# *Hey and Associates, Inc.*

## DREW CREEK MONITORING PROJECT
## FINAL REPORT

## FOX LAKE, DODGE COUNTY, WISCONSIN


Prepared for:

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# INTRODUCTION

Fox Lake is a 1,022-hectare (2,625-acre) lake located in northwestern Dodge County. In the 1980's and 1990's, Fox Lake experienced a rapid shift in water quality from a clear-water lake to one characterized by poor-water transparency, increased algae populations, loss of aquatic macrophytes, loss of wetland fringe, and declining sports fishery. In the mid 1990's, the Fox Lake Inland Lake Protection and Rehabilitation District (FLILPRD), in partnership with the Wisconsin Department of Natural Resources (WDNR) began implementation of a long-range management project to shift the lake back into a clear-water state. In 1995 a long-range management strategy for Fox Lake was developed by an advisory committee that included FLILPRD, WDNR, Dodge County, University of Wisconsin-Extension, Town of Fox Lake, City of Fox Lake, and civic and sportsman groups. The project management strategy is outlined in a report tilted, *Long Range Planning Strategy for the Rehabilitation of Fox Lake, Dodge County* (R. A. Smith and Associates, Inc. 1998).

To deal with the complex water quality problems at Fox Lake, the planning and rehabilitation process was broken down into the following components:

1. Watershed management to reduce sediment and nutrient inputs
2. Shoreline stabilization to reduce erosion
3. Aquatic plant management to restore rooted aquatic vegetation
4. Fishery Management (bio-manipulation to reduce rough fish and increase top predators)
5. Lake use management to protect sensitive areas
6. Public education

In 2005 and 2006 the University of Wisconsin and Hey and Associates, Inc. conducted an intensive lake and watershed monitoring program to evaluate the success of the above management strategy. The results of the monitoring are summarized in a report titled: *Fox Lake Management Strategy Evaluation and Recommendations for Future Action – 2008*, (Hey and Associates, Inc. and UW-Milwaukee, 2008). The monitoring documented that high levels of nitrogen and phosphorus were entering the lake from the lake's three tributaries.

The purpose of this project was to collect additional data on sources of nitrogen, phosphorus and sediment entering Fox Lake from the Drew Creek watershed. The work is a follow-up to sampling in 2005 and 2006 conducted by the University of Wisconsin-Milwaukee. The goal of the project is to narrow down which watershed activities, such as feedlots, animal waste storage and spreading, wastewater treatment, and tillage practices on specific properties are contributing to the high concentration of nitrogen and phosphorus being experienced in the previous sampling.

## SAMPLING METHODS

Sampling was conducted at six sites illustrated on Figure 1. Samples were collected on four dates in the fall of 2008 and summer of 2009. Samples were analyzed for the following parameters:

- TOTAL KJELDAHL NITROGEN
- NITRATE PLUS NITRITE-NITROGEN
- TOTAL PHOSPHORUS
- DISSOLVED PHOSPHORUS
- TOTAL SUSPENDED SOLIDS (SEDIMENT)
- FECAL COLIFORM (MFFCC) (BACTERIA)
- STREAM FLOW

All sampling was conducted using the methods outlined in:

- Edwards, T.K., and G.D. Glysson. 1999. *Field Methods for Measurement of Fluvial Sediment, Book 3, Chapter C2*. Techniques of Water-Resources Investigations of the United States Geological Survey, U.S. Government Printing Office, Washington, DC.

- Shelton, L. R., 1994. *Field Guide for Collecting and Processing Stream Water Samples for the National Water-Quality Assessment Program*, Open-File Report 94-455, United States Geological Survey, Sacramento, California.

- United States Geological Survey (USGS). 2005. *Techniques of Water Resources Investigations Reports. Book 3: Applications of hydraulics, Section A: Surface-water techniques.* (21 chapters). United States Department of Interior, U.S. Geological Survey. Washington D.C. http://water.usgs.gov/pubs/twri/.

All water quality and bacterial samples were iced upon collection and transported by cooler to the Wisconsin State Laboratory of Hygiene in Madison Wisconsin for analysis.

Flow velocities were measured using a Marsh McBerny FlowMate® flow meter.

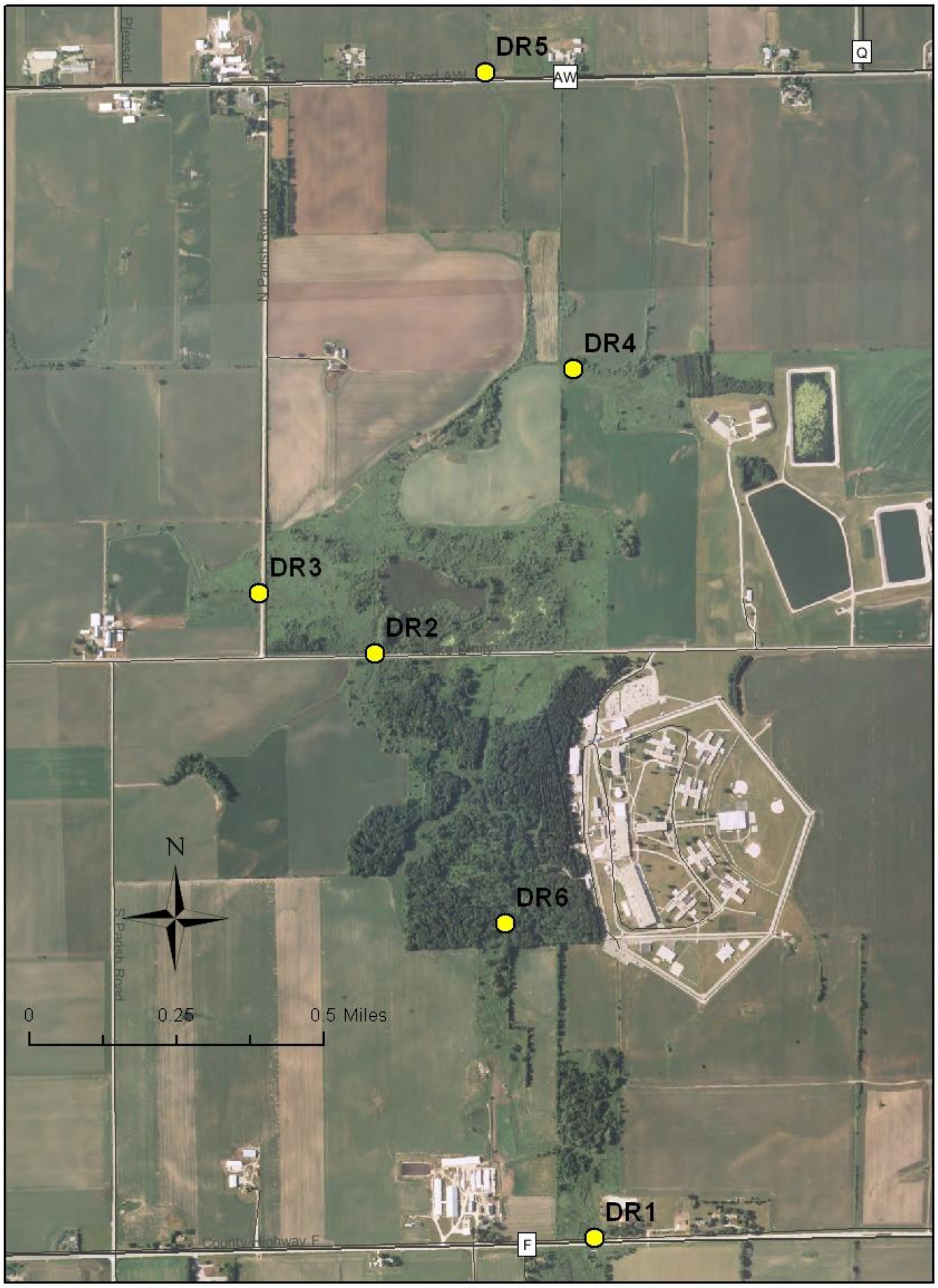


Figure 1
Location of Sampling Points

## SUMMARY OF UW-MILWAUKEE 2006 SAMPLING

As discussed above, the University of Wisconsin-Milwaukee (UWM) conducted tributary monitoring of Alto, Drew and Cambra Creeks in spring of 2006. In the Drew Creek watershed samples were collected at three sites. The sites were No. 1 (CTH F), No. 2 (Lake Emily Road) and No. 3 (Parish Road) illustrated on Figure 1. The mean values of the UWM sampling are summarized in Table 1. The full results are summarized in Appendix A. Included in the table for comparisons are statewide means and ranges for nitrogen and phosphorus based on data for 240 streams as part of the study, *Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin* (USGS, 2006). Values in bold text indicate mean concentrations above the state, ecoregion or environmental phosphorus zone averages as reported by USGS.

**Table 1**

Results of UWM Tributary Monitoring
Mean Values from Five Sampling Dates

| Watershed and Station No. | Total Suspended Solids (mg/l) | Organic Nitrogen (TKN) (mg/l) | Nitrate/Nitrite (mg/l) | Total Nitrogen (mg/l) | Total Phosphorus (mg/l) | Dissolved Phosphorus (SRP) (mg/l) |
|---|---|---|---|---|---|---|
| Drew No. 1 | 8.600 | 0.456 | ***18.800*** | ***19.256*** | ***0.094*** | 0.062 |
| Drew No. 2 | 10.100 | ***0.694*** | ***21.040*** | ***21.734*** | ***0.101*** | 0.040 |
| Drew No. 3 | 71.333 | ***1.074*** | ***20.740*** | ***21.814*** | ***0.200*** | 0.055 |
| | **Statewide Means (USGS, 2006)** | | | | | |
| Mean | - | 0.675 | 2.086 | 2.807 | 0.116 | 0.079 |
| Median | | 0.563 | 1.048 | 1.695 | 0.085 | 0.050 |
| Minimum | - | 0.070 | 0.005 | 0.131 | 0.012 | 0.004 |
| Maximum | - | 2,350 | 20.550 | 21.260 | 1.641 | 1.495 |
| Standard deviation | - | 0.414 | 2.865 | 2.860 | 0.144 | 0.122 |
| | **Eco-region Means (USGS, 2006)** | | | | | |
| Median | - | - | - | 0.811 | 0.025 | - |
| 0% percentile | - | - | - | 0.777 | 0.023 | - |
| 100 percentile | - | - | - | 21.260 | 1.641 | - |
| | **Environmental Phosphorus Zone Means (USGS, 2006)** | | | | | |
| Median | - | - | - | 0.632 | 0.042 | - |
| 0% percentile | - | - | - | 0.298 | 0.016 | - |
| 100 percentile | - | - | - | 21.260 | 0.304 | - |

Source: University of Wisconsin-Milwaukee and Wisconsin Laboratory of Hygiene and USGS (2006)

As can be seen Drew Creek has concentrations of organic nitrogen (TKN), nitrate/nitrite, and total phosphorus that exceed the statewide means. Concentrations of nitrate/nitrite on some dates actually exceed the USGS maximum value for their 240 watersheds making these levels some of the highest recorded in Wisconsin.

## RESULTS OF HEY SAMPLING

The results of the 2008-2009 sampling by Hey and Associates are summarized in Table 2.

**Table 2**

Results of Drew Creek Tributary Monitoring 2008 -2009

| Site Location | Site No. | Date | Flow (cfs) | Flow (MGD) | TP (mg/l) | SRP (mg/l) | TSS (mg/l) | TKN (mg/l) | NO2 NO3 (mg/l) | E-Coli (Counts per 100 ml) |
|---|---|---|---|---|---|---|---|---|---|---|
| HWY F | DR1 | 8/5/08 | 10.83 | 7.00 | **0.10** | 0.07 | 7.00 | 0.55 | **15.90** | **866.00** |
| | | 9/9/08 | 10.31 | 6.66 | **0.07** | 0.04 | 7.00 | 0.52 | **18.10** | 129.00 |
| | | 10/9/08 | 6.89 | 4.45 | **0.09** | 0.05 | 13.00 | 0.67 | **14.50** | **2419.00** |
| | | 7/14/09 | 2.79 | 1.80 | **0.07** | 0.04 | 8.00 | 0.27 | **16.70** | **-** |
| | | **Mean** | | | **0.08** | **0.05** | **8.75** | **0.50** | **16.30** | **1138.00** |
| Lake Emily Road | DR2 | 8/5/08 | 19.26 | 12.45 | **0.08** | 0.06 | 7.00 | 0.38 | **18.30** | **225.00** |
| | | 9/9/08 | 11.61 | 7.50 | **0.06** | 0.03 | 10.00 | 0.35 | **19.20** | 70.00 |
| | | 10/9/08 | 7.34 | 4.74 | **0.06** | 0.03 | 4.00 | 0.48 | **16.10** | 133.00 |
| | | 7/14/09 | 0.78 | 0.50 | **0.07** | 0.03 | 13.00 | 0.15 | **17.80** | - |
| | | **Mean** | | | **0.07** | **0.04** | **8.50** | **0.34** | **17.85** | **142.67** |
| Parish Road | DR3 | 8/5/08 | 3.00 | 1.94 | **0.20** | **0.27** | 3.00 | 0.58 | **13.70** | 196.00 |
| | | 9/9/08 | 2.35 | 1.52 | **0.13** | 0.03 | 29.40 | 0.63 | **17.70** | 167.00 |
| | | 10/9/08 | 3.94 | 2.55 | **0.06** | 0.05 | 3.00 | 0.52 | **16.50** | 32.00 |
| | | 7/14/09 | 0.62 | 0.40 | **0.08** | 0.04 | 10.00 | 0.30 | **15.30** | - |
| | | **Mean** | | | **0.12** | **0.10** | **11.35** | **0.51** | **15.80** | **131.67** |
| Prison Creek | DR4 | 8/5/08 | 3.10 | 2.00 | **0.07** | 0.04 | 22.00 | 0.29 | **19.30** | 121 |
| | | 9/9/08 | 9.26 | 5.98 | **0.06** | 0.03 | 14.00 | 0.45 | **20.20** | 111.00 |
| | | 10/9/08 | 1.33 | 0.86 | **0.06** | 0.03 | 20.00 | 0.36 | **18.10** | 34.00 |
| | | 7/14/09 | 1.40 | 0.90 | **0.07** | 0.03 | 34.00 | 0.21 | **19.10** | - |
| | | **Mean** | | | **0.06** | **0.03** | **22.50** | **0.33** | **19.18** | **88.67** |
| CTH AW | DR5 | 8/5/08 | No Flow | No Flow | - | - | - | - | - | - |
| | | 9/9/08 | No Flow | No Flow | - | - | - | - | - | - |
| | | 10/9/08 | No Flow | No Flow | - | - | - | - | - | - |
| | | 7/14/09 | No Flow | No Flow | - | - | - | - | - | - |
| Prison Grounds | DR6 | 9/9/08 | 9.37 | 6.06 | **0.06** | 0.03 | 8.00 | 0.22 | **18.90** | 88.00 |
| | | 10/9/08 | 2.79 | 1.81 | **0.08** | 0.04 | 16.00 | 0.62 | **15.50** | **517.00** |
| | | 7/14/09 | 1.86 | 1.20 | **0.06** | 0.03 | 7.00 | 0.14 | **17.70** | |
| | | **Mean** | | | **0.06** | **0.03** | **10.33** | **0.33** | **17.37** | **302.50** |

Concentrations highlighted in Table 2 are levels above statewide means for nitrogen and phosphorus based on data for 240 streams as part of the study, *Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin* (USGS, 2006), or above state water quality standards for bacteria.

## Stream Flow

Stream flow was measured on each of the sampling dates. Exhibit 1 in Appendix B illustrates the variability of flow from upstream to downstream. At station DR5, at the headwater at CTH AW, no flow was observed on any of the sampling dates. At the DR3 and DR4 flows ranged from 0.4 to 9.6 cfs. At site DR2 flows increased dramatically on all of the sampling dates, indicating groundwater discharges just above this site in a large wetland complex. Much of the groundwater was likely recharged by groundwater discharges of the Fox Lake Correctional Institution Wastewater Treatment Plant which operates a series of seepage cells and a spray irrigation system. As water flowed downstream to Site DR6 and DR1 flow was lost on all of the sampling dates, likely due to water of Drew Creek seeping into the shallow bedrock that can be observed on the stream bottom.

