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The Study of Nitrogen Sources in the Municipal Wells of Cedar Falls, Iowa

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THE STUDY OF NITROGEN SOURCES IN THE

MUNICIPAL WELLS OF CEDAR FALLS, IOWA

A Thesis

Submitted

in Partial Fulfillment

of the Requirements for the Designation

University Honors with Distinction

Alison Renee Schell

University of Northern Iowa

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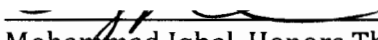This Study by: Alison Renee Schell

Entitled: The Study of Nitrogen Sources in the Municipal Wells of Cedar Falls, Iowa

has been approved as meeting the thesis or project requirement for the Designation

University Honors with Distinction

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12/18/12
Date

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I. Abstract

Groundwater nitrate contamination has been a persistent concern in the drinking water of Cedar Falls, Iowa. Identifying the source of the relatively high nitrates in Cedar Falls Municipal Well 3 is the primary focus of this investigation. Although none of the municipal wells have exceeded the maximum contaminant level for nitrogen (45 ppm NO_3), the purpose of this project is to investigate the general drinking water quality in the area. To identify the source of the nitrate contamination, groundwater samples from four municipal wells, surface water samples from three sites on the Cedar River, and soil from twelve sites within one mile radius' of the municipal wells were collected. A total of fifty water samples and sixty soil samples were collected for ten weeks from May until July 2012. Onsite parameters for water samples included dissolved oxygen (DO), pH, total dissolved solids (TDS), conductivity, and temperature. The water samples were tested for *E. Coli* back at the laboratory. For soils, nitrate was extracted using 2g of soil in 50mL of distilled water that was shaken for four hours. Soil moisture and organic content were analyzed by the method called Loss-on-Ignition (LOI). Major ion chemistry of water was determined by ion chromatography.

The results of this investigation show relatively higher nitrogen content in the soils around Well #3 (average nitrate (as NO_3) concentrations of .073 and .127 mg Nitrate/g Soil) and Well #11 (average nitrate (as NO_3) concentrations of .063 and .064 mg Nitrate/g Soil) that is derived through vertical infiltration of soil nitrate directly from the field through preferential pathways. The nitrate (as NO_3) level tested in Well #3 ranged from 34.4 ppm on 7/18/2012 to 39.5 ppm on 7/5/2012. Although nitrate coming from a far-away source through lateral migration within the aquifer cannot be ruled out at this point, predominant

evidences point to local origin of nitrate. It is likely that inorganic nitrogen that accumulated in the soil over many years of fertilization in the past is now being slowly released into the soil through the process of nitrification because the area is now predominantly residential and there is no major source of nitrate in the soil. All other hydrologic parameters in the area are within the expected range of limits.

II. Introduction and Review of Literature

The quality of groundwater in Iowa is of particular concern from the impact of agricultural practices. Water quality in Iowa has deteriorated over the past 45 years due to contamination from fertilizers, septic systems, and other non-point sources creating concerns for the future water supplies (Fields 2012).

Cedar Falls, IA, lies on the Iowa Erosion Surface Landform Region and has karst terrain (Prior, 1991). Karst is a term used to describe an area of limestone, or other highly soluble rock, in which the landforms are dominantly originated from solution and where the drainage is underground in conduits and caves, shown in Figure 1 (Drew 1999). There are many characteristics of karst topography, including complex interconnections between surface and

Figure 1. A diagram of Karst Topography showing the connection between the aquifer and the land (Fields 2012).

groundwater, usually there is little soil cover leading to rapid infiltration of water into the bedrock (Drew and Hotzel 1999).

The Silurian-Devonian aquifer is the primary source of drinking water for Cedar Falls (Shaap 1999). This limestone and dolomite unit has a highly variable bedrock depth depending on erosion and the amount of glacial till on top of the bedrock. The water from this source is fast moving and high yielding. Karst terrain is very susceptible to contamination. The greater the thickness of the confining layer above an aquifer, the less susceptible it will be to surface contamination. Since many areas of Cedar Falls have less

than a 25 foot confining layer, there is great interaction between the surface and groundwater (Fields 2012). Three of the eight municipal wells in Cedar Falls have relatively high nitrate concentrations (Fields 2012).

The 1999 U.S. Geological Survey isotopic study of nitrate in Cedar Falls concluded that the primary source of nitrates is inorganic nitrogen (Schaap 1999). The Iowa Department of Natural Resources (IDNR) 2012 Study of the groundwater of Cedar Falls found that despite the thick confining layer above the bedrock of Well 3, there is a significant connection to the near surface. The finding was confirmed through their water chemistry and isotope analysis (Fields 2012). The investigation also found evidence to support the hypothesis that Cedar Falls Utilities (CFU) Municipal Well 3 had a different water source than Wells 5,6,7, and 8 (Fields 2012). The study did not find conclusive evidence of the source of high
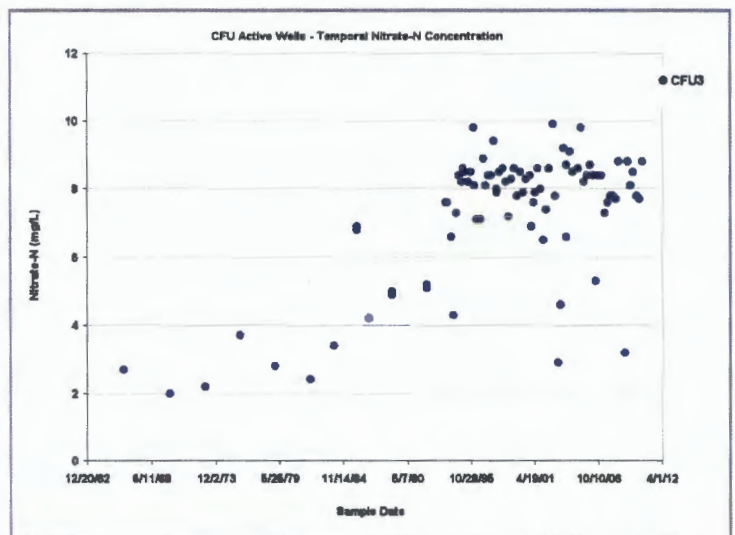
Figure 2. Concentration of Nitrate-N in Cedar Falls Utilities Well 3 since 1962 (Fields 2012).

nitrates in Well 3, nor did the researchers test the soil of Cedar Falls. This report also documented the general trend of increasing nitrates in Well 3 over the past 50 years, shown in Figure 2 (Field 2012).

Nitrogen compounds are a water quality concern because they contribute to aquatic plant growth, eutrophication and toxicity. Nitrate is readily soluble in water, therefore it is subject to water transport and will leach down away from the root zone of plants (Paul

1996). Excess nitrate can lead to excess growth of plants and algae leading to eutrophication (Paul 1996). The concentration of nitrate in the water supply will vary according to the season and the amount of excess water available (Hanway 1963).

Negative impacts on human health are caused by increased nitrate concentration. In 1945, nitrate was first recognized as a hazard to health in Iowa when two infants contracted blue baby syndrome (Wild 1993). Methemoglobinemia, or blue baby syndrome, is caused when nitrate is ingested and is reduced to nitrite which attaches to hemoglobin in the blood, blocking oxygen transport in the blood which leads to suffocation (Paul 1996). Young infants and animals are the most at risk for methemoglobinemia (Paul 1996, Zeman 2011). Exposure to nitrates in a number of illnesses has been studied to have long latency, including gastric and esophageal cancers and the risk of non-Hodgkin's Lymphoma (Guatam 2010). 150 private well users from Iowa were studied and shown to self-report or perceive being less healthy than municipal well users; self-evaluations found that private well users reported poorer health and a greater perception of susceptibility to illness than municipal well users (Zeman 2011). Leafy vegetables and certain cured meats and cheeses are sources of nitrate in foods (Wild 1993). Although nitrates are present in the average person's diet, most nitrate intake comes from the water we drink. Legislation has been developed to protect citizens from these health risks. The maximum contaminant level (MCL) for Nitrate is 45 ppm NO_3^- (10ppm NO_3-N), established by the Safe Drinking Water Act from the Environmental Protection Agency (EPA 2009).

The nitrogen cycle is very important for biological and physical processes, seen in Figure 3 (Paul 1996). The most important steps of the nitrogen cycle for soil studies are nitrification and denitrification. When organic matter in the soil decomposes, ammonium is

released and converted into nitrate by microbes, in the process known as nitrification (Butcher 1992). The nitrate form of nitrogen is most absorbed by plants from the soil and is commonly the most deficient nutrient in crop production (Paul 1996). Once nitrate formed in the soil there are many different paths it can take: nitrate may undergo a reduction by microorganisms (known as denitrification), organisms may use nitrate to synthesize amino acids, or nitrate may leach deeper into the soil or groundwater and accumulate or be transported away (Paul 1996). Denitrification is the reduction of nitrate into gaseous nitric
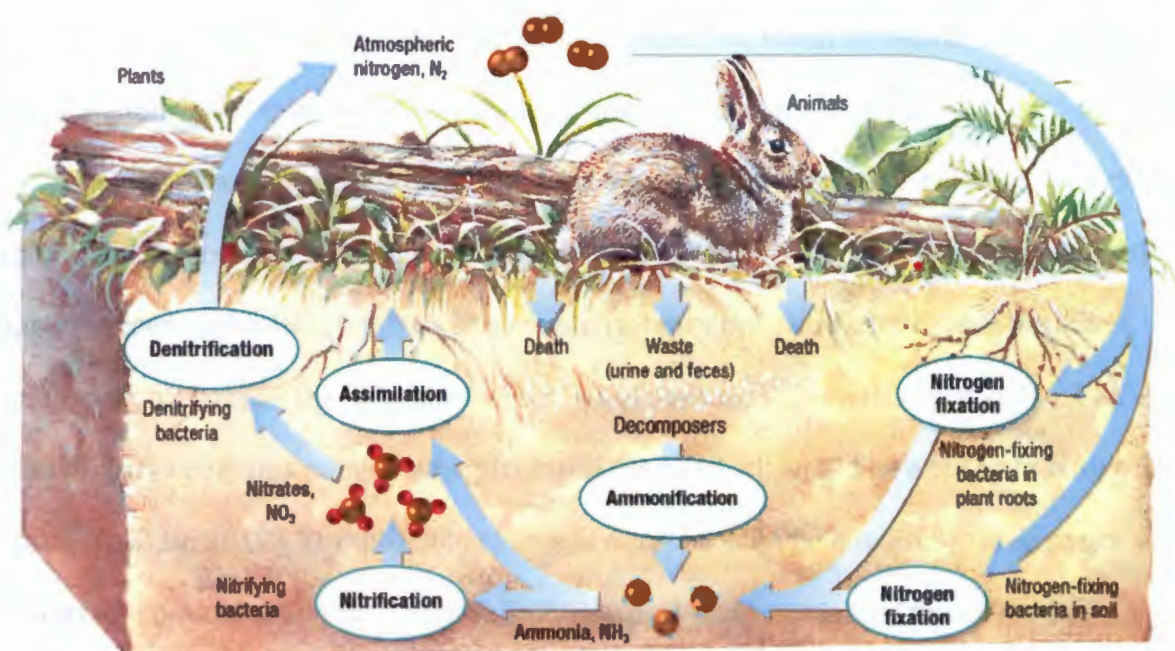
Figure 3. The Nitrogen Cycle

