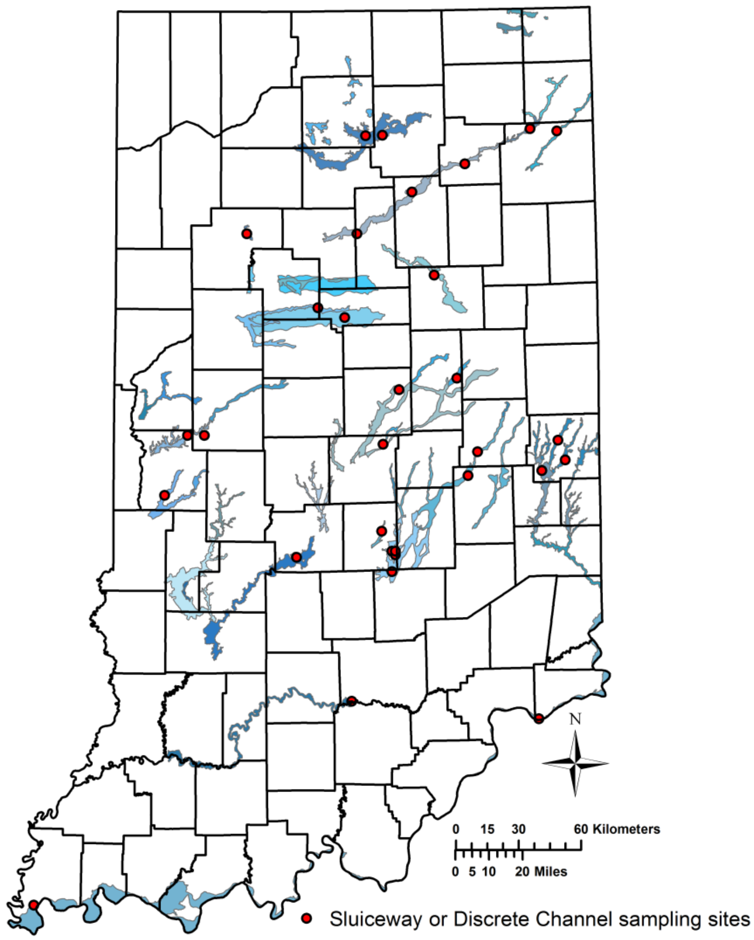
For Sampling Round 6 of the Ground Water Monitoring Network, 30 samples were collected in the Sand Plains and Loess Sands setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**, with some sodium/potassium types. Major anions and cations detected in this setting include: Mg (21.8 mg/L average concentration), Ca (59.3 mg/L), Na (36.3 mg/L), K (1.6 mg/L), SO_4 (25.2 mg/L), and Cl^- (18.5 mg/L).

Arsenic was detected in seven (around 23%) of the Round 6 samples from the Sand Plains and Loess Sands setting, including three samples (10%) that exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Sand Plains and Loess Sands setting, the highest average arsenic concentrations were found in samples from unconsolidated wells (6.28 µg/L average vs. non-detect for bedrock wells). The highest average concentrations were found in wells screened from 100 to 150 feet below the ground surface (11.33 µg/L). Areas of high aquifer sensitivity contained a higher average arsenic concentration (6.28 µg/) than low and moderate sensitivity areas. The cultivated crops land use area contained a higher average arsenic concentration (6.28 µg/L) than deciduous forest or developed, low intensity categories. Aquifers that were under reducing conditions had a higher average arsenic concentration (5.86 µg/L) than aquifers under oxidizing conditions (1.73 µg/L).

Nitrate was detected in 17 (around 57%) of the Round 6 samples from the Sand Plains and Loess Sands setting; one exceeded U.S. EPA's MCL (10 µg/L) at 16.0 mg/L. In the Sand Plains and Loess Sands setting, the highest average nitrate concentrations were found in samples from bedrock wells (3.04 mg/L average vs. 0.83 mg/L average for unconsolidated wells. The cultivated crops land use area contained a higher average nitrate concentration (2.30 µg/L) than deciduous forest or developed, low intensity categories.

3.6.13 Sluiceway or Discrete Channel Setting

Figure 26



The **Sluiceway and Discrete Channel** settings are very similar to Outwash Plains, but differ by being more channelized, narrower and are essentially well developed troughs that are significantly entrenched into surrounding terrains. Like outwash plains, sluiceways contain abundant sand and gravel deposits reaching significant depths. A combination of thick outwash sequences and shallow water table make this setting highly vulnerable to surficial contamination.

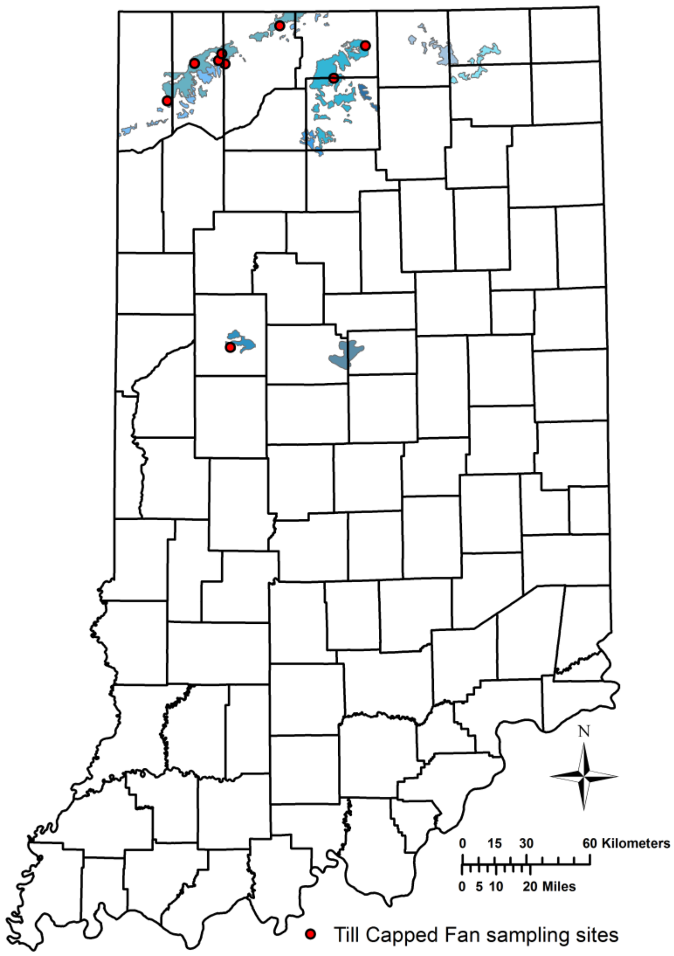
For Sampling Round 6 of the Ground Water Monitoring Network, 34 samples were collected in the Sluiceway and Discrete Channel setting. The water type in this setting is dominated by **calcium** and **bicarbonate type**. Major anions and cations detected in this setting include: Mg (26.1 mg/L average concentration), Ca (77.0 mg/L), Na (29.0 mg/L), K (1.3 mg/L), SO_4 (28.4 mg/L), and Cl^- (14.7 mg/L).