## Total Suspended Solids

Total suspended solids (TSS) include all particles suspended in water which will not pass through glass-fiber filter disk. Suspended solids are associated with nonpoint source pollution, such as soil erosion from agricultural and construction sites. As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen. Warmer water holds less oxygen than cooler water. Photosynthesis also decreases, since less light penetrates the water causing less oxygen to be produced by plants and algae. TSS can also destroy fish habitat because suspended solids settle to the bottom and cover coarse bottom materials. Suspended solids can smother the eggs of fish and aquatic insects, and can suffocate newly-hatched insect larvae. Suspended solids can also harm fish by clogging gills, reducing growth rates, and lowering resistance to disease. As suspended solids settle in the calm waters of the lake, they fill in bays impacting recreational use. Levels above 40 mg/l cause water to become cloudy and above 100 mg/l begin to damage aquatic life.

In 2008-2009 sampling, TSS values ranged from 3 to 34 mg/l, indicating low levels of suspended sediment. The sampling indicates that surface erosion on the sampling dates was not a major problem.

Table 3 summarizes the estimated loadings of TSS, nitrogen and phosphorus to Fox Lake at each of the Drew Creek sampling sites. Loading is the total mass in pounds that enters the lake per day or per year. Multiplying the measured stream flow times the pollutant concentration you can estimate daily pounds of a given pollutant that has entered the lake at that moment. Estimates of annual loading, as done in the 2005 -2006 UWM and Hey and Associates study would require additional flow and concentration data.

**Table 3**

Calculated Daily Pollutant Loadings in Pounds per day for the Drew Creek Tributary Monitoring by Sample Site 2008 -2009

| Site Location | Site No. | Date | Flow (cfs) | Flow (MGD) | Loadings (lbs/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | TP | SRP | TSS | TKN | NO2+NO3 |
| Drew Creek at HWY F | DR1 | 8/5/2008 | 10.83 | 7.00 | 5.95 | 4.14 | 408.66 | 32.11 | 928.24 |
| | | 9/9/2008 | 10.31 | 6.66 | 3.95 | 2.00 | 389.09 | 28.90 | 1606.61 |
| | | 10/9/2008 | 6.89 | 4.45 | 3.34 | 1.74 | 482.56 | 24.87 | 923.17 |
| | | 7/14/2009 | | 1.80 | 1.01 | 0.54 | 120.10 | 4.05 | 60.85 |
| Drew Creek at Lake Emily Road | DR2 | 8/5/2008 | 19.26 | 12.45 | 8.72 | 5.81 | 726.72 | 39.45 | 1899.85 |
| | | 9/9/2008 | 11.61 | 7.50 | 3.63 | 1.69 | 625.79 | 21.90 | 1370.64 |
| | | 10/9/2008 | 7.34 | 4.74 | 2.45 | 1.35 | 158.25 | 18.99 | 751.28 |
| | | 7/14/2009 | | 0.50 | 0.28 | 0.14 | 54.21 | 0.63 | 2.61 |
| Drew Creek at Parish Rd. | DR3 | 8/5/2008 | 3.00 | 1.94 | 3.18 | 4.40 | 48.50 | 9.38 | 221.46 |
| | | 9/9/2008 | 2.35 | 1.52 | 1.61 | 0.43 | 371.84 | 7.97 | 100.78 |
| | | 10/9/2008 | 3.94 | 2.55 | 1.34 | 0.96 | 63.68 | 11.04 | 234.29 |
| | | 7/14/2009 | | 0.40 | 0.26 | 0.13 | 33.36 | 1.00 | 3.34 |
| Prison Creek | DR4 | 8/5/2008 | 3.10 | 2.00 | 1.19 | 0.68 | 367.29 | 4.84 | 322.21 |
| | | 9/9/2008 | 9.26 | 5.98 | 2.74 | 1.35 | 698.52 | 22.45 | 1120.24 |
| | | 10/9/2008 | 1.33 | 0.86 | 0.44 | 0.21 | 142.95 | 2.57 | 18.39 |
| | | 7/14/2009 | | 0.90 | 0.51 | 0.21 | 255.20 | 1.58 | 11.83 |
| Drew Creek on Prison Grounds | DR6 | 9/9/2008 | 9.37 | 6.06 | 2.93 | 1.62 | 404.13 | 11.11 | 561.41 |
| | | 10/9/2008 | 2.79 | 1.81 | 1.19 | 0.57 | 240.92 | 9.34 | 140.57 |
| | | 7/14/2009 | | 1.20 | 0.55 | 0.33 | 70.06 | 1.40 | 14.02 |

## Phosphorus

Aquatic plants and algae require nutrients such as phosphorus, nitrogen, carbon, calcium, chlorides, iron, magnesium, sulfur, and silica for growth. In lakes where the supply of one or more of these nutrients is limited, plant and algae growth may also be limited. The two nutrients that most often limit and control the growth of plants are nitrogen and phosphorus. In nutrient limited lakes, if you add more nitrogen or phosphorus, you will get more plant or algae growth. The Southeastern Wisconsin Regional planning Commission (SEWRPC) has recommended that in-lake total phosphorus concentration be below 0.02 mg/l to prevent nuisance algae blooms. Currently the State of Wisconsin has no surface water standards for phosphorus.

Two types of phosphorus were sampled; total phosphorus (TP) and soluble reactive phosphorus (SRP).

Phosphorus is found in natural environments in several forms including (Snoeyink and Jenkins, 1980):

- Orthophosphate (${H_3PO_4}$, $H_2PO_4^-$, $HPO_4^-$, $HPO_4^{2-}$, $HPO_4^{2-}$ complexes)
- Polyphosphates ($H_4P_2O_7$, $H4P_2O_7^-$, $H_4P_2O_7^{2-}$, $H_4P_2O_7^{3-}$, $H_4P_2O_7^{4-}$, $H_4P_2O_7^{3-}$complexes)
- Metaphosphate ($HP_3O_9^{2-}$, $HP_3O_9^{3-}$)
- Organic phosphates (phosphorus tied up in organic matter)

A test for total-phosphorus (TP) will identify the combined concentration of all of the above compounds. Orthophosphate and the other complexes of phosphorus found in the natural environment are generally not very soluble and typically bind with various cations such as calcium (Ca), magnesium (Mg), aluminum (Al) or iron (Fe). The most common complexes include the following:

- Calcium hydrogen phosphate $CaHPO4_{(s)}$ ($pK_{so}$ +6.66)
- Calcium dihydrogen phosphate $Ca(H_2PO_4)_{2(s)}$ ($pK_{so}$ +1.14)
- Hydroxyapatite $Ca_5(PO_4)_2OH_{(s)}$ ($pK_{so}$ +55.9)
- Ferric phosphate $FePO_4$ ($pK_{so}$ +21.9)
- Aluminum phosphate $AlPO_4$ ($pK_{so}$ +21.0)

The solubility of these complexes in fresh water is defined by a solubility equilibrium constant ($pK_{so}$). The smaller the solubility constant the less soluble the compound is in water. Other complexes with sodium (Na), magnesium (Mg), manganese (Mn), and orthophosphate, pyrophosphate and tripophosphate also exist, making phosphorus equilibrium chemistry very complex.

The soluble reactive phosphorus (SRP) consists largely of the inorganic orthophosphate ($PO_4$) form of phosphorus. Orthophosphate is the phosphorus form that is directly taken up by algae, and the concentration of this fraction constitutes an index of the amount of phosphorus immediately available for algal growth. The presence of soluble phosphorus in high concentrations is unusual in areas with hard water and high calcium levels as found throughout Southern Wisconsin.

The test results show high concentration of total phosphorus on all of the sampling dates and at all of the sampling locations. The concentrations do not vary greatly by sample site, indicating that phosphorus contamination is a watershed wide problem. Exhibits 2 and 3 in Appendix B illustrate concentrations of total phosphorus and soluble reactive phosphorus by site respectively. It can be seen that approximately 60% of the total phosphorus is in the form of soluble reactive phosphorus. As outlined above this is unusual in the hard water of Southern Wisconsin. This indicates that the source of the phosphorus is not soil erosion where most phosphorus is typically bound to the soil particles, but is due a soluble source of phosphorus such as contamination of groundwater by sources such as treated wastewater, septic system waste or animal manure.

## Nitrogen

Nitrogen can be found in many different organic and inorganic forms in our environment. The air we breathe is composed of 78 percent nitrogen. Nitrogen can also be found in many varied forms in the soil. Plants need nitrogen from the soil for proper growth and development but are only able to use very specific forms of nitrogen. Plants cannot use the form of nitrogen found in the atmosphere.

Natural biological process carried out by microorganisms in the soil convert organic nitrogen to inorganic forms, which plants are able to use. Organic nitrogen is a common component in plant residues and organic matter. Ultimately, organic nitrogen is converted to inorganic ammonium (NH-). Nitrate is the form of nitrogen that is most used by plants for growth and development. Where crops are grown, nitrates can also emanate from nitrogen fertilizers, and manure.

Nitrogen becomes a concern to water quality when nitrogen in the soil is converted to the nitrate ($NO_3$) form. This is because nitrate is very mobile and easily moves with water. The concern of nitrates and water quality is generally directed at groundwater. However, nitrates can also enter surface waters such as ponds, streams and rivers. Nitrates in the soil result from natural biological processes associated with the decomposition of plant residues and organic matter. Nitrates can also come from animal manure, treated human waste effluents and nitrogen fertilizers.

Whether nitrates actually enter groundwater depends on underlying soil and/or bedrock conditions, as well as depth to groundwater. If depth to groundwater is shallow and the underlying soil is sandy, the potential for nitrates to enter groundwater is relatively high.

Two of the major problems with excess levels of nitrogen in the environment are:

- Excess nitrogen can cause overstimulation of growth of aquatic plants and algae. Excessive growth of these organisms, in turn, can clog water intakes, use up dissolved oxygen as they decompose, and block light to deeper waters. This seriously affects the respiration of fish and aquatic invertebrates, leads to a decrease in animal and plant diversity, and affects our use of the water for fishing, swimming, and boating.
- Too much nitrate in drinking water can be harmful to young infants or young livestock.

The two forms of nitrogen measured as part of this study were:

- Total Kjeldahl Nitrogen (TKN), a measurement of organic nitrogen and ammonia, and
- Nitrite/nitrate nitrogen which measures nitrogen in the forms of $NO_2$ and $NO_3$.

Total Kjeldahl Nitrogen (TKN) concentration ranged from 0.15 to 0.63 mg/l and did not show any trends from upstream to downstream. The concentrations of TKN are generally low indicating limited levels of organic nitrogen or ammonia.

Nitrite/nitrate nitrogen levels ranged from 14.5 to 20.2 mg/l. State and Federal laws set the maximum allowable level of nitrate-nitrogen in public drinking water at 10 milligrams per liter (10 parts per million). Nitrate-contaminated water should never be fed to an infant less than 6 months of age. In young infants, ingestion of nitrate can reduce the blood's ability to carry oxygen. In severe cases it can cause a condition that doctors call methemoglobinemia also called "blue baby syndrome" because the infant's skin appears blue-gray or lavender in color. This skin color change is caused by a lack of oxygen in the blood. An infant suffering from "blue baby syndrome" needs immediate medical care because the condition can lead to coma and death if it is not treated promptly. Some scientific studies have also found evidence suggesting that women who drink nitrate contaminated water during pregnancy are more likely to have babies with birth defects. People who have heart or lung disease, certain inherited enzyme defects or cancer may be more sensitive to the toxic effects of nitrate than healthy individuals. Some researchers also suspect that consuming nitrate-contaminated water may increase the risk of certain types of cancer (WDNR Publication: PUB-DG-001 2006).

High levels of nitrate/nitrite nitrogen were found at all of the Drew Creek sampling sites. Approximately 97 % of the total nitrogen is in the form of nitrate and nitrite. Drew Creek receives most of its water from groundwater seepage, indicating that the groundwater throughout the stream's watershed is highly contaminated. Potential sources of the nitrate/nitrite nitrogen is the Fox Lake Correctional Institution wastewater treatment plant, animal feedlots and the excess spreading of manure and other organic waste. Because levels are high everywhere it is difficult to pinpoint a single specific source.

### Fecal Bacteria

Fecal bacteria are bacteria that grow in the intestines of warm blooded animals and are found in fecal matter. E-coli (Escherichia coli) are a specific form of the fecal coliform group. E-coli have been associated with making humans sick through ingestion. The U. S. Environmental Protection Agency (USEPA) has recommended that E- coli be used to measure the safety of public beaches. The USEPA recommends that beaches be posted with an advisory sign informing the public of increased health risk when a water sample exceeds 235 colony-forming units of E. coli per 100 milliliters of water.

High levels of e-coli bacteria were found on one date each at stations DR2 (Lake Emily Road) and DR6 (Prison Creek), and on two dates at DR1 (HWY F). The highest values of 866 and 2,419 were found at DR1 just below the discharge of a major feedlot located to the west along HWY F.

## SAMPLING BY FOX LAKE CORRECTIONAL INSTITUTION

The Fox Lake Correctional Institution (FLCI) is situated on approximately 1200 acres owned by the State of Wisconsin located in the center of the Drew Creek Watershed (Figure 2). The FLCI is operated as a medium security facility with an adjoining minimum security compound for adult male offenders. The inmate population at the prison on June 27, 2008 was 1,339 with 411 security and non-security staff. The institution operates a waste water treatment plant on the property which discharges to series of infiltration cells and into the local groundwater. Wastewater is also land applied to agricultural fields on the FLCI property through a spray irrigation system. As part of the treatment plants license it is required to monitor the local groundwater system. Four monitoring well are monitored quarterly. A map of the well locations was not provided with the data obtained from FLCI. The results of the 2007 and 2008 sampling are summarized in Table 4. Samples were collected between 10 and 39 feet below the land surface depending on the date and location.

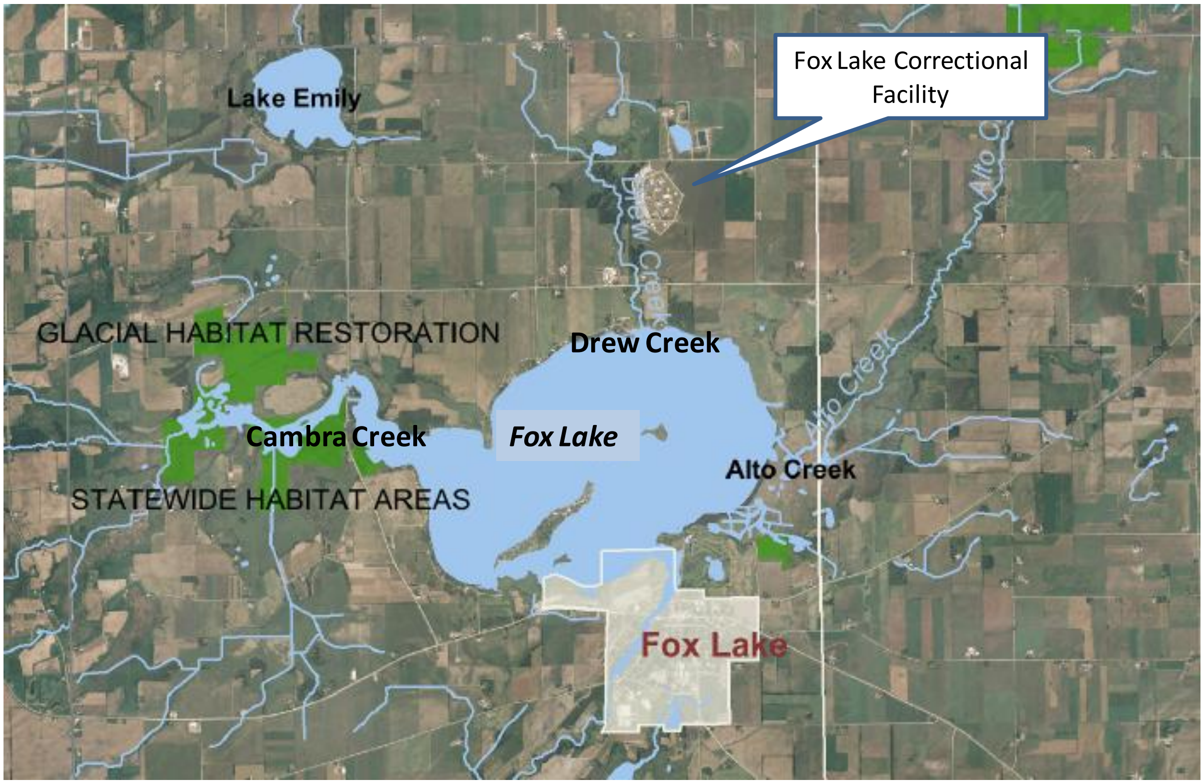


Figure 2
Location of Fox Lake Correctional Institution

As seen in Table 4, with the exception of one high value of 20.1 mg/l of nitrate/nitrite nitrogen on 9/28/2007 at one site (807), all values are below 6.10 mg/l with an average for all sites and dates of 2.5 mg/l. Levels of total Kjeldahl nitrogen, ammonia nitrogen, and dissolved organic nitrogen were low on all sampling dates. Phosphorus is not monitored by FLCI.