oxide, nitrous oxide, or nitrogen gas, which only occurs in an oxygen-free, reducing environment with available organic matter (Paul 1996). Vertical infiltration of nitrate happens when the movement of excess water from the upper soil profile to deeper layers of soil and groundwater carries nitrate; convection and diffusion drive this leaching process (Paul 1996). Removal of nitrate from the top layer of soil through vertical infiltration is most common during excess rainfall.

Recent research indicates that contaminated water can move preferentially through clay-soil macropores in soil and microfractures in bedrock, rather than the traditional view of water transport known as matrix flow (Iqbal 2000). This preferential flow of water moves through root channels, cracks, fissures, animal burrows and textural boundaries in surficial soil-rock systems (Iqbal 2000). Preferential flow allows for contaminated water to move rapidly through the soil profile with little interaction with the water that was initially in the soil. Studies have found that transport of water through macropores is often associated with heavy rain events, suggesting that this additional force is needed for the contaminated water to move quickly through macropores (Iqbal 2000).

Regional, lateral migration of nitrates is a possible source also. Analysis of 20 private wells in the Cedar River watershed at Janesville, IA (8 miles North of Cedar Falls) showed that 10 exceeded the MCL; analysis of nitrogen isotopes indicated commercial fertilizers and organic nitrates as the possible sources of nitrogen in the area (Gautam 2010). The Janesville area contains many tiled agricultural fields, which would be a possible source of nitrate (Guatam 2010). This possible source of nitrates could flow laterally through the subsurface contaminating the Cedar Falls Municipal Wells. This lateral flow hypothesis is unlikely because at that depth the environment is likely to be extremely reducing and the microorganisms would use the nitrogen before it traveled laterally from Janesville to Cedar Falls.

The application of commercial fertilizers has been common practice in Iowa since the late 1950's, and is now considered to be one of the most serious threats to Iowa's water quality (Iqbal 2000). In karst aquifers, the main source of contamination is from inorganic fertilizer usage (Drew 1999). The costs of overcoming nitrogen pollution are approaching

the costs to manufacture nitrogen fertilizers in some countries (Paul 1996). Nitrates can come from other sources, including municipal landfills, septic systems, soil, industrial waste and plant decomposition (Drew 1999).

It is evident then, that nitrates are known to cause health problems and negatively impact ecosystems. Therefore the purpose of this research project is to analyze the local surface water, groundwater and soil to determine if vertical infiltration is a viable source of nitrate contamination.

III. Hypothesis and Objectives

In a study by the Iowa Department of Natural Resources, some groundwater in Iowa exceeds the Environmental Protection Agency's (EPA) MCL (IDNR 2003). Since nitrate contamination can cause health problems and negatively impact ecosystems, it is important to find out the local sources of nitrate and the extent of its contamination in Cedar Falls.

The objective of this study was to identify the general source of nitrate contamination in the groundwater of the municipal wells in Cedar Falls, shown in Figure 4. This study assessed if the nitrate was vertically migrating from the overlying fields or a long-term result of regional, horizontal flow in the subsurface. The other objectives of this research included investigating the general water chemistry of the surface and the ground water of Cedar Falls, as well as determining general soil characteristics of the area.

The hypothesis of this project is that the major source of nitrate was past agricultural fertilization which the soil has retained, with nitrate flowing vertically down into the groundwater from the surface. This hypothesis was tested though sampling soil throughout Cedar Falls for an increased concentration of nitrogen while comparing it to the surface water and ground water concentrations over a period of ten weeks.

Figure 4. Cedar Falls Utilities Municipal Well Locations

Legend:
- Active CFU Well
- Active Wells 1-mi Buffer
- Inferred/possible direction of gwater flow

0 0.25 0.5   1 Miles

N

IV. Methodology

In order to conduct this research, standard scientific procedures were implemented. The methods included water and soil collection, water testing, nitrate extraction of soil, moisture analysis, and organic matter estimation.

Water Collection

Three water testing sites were established along the Cedar River. The sites included Island Park, Pheifer Park and George Wyth State Park. Additionally, Cedar Falls Utilities (CFU) staff sampled wells #3,7,9 and 11 for this project.

At the Cedar River collection sites, water was immediately tested for its temperature, conductivity, total dissolved solids (TDS), pH and dissolved oxygen (DO). TDS, temperature and conductivity were measured with a HANNA HI98311 meter. DO was tested using the HACH HQ 30d Meter. pH was determined using Extech S/N 33214 ExStik II probe. Water was collected in 125 mL plastic bottles and samples were refrigerated until they were analyzed. All water was tested with the Dionex DX 120 Ion Chromatograph to measure the levels of major ions in the water, namely chloride, nitrate and sulfate.

The well water samples were gathered by the project team several hours after their collection. As a result, the temperature, DO, and E. Coli tests were not performed since the transport of the water causes changes in the observed values.

Testing for E. Coli

Coliscan Easygel was used when testing the water samples for *E. Coli*. Before sampling, the bottles of frozen Coliscan Easygel were taken out of the freezer to thaw. Within one hour of sampling the river sites, 5mL of river water from each location was transferred from the sample container to a thawed bottle of Coliscan Easygel. The bottles

were then swirled to mix the inoculum and then poured directly into petri dishes. The petri dishes were then swirled to uniformly distribute the liquid over the entire surface area of the dish. The dishes were left out at room temperature approximately 45 minutes until the liquid solidified. Then petri dishes were incubated upside down in an oven at 35°C for 24 hours. After inoculation each petri dish was inspected for purple colonies, which are considered to be the *E. Coli* colonies. The results were reported in colonies of *E. Coli* per 100 mL of water (Detection of Waterborne Coliforms and Fecal Coliforms with Coliscan® Easygel®).

Soil Collection

Twelve soil collection sites were selected for this study. Two sites were selected within a one mile radius of CFU Well 3, 5, 6, 7, 8, and 11; the one mile radius was selected because typical modeling software does not work for karst systems (Fields 2012). Most samples were collected from private property through proper permission from the owner. Soil was collected directly below the humus layer using a soil probe from each site. The samples were then transported to the lab in labeled quart-sized ziplock bags.

Nitrate Extraction

To determine the nitrate content in the soil, a nitrate extraction procedure was used. Nitrate is water-soluble, so water is commonly used as a extractant in this procedure (Crumbaugh 2008). Approximately 2 grams of soil from each location was weighed and added to a separate, labeled 125 mL Earlenmeyer flask. 50 mL of deionized water was added to each flask and swirled once. All twelve Erlenmeyer flasks were covered and placed on the shaker. The samples were then shaken at 200 rpm for 4 hours. After the extraction procedure, the 10 mL of the solution was centrifuged at level 8 for 30 minutes. Through this

procedure, water was separated from the soil, which was then analyzed by ion chromatography for nitrate.

Loss on Ignition

Loss on ignition has been used for decades and is a reliable, inexpensive technique in determining the carbon content in soil (Konen 2002). The water in soil evaporates readily, so the organic matter loses weight upon heating until oxidation. The process takes place between room temperature and 540°C (Vreeken).

Ten grams of soil were added to a weighed crucible, then weighed again. The crucible was then put in an oven at 110°C overnight to determine the gravimetric moisture content (Vreeken). The samples were subsequently cooled and weighed. In continuation, samples were heated at 375°C for an hour, and then at 540°C for another hour to determine the organic matter content (Vreeken). Subsequently, the samples were cooled and weighed. The remaining soil was then stored in a 125mL glass sample bottle.

V. Results and Discussion

There is a correlation between the high concentration of soil nitrate and the high nitrate in the wells. The nitrate (as NO_3) level tested in Well #3 ranged from 34.4 ppm on 7/18/2012 to 39.5 ppm on 7/5/2012. The concentration of nitrate in the one mile radius around Well #3 increased over time along with the soil around Well #11. See the Appendix for complete water and soil collection data sets.

Dissolved Oxygen

Dissolved Oxygen (DO) is of extreme importance chemically and biologically. DO is essential for high forms of life that live in water. DO concentrations are controlled by air-water gas transfer, ambient temperature and pressure, ion activity, and photosynthesis. Under high DO conditions redox-sensitive elements are present in their oxidized form. Nitrate is the oxidized form of nitrogen; if DO is not present or in low concentrations, groundwater favors denitrification, a mechanism that causes nitrate to become an electron acceptor evoking nitrogen to be present in the reduced state as nitrogen gas (N_2).

In this study from May through July, the DO generally decreased in the Cedar River sites. The concentration of DO ranged from 6.38 ppm at the Cedar River 1 on 7/25/2012 to 12.41 ppm at Cedar River 2 on 6/27/2012. In May, the DO levels in surface water ranged from 10.70 ppm to 12.18 ppm. In June, the DO levels ranged from 7.78 ppm to 12.41 ppm at the Cedar River sites. In July, the concentration ranged from 6.38 ppm to 10.94 ppm. The average DO value was 9.5 ppm (Figure 5).