Arsenic was detected in 13 (around 38%) of the Round 6 samples from the Sluiceway and Discrete Channel setting, including three samples (9%) that exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Sluiceway and Discrete Channel setting, the highest average arsenic concentrations were found in samples from unconsolidated wells (6.67 µg/L average vs. 2.1 µg/L average for bedrock wells). The highest average concentrations were found in wells screened from 50 to 100 feet below the ground surface (9.67 µg/L). Aquifers that were under reducing conditions had a higher average arsenic concentration (8.87 µg/L) than aquifers under oxidizing conditions (non-detect).

Nitrate was detected in 15 (around 44%) of the Round 6 samples from the Sluiceway and Discrete Channel setting, including two of the samples that exceeded U.S. EPA's MCL (10 µg/L). In the Sluiceway and Discrete Channel setting, the highest average nitrate concentrations were found in samples from unconsolidated wells (2.18 mg/L average vs. 0.02 mg/L average for bedrock wells), and in wells screened less than 50 feet below the ground surface (3.87 mg/L average). Aquifers that were under oxidizing conditions had a higher average nitrate concentration (4.70 mg/L) than aquifers under reducing conditions (0.008 mg/L).
Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in 20 of the samples from the Sluiceway and Discrete Channel setting (59%). **Pesticide Degradates** were found in several samples, including: **Alachlor ESA** (1 sample, 0.6 µg/L), **Metolachlor ESA** (1 samples, 0.4 µg/L), and **Metolachlor OA** (1 sample, 0.2 µg/L).

3.6.14 Till Capped Fan Setting

Figure 27



The **Till Capped Fan** setting consists of a thin to thick cap of silt loam till atop thin to very thick sequences of sand and gravel. The principal aquifers in this setting are the various sand and gravel units below the till cap. The depth to water is shallow due to perching on the fine-grained capping units.

For Sampling Round 6 of the Ground Water Monitoring Network, nine samples were collected in the Till Capped Fan setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (33.1 mg/L average concentration), Ca (89.3 mg/L), Na (46.8 mg/L), K (3.5 mg/L), SO_4 (61.9 mg/L), and Cl^- (46.5 mg/L).

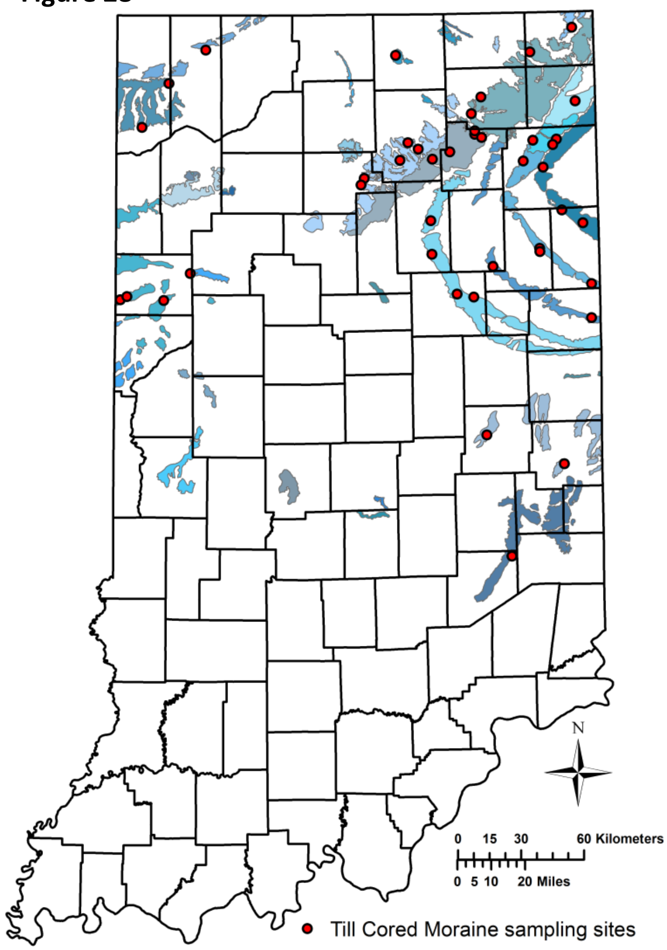
Arsenic was detected in three (around 33%) of the Round 6 samples from the Till Capped Fan setting, including one sample that exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Till Capped Fan setting, the highest average arsenic concentrations were found in samples from low sensitivity areas (15.15 µg/L average). The highest average concentrations were also found in wells screened from 100 to 150 feet below the ground surface (8.15 µg/L). Aquifers that were under reducing conditions had a higher average arsenic concentration (6.4 µg/L) than aquifers under oxidizing conditions (1.4 µg/L).

Nitrate was detected in four (around 44%) of the Round 6 samples from the Till Capped Fan setting; none exceeded U.S. EPA's MCL (10 µg/L). In the Till Capped Fan setting, the highest average nitrate concentrations were found in samples from the cultivated crops land use area (0.81 mg/L average) and in wells screened between 100 to 150 feet below the ground surface (1.04 mg/L average). Aquifers that were under oxidizing conditions had a higher average nitrate concentration (1.4 mg/L) than aquifers under reducing conditions (0.008 mg/L).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in six of the samples from the Till Capped Fan setting (67%). **Pesticide Degradates** of Acetochlor, Alachlor, and Metolachlor were not detected in these samples.

3.6.15 Till Cored Moraine Setting

Figure 28



The **Till Cored Moraine** setting consists of morainal ridges typical cored by loam till and till-like sediments. The morainal sediments range between 25 and 75 feet thick and commonly overlie a zone of fairly thick outwash. Aquifers are generally limited to confined sand and gravel units below the till, as well as the limestone or sandstone bedrock.

For Sampling Round 6 of the Ground Water Monitoring Network, 42 samples were collected in the Till Cored Moraine setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**, with some sulfate and sodium/potassium types. Major anions and cations detected in this setting include: Mg (50.5 mg/L average concentration), Ca (103.6 mg/L), Na (32.1 mg/L), K (2.3 mg/L), SO_4 (180.2 mg/L), and Cl^- (15.4 mg/L).