We know from continuous stream flow monitoring conducted by the University of Wisconsin-Milwaukee in 2004 through 2005 (Hey and Associates, Inc. and UW-Milwaukee, 2008) that the majority of flow in Drew Creek is from groundwater discharges to the creek. The stream flow should be representing the same groundwater that FLCI is monitoring. However, FLCI is measuring moderate to low levels of nitrogen and UWM and Hey and Associates are measuring very high levels of nitrate/nitrite nitrogen. This large difference in the monitored concentrations is not understood. We know from mapping of local soils (Appendix C) that bedrock is located within 5 to 20 feet below the land surface in the Drew Creek watershed. It is possible that water is percolating through the surface soil layer down to the surface of the bedrock and them moving laterally towards to stream. It is possible that FLCI is monitoring groundwater within the bedrock and the stream sampling is representing shallow groundwater in the upper soil layer. Without more detailed mapping of the local geology it is difficult to understand the local groundwater flow patterns. A first place to start in understanding the local geology would be to examine the well logs from the FLCI monitoring wells and any other soil borings that have been conducted in the areas.

Table 4
Groundwater Sampling by Fox Lake Correctional Institution

| Sample Point | Date | Depth to Ground-water (feet) | pH | Chloride Dissolved (mg/l) | Total Dissolved Solids (mg/l) | Nitrite + Nitrate (mg/l) | Total Kjeldahl Nitrogen (mg/l) | Ammonia Nitrogen (mg/l) | Organic Dissolved Nitrogen (mg/l) |
|---|---|---|---|---|---|---|---|---|---|
| 804 | 3/20/07 | 19.58 | 7.50 | 16 | 380 | 1.00 | <0.25 | <0.10 | <0.25 |
| 805 | 3/20/07 | 23.79 | 7.49 | - | 430 | 2.50 | 0.34 | <0.10 | 0.34 |
| 807 | 3/20/07 | 28.23 | 7.30 | 82 | 610 | <0.10 | <0.25 | <0.10 | <0.25 |
| 808 | 3/20/07 | 31.33 | 7.44 | 33 | 460 | 0.42 | 0.34 | <0.10 | 0.34 |
| 804 | 6/12/07 | 19.83 | 7.77 | 7 | 340 | 0.67 | 0.38 | <0.10 | 0.38 |
| 805 | 6/12/07 | 23.96 | 7.76 | 40 | 460 | 6.10 | 0.31 | <0.10 | 0.31 |
| 807 | 6/12/07 | 29.57 | 7.38 | 120 | 590 | <0.10 | 0.33 | <0.10 | 0.33 |
| 808 | 6/12/07 | 34.63 | 7.59 | 23 | 400 | 0.39 | 0.40 | <0.10 | 0.40 |
| 804 | 9/28/07 | 21.18 | 7.68 | 5 | 330 | 0.65 | <0.25 | <0.10 | <0.25 |
| 805 | 9/28/07 | 23.99 | 7.54 | 44 | 480 | 4.70 | 0.39 | <0.10 | 0.39 |
| 807 | 9/28/07 | 28.87 | 7.82 | 110 | 600 | 20.10 | <0.25 | <0.10 | <0.25 |
| 808 | 9/28/07 | 32.81 | 7.40 | 67 | 490 | 0.51 | <0.25 | <0.10 | <0.25 |
| 804 | 12/26/07 | 22.98 | 7.18 | 52 | 690 | 2.60 | 0.739 | <0.10 | 0.739 |
| 805 | 12/26/07 | 25.38 | 7.32 | 48 | 610 | 3.70 | 0.976 | <0.10 | 0.976 |
| 807 | 12/26/07 | 30.41 | 7.11 | 71 | 630 | 0.14 | 0.907 | <0.10 | 0.907 |
| 808 | 12/26/07 | 39.92 | 7.05 | 23 | 500 | 0.20 | 0.441 | <0.10 | 0.411 |
| 804 | 3/25/08 | 17.77 | 7.45 | 9 | 310 | 0.62 | 0.29 | <0.10 | 0.29 |
| 805 | 3/25/08 | 23.75 | 8.64 | 63 | 430 | 2.30 | 0.29 | <0.10 | 0.29 |
| 807 | 3/25/08 | 25.91 | 8.32 | 130 | 530 | <0.10 | <0.25 | <0.10 | <0.25 |
| 808 | 3/25/08 | 24.95 | 9.13 | 45 | 390 | 0.66 | 0.27 | <0.10 | 0.27 |
| 804 | 6/24/08 | 10.07 | 7.52 | 20 | 340 | 1.00 | <0.25 | <0.10 | <0.25 |
| 805 | 6/24/08 | 17.06 | 7.30 | 110 | 580 | 2.90 | 2.90 | <0.10 | <0.25 |
| 807 | 6/24/08 | 18.37 | 7.45 | 98 | 600 | <0.10 | <0.25 | <0.10 | <0.25 |
| 808 | 6/24/08 | 12.82 | 8.02 | 120 | 580 | 2.60 | <0.25 | <0.10 | <0.25 |
| 804 | 9/16/08 | 19.39 | 7.50 | 65 | 570 | 2.10 | <0.25 | <0.10 | <0.25 |
| 805 | 9/16/08 | 24.08 | 7.58 | 79 | 560 | 4.40 | <0.25 | <0.10 | <0.25 |
| 807 | 9/16/08 | 29.44 | 7.34 | 130 | 630 | <0.10 | <0.25 | <0.10 | <0.25 |
| 808 | 9/16/08 | 35.12 | 7.46 | 51 | 460 | 0.59 | <0.25 | <0.10 | <0.25 |
| 804 | 12/30/08 | 22.77 | 7.16 | 86 | 560 | 1.90 | <0.25 | <0.10 | <0.25 |
| 805 | 12/30/08 | 24.50 | 7.30 | 54 | 460 | 2.20 | <0.25 | <0.10 | <0.25 |
| 807 | 12/30/08 | 30.13 | 7.27 | 110 | 540 | <0.10 | <0.25 | <0.10 | <0.25 |
| 808 | 12/30/08 | 38.41 | 7.32 | 35 | 390 | 0.23 | <0.25 | <0.10 | <0.25 |

## CONCLUSIONS

It's been stated that "A lake is a Reflection of its Watershed". In the case of Fox Lake that reflection is one of high levels of pollution. Based on monitoring by the University of Wisconsin-Milwaukee in 2004 and 2005 it was estimated that annually approximately 499,000 pounds of sediment, 430,690 pounds of nitrogen and 44,330 pounds of phosphorus entered Fox Lake from its watershed. To identify the sources of the sediment and nutrients entering Fox Lake a sampling program of the Drew Creek watershed was conducted in 2008 and 2009.

The most shocking result of the sampling was the high levels of nitrate/nitrite nitrogen ($NO_2$+$NO_3$) found at all of the sampling sites. Nitrite/nitrate nitrogen levels ranged from 14.5 to 20.2 mg/l well above the state's drinking water standard of 10 mg/l.

Sediment levels in the water were generally low ranging from 3.0 to 34.0 mg/l. The largest source of sediment is runoff from agricultural fields. The Drew Creek watershed contains soils with moderate levels of sand and allows rainwater to seep into the ground during moderate storms. To generate large enough runoff events to move sediment we need rain storms with high intensity or on frozen ground. None of the sampling took place during one of these large storms. This does not mean that Drew Creek is not a source of sediment to the lake.

While the State of Wisconsin does not have water quality standards for phosphorus, scientists believe levels above 0.02 mg/l can cause nuisance algae blooms. All of the monitored values were above 0.06 mg/l, three times above what is considered safe for the lake.

E-coli bacteria (Escherichia coli) are bacteria that live in the digestive track of warm blooded animals including man and livestock. The presence of e-coli bacteria in the water is an indication of animal waste. To protect public health the U. S. Environmental Protection Agency has recommended that beaches be closed when e-coli levels exceed 235 CFU/100 ml. In Drew Creek levels at CTH F exceeded this value on more than half of the sampling dates, indicating an upstream source of animal waste, likely a local dairy farm.

## RECOMMENDATIONS FOR FUTURE ACTION

1. E-coli bacteria sampling indicates the Shultz farm on CTH F and Drew farm on Lake Emily Road may be sources of animal waste entering Drew Creek and Fox Lake. The Wisconsin Department of Natural Resources should conduct an investigation under Wisconsin Administrative Code NR243 as to whether or not these farms should be ordered to take corrective actions.

2. The Drew Creek watershed has been identified as an area with high potential for groundwater contamination by the U. S. Geological Survey (Appendix C). Nitrate/nitrate and phosphorus sampling of Drew Creek has demonstrated that this contamination has already taken place. Likely sources of the contamination include barnyard runoff, spreading of manure and other industrial waste, and land

application of treated wastewater from the Fox Lake Correctional Institution. Based on the existing problems three things should take place:

a. No new sources of animal or human waste should be imported into the watershed.
b. Existing land applications of animal or human waste should be minimized. The Wisconsin Legislature should explore new regulations for the land application of waste in areas with high potential for groundwater contamination.
c. The Fox Lake Correctional Institution (FLCI), Wisconsin Department Natural Resources (WDNR) and Fox Lake Inland Lake Protection and Rehabilitation District should explore the development of treatment system to remove nitrogen and phosphorus from the Drew Creek flow before it enters the lake. The system would need to be designed to remove soluble nitrogen and soluble phosphorus. Practices such as wet detention designed to remove particulate pollutants will not be effective on these soluble pollutants. Potential treatment systems could include artificial wetlands treatment and or alum treatment systems.

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# APPENDIX A

University of Wisconsin-Milwaukee and Hey and Associates, Inc.
Drew Creek Monitoring Data: 2005 - 2009

| Site | Site No. | Source | Date | Flow (MGD) | Concentration (mg/l) | | | | | | Loadings (lbs/day) | | | | | E-Coli |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | TP | SRP | TSS | TKN | NO2+ NO3 | TN | TP | SRP | TSS | TKN | $NO_2$+N $O_3$ | |
| Drew Creek at HWY F | DR1 | UWM | 5/18/2006 | 2.81 | **0.163** | 0.112 | 13 | 0.78 | **14.40** | 15.18 | 3.82 | 2.63 | 304.79 | 18.29 | 428.76 | |
| | | UWM | 5/25/2006 | 2.39 | **0.057** | 0.041 | 5 | 0.31 | **18.00** | 18.31 | 1.14 | 0.82 | 99.82 | 6.19 | 123.54 | |
| | | UWM | 5/31/2006 | 2.40 | **0.097** | 0.062 | 9 | 0.29 | **18.70** | 18.99 | 1.94 | 1.24 | 180.30 | 5.81 | 116.38 | |
| | | UWM | 6/13/2006 | 2.16 | **0.068** | 0.041 | 7 | 0.34 | **21.40** | 21.74 | 1.22 | 0.74 | 125.84 | 6.11 | 109.88 | |
| | | UWM | 6/19/2006 | 1.96 | **0.087** | 0.056 | 9 | 0.56 | **21.50** | 22.06 | 1.42 | 0.92 | 147.41 | 9.17 | 150.23 | |
| | | Hey | 8/5/2008 | 7.00 | **0.102** | 0.07 | 7.00 | 0.55 | **15.90** | 16.45 | 5.95 | 4.14 | 408.49 | 32.10 | 1872.96 | **866.00** |
| | | Hey | 9/9/2008 | 6.66 | **0.071** | 0.04 | 7.00 | 0.52 | **18.10** | 18.62 | 3.94 | 2.00 | 388.93 | 28.89 | 1605.26 | 129.00 |
| | | Hey | 10/9/2008 | 4.45 | **0.090** | 0.05 | 13.00 | 0.67 | **14.50** | 15.17 | 3.34 | 1.74 | 482.35 | 24.86 | 922.39 | **2419.00** |
| | | Hey | 7/14/2009 | 1.80 | **0.067** | 0.04 | 8.00 | 0.27 | **16.70** | 16.97 | 1.01 | 0.54 | 120.10 | 4.05 | 60.85 | |
| | | | Mean | 3.51 | **0.089** | 0.06 | 8.67 | 0.48 | **17.69** | 18.17 | 2.64 | 1.64 | 250.89 | 15.05 | 598.92 | 1138.00 |
| Drew Creek at Lake Emily Road | DR2 | UWM | 5/18/2006 | 3.58 | **0.078** | 0.05 | 6 | 0.52 | **16.30** | 16.82 | 2.33 | 1.49 | 179.27 | 15.54 | 464.23 | |
| | | UWM | 5/25/2006 | 2.51 | **0.037** | 0.026 | 4 | 0.48 | **21.30** | 21.78 | 0.77 | 0.54 | 83.69 | 10.04 | 210.10 | |
| | | UWM | 5/31/2006 | 2.48 | **0.299** | 0.066 | 35.5 | 1.64 | **19.80** | 21.44 | 6.20 | 1.37 | 735.72 | 33.99 | 704.39 | |
| | | UWM | 6/13/2006 | 1.65 | **0.042** | 0.025 | 3 | 0.34 | **23.80** | 24.14 | 0.58 | 0.34 | 41.28 | 4.68 | 64.37 | |
| | | UWM | 6/19/2006 | 5.10 | **0.033** | 0.049 | 2 | 0.49 | **24.00** | 24.49 | 1.40 | 2.08 | 85.03 | 20.83 | 885.65 | |
| | | Hey | 8/5/2008 | 12.44 | **0.084** | 0.06 | 7.00 | 0.38 | **18.30** | 18.68 | 8.72 | 5.81 | 726.41 | 39.43 | 4092.18 | **225.00** |
| | | Hey | 9/9/2008 | 7.50 | **0.058** | 0.03 | 10.00 | 0.35 | **19.20** | 19.55 | 3.63 | 1.69 | 625.53 | 21.89 | 1369.49 | 70.00 |
| | | Hey | 10/9/2008 | 4.74 | **0.062** | 0.03 | 4.00 | 0.48 | **16.10** | 16.58 | 2.45 | 1.34 | 158.18 | 18.98 | 750.65 | 133.00 |
| | | Hey | 7/14/2009 | 0.00 | **0.066** | 0.03 | 13.00 | 0.15 | **17.80** | 17.95 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| | | | Mean | 4.45 | **0.084** | 0.04 | 9.39 | 0.54 | **19.62** | 20.16 | 2.90 | 1.63 | 292.79 | 18.38 | 949.01 | 142.67 |
| Drew Creek at Parish Rd. | DR3 | UWM | 5/18/2006 | 0.96 | **0.180** | 0.115 | 10 | 0.78 | **18.90** | 19.68 | 1.44 | 0.92 | 79.73 | 6.22 | 49.59 | |
| | | UWM | 5/25/2006 | 0.94 | **0.074** | 0.048 | 6 | 0.41 | **20.40** | 20.81 | 0.58 | 0.38 | 47.06 | 3.22 | 25.22 | |
| | | UWM | 5/31/2006 | 0.55 | **0.626** | 0.032 | 198 | 3.4 | **21.70** | 25.10 | 2.85 | 0.15 | 901.74 | 15.48 | 70.52 | |
| | | UWM | 6/13/2006 | 0.17 | **0.054** | 0.0378 | 2 | 0.24 | **21.10** | 21.34 | 0.08 | 0.05 | 2.87 | 0.34 | 0.49 | |
| | | UWM | 6/19/2006 | 0.55 | **0.066** | 0.04 | 2 | 0.54 | **21.60** | 22.14 | 0.30 | 0.18 | 9.20 | 2.48 | 11.42 | |
| | | Hey | 8/5/2008 | 1.94 | **0.197** | 0.27 | 3.00 | 0.58 | **13.70** | 14.28 | 3.18 | 4.40 | 48.48 | 9.37 | 151.44 | 196.00 |