DO (ppm)

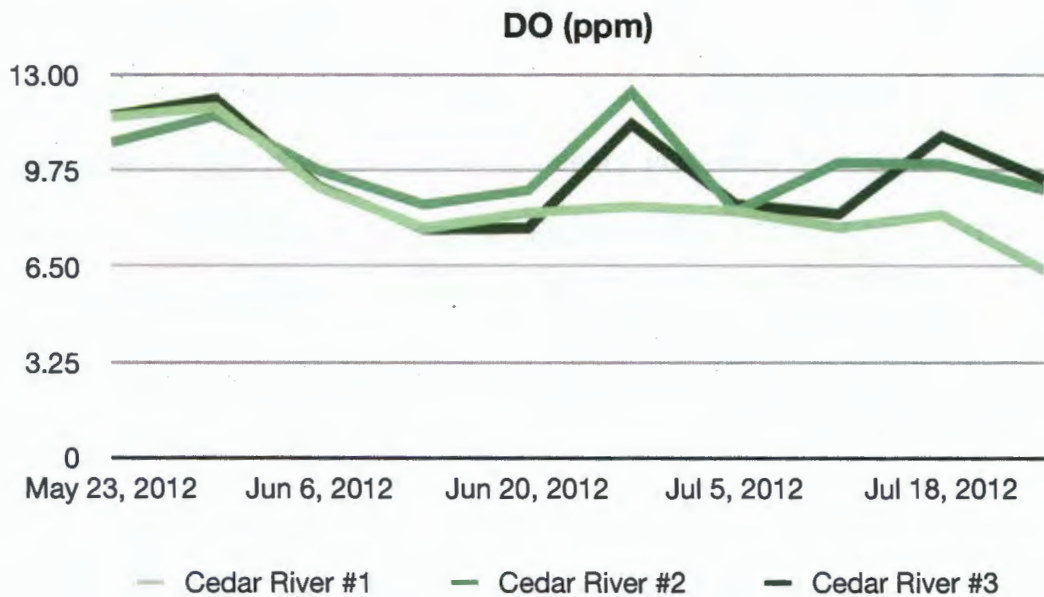Figure 5. Dissolved Oxygen concentrations in river sites

The record high temperatures of the summer of 2012 affected the DO concentrations. The temperature of the surface water ranged from 15.9 to 31.6 degrees Celsius during the ten week study (Figure 6). Higher temperatures resulted in lower DO concentrations of surface water.

Temperature (degrees Celcius)
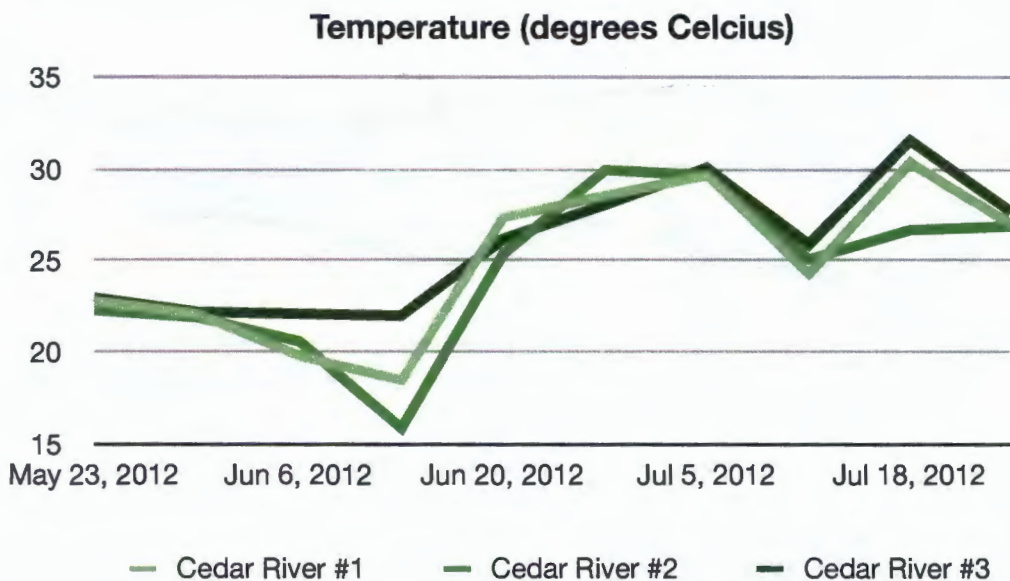
Figure 6. Temperature of river sites

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Total Dissolved Solids

Total dissolved solids (TDS) measures the amount of charged ions that are mobile within a given volume of water. The Environmental Protection Agency's Secondary Drinking Water Standard's maximum contaminant level for TDS is 500 ppm (US EPA, 2012). Iowa Water Quality Standards allow for 750 ppm of TDS in surface water.

The total dissolved solids are generally higher in the groundwater of Cedar Falls than the surface water of the Cedar River. In the groundwater, the TDS values ranged from 315 ppm in Well 7 on 6/20/2012 to 429 ppm in Well 11 on 5/23/2012. The average TDS value in ground water was 360 ppm. In the surface water, the TDS values ranged from 278 ppm at Cedar River 1 on 7/18/2012 to 339 ppm at Cedar River 3 on 6/27/2012. The average TDS value in surface water was 301 ppm (Figure 7).
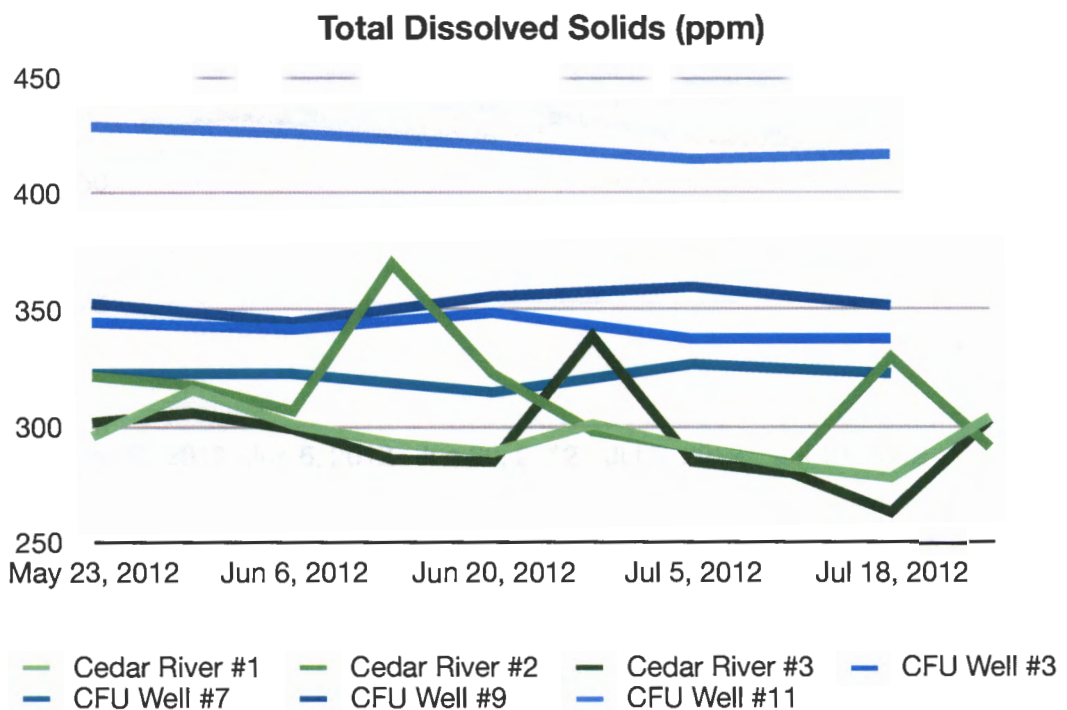
Figure 7. Total Dissolved Solids of surface water and groundwater

Conductivity

Conductivity is defined as the ability of water to conduct an electrical current. Conductivity is a function of the concentration of dissolved inorganic components that ionize to form electrolytes. Conductivity is temperature dependent. The conductivity of groundwater ranged from 457 µS/cm on 6/20/2012 in Well 7 to 622 µS/cm on 5/23/2012 in Well 11. The average conductivity value of groundwater was 522 µS/cm. The conductivity of surface water ranged from 404 ppm at Cedar River 1 on 7/18/2012 to 478 ppm at Cedar River 2 on 7/18/2012 . The average conductivity value of surface water was 436 µS/cm (Figure 8).