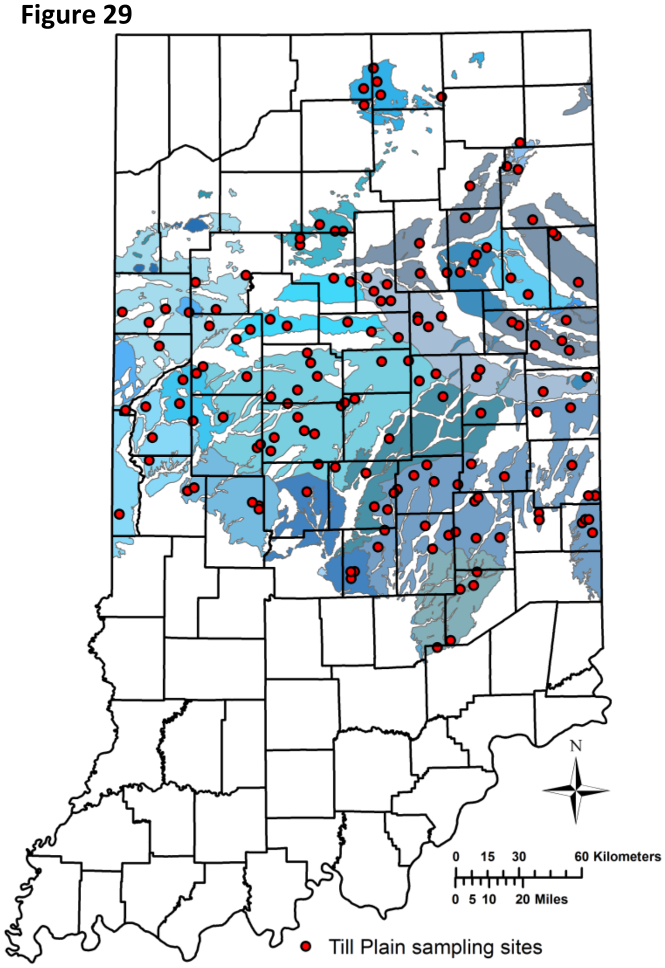
Arsenic was detected in 20 (around 45%) of the Round 6 samples from the Till Cored Moraine setting, including two samples (5%) that exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Till Cored Moraine setting, the highest average arsenic concentrations were found in samples from unconsolidated wells (3.5 µg/L average vs. 2.0 µg/L average for bedrock wells). The highest average concentrations were found in wells screened more than 150 feet below the ground surface (4.1 µg/L). Aquifers that were under reducing conditions had a higher average arsenic concentration (3.43 µg/L) than aquifers under oxidizing conditions (1.58 µg/L).

Nitrate was detected in nine (around 20%) of the Round 6 samples from the Till Cored Moraine setting; none exceeded U.S. EPA's MCL (10 µg/L). In the Till Cored Moraine setting, the highest average nitrate concentrations were found in samples from wells screened less than 50 feet below the ground surface (1.4 mg/L average).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in 37 of the samples from the Till Cored Moraine setting (84%). **Pesticide Degradates** were found in several samples, including **Alachlor ESA** (3 samples, 0.3 µg/L max) and **Metolachlor ESA** (3 samples, 1.6 µg/L max).

3.6.16 Till Plain Setting

Figure 29



The **Till Plain** general hydrogeologic setting is a vast region of predominantly low relief that covers virtually all of central Indiana. Sediments are typified by several till-dominated sequences deposited during numerous glacial events. Ground water is present in unconsolidated or bedrock aquifers at depths ranging from less than 30 feet to hundreds of feet. Most aquifers in the central Till Plain are confined or semi-confined.

For Sampling Round 6 of the Ground Water Monitoring Network, 151 samples were collected in the Till Plain setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**, with some sulfate and sodium/potassium types. Major anions and cations detected in this setting include: Mg (32.9 mg/L average concentration), Ca (82.2 mg/L), Na (32.7 mg/L), K (1.5 mg/L), SO_4 (56.1 mg/L), and Cl^- (16.1 mg/L).

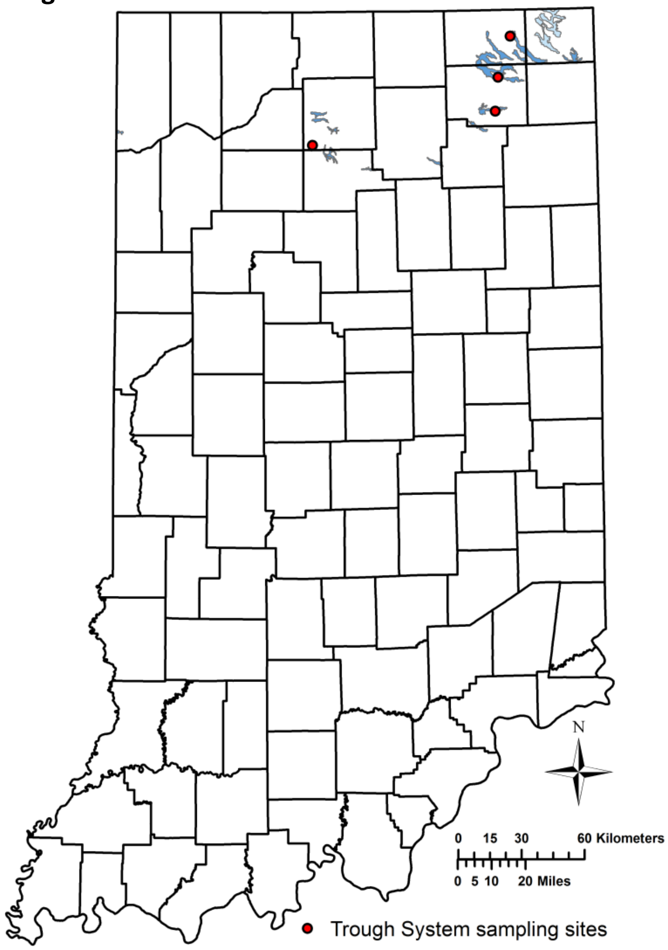
Arsenic was detected in 67 (around 44%) of the Round 6 samples from the Till Plain setting, including 25 samples (17%) that exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Till Plain setting, the highest average arsenic concentrations were found in samples from unconsolidated wells (5.8 µg/L average vs. 3.9 µg/L average for bedrock wells). The highest average concentrations were found in wells screened from 100 to 150 feet below the ground surface (8.5 µg/L). Areas of low and variable aquifer sensitivity contained a higher average arsenic concentration (5.6 and 6.6 µg/) than high sensitivity areas (3.7 µg/L average). Aquifers that were under reducing conditions had a higher average arsenic concentration (5.88 µg/L) than aquifers under oxidizing conditions (1.24 µg/L).

Nitrate was detected in 40 (around 26%) of the Round 6 Samples from the Till Plain setting; none exceeded U.S. EPA's MCL (10 µg/L). In the Till Plain setting, the highest average nitrate concentrations were found in samples from unconsolidated wells (0.20 mg/L average vs. 0.14 mg/L average for bedrock wells), and in wells screened less than 50 feet below the ground surface (0.59 mg/L average). Aquifers that were under oxidizing conditions had a higher average nitrate concentration (0.97 mg/L) than aquifers under reducing conditions (0.04 mg/L).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in 121 of the samples from the Till Plain setting (80%). **Pesticide Degradates** were found in several samples, including: **Acetochlor OA** (1 sample, 0.2 µg/L max), **Alachlor ESA** (7 samples, 0.6 µg/L max), **Alachlor OA** (1 sample, 1.4 µg/L max), **Metolachlor ESA** (3 samples, 0.6 µg/L max), and **Metolachlor OA** (4 samples, 0.3 µg/L max).

3.6.17 Trough System Setting

Figure 30



The **Trough System** setting consists of entrenched troughs of various lake sediments within morainal areas that range in width from 500 feet to 2 miles. The depth to water tends to be shallow in these areas (less than 5 feet).

For Sampling Round 6 of the Ground Water Monitoring Network, four samples were collected in the Trough System setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**, with some sodium/potassium types. Major anions and cations detected in this setting include: Mg (17.3 mg/L average concentration), Ca (56.5 mg/L), Na (46.1 mg/L), K (1.3 mg/L), SO_4 (29.6 mg/L), and Cl^- (12.4 mg/L).