| Site | Site No. | Source | Date | Flow (MGD) | Concentration (mg/l) | | | | | | Loadings (lbs/day) | | | | | E-Coli |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | TP | SRP | TSS | TKN | NO2+ NO3 | TN | TP | SRP | TSS | TKN | $NO_2+NO_3$ | |
| | | Hey | 9/9/2008 | 1.52 | **0.127** | 0.03 | 29.40 | 0.63 | **17.70** | 18.33 | 1.61 | 0.43 | 371.68 | 7.96 | 100.69 | 167.00 |
| | | Hey | 10/9/2008 | 2.54 | **0.063** | 0.05 | 3.00 | 0.52 | **16.50** | 17.02 | 1.34 | 0.95 | 63.65 | 11.03 | 234.09 | 32.00 |
| | | Hey | 7/14/2009 | 0.00 | **0.078** | 0.04 | 10.00 | 0.30 | **15.30** | 15.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| | | | Mean | 1.02 | **0.163** | 0.07 | 29.27 | 0.82 | **18.54** | 19.37 | 1.26 | 0.83 | 169.38 | 6.24 | 71.50 | 131.67 |
| Prison Creek | DR4 | Hey | 8/5/2008 | 2.00 | **0.071** | 0.04 | 22.00 | 0.29 | **19.30** | 19.59 | 1.19 | 0.68 | 367.29 | 4.84 | 80.83 | 121 |
| | | Hey | 9/9/2008 | 5.98 | **0.055** | 0.03 | 14.00 | 0.45 | **20.20** | 20.65 | 2.74 | 1.35 | 698.52 | 22.45 | 1120.24 | 111.00 |
| | | Hey | 10/9/2008 | 0.86 | **0.062** | 0.03 | 20.00 | 0.36 | **18.10** | 18.46 | 0.44 | 0.21 | 142.95 | 2.57 | 18.39 | 34.00 |
| | | Hey | 7/14/2009 | 0.90 | **0.068** | 0.03 | 34.00 | 0.21 | **19.10** | 19.31 | 0.51 | 0.21 | 255.20 | 1.58 | 11.83 | |
| | | | Mean | 2.44 | **0.064** | 0.03 | 22.50 | 0.33 | **19.18** | 19.50 | 1.22 | 0.61 | 365.99 | 7.86 | 307.82 | 88.67 |
| Drew Creek on Prison Grounds | DR6 | Hey | 9/9/2008 | 6.06 | **0.058** | 0.03 | 8.00 | 0.22 | **18.90** | 19.12 | 2.93 | 1.62 | 404.13 | 11.11 | 561.41 | 88.00 |
| | | Hey | 10/9/2008 | 1.81 | 0.079 | 0.04 | 16.00 | 0.62 | **15.50** | 16.12 | 1.19 | 0.57 | 240.92 | 9.34 | 140.57 | **517.00** |
| | | Hey | 7/14/2009 | 1.20 | 0.055 | 0.03 | 7.00 | 0.14 | **17.70** | 17.84 | 0.55 | 0.33 | 70.06 | 1.40 | 14.02 | |
| | | | Mean | 3.02 | 0.064 | 0.03 | 10.33 | 0.33 | **17.37** | 17.69 | 1.56 | 0.84 | 238.37 | 7.28 | 238.67 | 302.50 |

# APPENDIX B

Graphical Presentation of Hey and Associates, Inc.
Drew Creek Monitoring Data: 2008 - 2009

| Site | Site No. | Date | Flow (cfs) | Flow (MGD) | Concentration TP (mg/l) | SRP (mg/l) | TSS (mg/l) | TKN (mg/l) | NO2+NO3 (mg/l) | Loadings TP (lbs/day) | SRP (lbs/day) | TSS (lbs/day) | TKN (lbs/day) | NO2+NO3 (lbs/day) | E-Coli |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drew Creek at HWY F | DR1 | 8/5/2008 | 10.83 | 7.00 | **0.10** | 0.07 | 7.00 | 0.55 | **15.90** | 5.95 | 4.14 | 408.66 | 32.11 | 928.24 | **866.00** |
| | | 9/9/2008 | 10.31 | 6.66 | **0.07** | 0.04 | 7.00 | 0.52 | **18.10** | 3.95 | 2.00 | 389.09 | 28.90 | 1606.61 | 129.00 |
| | | 10/9/2008 | 6.89 | 4.45 | **0.09** | 0.05 | 13.00 | 0.67 | **14.50** | 3.34 | 1.74 | 482.56 | 24.87 | 923.17 | **2419.00** |
| | | 7/14/2009 | | 1.80 | **0.07** | 0.04 | 8.00 | 0.27 | **16.70** | 1.01 | 0.54 | 120.10 | 4.05 | 60.85 | |

| Site | Site No. | Date | Flow (cfs) | Flow (MGD) | Concentration TP (mg/l) | SRP (mg/l) | TSS (mg/l) | TKN (mg/l) | NO2+NO3 (mg/l) | Loadings TP (lbs/day) | SRP (lbs/day) | TSS (lbs/day) | TKN (lbs/day) | NO2+NO3 (lbs/day) | E-Coli |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drew Creek at Lake Emily Road | DR2 | 8/5/2008 | 19.26 | 12.45 | **0.08** | 0.06 | 7.00 | 0.38 | **18.30** | 8.72 | 5.81 | 726.72 | 39.45 | 1899.85 | **225.00** |
| | | 9/9/2008 | 11.61 | 7.50 | **0.06** | 0.03 | 10.00 | 0.35 | **19.20** | 3.63 | 1.69 | 625.79 | 21.90 | 1370.64 | 70.00 |
| | | 10/9/2008 | 7.34 | 4.74 | **0.06** | 0.03 | 4.00 | 0.48 | **16.10** | 2.45 | 1.35 | 158.25 | 18.99 | 751.28 | 133.00 |
| | | 7/14/2009 | | 0.50 | **0.07** | 0.03 | 13.00 | 0.15 | **17.80** | 0.28 | 0.14 | 54.21 | 0.63 | 2.61 | |

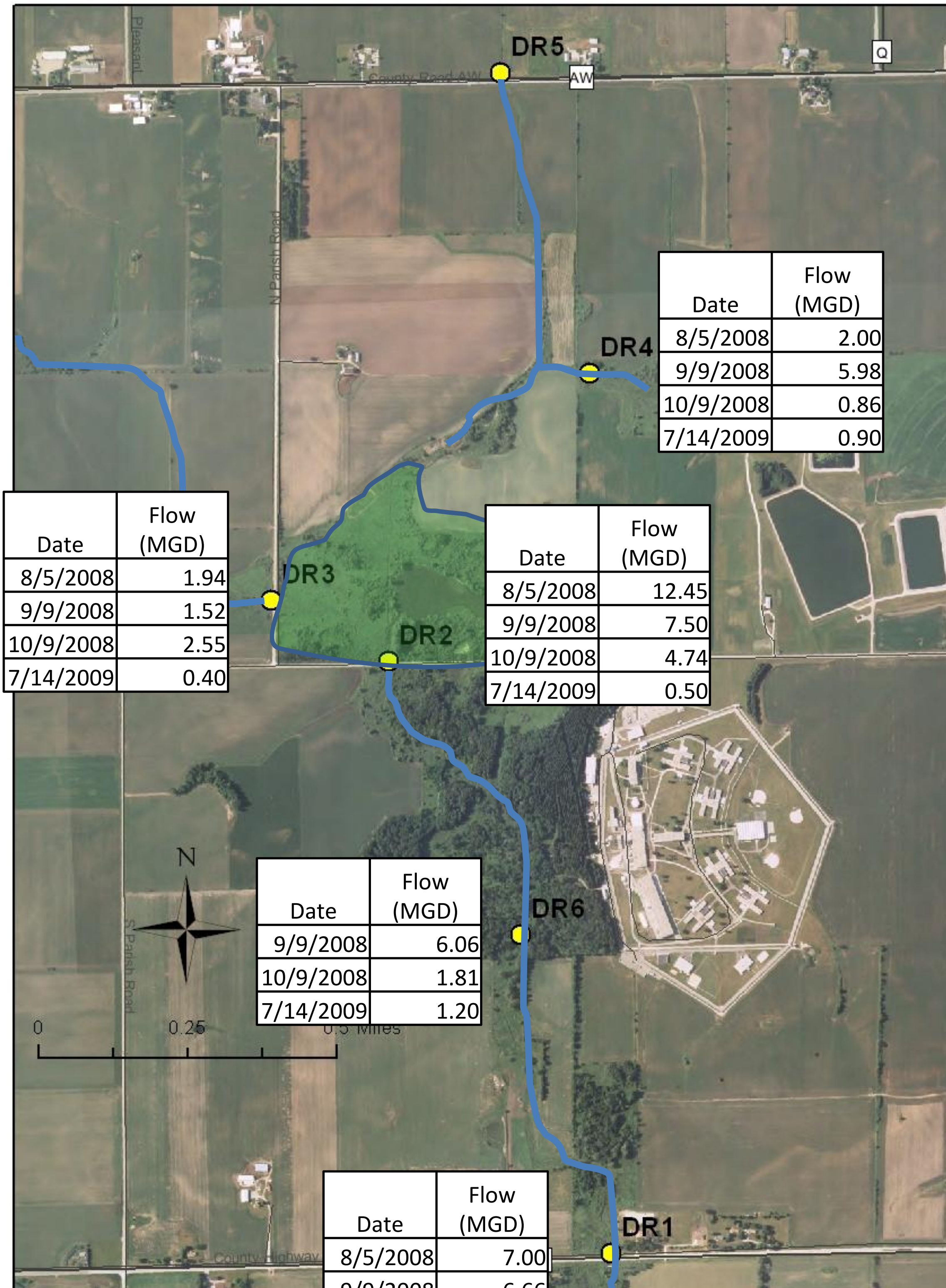
| Site | Site No. | Date | Flow (cfs) | Flow (MGD) | Concentration TP (mg/l) | SRP (mg/l) | TSS (mg/l) | TKN (mg/l) | NO2+NO3 (mg/l) | Loadings TP (lbs/day) | SRP (lbs/day) | TSS (lbs/day) | TKN (lbs/day) | NO2+NO3 (lbs/day) | E-Coli |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drew Creek at Parish Rd. | DR3 | 8/5/2008 | 3.00 | 1.94 | **0.20** | 0.27 | 3.00 | 0.58 | **13.70** | 3.18 | 4.40 | 48.50 | 9.38 | 221.46 | 196.00 |
| | | 9/9/2008 | 2.35 | 1.52 | **0.13** | 0.03 | 29.40 | 0.63 | **17.70** | 1.61 | 0.43 | 371.84 | 7.97 | 100.78 | 167.00 |
| | | 10/9/2008 | 3.94 | 2.55 | **0.06** | 0.05 | 3.00 | 0.52 | **16.50** | 1.34 | 0.96 | 63.68 | 11.04 | 234.29 | 32.00 |
| | | 7/14/2009 | | 0.40 | **0.08** | 0.04 | 10.00 | 0.30 | **15.30** | 0.26 | 0.13 | 33.36 | 1.00 | 3.34 | |

| Site | Site No. | Date | Flow (cfs) | Flow (MGD) | Concentration TP (mg/l) | SRP (mg/l) | TSS (mg/l) | TKN (mg/l) | NO2+NO3 (mg/l) | Loadings TP (lbs/day) | SRP (lbs/day) | TSS (lbs/day) | TKN (lbs/day) | NO2+NO3 (lbs/day) | E-Coli |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Prison Creek | DR4 | 8/5/2008 | 3.10 | 2.00 | **0.07** | 0.04 | 22.00 | 0.29 | **19.30** | 1.19 | 0.68 | 367.29 | 4.84 | 322.21 | 121 |
| | | 9/9/2008 | 9.26 | 5.98 | **0.06** | 0.03 | 14.00 | 0.45 | **20.20** | 2.74 | 1.35 | 698.52 | 22.45 | 1120.24 | 111.00 |
| | | 10/9/2008 | 1.33 | 0.86 | **0.06** | 0.03 | 20.00 | 0.36 | **18.10** | 0.44 | 0.21 | 142.95 | 2.57 | 18.39 | 34.00 |
| | | 7/14/2009 | | 0.90 | **0.07** | 0.03 | 34.00 | 0.21 | **19.10** | 0.51 | 0.21 | 255.20 | 1.58 | 11.83 | |

| Site | Site No. | Date | Flow (cfs) | Flow (MGD) | Concentration TP (mg/l) | SRP (mg/l) | TSS (mg/l) | TKN (mg/l) | NO2+NO3 (mg/l) | Loadings TP (lbs/day) | SRP (lbs/day) | TSS (lbs/day) | TKN (lbs/day) | NO2+NO3 (lbs/day) | E-Coli |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drew Creek on Prison Grounds | DR6 | 9/9/2008 | 9.37 | 6.06 | **0.06** | 0.03 | 8.00 | 0.22 | **18.90** | 2.93 | 1.62 | 404.13 | 11.11 | 561.41 | 88.00 |
| | | 10/9/2008 | 2.79 | 1.81 | **0.08** | 0.04 | 16.00 | 0.62 | **15.50** | 1.19 | 0.57 | 240.92 | 9.34 | 140.57 | **517.00** |
| | | 7/14/2009 | | 1.20 | **0.06** | 0.03 | 7.00 | 0.14 | **17.70** | 0.55 | 0.33 | 70.06 | 1.40 | 14.02 | |

# Sample Site Locations

# Flow (MGD)




| Date | Flow (MGD) |
|---|---|
| 8/5/2008 | 2.00 |
| 9/9/2008 | 5.98 |
| 10/9/2008 | 0.86 |
| 7/14/2009 | 0.90 |

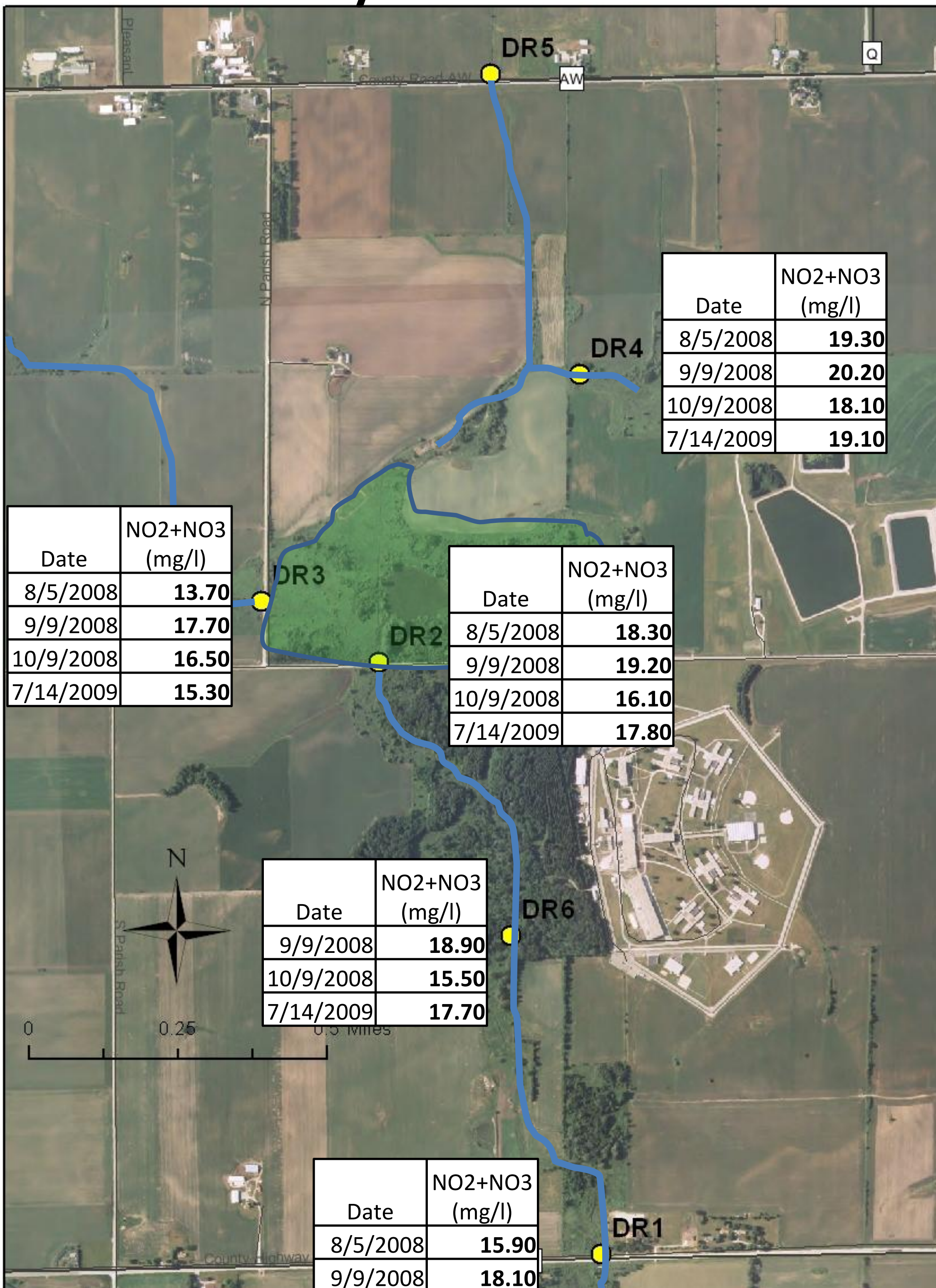
| Date | Flow (MGD) |
|---|---|
| 8/5/2008 | 1.94 |
| 9/9/2008 | 1.52 |
| 10/9/2008 | 2.55 |
| 7/14/2009 | 0.40 |

| Date | Flow (MGD) |
|---|---|
| 8/5/2008 | 12.45 |
| 9/9/2008 | 7.50 |
| 10/9/2008 | 4.74 |
| 7/14/2009 | 0.50 |

| Date | Flow (MGD) |
|---|---|
| 9/9/2008 | 6.06 |
| 10/9/2008 | 1.81 |
| 7/14/2009 | 1.20 |

| Date | Flow (MGD) |
|---|---|
| 8/5/2008 | 7.00 |
| 9/9/2008 | 6.66 |
| 10/9/2008 | 4.45 |
| 7/14/2009 | 1.80 |