Conductivity (µS/cm)

Cedar River #1 — Cedar River #2 — Cedar River #3 — CFU Well #3
CFU Well #7 — CFU Well #9 — CFU Well #11
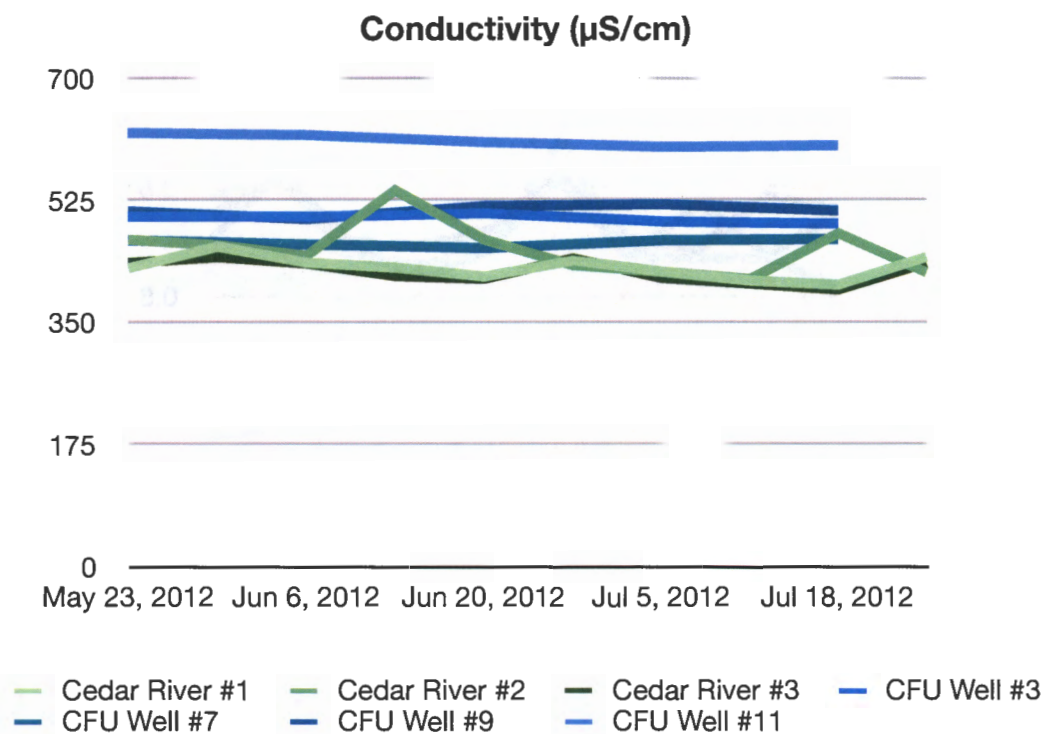
Figure 8. Conductivity of surface water and groundwater

pH

pH is a value of measurement of the amount of hydrogen ions in a solution; it indicates the acidity and alkalinity of the solution. A pH of 7 is considered neutral. The National Secondary Drinking Water Regulations provide the standard for pH to be a range of 6.5-8.5 (US EPA 2012). All groundwater samples taken were within the EPA's standards. The highest pH observed was 8.71 in surface water and 7.72 in groundwater. The average pH of surface water was 8.31, while the average pH of groundwater was 7.59 (Figure 9). The groundwater pH seems to have an increasing trend throughout the sampling period, while the surface water generally has a higher pH than groundwater.
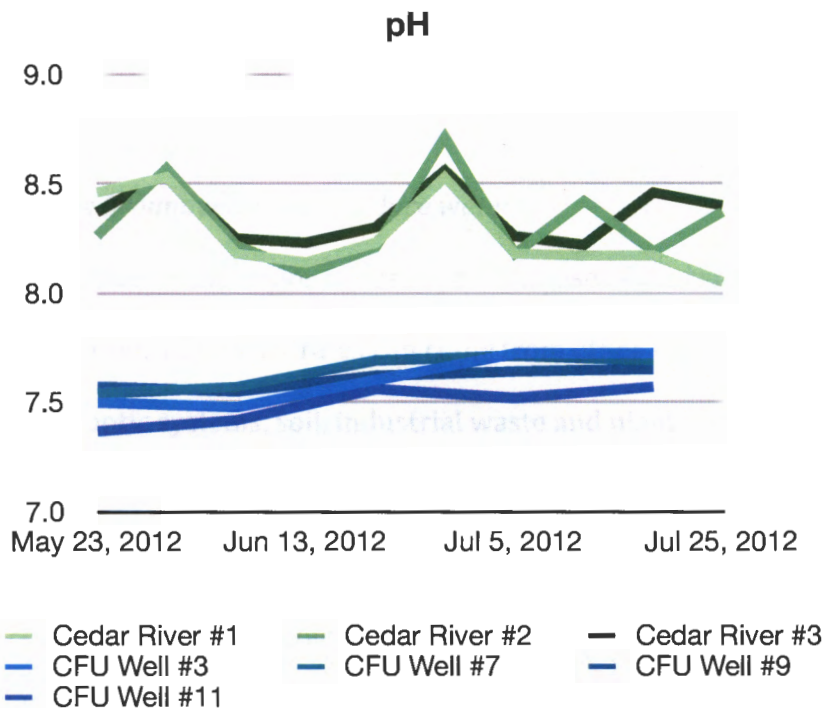
Figure 9. pH of surface water and groundwater

E. Coli Testing

This summer, *Escherichia Coli* was found to be not prevalent in the Cedar River. *E. Coli* is an important indicator in surface water of fecal contamination from agriculture or residential areas. The concentration of *E. Coli* is dependent on the amount of contaminated run off that enters surface water. Since this summer was a very severe drought, there was little run off entering the Cedar River. The EPA's standard, which was adopted by the State of Iowa, was established to be 235 Colony Forming Units/100mL for a maximum one time sample and 126 Colony Forming Units/100mL for a geometric mean based upon five or more samples over a 30 day period (EPA 2012). At Cedar River Site 1, 20 colonies per 100 mL were found on 5/30/2012 and 6/20/2012. *E. Coli* was not found in all other surface water samples.

Nitrate Anions Groundwater and Surface water

Inorganic fertilizer is the major factor in the increase of concentration of nitrate in the water supplies for our nation. Nitrates can come from other sources, including municipal landfills, septic systems, soil, industrial waste and plant decomposition. The maximum contaminant level (MCL) for nitrate established by the Environmental Protection Agency's Safe Drinking Water Act is 45 ppm NO_3^- (10ppm NO_3-N) (US EPA 2012).

Nitrate concentration for groundwater stayed fairly constant throughout the sampling period. In Well 7, nitrate was below detection for all samples. The highest concentration in groundwater was found to be 39.5 ppm at Well 3 on 7/5/2012. The average concentration of nitrate at Well 3 was 38.1 ppm. The average concentration of

nitrate at Well 9 was 35.3 ppm. The average concentration of Nitrate at Well 11 was 18.46 ppm (Figure 10).

Nitrate Concentrations (ppm)
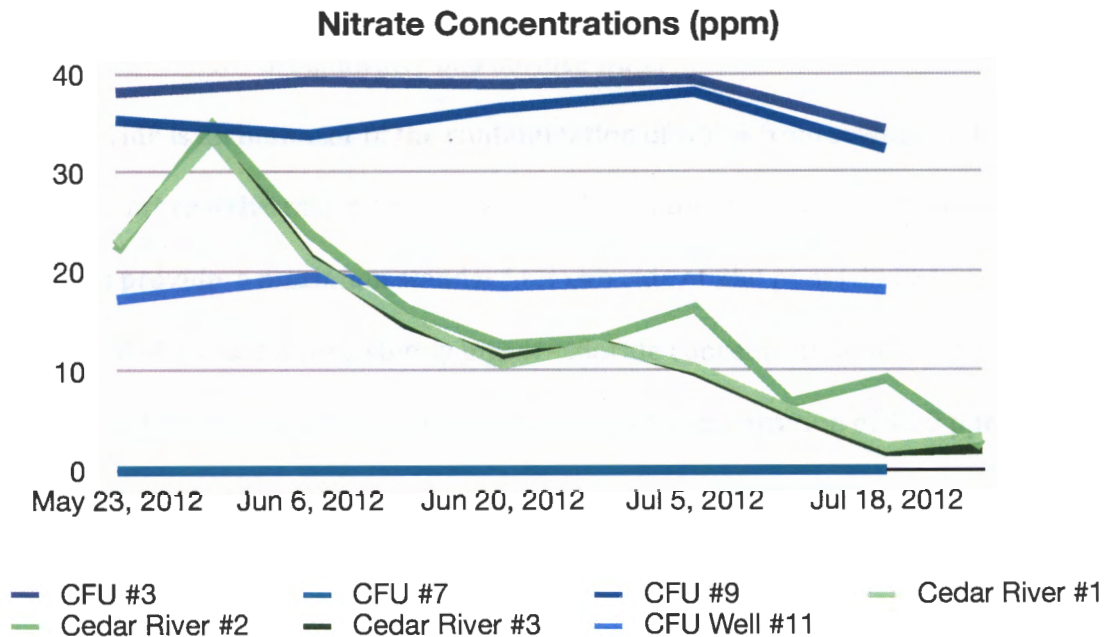
Figure 10. Nitrate concentrations of surface water and groundwater

The nitrate concentration for surface water shows a steady decrease across the 10 weeks. The average concentration of surface water sites was 14.42 ppm. The range of concentration over the sampling period of groundwater was 1.9 ppm to 34.9 ppm. The concentrations of all three well sites were very similar over the 10 week study (Figure 10).

Wells 3 and 9 show similar levels of nitrogen throughout the sampling period, indicating similar chemistry. The nitrate levels in the groundwater from these two wells were on average 20 ppm higher than in the river water, indicating the source to be more concentrated than the river. This finding shows the possibility of nitrates traveling from the river to the well very unlikely.

Higher temperature has been shown to cause lower nitrate concentrations of groundwater, while increased average precipitation dilutes nitrate content in soil and groundwater (Wick 2010). The summer of 2012 had record high heat and drought.

Chloride Anions Groundwater and Surface water

Chloride is an indicator of the contamination of water from sewage. Chloride is among the least reactive major anions in water. The National Secondary Drinking Water Regulations provide a maximum standard for chloride of 250 ppm (US EPA 2012).

CFU Well 11 had a consistently higher chloride concentration than the surface water and the other wells in the area. Well 11 had a average concentration of 45.9 ppm. All other groundwater sites had an average concentration of 11.8 ppm (Figure 11).