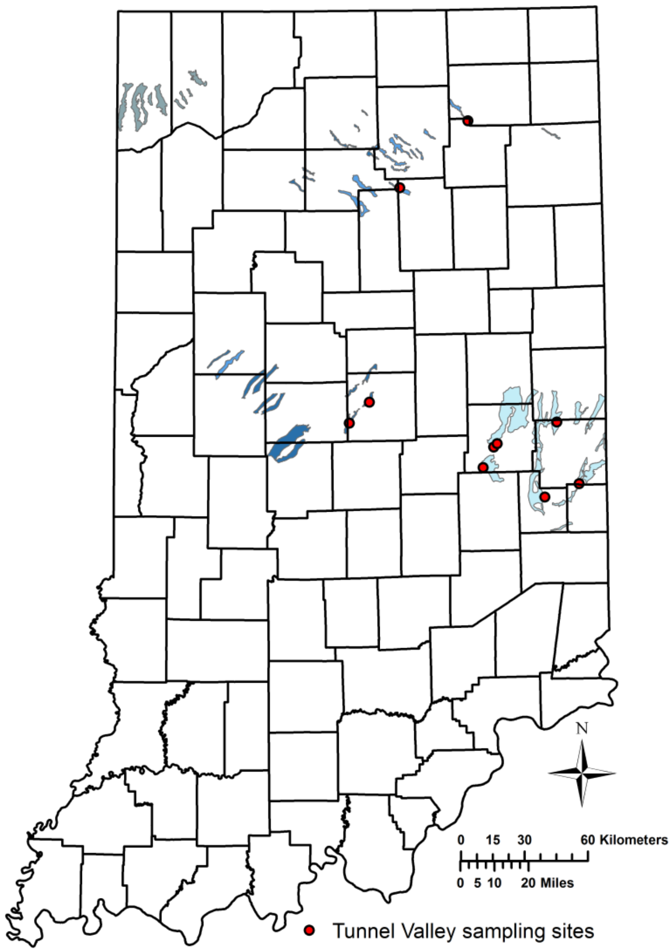
Arsenic was detected in one (25%) of the Round 6 samples from the Trough System setting, at a concentration that did not exceed U.S. EPA's maximum contaminant level (10 µg/L).

Nitrate was detected in one (25%) of the Round 6 samples from the Trough System setting, at a concentration that did not exceed U.S. EPA's MCL (10 µg/L).

Iron was found above U.S. EPA's secondary MCL (0.3 mg/L) in two of the samples from the Trough System setting (50%). **Pesticide Degradates** for Acetochlor, Alachlor, and Metolachlor were not observed in these samples.

3.6.18 Tunnel Valley Setting

Figure 31



Tunnel Valleys are melt water discharge channels which formed at the base of the ice sheet and carried away melt water and deposits to the front of the glacier. Tunnel valleys may possess a highly variable sequence of deposits ranging from thick sand and gravel at one location and thick till only a short distance away. Vulnerability to ground water contamination can be highly variable within a tunnel valley depending upon the nature of deposits along that length.

For Sampling Round 6 of the Ground Water Monitoring Network, 10 samples were collected in the Tunnel Valley setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (30.2 mg/L average concentration), Ca (88.1 mg/L), Na (16.0 mg/L), K (1.7 mg/L), SO_4 (24.7 mg/L), and Cl^- (18.7 mg/L).

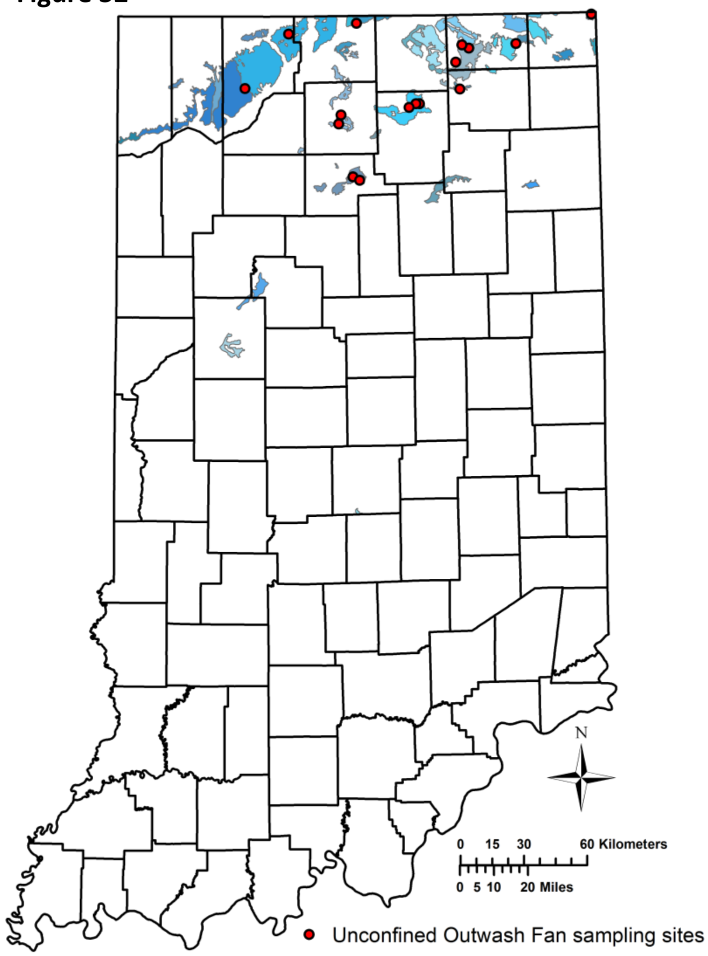
Arsenic was detected in four (40%) of the Round 6 samples from the Tunnel Valley setting, including one sample (10%) that exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Tunnel Valley setting, the highest average arsenic concentrations were found in samples from unconsolidated wells (5.1 µg/L average vs. 1.67 µg/L average for bedrock wells). The highest average concentrations were found in wells screened from 50 to 100 feet below the ground surface (5.62 µg/L). Aquifers that were under reducing conditions had a higher average arsenic concentration (5.4 µg/L) than aquifers under oxidizing conditions (non-detect).

Nitrate was detected in three (30%) of the Round 6 samples from the Tunnel Valley setting; none exceeded U.S. EPA's MCL (10 µg/L). In the Tunnel Valley setting, the highest average nitrate concentrations were found in samples from bedrock wells (1.73 mg/L average vs. 0.016 mg/L average for unconsolidated wells). Aquifers that were under oxidizing conditions had a higher average nitrate concentration (1.73 mg/L) than aquifers under reducing conditions (0.016 mg/L).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in eight of the samples from the Tunnel Valley setting (80%). A couple of **Pesticide Degradates** were found, including **Acetochlor OA** (1 sample, 0.3 µg/L) and **Alachlor ESA** (1 sample, 0.2 µg/L).