# Nitrate/Nitrite Conc.




DR4:

| Date | NO2+NO3 (mg/l) |
|---|---|
| 8/5/2008 | **19.30** |
| 9/9/2008 | **20.20** |
| 10/9/2008 | **18.10** |
| 7/14/2009 | **19.10** |

DR3:

| Date | NO2+NO3 (mg/l) |
|---|---|
| 8/5/2008 | **13.70** |
| 9/9/2008 | **17.70** |
| 10/9/2008 | **16.50** |
| 7/14/2009 | **15.30** |

DR2:

| Date | NO2+NO3 (mg/l) |
|---|---|
| 8/5/2008 | **18.30** |
| 9/9/2008 | **19.20** |
| 10/9/2008 | **16.10** |
| 7/14/2009 | **17.80** |

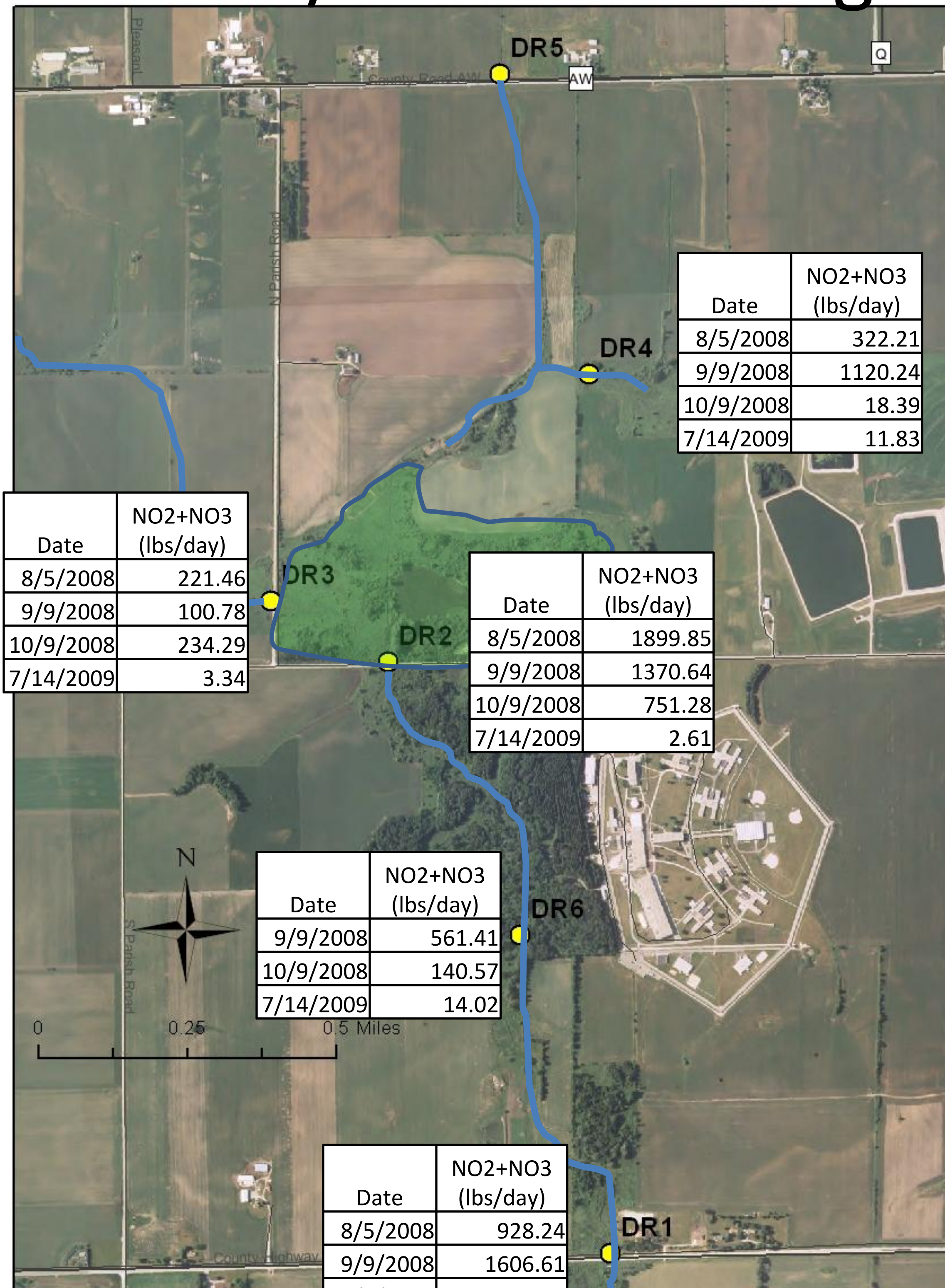
DR6:

| Date | NO2+NO3 (mg/l) |
|---|---|
| 9/9/2008 | **18.90** |
| 10/9/2008 | **15.50** |
| 7/14/2009 | **17.70** |

DR1:

| Date | NO2+NO3 (mg/l) |
|---|---|
| 8/5/2008 | **15.90** |
| 9/9/2008 | **18.10** |
| 10/9/2008 | **14.50** |
| 7/14/2009 | **16.70** |

# Nitrate/Nitrite Loadings




| Date | NO2+NO3 (lbs/day) |
|---|---|
| 8/5/2008 | 322.21 |
| 9/9/2008 | 1120.24 |
| 10/9/2008 | 18.39 |
| 7/14/2009 | 11.83 |

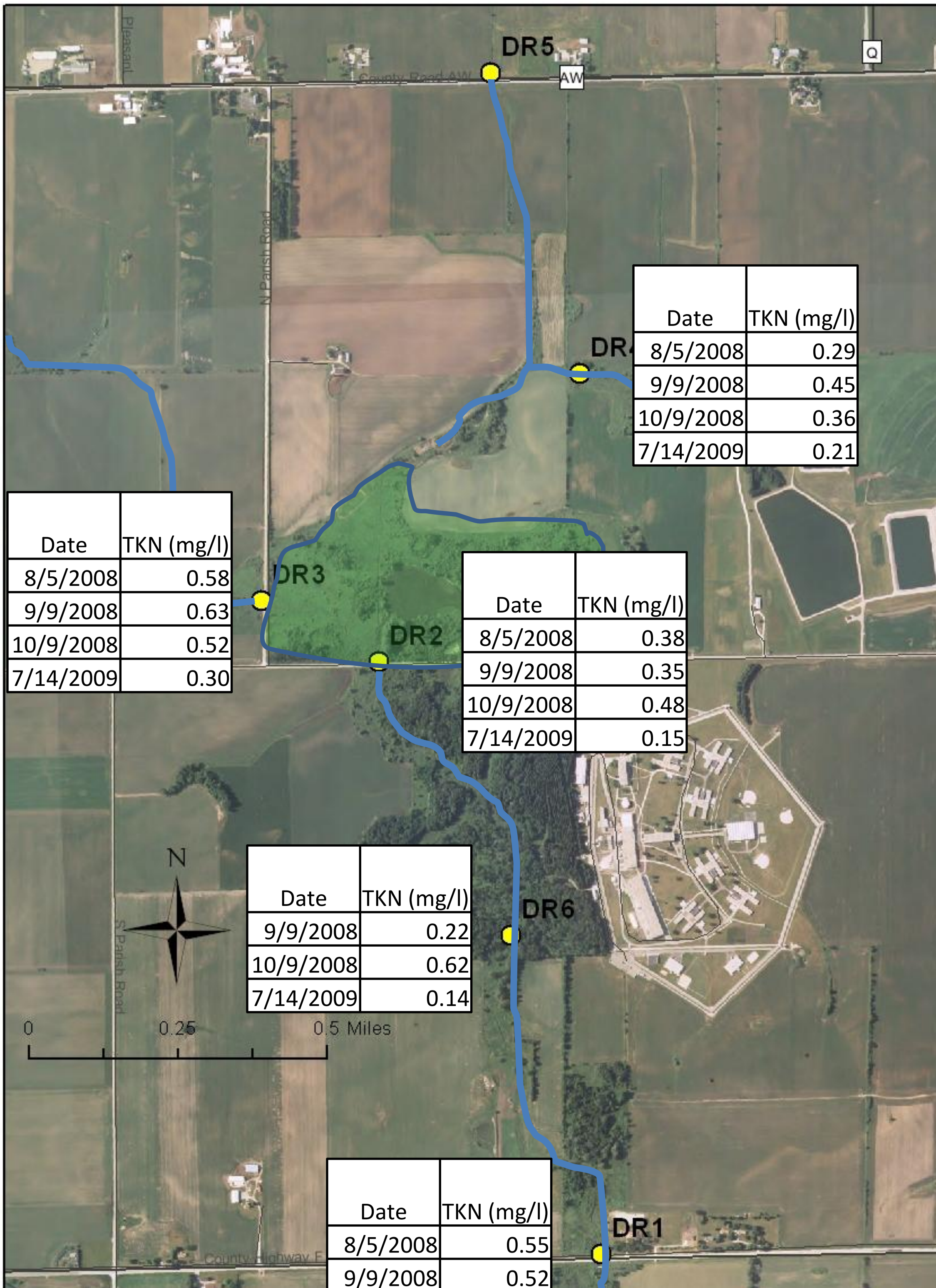
| Date | NO2+NO3 (lbs/day) |
|---|---|
| 8/5/2008 | 221.46 |
| 9/9/2008 | 100.78 |
| 10/9/2008 | 234.29 |
| 7/14/2009 | 3.34 |

| Date | NO2+NO3 (lbs/day) |
|---|---|
| 8/5/2008 | 1899.85 |
| 9/9/2008 | 1370.64 |
| 10/9/2008 | 751.28 |
| 7/14/2009 | 2.61 |

| Date | NO2+NO3 (lbs/day) |
|---|---|
| 9/9/2008 | 561.41 |
| 10/9/2008 | 140.57 |
| 7/14/2009 | 14.02 |

| Date | NO2+NO3 (lbs/day) |
|---|---|
| 8/5/2008 | 928.24 |
| 9/9/2008 | 1606.61 |
| 10/9/2008 | 923.17 |
| 7/14/2009 | 60.85 |

# TKN Conc.




| Date | TKN (mg/l) |
|---|---|
| 8/5/2008 | 0.29 |
| 9/9/2008 | 0.45 |
| 10/9/2008 | 0.36 |
| 7/14/2009 | 0.21 |

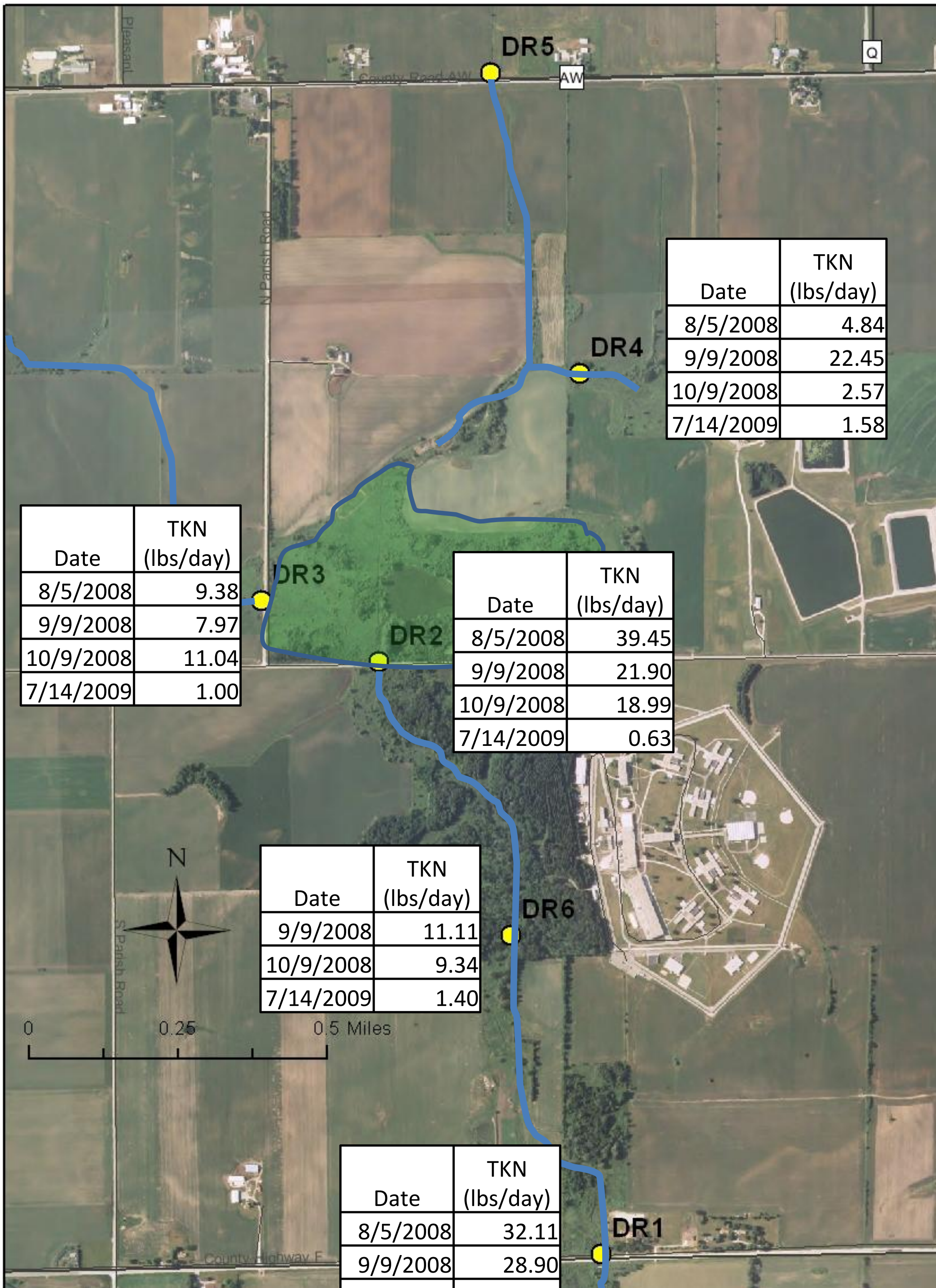
| Date | TKN (mg/l) |
|---|---|
| 8/5/2008 | 0.58 |
| 9/9/2008 | 0.63 |
| 10/9/2008 | 0.52 |
| 7/14/2009 | 0.30 |

| Date | TKN (mg/l) |
|---|---|
| 8/5/2008 | 0.38 |
| 9/9/2008 | 0.35 |
| 10/9/2008 | 0.48 |
| 7/14/2009 | 0.15 |

| Date | TKN (mg/l) |
|---|---|
| 9/9/2008 | 0.22 |
| 10/9/2008 | 0.62 |
| 7/14/2009 | 0.14 |

| Date | TKN (mg/l) |
|---|---|
| 8/5/2008 | 0.55 |
| 9/9/2008 | 0.52 |
| 10/9/2008 | 0.67 |
| 7/14/2009 | 0.27 |