The concentration of chloride in surface water ranged from 25.0 to 31.2 ppm. The average concentration of chloride in surface water was 27.0 ppm (Figure 11). All samples were within the EPA's secondary standard limit.
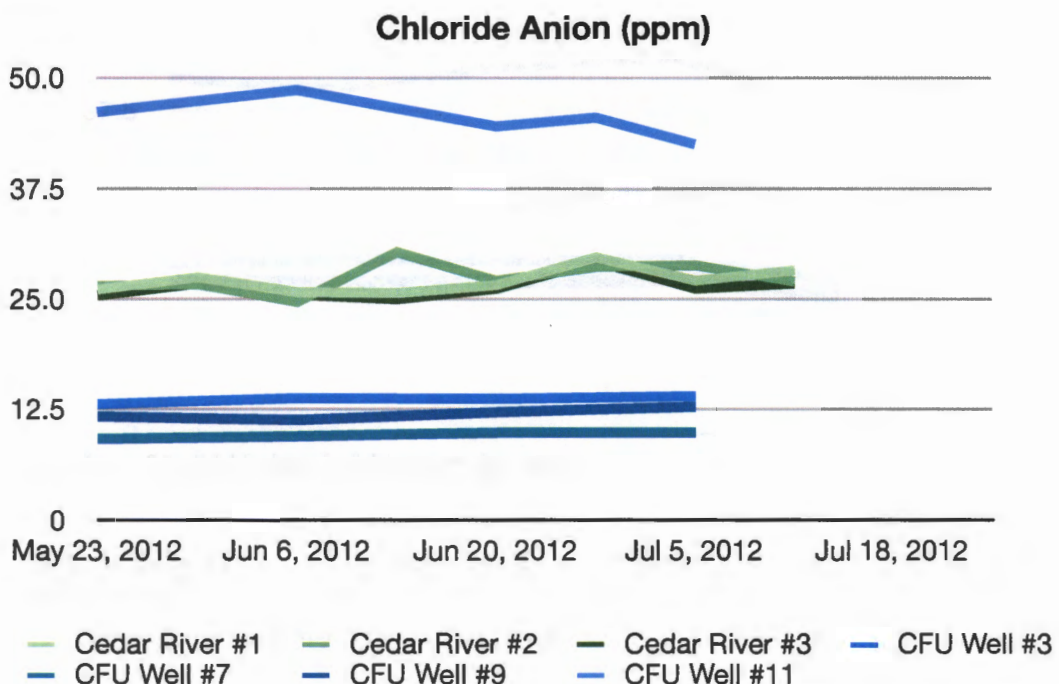
Figure 11. Chloride concentrations in surface water and groundwater

Sulfate Anions Groundwater and Surface water

The sources of sulfate in groundwater can include fertilizer, decomposition of organic matter and gypsum. When conditions are anoxic sulfate is an electron acceptor, causing it to be reduced to sulfite. Sulfate is the main source of sulfur for microorganisms, which is essential for life processes. The National Secondary Drinking Water Regulations provide a maximum standard for sulfate of 250 ppm (US EPA 2012).

The sulfate concentration ranged from 15.6 - 43.7 ppm in groundwater. CFU Well 11 had much higher concentrations of sulfate than all other sites throughout sampling; the average concentration in Well 11 was 40.9 ppm. The average of the rest of the groundwater sites was 18.1 ppm. The surface water concentrations stayed very consistent for all sites along the Cedar River throughout the sampling period. The average concentration of the surface water sites was 25.9 ppm (Figure 12).

Sulfate Concentrations (ppm)

Legend:
— Cedar River #1   — Cedar River #2   — Cedar River #3   — CFU Well #3
— CFU Well #7   — CFU Well #9   — CFU Well #11
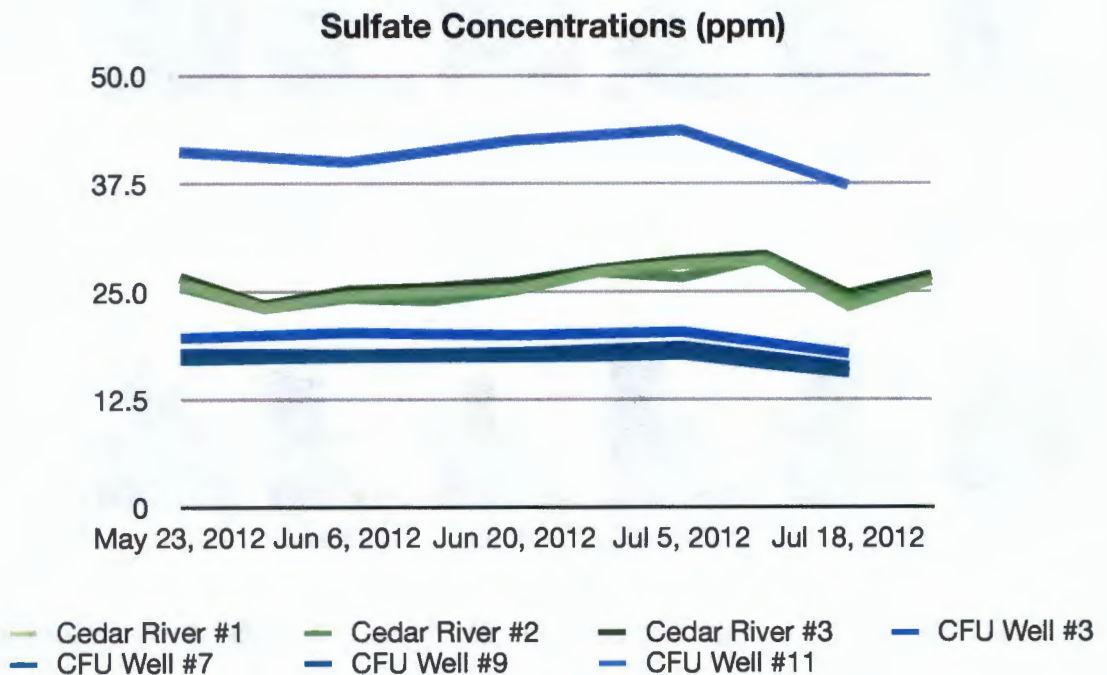
Figure 12. Sulfate concentrations in surface water and

Percent Moisture

Soil moisture is important in the amount of precipitation run off entering streams and rivers. The amount of moisture in the soil also is important in the processes of evaporation and plant transpiration in the exchange of water and heat energy between the land and atmosphere. Water is an essential part of plant growth and photosynthesis. Percent moisture also gives us information about the soil, including porosity, aggregation qualities and water retention. The percent moisture of the soil in Cedar Falls was fairly variable. The average for all sites was 13.4% moisture (Figure 13). The percent moisture in the soil generally decreased in July.
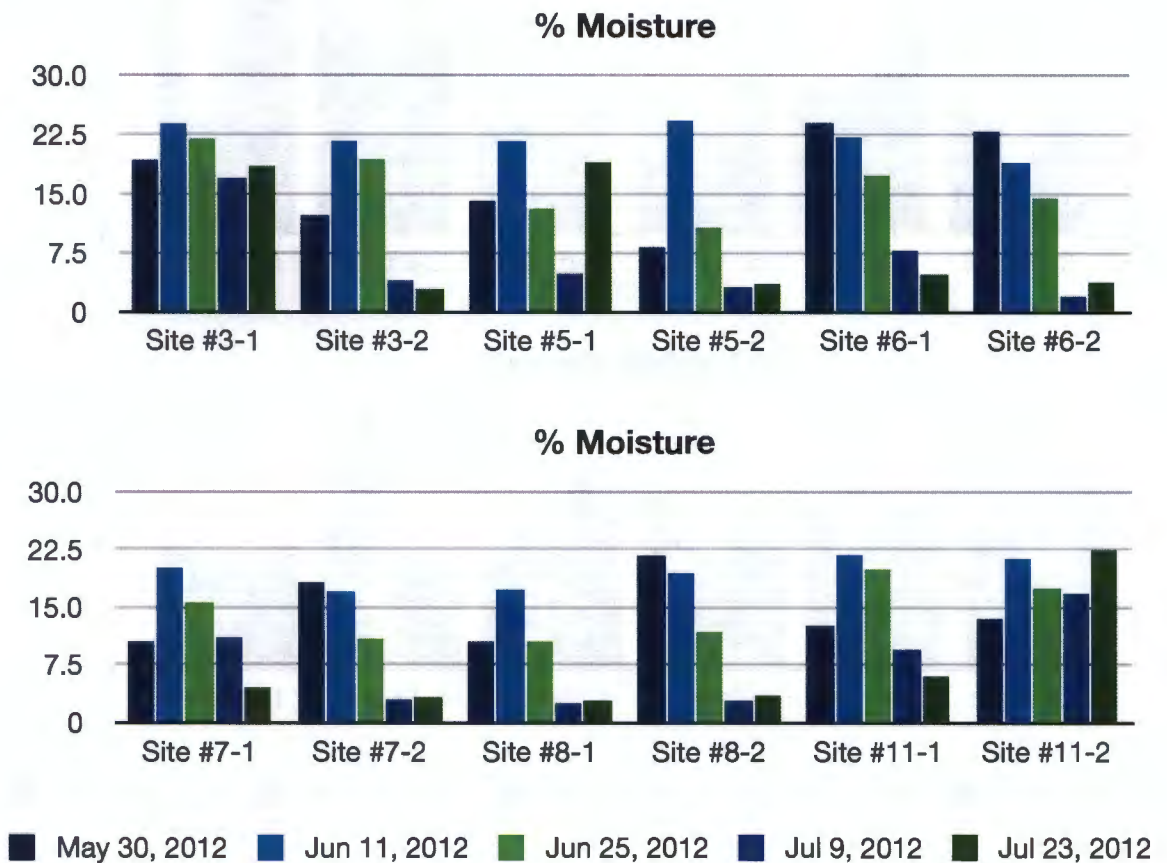
Figure 13. Percent moisture of soil