3.6.19 Unconfined Outwash Fan Setting

Figure 32



Unconfined Outwash is a generic term referring to surficial sand and gravel outwash deposits which have no limiting clay or till cover restricting infiltration. These deposits are generally found along valley train sluiceways and outwash plain settings and on unconfined fan and fan head settings. Outwash deposits relatively close to the source of the melt water are commonly quite coarse grained (sand and abundant gravel), whereas outwash deposited farther from the ice source is often fine grained (sand and lesser gravel). All these deposits are highly permeable and are vulnerable to surficial contamination.

For Sampling Round 6 of the Ground Water Monitoring Network, 16 samples were collected in the Unconfined Outwash Fan setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (22.6 mg/L average concentration), Ca (78.8 mg/L), Na (19.7 mg/L), K (1.2 mg/L), SO_4 (47.6 mg/L), and Cl^- (30.0 mg/L).

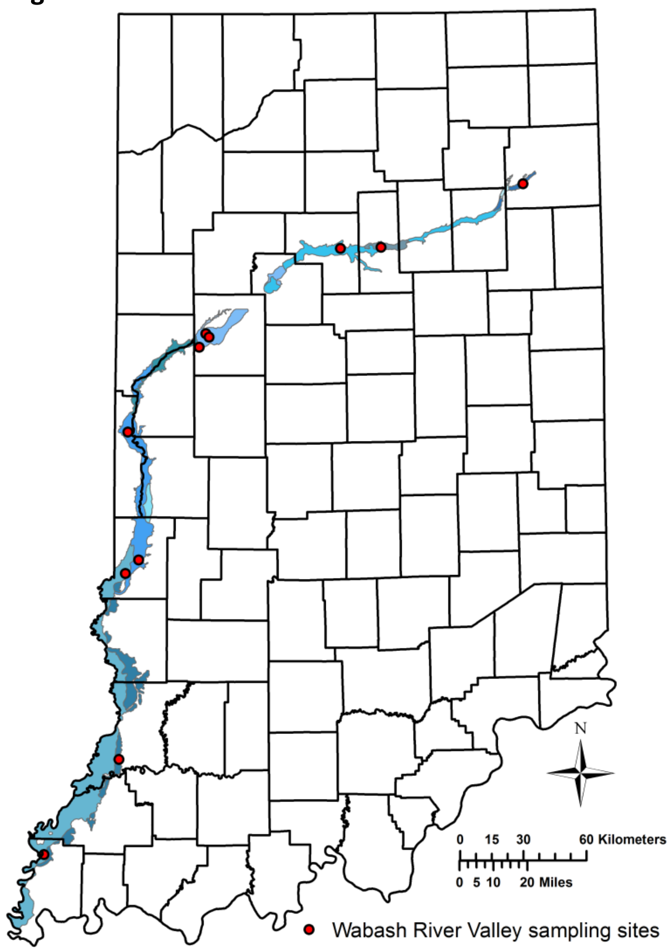
Arsenic was detected in eight (50%) of the Round 6 samples from the Unconfined Outwash Fan setting, including one sample (6%) that exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Unconfined Outwash Fan setting, the highest average arsenic concentrations were found in wells screened from 50 to 100 feet and 100 to 150 feet below the ground surface (5.66 and 5.2 µg/L, respectively). Aquifers that were under reducing conditions had a higher average arsenic concentration (4.96 µg/L) than aquifers under oxidizing conditions (non-detect).

Nitrate was detected in six (around 38%) of the Round 6 samples from the Unconfined Outwash Fan setting; none exceeded U.S. EPA's MCL (10 µg/L). In the Unconfined Outwash Fan setting, the highest average nitrate concentrations were found in wells screened from 50 to 100 feet and 100 to 150 feet below the ground surface (0.35 and 0.62 mg/L, respectively). Aquifers that were under oxidizing conditions had a higher average nitrate concentration (0.85 mg/L) than aquifers under reducing conditions (0.27 mg/L).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in 13 of the samples from the Unconfined Outwash Fan setting (81%). A couple of **Pesticide Degradates** were detected, including **Alachlor OA** (1 sample, 1.8 µg/L), and **Metolachlor ESA** (1 sample, 1.2 µg/L).

3.6.20 Wabash River Valley Setting

Figure 33



The **Wabash River Valley** is the largest and longest glacial sluiceway/outwash plain system within Indiana. The Wabash River Valley has thick deposits of sand and gravel along its length with shallow bedrock outcropping at several areas as well. The Wabash River Valley is a major ground water discharge point for vast areas of Indiana and is a very significant ground water resource.

For Sampling Round 6 of the Ground Water Monitoring Network, 11 samples were collected in the Wabash River Valley setting. The water type in this setting is dominated by **calcium** and **bicarbonate types**. Major anions and cations detected in this setting include: Mg (32.7 mg/L average concentration), Ca (100.8 mg/L), Na (13.7 mg/L), K (5.6 mg/L), SO_4 (53.8 mg/L), and Cl^- (15.4 mg/L).

Arsenic was detected in two (around 18%) of the Round 6 samples from the Wabash River Valley setting, including one sample (9%) that exceeded U.S. EPA's maximum contaminant level (10 µg/L). In the Wabash River Valley setting, the highest average arsenic concentrations were found in samples from bedrock wells (10.43 µg/L average vs. non-detect for unconsolidated wells). The highest average concentrations were found in wells screened from greater than 100 feet below the ground surface. Aquifers that were under reducing conditions had a higher average arsenic concentration (6.2 µg/L) than aquifers under oxidizing conditions (1.38 µg/L).

Nitrate was detected in seven (around 64%) of the Round 6 samples from the Wabash River Valley setting, including two samples (18%) that exceeded U.S. EPA's MCL (10 µg/L). In the Wabash River Valley setting, the highest average nitrate concentrations were found in samples from unconsolidated wells (6.9 mg/L average vs. 0.006 mg/L average for bedrock wells), and in wells screened less than 50 feet below the ground surface (8.52 mg/L average). Aquifers that were under oxidizing conditions had a higher average nitrate concentration (6.36 mg/L) than aquifers under reducing conditions (3.4 mg/L).

Iron was also found above U.S. EPA's secondary MCL (0.3 mg/L) in four of the samples from the Wabash River Valley setting (36%). The **Pesticide Degradate Metolachlor ESA** was found in one sample at a concentration of 0.8 µg/L.

3.7 General Water Chemistry

3.7.1 Charge Balance Equation

Ground water samples collected during the 2013 sampling round were analyzed for cations and anions. These are used to calculate the charge balance error, which can be used for data quality analysis. The concentration of cations in the ground water samples were determined through lab analysis, while bicarbonate (HCO_3^-), the main anion found in ground water from Indiana, was calculated using the pH and alkalinity. Alkalinity data for the Round 6 samples collected in 2014 were not available at the time of report preparation. The cations and anions were converted to millequivalents per liter (meq/L), and the cation/anion sum is displayed in meq/L. The charge balance error is indicative of data quality. Results that are between +/- 5% are considered acceptable (Freeze and Cherry, 1979). In 2013, 155 of the 331 samples contained a charge balance error less than +/- 5%. The average charge balance error for the data set is -3.1%. The project chemist is reviewing the laboratory procedures and alkalinity calculations, and the report will be updated if issues are found.