# TKN Loadings




| Date | TKN (lbs/day) |
|---|---|
| 8/5/2008 | 4.84 |
| 9/9/2008 | 22.45 |
| 10/9/2008 | 2.57 |
| 7/14/2009 | 1.58 |

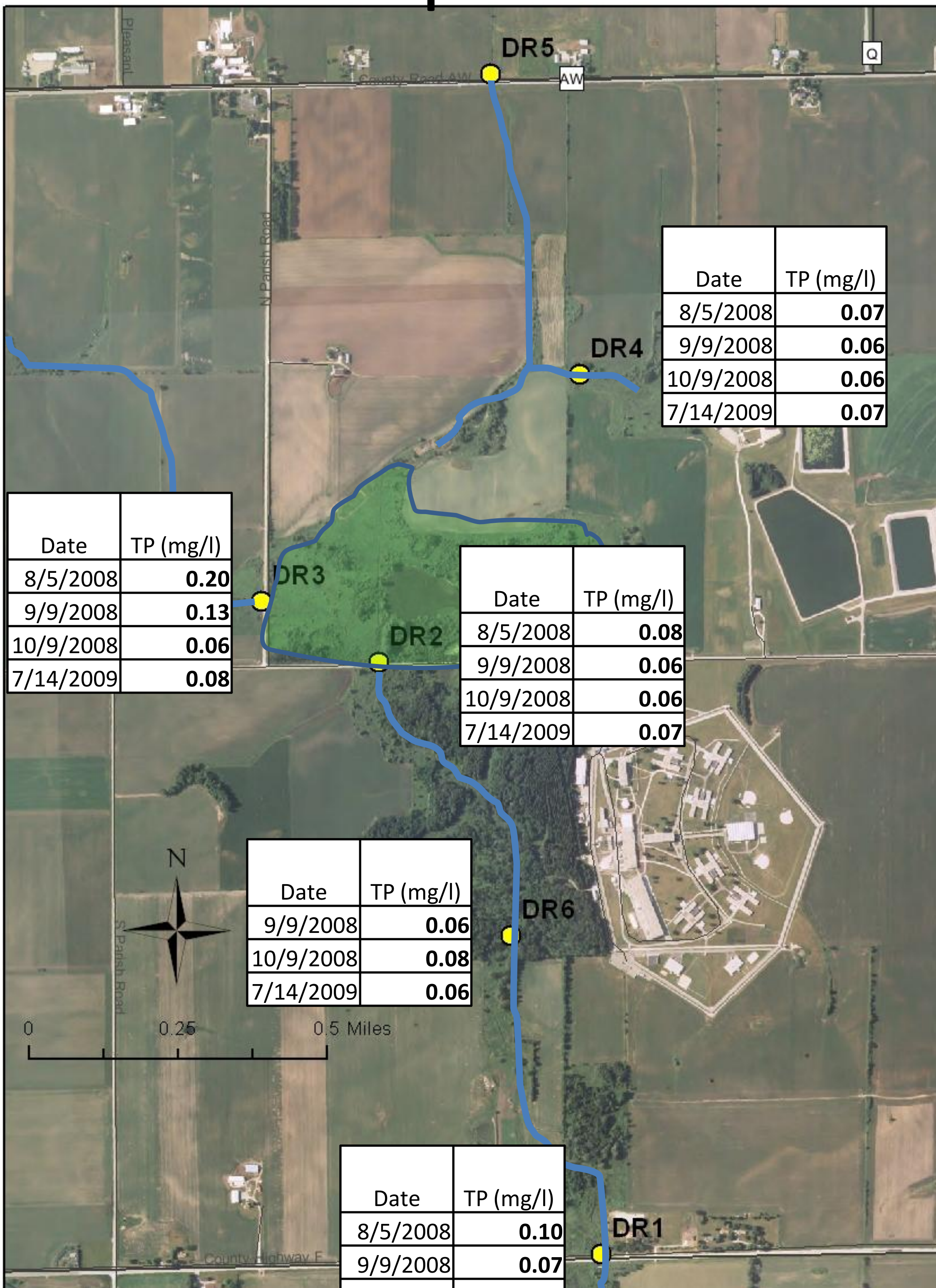
| Date | TKN (lbs/day) |
|---|---|
| 8/5/2008 | 9.38 |
| 9/9/2008 | 7.97 |
| 10/9/2008 | 11.04 |
| 7/14/2009 | 1.00 |

| Date | TKN (lbs/day) |
|---|---|
| 8/5/2008 | 39.45 |
| 9/9/2008 | 21.90 |
| 10/9/2008 | 18.99 |
| 7/14/2009 | 0.63 |

| Date | TKN (lbs/day) |
|---|---|
| 9/9/2008 | 11.11 |
| 10/9/2008 | 9.34 |
| 7/14/2009 | 1.40 |

| Date | TKN (lbs/day) |
|---|---|
| 8/5/2008 | 32.11 |
| 9/9/2008 | 28.90 |
| 10/9/2008 | 24.87 |
| 7/14/2009 | 4.05 |

# Total Phosphorus Conc.




| Date | TP (mg/l) |
|---|---|
| 8/5/2008 | **0.07** |
| 9/9/2008 | **0.06** |
| 10/9/2008 | **0.06** |
| 7/14/2009 | **0.07** |

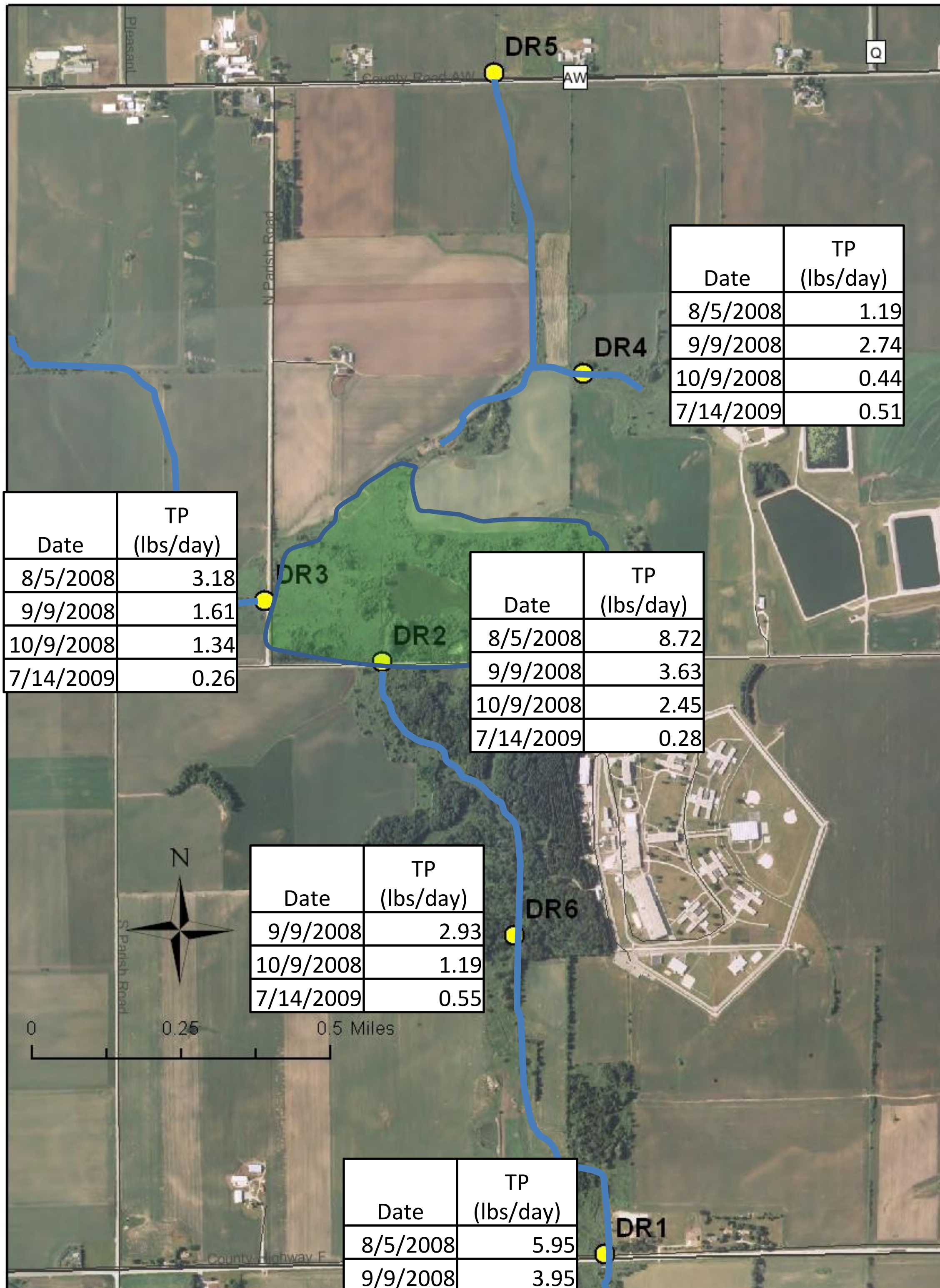
| Date | TP (mg/l) |
|---|---|
| 8/5/2008 | **0.20** |
| 9/9/2008 | **0.13** |
| 10/9/2008 | **0.06** |
| 7/14/2009 | **0.08** |

| Date | TP (mg/l) |
|---|---|
| 8/5/2008 | **0.08** |
| 9/9/2008 | **0.06** |
| 10/9/2008 | **0.06** |
| 7/14/2009 | **0.07** |

| Date | TP (mg/l) |
|---|---|
| 9/9/2008 | **0.06** |
| 10/9/2008 | **0.08** |
| 7/14/2009 | **0.06** |

| Date | TP (mg/l) |
|---|---|
| 8/5/2008 | **0.10** |
| 9/9/2008 | **0.07** |
| 10/9/2008 | **0.09** |
| 7/14/2009 | **0.07** |

# Total Phosphorus Loadings.




| Date | TP (lbs/day) |
|---|---|
| 8/5/2008 | 1.19 |
| 9/9/2008 | 2.74 |
| 10/9/2008 | 0.44 |
| 7/14/2009 | 0.51 |

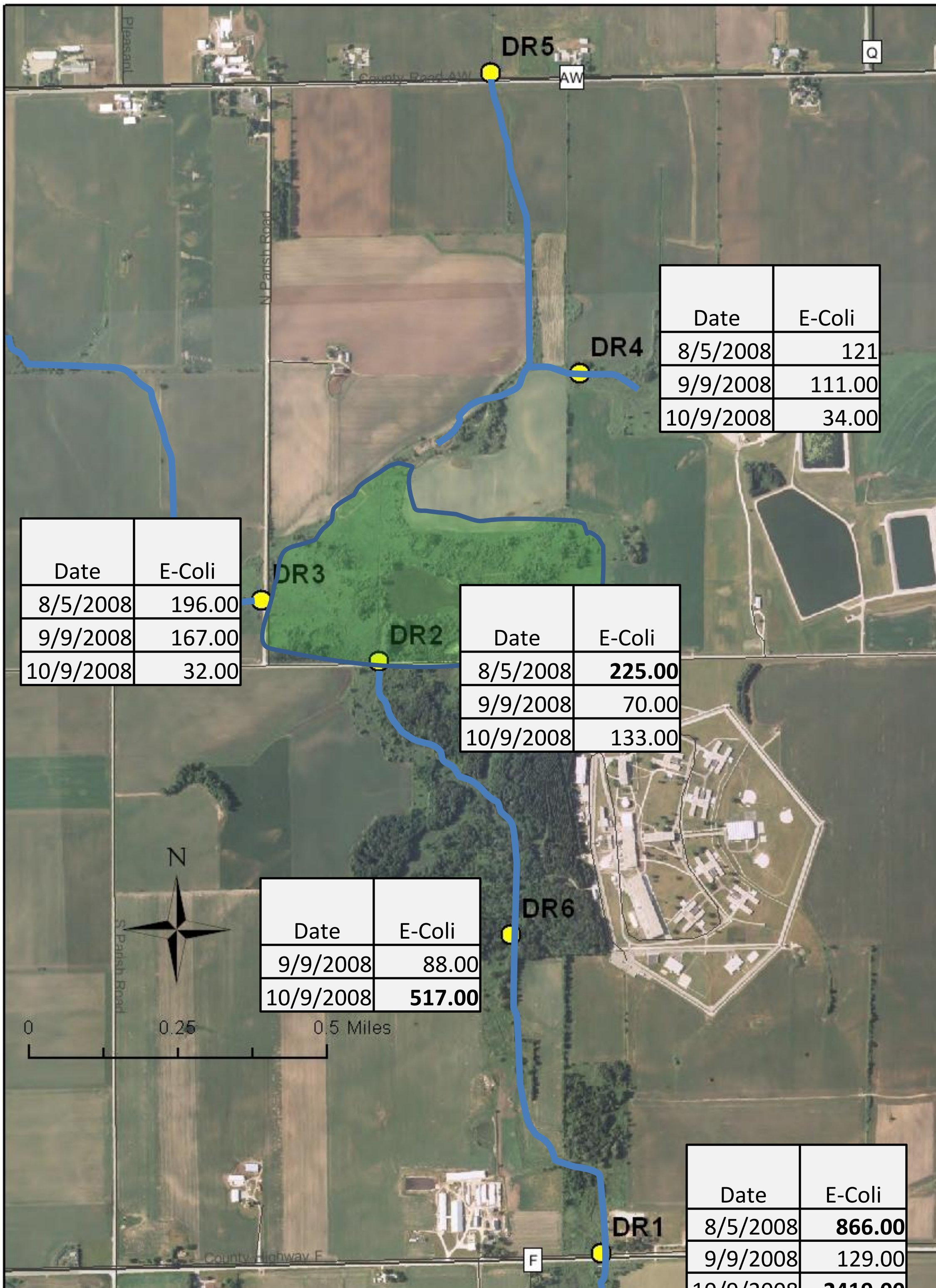
| Date | TP (lbs/day) |
|---|---|
| 8/5/2008 | 3.18 |
| 9/9/2008 | 1.61 |
| 10/9/2008 | 1.34 |
| 7/14/2009 | 0.26 |

| Date | TP (lbs/day) |
|---|---|
| 8/5/2008 | 8.72 |
| 9/9/2008 | 3.63 |
| 10/9/2008 | 2.45 |
| 7/14/2009 | 0.28 |

| Date | TP (lbs/day) |
|---|---|
| 9/9/2008 | 2.93 |
| 10/9/2008 | 1.19 |
| 7/14/2009 | 0.55 |

| Date | TP (lbs/day) |
|---|---|
| 8/5/2008 | 5.95 |
| 9/9/2008 | 3.95 |
| 10/9/2008 | 3.34 |
| 7/14/2009 | 1.01 |

# E-Coli




DR4

| Date | E-Coli |
|---|---|
| 8/5/2008 | 121 |
| 9/9/2008 | 111.00 |
| 10/9/2008 | 34.00 |

DR3

| Date | E-Coli |
|---|---|
| 8/5/2008 | 196.00 |
| 9/9/2008 | 167.00 |
| 10/9/2008 | 32.00 |

DR2

| Date | E-Coli |
|---|---|
| 8/5/2008 | **225.00** |
| 9/9/2008 | 70.00 |
| 10/9/2008 | 133.00 |

DR6

| Date | E-Coli |
|---|---|
| 9/9/2008 | 88.00 |
| 10/9/2008 | **517.00** |

DR1

| Date | E-Coli |
|---|---|
| 8/5/2008 | **866.00** |
| 9/9/2008 | 129.00 |
| 10/9/2008 | **2419.00** |

# APPENDIX C

USGS Groundwater Susceptibility Map Dodge County

## GROUNDWATER CONTAMINATION SUSCEPTIBILITY MAP DODGE COUNTY

Use of this Map:

The composite Groundwater Contamination Susceptibility Map can be used by state agencies and others when deciding where they should more closely study impacts on groundwater. Local officials can also use this in determining whether they should study their region in more detail for potential groundwater problems. The groundwater contamination susceptibility map can be combined with other planning tools such as land use maps, groundwater quality data and contamination source information to help make sound groundwater management and land use decisions.