Percent Organic Matter

The amount of organic matter in soil is affected by the temperature, rainfall, natural vegetation, texture and drainage of the soil. Greater amounts of organic matter are sources of energy for bacteria to perform the process of denitrification, converting inorganic nitrogen forms to organic nitrogen forms, in soil. The soil samples around Well 3 showed a increased amount of organic matter from the rest of the sampling sites. The average percent organic matter of the two sites around Well 3 was 10.4% (Figure 14).
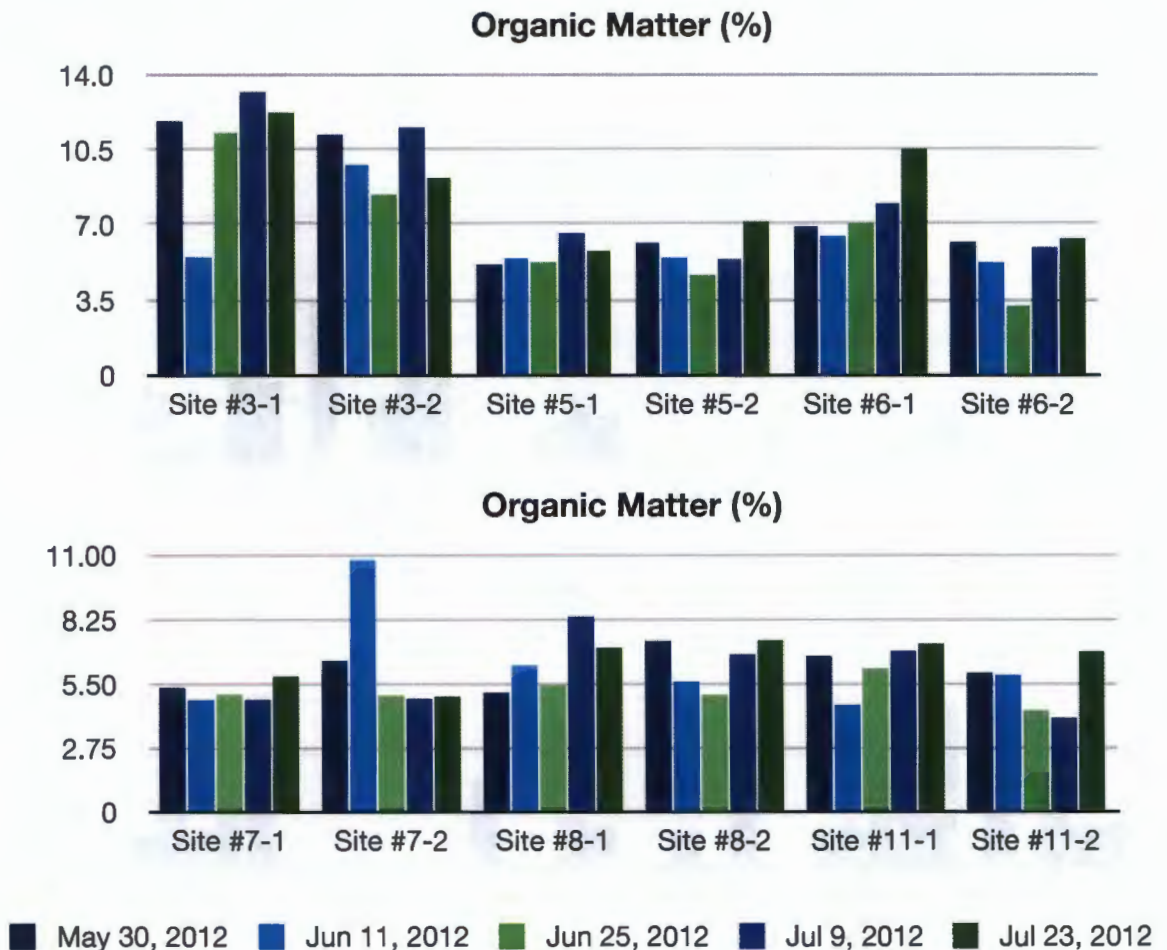
Figure 14. Percent Organic Matter in Soil Sites

Nitrate in Soil

Nitrogen is a very important nutrient used to increase crop production. The nitrogen cycle allows for nitrogen to be present in the environment in many different forms. The nitrate form of nitrogen is the one that is most absorbed by plants.

On average, the amount of nitrate found in the soil surrounding Well 3 was significantly higher than the other soil sites (Figure 15 and Figure 16). Well 11 also had an increase in nitrate concentration. There were variations in the concentration throughout the ten weeks of study (Figure 17). Possible causes of this variation could include rainfall and temperature changes.
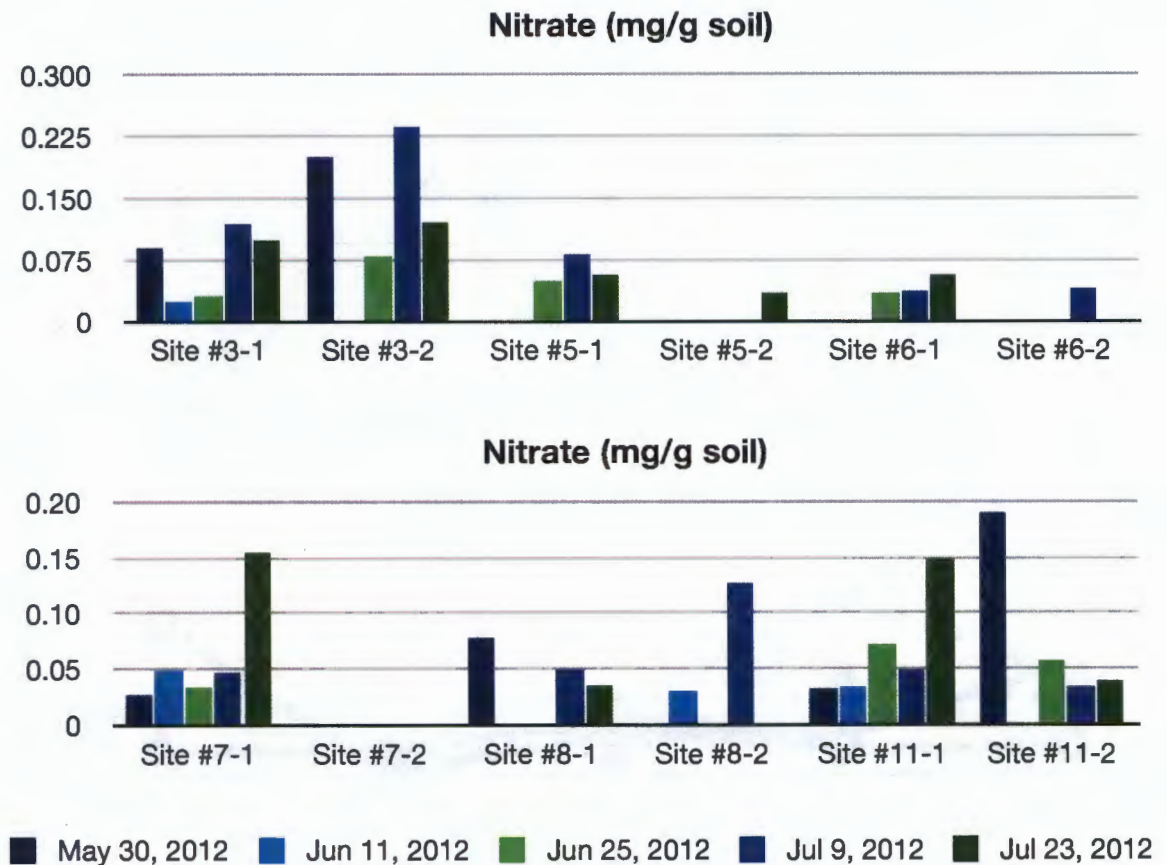
Figure 15. Nitrate concentration of the soil

The increased nitrogen content around the soil of Well 3 is most likely from nitrification of the soil. Inorganic nitrogen probably entered the soil through fertilization when the land was used for agriculture. Even though the land is now used for residential purposes, the organic nitrogen from decayed vegetation is still present and is beginning to convert to inorganic nitrogen through the process of nitrification. This process is creating a higher amount of nitrate to be present in these areas. The nitrate levels will eventually decrease through the process of denitrification, allowing for the nitrate to change form into nitrogen gas and enter the atmosphere.
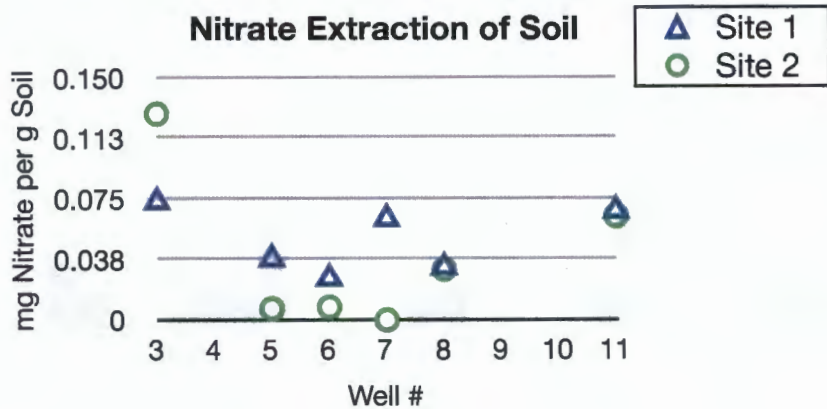
Figure 16. Average nitrate concentration at each soil site
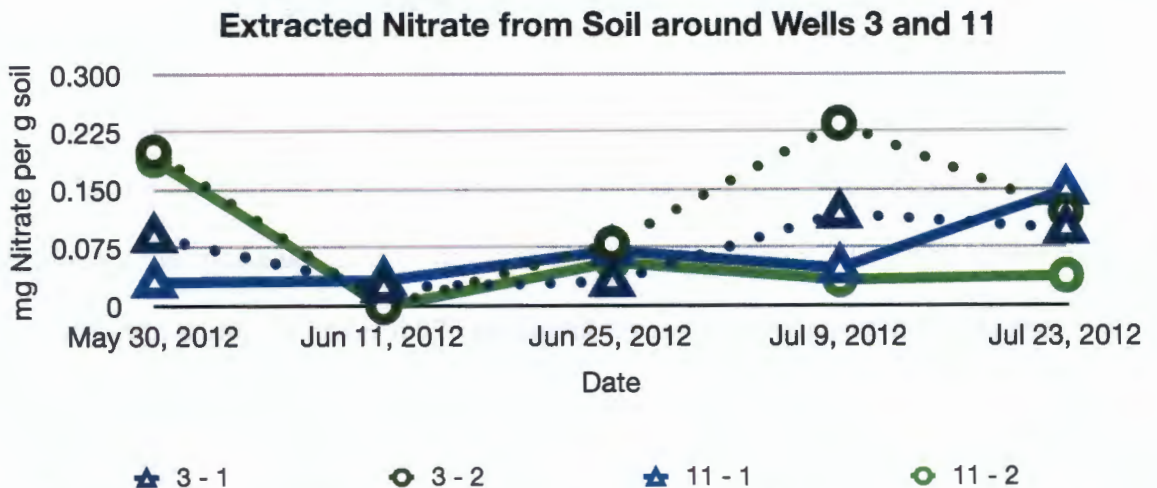
Figure 17. Nitrate concentration around Well #3 and #11 throughout ten weeks

Chloride in Soil

Chloride is an essential nutrient for plants. The functions of photosynthesis require chloride (Terry 1977). The concentrations of chloride were generally under 0.075 mg/g soil during the testing, with the exception of the 7/23/2012 samples (Figure 18).