3.7.2 Water Typing

When water flows through aquifers, the water will interact with the aquifer and will take on the chemical characteristics of the aquifer. These are called hydrogeochemical facies, or water types, and the general classification diagram is displayed in Figure 34 (Freeze and Cherry, 1979).

A piper diagram is an effective way to plot multiple samples and determine a dominant water type. The piper diagram for the 2013 Ground Water Monitoring Network data (Figure 35) displays a bicarbonate dominant water type for the anions, and a slightly calcium dominant water type. From this, the dominant type of ground water encountered during sampling can be classified in the Primary Hardness hydrochemical facies, which generally consists of water found in limestone aquifers or unconsolidated deposits containing abundant carbonate minerals (Walton, 1970). This is typical of Indiana ground water. Note that the samples from bedrock aquifers generally occupy a larger range on the piper diagram than the unconsolidated samples, with some of the samples classified as sulfate or sodium/potassium type. Piper plots for each of the generalized hydrogeologic settings are included as Appendix C.

Radial plots showing the average concentration of the major cations and anions (in millequivalents per liter) for ground water samples from each of the generalized hydrogeologic settings is shown as Figure 36. The figures show that each setting tends to be strongly influenced by calcium and bicarbonate, with varying amounts of sodium and sulfate.

Figure 34: Classification Diagram for Anion and Cation Facies (Freeze and Cherry, 1979)