The Groundwater Contamination Susceptibility Map of Wisconsin doesn't show areas that will be contaminated, or areas that cannot be contaminated. Whether an area will have groundwater contamination depends on the likelihood of contaminant release, the type of contaminants released and the sensitivity of the area to the contamination. In turn, the likelihood of contaminant release depends on the type and intensity of the land use and contaminant sources in an area.This map highlights areas sensitive to contamination and shows them in a generalized way.

There are many limitations in the use of this composite map. It is compiled from very generalized statewide information at a small scale, and therefore, cannot be used for any site specific purposes. For example, siting waste disposal facilities or locating an industry requires site-specific, geologic and hydrogeologic information, and can't be made based on this composite map. The Groundwater Contamination Susceptibility Map doesn't consider the individual characteristics of specific contaminants or the subsurface release of contaminants. That is, it only considers the ability of water to move from the land surface to the water table.

Map source: Schmidt, R.R., 1987, Groundwater contamination susceptibility map and evaluation: Wisconsin Department of Natural Resources, Wisconsin's Groundwater Management Plan Report 5, PUBL-WR-177-87, 27 p.

More information about individual data layers can be found in this guidance.

County data: Wisconsin Department of Natural Resources, 2004, 1:24,000 digital data, Wisconsin Transverse Mercator Projection, North American Datum of 1983 (1991 adjustment).

Lake and stream data: U.S. Geological Survey, 2003, 1:2,000,000 digital data, North American Datum of 1983.

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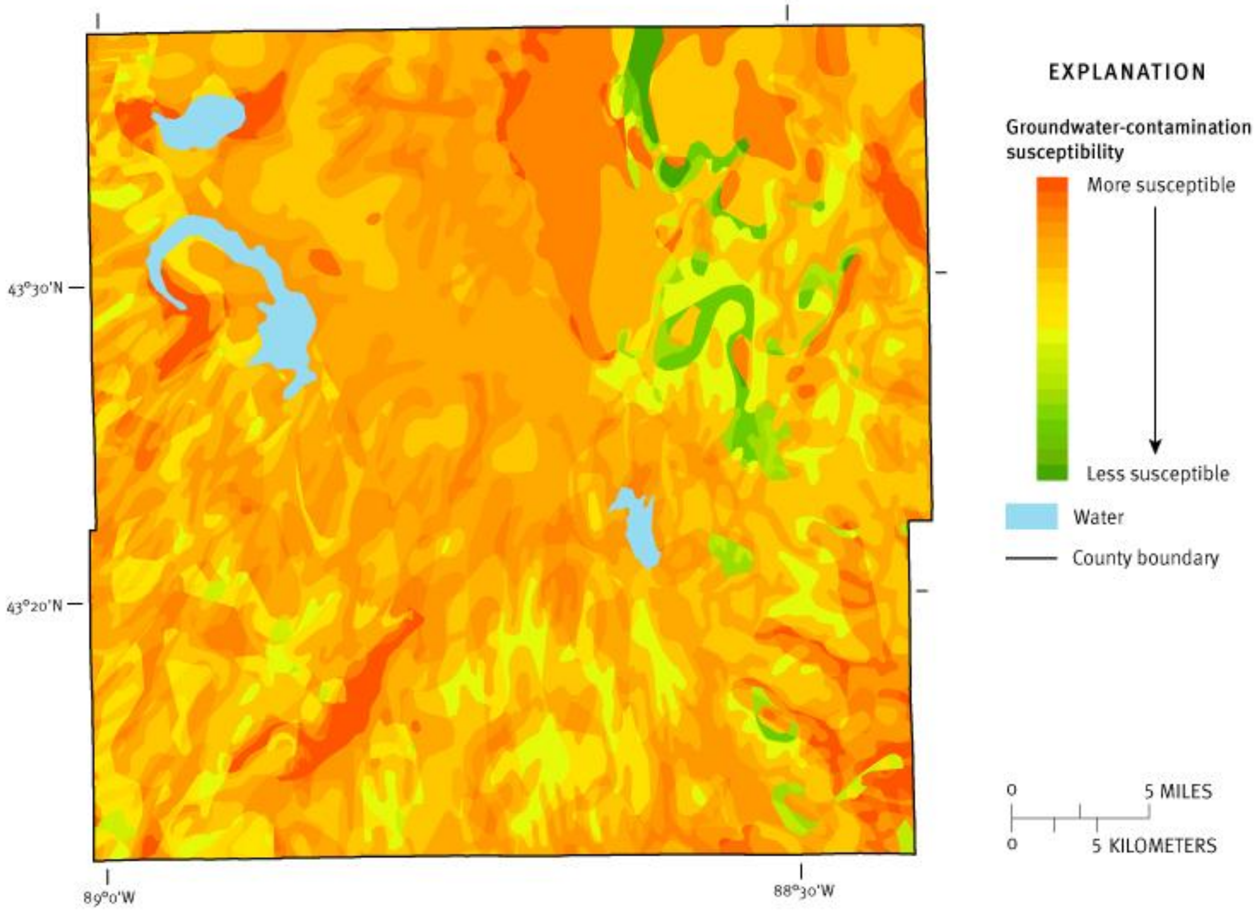
**Dodge County – Groundwater-Contamination Susceptibility Analysis**




**This groundwater-contamination susceptibility map is a composite of five resource characteristic maps, each of which was derived from generalized statewide information at small scales, and cannot be used for any site-specific purposes.**

Map source: Schmidt, R.R., 1987, Groundwater contamination susceptibility map and evaluation: Wisconsin Department of Natural Resources, Wisconsin's Groundwater Management Plan Report 5, PUBL-WR-177-87, 27 p.

Figure created for the "Protecting Wisconsin's Groundwater Through Comprehensive Planning" web site, 2007, *http://wi.water.usgs.gov/gwcomp/*

In Wisconsin, 70% of residents and 97% of communities rely on groundwater as their drinking water source. Wisconsin has abundant quantities of high-quality groundwater, but once groundwater is contaminated, it's expensive and often not technically possible to clean. Because of these factors, we need to be careful to protect our groundwater from contamination. Our activities on the land can contaminate groundwater - most contaminants originate on the land surface and filter down to the groundwater. In some cases however, groundwater can become contaminated from natural causes such as radioactivity due to the presence of radium in certain types of rocks.

"Susceptibility of Groundwater to Pollutants" is defined here as the ease with which a contaminant can be transported from the land surface to the top of the groundwater called the "water table". Many materials that overlie the groundwater offer good protection from contaminants that might be transported by infiltrating waters. The amount of protection offered by the overlying material varies, however, depending on the materials. Thus, in some areas, the overlying soil and bedrock materials allow contaminants to reach the groundwater more easily than in other areas of the state.

In order to identify areas sensitive to contamination, the Wisconsin Department of Natural Resources, in cooperation with the University of Wisconsin Extension, Wisconsin Geological and Natural History Survey and the USGS, has evaluated the physical resource characteristics that influence this sensitivity.

Five physical resource characteristics were identified as important in determining how easily a contaminant can be carried through overlying materials to the groundwater. These characteristics are depth to bedrock, type of bedrock, soil characteristics, depth to water table and characteristics of surficial deposits. Existing statewide maps of these five characteristics were used whenever possible. New maps were compiled when existing information wasn't already mapped. The resource characteristic maps used in this project were compiled from generalized maps at a scale of 1:250,000 or 1:500,000.

Each of the five resource characteristic maps was put into digital form using a Geographic Information Systems (GIS) program. All of the information contained in the five maps was overlaid and combined into one composite map. A numeric rating scheme developed for each map was used to score the maps and the five resource map scores were added together within GIS. The composite map shows the scores for each area – low scores represent areas that are more susceptible to contamination and high scores represent areas that are less susceptible to contamination.

The method described above is a subjective rating method; specifically an index method. An index method assigns a subjective ratings or score to physical resource characteristics of an area to develop a range of contamination susceptibility categories (ranging, in this case, from more susceptible to less susceptible). Index methods are fairly popular approaches to groundwater susceptibility, because they are quick and straightforward, and they use data that are readily available. However, the mapped distribution of susceptibility categories produced by an index method is typically fraught with uncertainty, primarily due to the subjectivity in the approach. The susceptibility categories include little quantifiable or statistical information on uncertainty and this limits their use for defensible decision making. So while susceptibility maps produced using index methods can be useful, their inherent uncertainty must be kept in mind. (National Research Council, 1993; Focazio and others, 2002).

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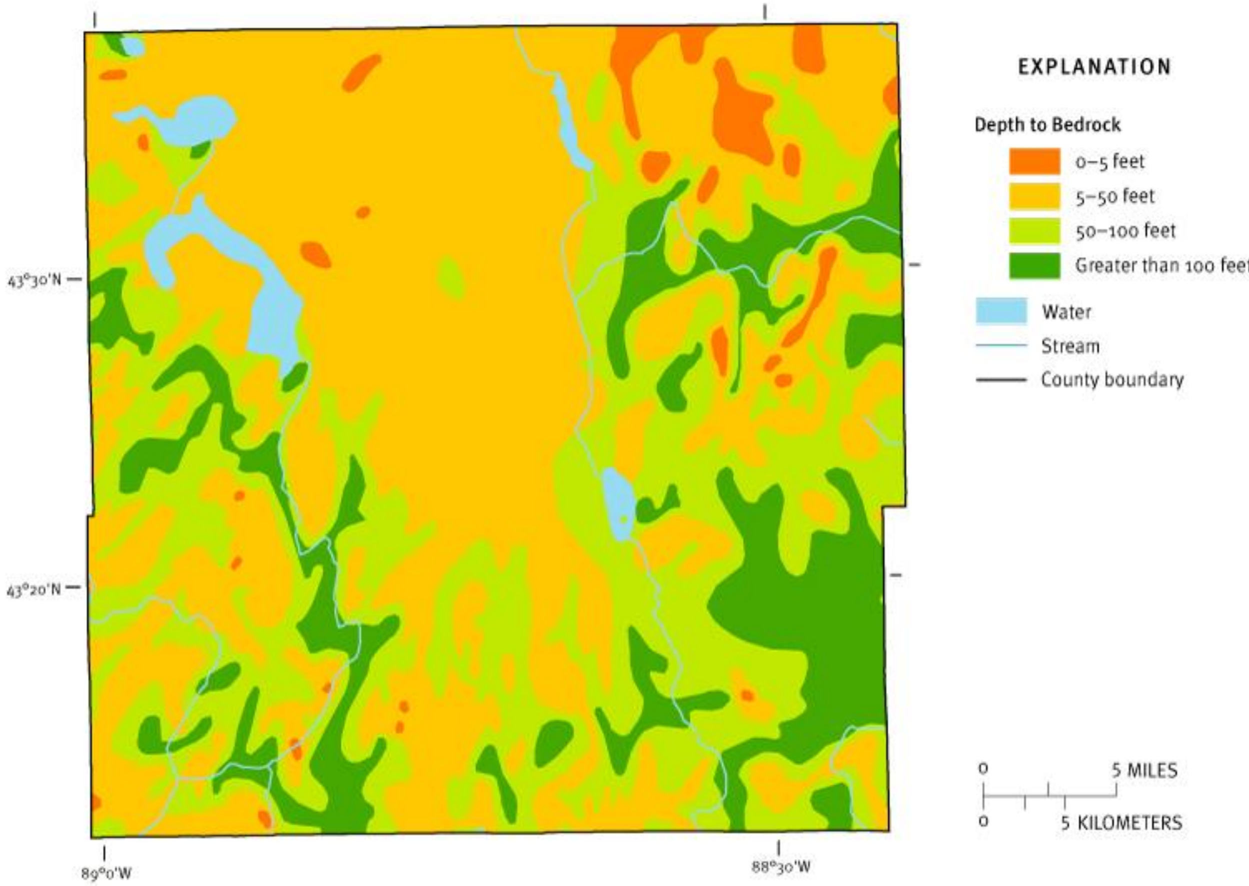
## Dodge County – Depth to Bedrock




**This resource characteristic map was derived from generalized statewide information at small scales, and cannot be used for any site-specific purposes.**

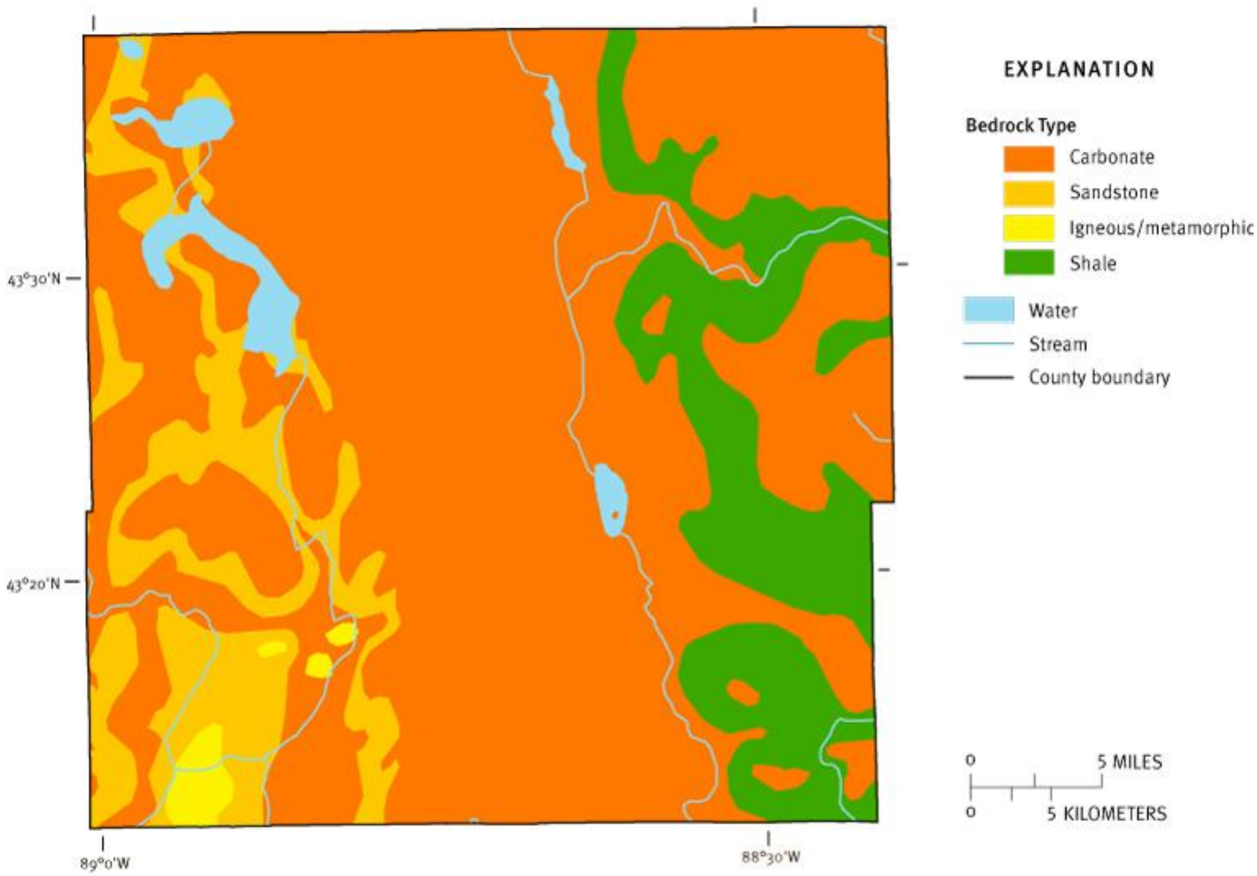
Map source: Schmidt, R.R., 1987, Groundwater contamination susceptibility map and evaluation: Wisconsin Department of Natural Resources, Wisconsin's Groundwater Management Plan Report 5, PUBL-WR-177-87, 27 p.