Chloride (mg/g soil)

Chloride (mg/g soil)

■ May 30, 2012　■ Jun 11, 2012　■ Jun 25, 2012　■ Jul 9, 2012　■ Jul 23, 2012

Figure 18. Chloride concentration of soil sites

Sulfate in Soil

The concentration of sulfate in soil is important for plant growth. Sulfur is found in amino acids that make up plant proteins and vitamin A (Crozier 2007). The concentrations of sulfate were generally under 0.075 mg/g soil during the testing, with the exception of the samples taken on 30/5/2012 (Figure 19).

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Figure 19. Sulfate concentration of soil sites

VI. Conclusion

Although the nitrate contamination of the Cedar Falls municipal wells has been studied previously there have been no studies specifically focusing on the soil nitrate concentrations for the possibility of vertical infiltration to the groundwater. This study assessed if the nitrate was vertically migrating from the overlying fields or a long-term result of regional, horizontal flow in the subsurface. The other objectives of this research included investigating the general water chemistry of the surface and the ground water of Cedar Falls, as well as determining general soil characteristics of the area.

The results of this investigation show relatively higher nitrogen content in the soils around Well 3 and Well 11. It indicates that the high dissolved nitrate in Well 3 is derived through vertical infiltration of soil nitrate directly from the field. Although nitrate coming from a far-away source through lateral migration within the aquifer cannot be ruled out at this point, predominant evidences point to local origin of nitrate. It is likely that organic nitrogen that accumulated in the soil over many years of fertilization in the past is now being slowly released into the soil through the process of nitrification into inorganic nitrate. The soil around Well 3 also has an increased amount of organic matter compared to the other sites, which would be an energy source for bacteria that perform nitrification.

Permeability of the soil in Cedar Falls is very poor, which restricts major diffusion of the chemical in the subsurface. It is very likely that the vertical infiltration of nitrate is happening through preferential pathways, including fractures in clay and root channels. In the future it is very probable that the level of nitrate in the soil will go down through the process of denitrification, which converts nitrate into nitrous oxide and nitrogen gas. Soil nitrate is expected to decrease because the area is now predominantly residential and there

is no major source of nitrate in the soil. The nitrogen content in the sites around Wells 3 and 11 showed some variations throughout the ten weeks of study. The possible reasons for 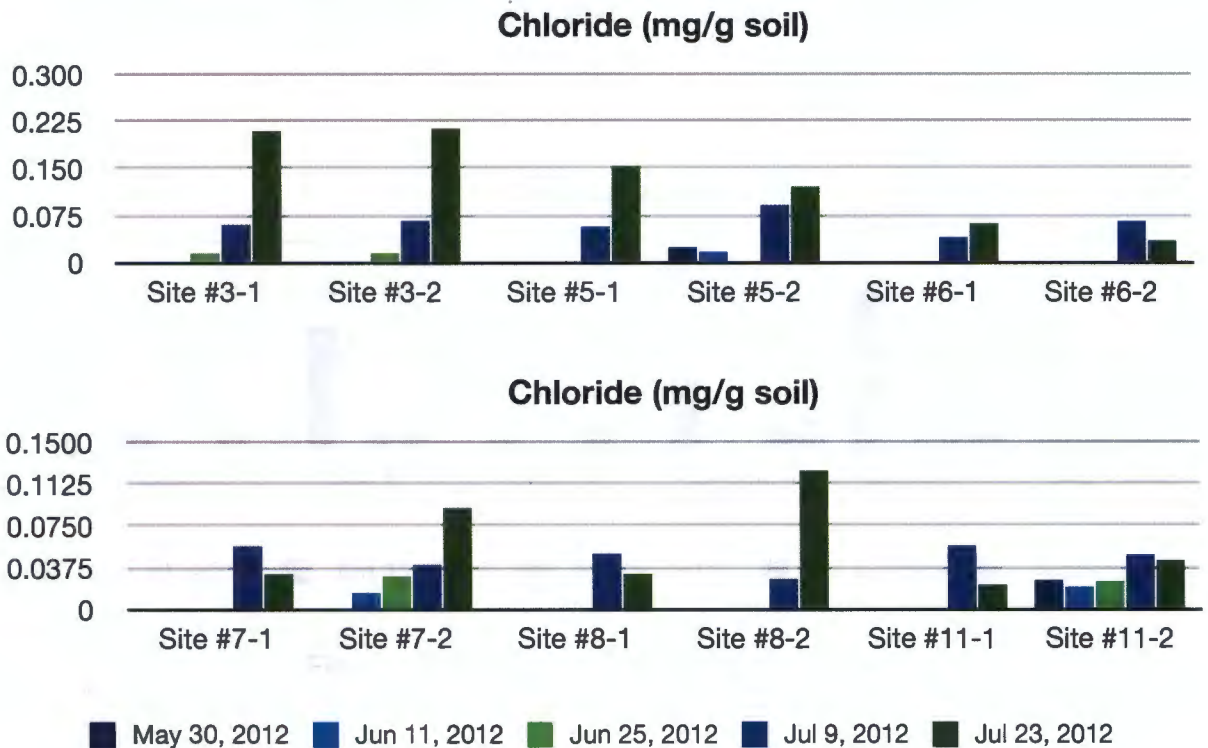this variation could be the pattern of rainfall in the area. All other hydrologic parameters in the area are within the expected range of limits.

The data collected has provided new insights on the source of nitrates in the Cedar Falls Municipal Wells. However there were temporal and funding limitations. All sampling was completed during a 10 week span this summer. To gain more information about the nitrate contamination, it would be beneficial to sample year around. These findings could be different than the normal situation due to long periods without rainfall this summer.

For future work, isotope analysis of nitrogen would enable us to differentiate if the nitrate was coming from fertilizers, waste or other non-point sources. The potentiometric surface of Cedar Falls especially around the municipal wells should be mapped, to give a us a greater idea of how ground water flows in this area. Geophysical studies should be performed to obtain data about microfractures in the Cedar Falls area.

I conclude that this study provides evidence that supports vertical infiltration of nitrate contamination in CFU Well 3. This evidence can be used to remedy the source of nitrate contamination, which would allow for Well 3 to continue to be actively used. If the source of the contamination is not remedied and the concentration of nitrate surpasses the Maximum Contaminant Level set by the Environmental Protection Agency, CFU Well 3 would most likely be shut down causing environmental and economic impacts.

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VIII. Literature Cited

Butcher, S.S., Charlson, R.J., Orians, G.H., and Wolfe, G.V., 1992, Global Biogeochemical Cycles, New York, NY, Academic Press, 379 p.

Crozier, C.R., Hoyt, G.D., and Hardy, D.H., 2007, Sulfur Fertilization of North Carolina Crops, North Carolina State University, North Carolina Cooperative Extension Service, AG-439-63W

Crumbaugh, J.A., Kalra, Y.P. and Maynard, D.G., 2008, Soil Sampling and Methods of Analysis, Second Edition: Nitrate and Exchangeable Ammonium Nitrogen, Canadian Society of Soil Science, Boca Raton, FL, CRC Press, p. 71-73.

Detection of Waterborne Coliforms and Fecal Coliforms with Coliscan® Easygel®, Micrology Laboratories, LLC. P.O. Box 340. Goshen, Indiana 46527 USA.

Drew, D., and Hotzl, H., 1999, Karst Hydrogeology and Human Activities: Impacts, Consequences and Implications, International Association of Hydrogeologists, Rotterdam, Netherlands, A.A. Balkema Publishers, 322 p.

Environmental Protection Agency, 2009, National Primary Drinking Water Regulations: http://water.epa.gov/drink/contaminants/index.cfm#Inorganic (13 August 2012).

Fields, C.L., 2012, The Cedar Falls Groundwater Investigation, Iowa Department of Natural Resources: Source Water Protection: Iowa Geological Survey Technical Information Series 55, 34 p.

Gautam, S., 2007, Assessment of the Source and Transformation of Nitrate in the Cedar River Watershed by using Stable Isotopes of Nitrogen [Masters thesis]: University of Northern Iowa, 103 p.

Guatam, S., and Iqbal, M.Z., 2010, Using stable isotopes of nitrogen to study its source and transformation in a heavily farmed watershed. Environmental Earth Science Journal, 60: p. 11-20.

Hanway, J.J., Herrick, T.L., Willrich, T.L., Bennet,P.C., and McCall, J.T., 1963, The Nitrate Problem, Iowa State University of Science and Technology Cooperative Extension Service in Agriculture and Home Economics Special Report No. 34, 20 p.

Iqbal, M.Z., 2000, Effects of layered hetergeneity in subsurface geologic materials on solute transport under field conditions: A case study from northeastern Iowa, USA, Hydrogeology Journal, 8: p. 257-270.

Konen, M.E., Jacobs, P.M., Burras, C.L., Talaga, B.J., and Mason, J.A., 2002, Equations for Predicting Soil Organic Carbon Using Loss-on-Ignition for North Central U.S. Soils, Soil Science Society American Journal, 66: p. 1878-1881.

Paul, E.A., and Clark, F.E., 1996, Soil Microbiology and Biochemistry, New York, NY, Academic Press, 340 p.

Prior, J.C., 1991, Landforms of Iowa, University of Iowa Press, 154 p.

Schaap, B.D., 1999, Concentrations and possible sources of nitrate in water from the Silurian-Devonian aquifer, Cedar Falls, Iowa: U.S. Geological Survey Water-Resources Investigations Report 99-4106, 19 p.

Terry, N., 1977, Photosynthesis, Growth, and the Role of Chloride, Plant Physiology, 60(1): p. 60-75.