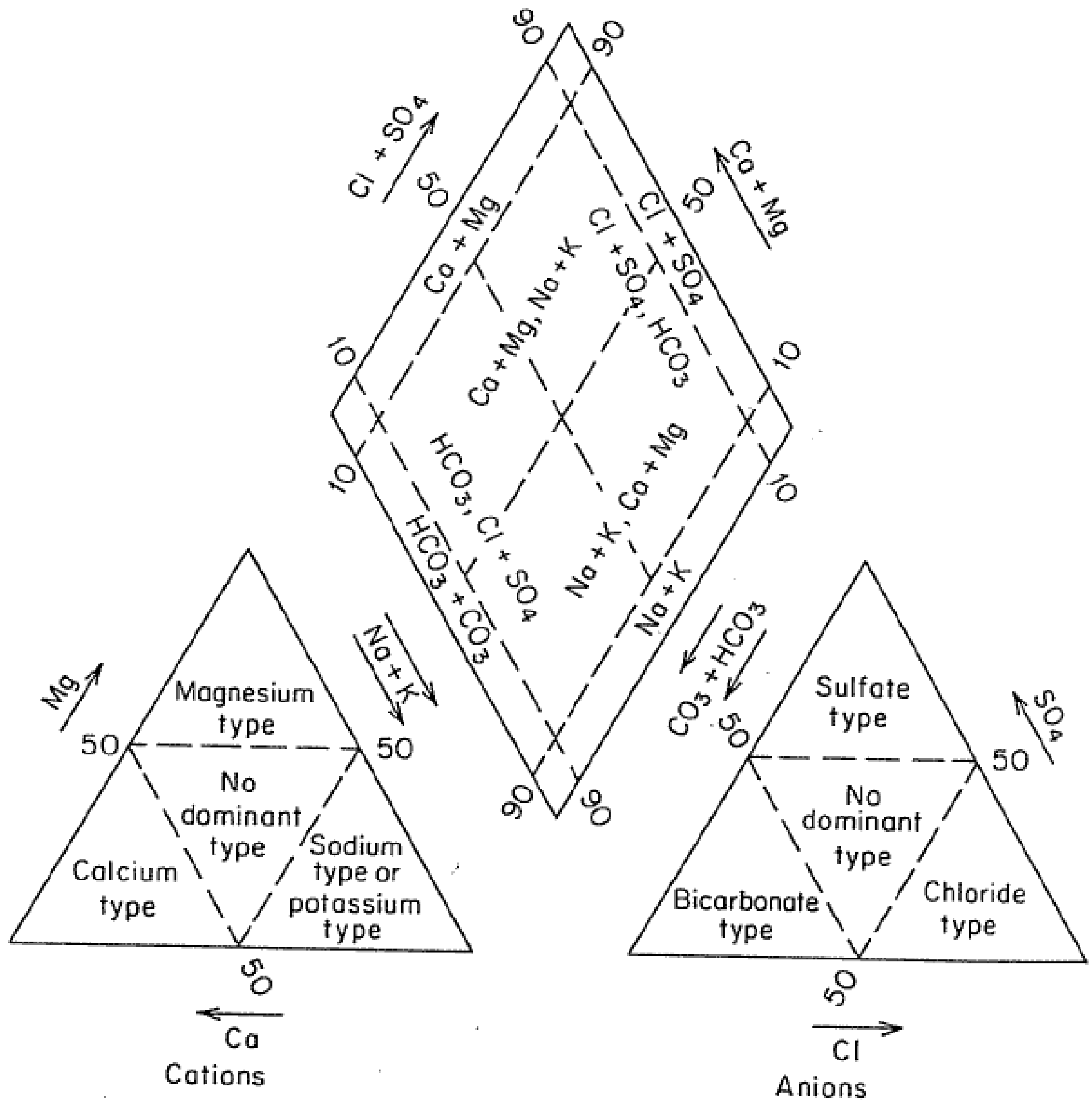


Figure 35: Piper Plot for 2013 Ground Water Monitoring Network Data

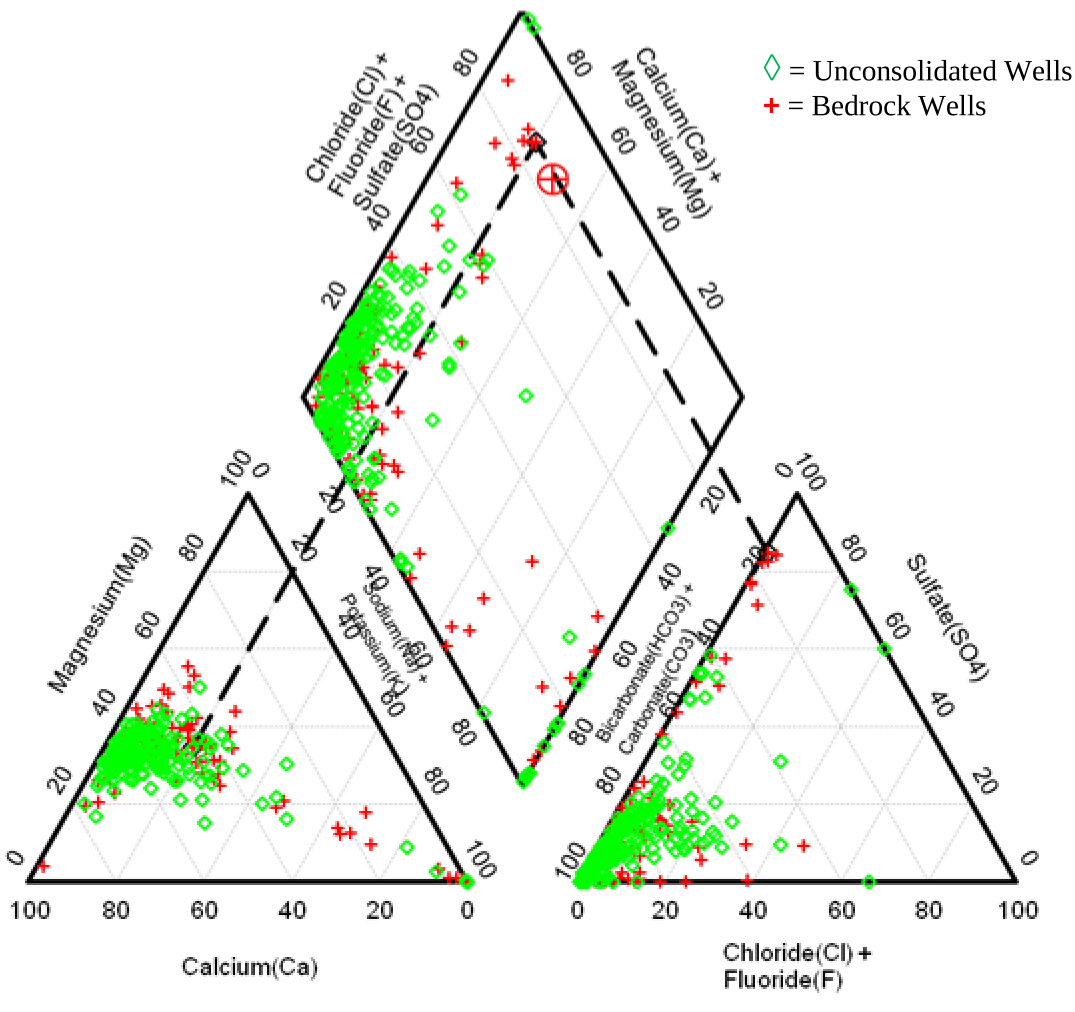
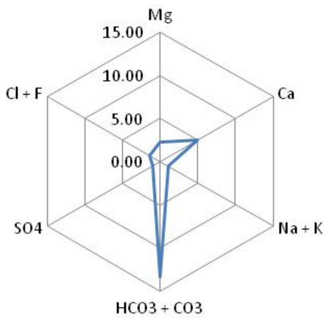
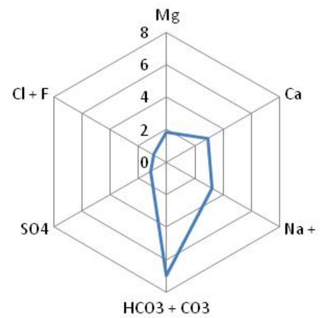


Figure 36: Radial Anion/Cation Plots for 2013 Ground Water Monitoring Network Data

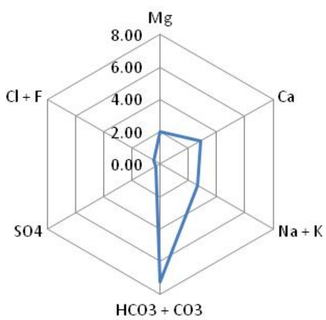
Ablation Sequence



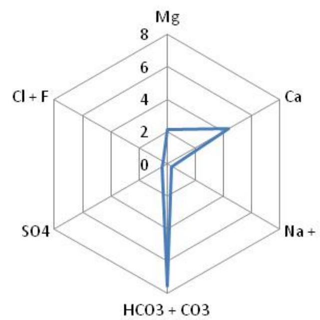
Fan Head Complex



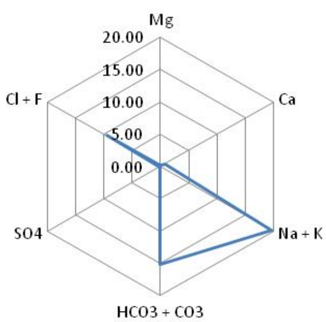
Alluvial Valley



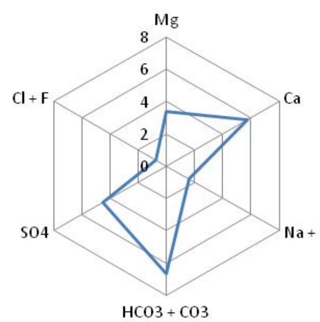
Ice Contact Deposits



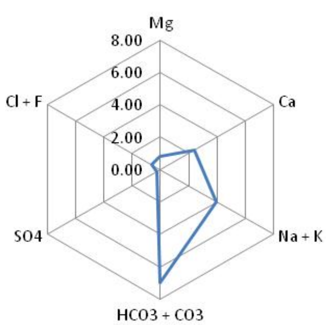
Dissected Bedrock



Karst Plain and Escarpment



Dissected Bedrock Thin Till



Lake Deposits

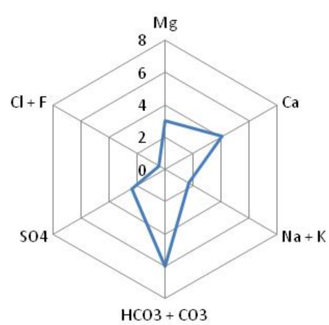
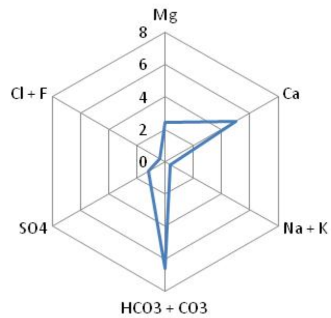
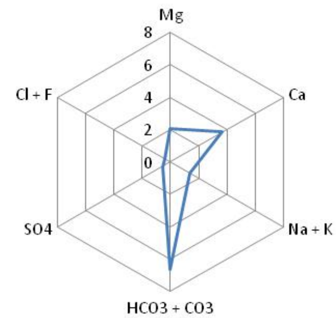


Figure 36: Radial Anion/Cation Plots for 2013 Ground Water Monitoring Network Data (continued)