Figure created for the "Protecting Wisconsin's Groundwater Through Comprehensive Planning" web site, 2007, *http://wi.water.usgs.gov/gwcomp/*

The depth to bedrock indicates the amount of soil and surficial deposits that exist in an area and, therefore how important the type of bedrock is in evaluating pollution potential. Information on the depth to bedrock map is used to determine the relative weight given to the other resource characteristic maps. For example, where the bedrock surface is deep and the water table occurs above the bedrock, the type of bedrock is not considered in determining groundwater contamination susceptibility. Where the depth to bedrock is shallow (less than 50 feet below the land surface), the water table is likely to occur in the bedrock. In that case, the type of bedrock is considered because it could influence a contaminant's ability to reach the groundwater. This map identifies areas where the depth to bedrock is 0-5 feet (in at least 35% of the area), 5-50 feet, 50-100 feet and greater than 100 feet.

---------------------------------------------------------------------------------

## Dodge County – Bedrock Type




**This resource characteristic map was derived from generalized statewide information at small scales, and cannot be used for any site-specific purposes.**

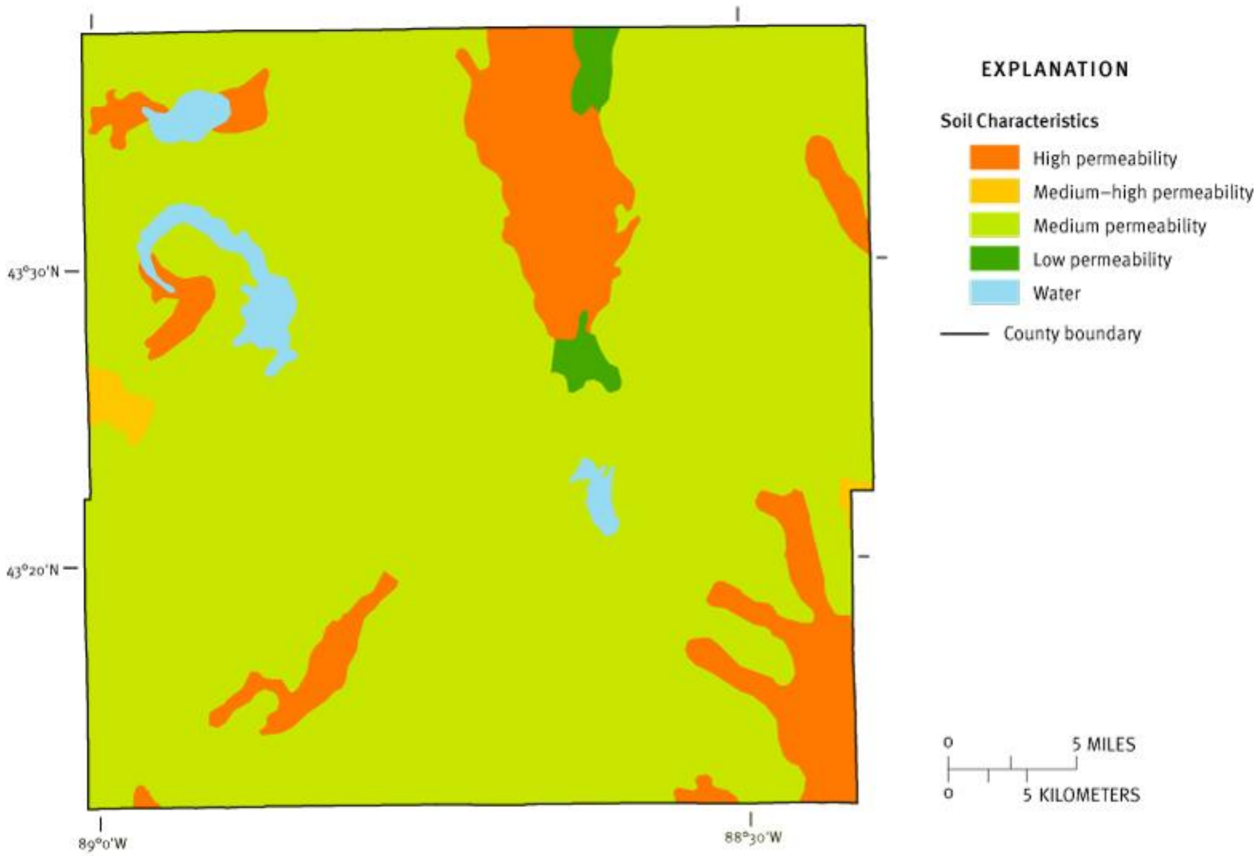
Map source: Schmidt, R.R., 1987, Groundwater contamination susceptibility map and evaluation: Wisconsin Department of Natural Resources, Wisconsin's Groundwater Management Plan Report 5, PUBL-WR-177-87, 27 p.

Figure created for the "Protecting Wisconsin's Groundwater Through Comprehensive Planning" web site, 2007, *http://wi.water.usgs.gov/gwcomp/*

When bedrock is less than 50 feet from the land surface and the water table occurs in the bedrock, the type of bedrock is important in determining how easily a contaminant can reach the groundwater. Bedrock types that allow water to pass quickly through them will offer less protection from contaminants. In Wisconsin, these types of bedrock are typically limestone and dolomite which are highly fractured. Igneous and metamorphic rocks (e.g. granite) and sandstone are less fractured and offer some protection from infiltrating water which may contain contaminants. On the other hand, shale bedrock is almost impermeable, and doesn't allow water and accompanying contaminants to pass through it as easily. The bedrock categories used for this project are carbonates, sandstone, igneous/metamorphic/volcanic, and shale.

--------------------------------------------------------------------------------

## Dodge County – Soil Characteristics




**This resource characteristic map was derived from generalized statewide information at small scales, and cannot be used for any site-specific purposes.**

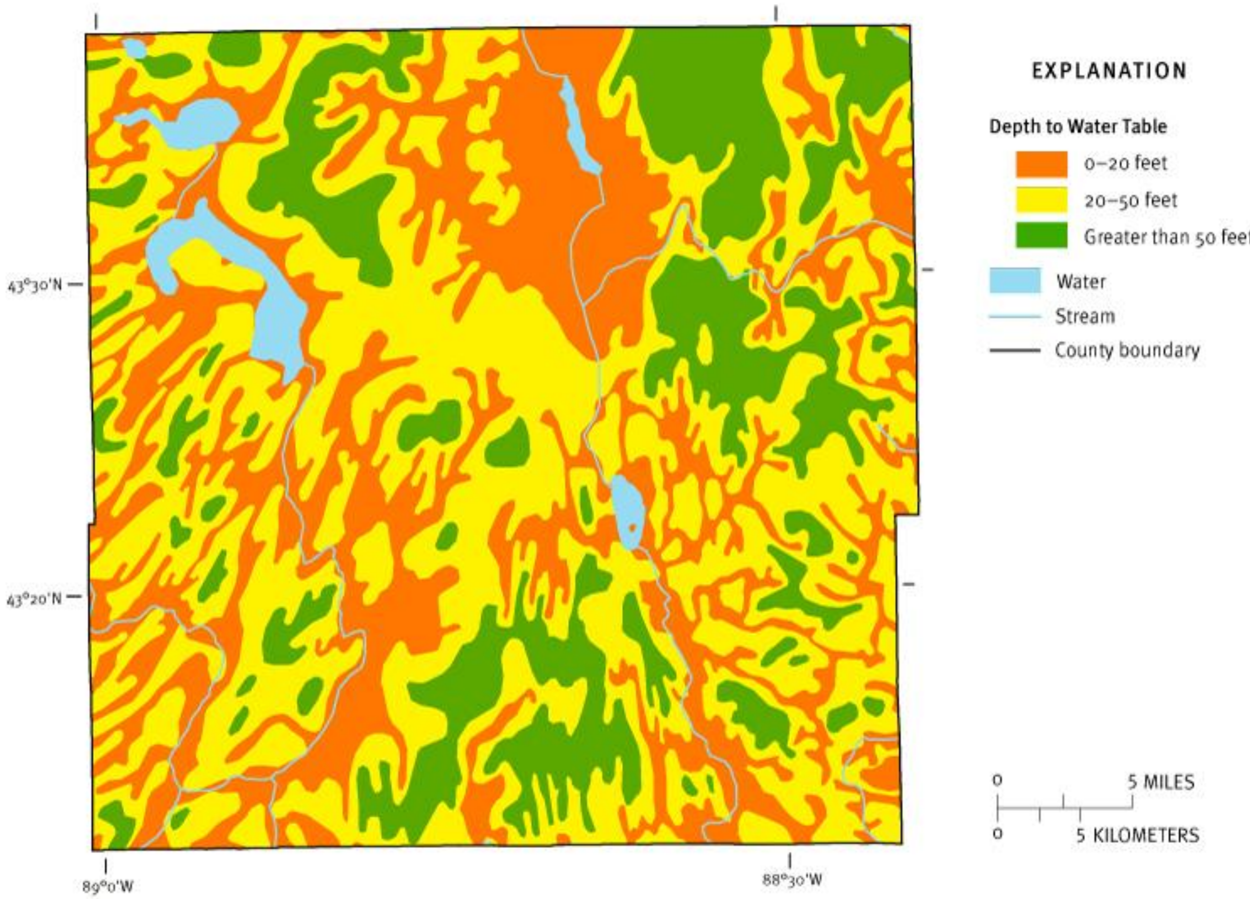
Map source: Schmidt, R.R., 1987, Groundwater contamination susceptibility map and evaluation: Wisconsin Department of Natural Resources, Wisconsin's Groundwater Management Plan Report 5, PUBL-WR-177-87, 27 p.

Figure created for the "Protecting Wisconsin's Groundwater Through Comprehensive Planning" web site, 2007, *http://wi.water.usgs.gov/gwcomp/*

The top layer of materials covering most of the land in Wisconsin is the soil. The soil is defined as the unconsolidated material occurring from the land surface to five feet below the land surface. This is the first material through which water (and accompanying contaminants from the land surface) flow on their way to recharging the groundwater. The soil categories called "associations" have been rated by their ability to restrict the downward movement of water and accompanying pollutants. Important characteristics to consider are soil texture (the amount of sand, silt and clay), organic matter content, permeability and water holding capacity. The soil associations were grouped according to the following characteristics: high susceptibility (highly permeable soils with coarse texture, e.g., sand and gravel); medium/high susceptibility (permeable soils with coarse texture, e.g., sandy soils); medium susceptibility (moderately permeable soils with medium texture, e.g., loamy soils); and low susceptibility (least permeable soils with fine texture, e.g., silty and clayey soils).

--------------------------------------------------------------------------------

## Dodge County – Depth to Water Table




**This resource characteristic map was derived from generalized statewide information at small scales, and cannot be used for any site-specific purposes.**

Map source: Schmidt, R.R., 1987, Groundwater contamination susceptibility map and evaluation: Wisconsin Department of Natural Resources, Wisconsin's Groundwater Management Plan Report 5, PUBL-WR-177-87, 27 p.

Figure created for the "Protecting Wisconsin's Groundwater Through Comprehensive Planning" web site, 2007, *http://wi.water.usgs.gov/gwcomp/*

It is important to know where the water table is when trying to determine groundwater contamination susceptibility. The closer the water table is to the land surface, the less contact contaminants have with filtering materials overlying the water table. The depth to water table is difficult to map on a statewide basis because it's almost as variable as the terrain. The information used in this mapping project identified where the water table was less than 20 feet, between 20 and 50 feet, and greater than 50 feet from the land surface.

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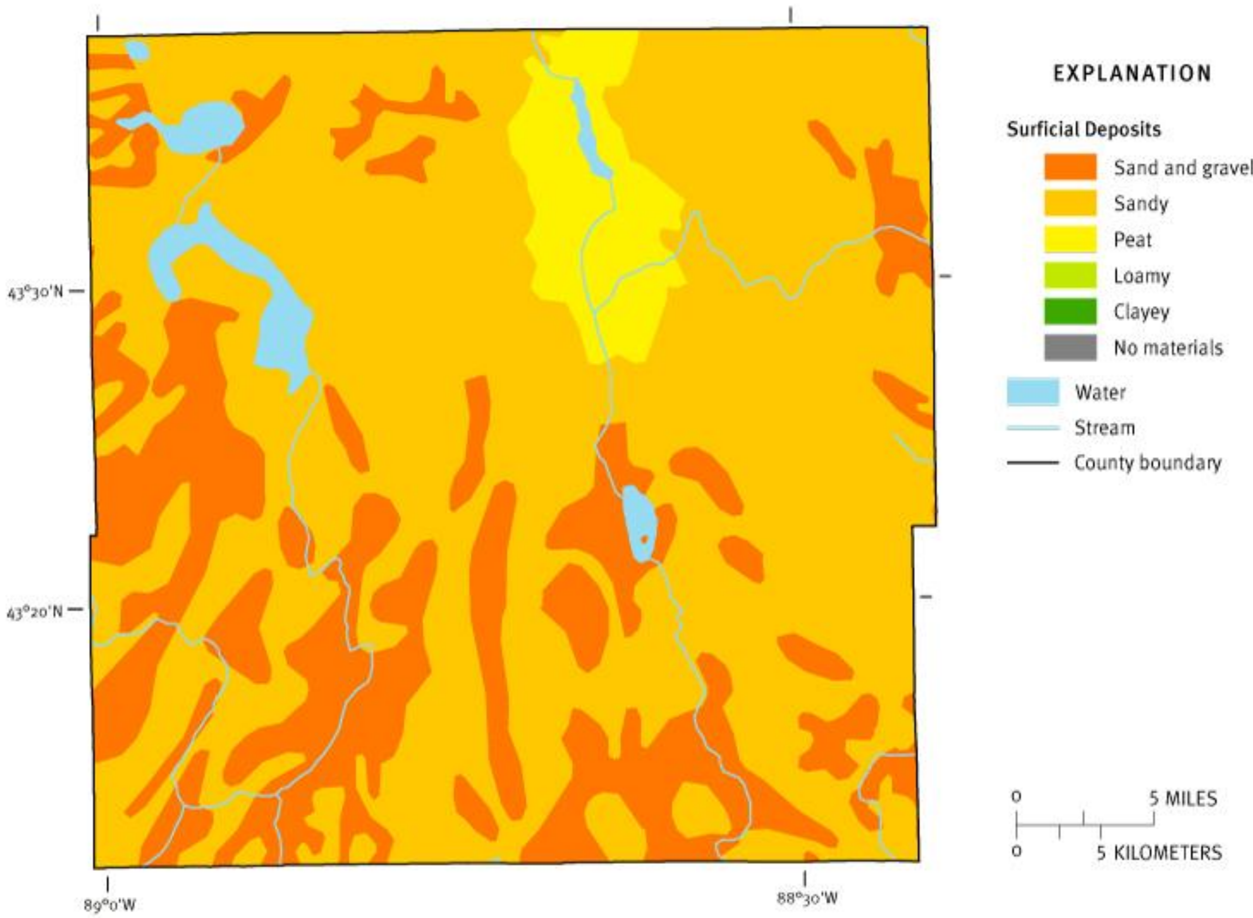
## Dodge County – Surficial Deposits




**This resource characteristic map was derived from generalized statewide information at small scales, and cannot be used for any site-specific purposes.**

Map source: Schmidt, R.R., 1987, Groundwater contamination susceptibility map and evaluation: Wisconsin Department of Natural Resources, Wisconsin's Groundwater Management Plan Report 5, PUBL-WR-177-87, 27 p.

Figure created for the "Protecting Wisconsin's Groundwater Through Comprehensive Planning" web site, 2007, *http://wi.water.usgs.gov/gwcomp/*

Surficial deposits are unconsolidated materials lying on top of bedrock. Except for the unglaciated southwest portion of the state, most of the surficial deposits in Wisconsin were left by glaciers. These materials differ, depending on how they were deposited. Some glacial materials were deposited by melting waters, and are well sorted or have layers of both fine materials and gravelly materials. Infiltrating waters must pass through these materials en route to the groundwater. Except in areas of shallow bedrock, the surficial deposits are considered the most important factor in determining how susceptible an area is to groundwater contamination. The surficial deposits have been categorized into six groups: sand and gravel; sandy; loamy; peat; and no materials (not shown at this scale). Areas having sand and gravel deposits are considered susceptible to groundwater contamination; and areas with clayey deposits are considered less susceptible.

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