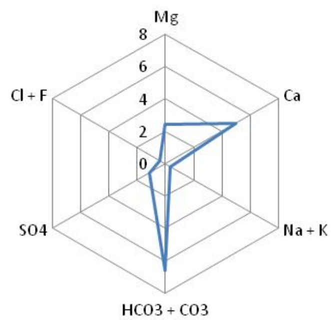
Meltwater Channel



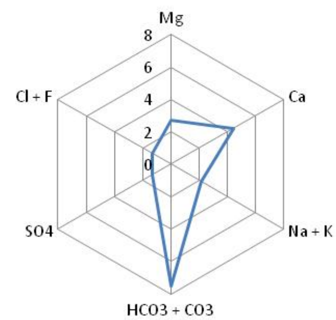
Sluiceway or Discrete Channel



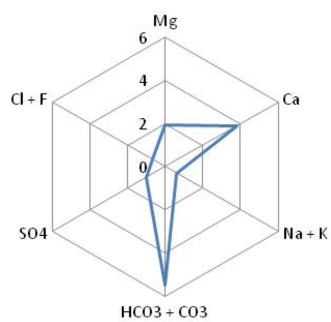
Outwash Complex



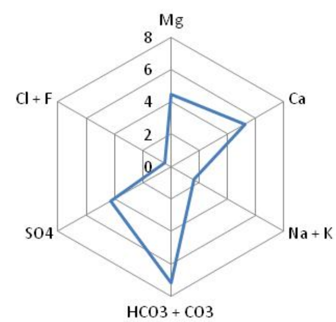
Till Capped Fan



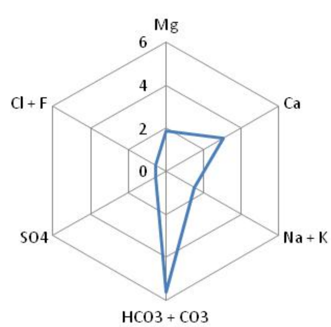
Outwash Plain



Till Cored Moraine



Sand Plains and Loess Sands



Till Plain

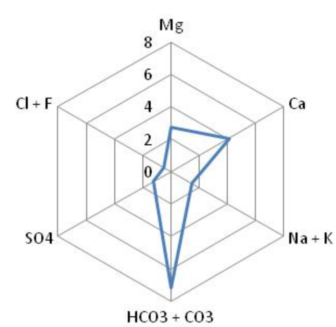
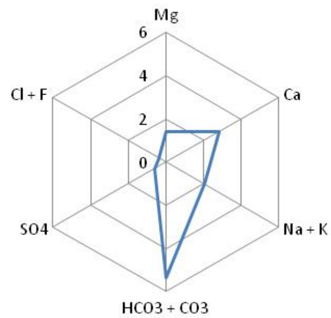
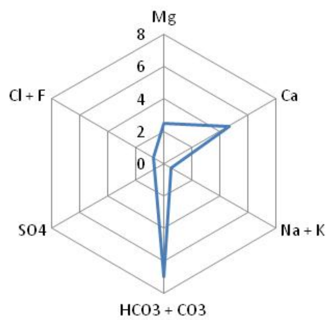


Figure 36: Radial Anion/Cation Plots for 2013 Ground Water Monitoring Network Data (continued)

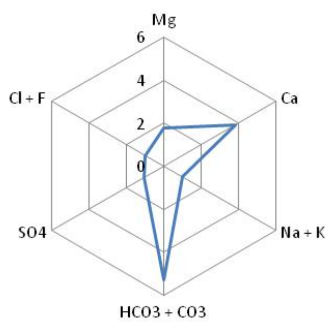
Trough System



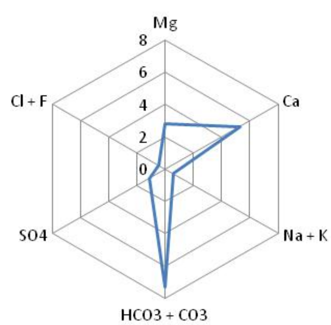
Tunnel Valley



Unconfined Outwash Fan



Wabash River Valley



Section 4.0 Outreach Activities

Participants who had their well sampled as part of the Ground Water Monitoring Network were provided detailed analytical results for their ground water, descriptions of any detected constituents, and additional information from U.S. EPA about household wells and filtering options. Examples of the cover letters sent to residents with maximum contaminant level (MCL) exceedances and no MCL exceedances are included as Appendix D and E (respectively). An example of the results table from the reports is also included as Appendix F. If contamination was present in their well at a concentration above the U.S. EPA MCL, the participants were contacted by Drinking Water Branch staff via telephone and provided support, if needed, to improve their drinking water.

In March 2015, IDEM issued another statewide press release to inform the public about the opportunity to have their drinking water wells sampled as part of the Ground Water Monitoring Network. To date, this effort has yielded an additional 1300 residents interested in having IDEM sample their water, free of charge. Wells that meet the eligibility requirements will be added to the Ground Water Monitoring Network for Round 7, or will be considered for a planned Round 8. Well owners not chosen for sampling with be notified either by email or postal mail and directed towards labs that can test their ground water for critical parameters at low cost.

Section 5.0 Future Projects

Sampling is currently underway for Ground Water Monitoring Network Round 7 (i.e., a second round of random, statistically-based sampling). Round 7 sites were randomly chosen from the pool of qualified applicants from the March 2015 signup period. Round 7 sampling is expected to be completed in 2015. Concurrently, additional samples are being collected from key hydrogeologic settings for Round 8. Round 8 sampling will continue into the 2016 sampling season.

Beginning in early 2016, Arsenic speciation sampling will be conducted to provide additional details on Arsenic mobility in Indiana. Round 6 sampling sites that showed total Arsenic concentrations of 8 µg/L or higher will be resampled for As(III), As(V), metals, nitrates, and major anions and cations. Also, focused studies are being planned for areas showing high levels of Nitrogen, Nitrate-Nitrite contamination based on the results of the Round 6 sampling. For future sampling rounds, the analytical parameter list will be expanded to include additional pesticide degradates. This expanded parameter list will assist IDEM in determining recharge rates for the affected aquifers by demonstrating how quickly anthropogenic chemicals applied at the ground surface can migrate into the aquifer.

Section 6.0 Summary and Conclusions

In 2013 and 2014, ground water samples were collected from 398 sites using a statistically-based sampling approach as part of Round 6 of the Statewide Ground Water Monitoring Network. The samples were collected from private residential wells and small noncommunity public water supplies and were distributed across the 20 general hydrogeologic settings using a stratified sampling process. Samples were analyzed for over 400 parameters; including alkalinity, anions/cations, metals, nitrate-nitrite, synthetic organic compounds, volatile organic compounds, and pesticide degradates.

Nine of the samples contained Nitrogen, Nitrate-Nitrite above the MCL (10 mg/L), with the highest reported concentration of 22 mg/L. Based on the available data, Nitrogen, Nitrate-Nitrite concentrations tend to be higher in shallow, unconsolidated wells. Wells showing with oxidation reduction potential readings indicative of oxidizing conditions generally had higher average Nitrogen, Nitrate-Nitrite concentrations. Highly sensitive aquifers also had higher concentrations, due to higher likelihood for surficial contamination to be transported into the aquifer by recharge.

Forty-three samples contained Arsenic above the MCL, with the highest reported concentration of 68 µg/L. Forty-one of the samples with MCL exceedances for Arsenic occurred north of the Wisconsinan Glacial Boundary with wells in unconsolidated deposits having higher average Arsenic concentrations than bedrock wells. Aquifers under reducing conditions contained a higher average Arsenic concentration than oxidizing aquifers, which confirms the results of previous studies of glacial deposits. Additional investigation of the effect of redox conditions on Arsenic concentrations is planned.

Pesticide degradates were found in 68 of the Round 6 Ground Water Monitoring Network samples, with the highest reported concentration of 7.8 µg/L of Metolachlor ESA. These compounds do not have an established MCL or health-based recommendation. Highly sensitive aquifers had a higher average concentration of pesticide degradates due to higher likelihood for surficial contamination to be transported into the aquifer by recharge.

Around 263 of the samples contained Iron concentrations above the U.S. EPA secondary MCL (0.3 mg/L), with the highest detected concentration of 14 mg/L. As in previous studies, ground water in Indiana is generally bicarbonate and calcium dominant.

Section 7.0 References

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