US Environmental Protection Agency (US EPA), 2012, Drinking Water Contaminant: <http://water.epa.gov/drink/contaminants/index.cfm#primary> (28 September 2012).

Vreeken, W.J., Methods for Field and Laboratory Study of Soils, Geography Department, Queens University, p. L VI.

Wick, K., Heumesser, C., Schmid, E., 2012, Nitrate Contamination of Groundwater: Determinants and Indicators, European Association of Agricultural Economists, 120th Seminar, Chania, Crete, 24 p.

Wild, A., 1993, Soils and the Environment: An Introduction, Cambridge, Great Britain, University Press, 287 p.

Zeman, C., Beltz, L., Linda, M., Maddux, J., Depken, D., Orr, J., Theran, P., 2011, New Questions and Insights Into Nitrate/Nitrite and Human Health Effects, Journal of Environmental Health, vol. 74 #4, p. 8-18.

IX. Appendix

Water Collection Data Summer 2012

CFU Well # 3

Date	Temp (oC)	pH	Cond. (µS/cm)	DO (ppm)	TDS (ppm)	Cl- (ppm)	NO3- (ppm)	SO4= (ppm)	E Coli Colonies colonies/100mL
May 23, 2012	-	7.50	502	-	345	13.1	38.2	19.7	-
Jun 6, 2012	-	7.48	502	-	342	13.8	39.3	20.3	-
Jun 20, 2012	-	7.60	507	-	349	13.7	39.0	20.0	-
Jul 5, 2012	-	7.72	495	-	338	14.0	39.5	20.4	-
Jul 18, 2012	-	7.72	492	-	338	45.4	34.4	17.8	-

CFU Well # 7

Date	Temp (oC)	pH	Cond. (µS/cm)	DO (ppm)	TDS (ppm)	Cl- (ppm)	NO3- (ppm)	SO4= (ppm)	E Coli Colonies colonies/100mL
May 23, 2012	-	7.54	468	-	323	9.2	*	17.1	-
Jun 6, 2012	-	7.57	462	-	323	9.5	*	17.4	-
Jun 20, 2012	-	7.69	457	-	315	9.9	*	17.4	-
Jul 5, 2022	-	7.71	468	-	327	9.9	*	17.7	-
Jul 18, 2012	-	7.69	470	-	323	34.6	*	15.6	-

CFU Well # 9

Date	Temp (oC)	pH	Cond. (µS/cm)	DO (ppm)	TDS (ppm)	Cl- (ppm)	NO3- (ppm)	SO4= (ppm)	E Coli Colonies colonies/100mL
May 23, 2012	-	7.57	510	-	353	11.7	35.4	17.9	-
Jun 6, 2012	-	7.55	499	-	345	11.3	33.9	17.8	-
Jun 20, 2012	-	7.62	517	-	356	12.2	36.6	18.0	-
Jul 5, 2012	-	7.64	520	-	360	12.8	38.2	18.7	-
Jul 18, 2012	-	7.65	511	-	352	34.5	32.4	16.3	-

CFU Well # 11

Date	Temp (oC)	pH	Cond. (µS/cm)	DO (ppm)	TDS (ppm)	Cl- (ppm)	NO3- (ppm)	SO4= (ppm)	E Coli Colonies colonies/100mL
May 23, 2012	-	7.37	622	-	429	46.2	17.2	41.2	-
Jun 6, 2012	-	7.42	619	-	426	48.7	19.4	40.0	-
Jun 20, 2012	-	7.56	609	-	421	44.6	18.5	42.5	-
Jul 5, 2012	-	7.52	602	-	415	42.6	19.1	43.7	-
Jul 18, 2012	-	7.57	604	-	417	47.2	18.1	37.3	-

Cedar River #1　George Wyth Boat Ramp

Date	Temp (oC)	pH	Cond. (µS/cm)	DO (ppm)	TDS (ppm)	Cl- (ppm)	NO3- (ppm)	SO4= (ppm)	E Coli Colonies colonies/100mL
May 23, 2012	22.8	8.46	428	11.56	296	26.1	22.8	26.1	-
May 30, 2012	22.1	8.53	459	11.91	316	27.5	33.6	23.2	20
Jun 6, 2012	19.8	8.18	436	9.16	301	25.8	21.1	24.6	0

Date	Temp (oC)	pH	Cond. (µS/cm)	DO (ppm)	TDS (ppm)	Cl- (ppm)	NO3- (ppm)	SO4= (ppm)	E Coli Colonies colonies/100mL
Jun 13, 2012	18.5	8.14	429	7.81	293	25.7	15.3	25.0	0
Jun 20, 2012	27.4	8.23	416	8.33	289	26.6	10.7	25.4	20
Jun 27, 2012	28.6	8.53	439	8.53	301	29.8	12.6	27.3	0
Jul 5, 2012	29.7	8.18	423	8.38	291	27.1	10.3	28.2	0
Jul 11, 2012	24.3	8.17	410	7.83	283	28.3	6.0	28.6	0
Jul 18, 2012	30.4	8.17	404	8.25	278	909.1	2.3	23.3	0
Jul 25, 2012	27.0	8.05	444	6.38	304	38.3	3.3	26.3	0

Cedar River #2 Pheiffer Park

Date	Temp (oC)	pH	Cond. (µS/cm)	DO (ppm)	TDS (ppm)	Cl- (ppm)	NO3- (ppm)	SO4= (ppm)	E Coli Colonies colonies/100mL
May 23, 2012	22.3	8.26	469	10.70	322	26.5	22.1	25.6	-
May 30, 2012	21.9	8.57	461	11.61	318	26.7	34.9	23.1	0
Jun 6, 2012	20.6	8.22	446	9.74	307	24.7	23.9	24.3	0
Jun 13, 2012	15.9	8.09	540	8.59	370	30.4	16.3	24.0	0
Jun 20, 2012	25.4	8.21	469	9.09	323	27.1	12.6	25.2	0
Jun 27, 2012	30.0	8.71	432	12.41	298	28.7	13.2	27.3	0
Jul 5, 2012	29.7	8.18	423	8.38	291	28.9	16.3	26.7	0
Jul 11, 2012	25.1	8.42	412	10.04	284	27.0	6.8	28.9	0
Jul 18, 2012	26.7	8.19	478	9.98	330	94.5	9.2	24.1	0
Jul 25, 2012	26.9	8.37	422	9.11	291	31.2	2.4	26.3	0

Cedar River #3 Island Park

Date	Temp (oC)	pH	Cond. (µS/cm)	DO (ppm)	TDS (ppm)	Cl- (ppm)	NO3- (ppm)	SO4= (ppm)	E Coli Colonies colonies/100mL
May 23, 2012	23.0	8.37	436	11.61	302	25.4	22.7	26.7	-
May 30, 2012	22.2	8.55	444	12.18	306	26.8	34.3	23.5	0
Jun 6, 2012	22.1	8.25	435	9.20	299	25.5	21.4	25.2	0
Jun 13, 2012	22.0	8.23	417	7.78	286	25.0	14.8	25.5	0
Jun 20, 2012	26.2	8.30	413	7.82	285	26.2	11.2	26.2	0
Jun 27, 2012	28.1	8.56	442	11.34	339	29.3	12.8	27.6	0
Jul 5, 2012	30.1	8.26	414	8.63	285	26.2	10	28.6	0
Jul 11, 2012	25.9	8.22	406	8.30	280	26.8	5.7	29.2	0
Jul 18, 2012	31.6	8.46	397	10.94	263	77.1	1.9	24.7	0
Jul 25, 2012	27.7	8.40	436	9.46	303	30.8	2.1	26.9	0

- = not tested
* = not detected

Soil Collection Data Summer 2012

Site	Date	Chloride (mg/g Soil)	Nitrate (mg/g Soil)	Sulfate (mg/g Soil)	% Moisture	% Organic Matter
Well #3 Site 1	May 30, 2012	*	0.090	0.167	19.28	11.83
Well #3 Site 1	Jun 11, 2012	*	0.025	0.020	23.85	5.48
Well #3 Site 1	Jun 25, 2012	0.015	0.032	0.047	21.98	11.30
Well #3 Site 1	Jul 9, 2012	0.060	0.119	0.037	16.99	13.21
Well #3 Site 1	Jul 25, 2012	0.209	0.099	0.032	18.54	12.24
Well #3 Site 2	May 30, 2012	*	0.200	0.230	12.25	11.19
Well #3 Site 2	Jun 11, 2012	*	*	*	21.65	9.78
Well #3 Site 2	Jun 25, 2012	0.015	0.080	*	19.38	8.41
Well #3 Site 2	Jul 9, 2012	0.066	0.236	0.037	4.00	11.54
Well #3 Site 2	Jul 25, 2012	0.213	0.121	0.020	2.95	9.17
Well #5 Site 1	May 30, 2012	*	*	0.079	14.11	5.13
Well #5 Site 1	Jun 11, 2012	*	*	*	21.68	5.42
Well #3 Site 1	Jun 25, 2012		0.050	0.025	13.16	5.25
Well #5 Site 1	Jul 9, 2012	0.057	0.082	0.040	4.88	6.58
Well #5 Site 1	Jul 25, 2012	0.154	0.057	0.017	19.02	5.76
Well #5 Site 2	May 30, 2012	0.024	*	0.151	8.23	6.14
Well #5 Site 2	Jun 11, 2012	0.017	*	*	24.21	5.45
Well #5 Site 2	Jun 25, 2012	*	*	*	10.75	4.66
Well #5 Site 2	Jul 9, 2012	0.091	*	0.056	3.17	5.37
Well #5 Site 2	Jul 25, 2012	0.121	0.035	*	3.62	7.14
Well #6 Site 1	May 30, 2012	*	*	0.068	23.94	6.88
Well #6 Site 1	Jun 11, 2012	*	*	*	22.15	6.45
Well #6 Site 1	Jun 25, 2012	*	0.035	*	17.40	7.06
Well #6 Site 1	Jul 9, 2012	0.040	0.037	0.035	7.83	7.98
Well #6 Site 1	Jul 25, 2012	0.062	0.057	0.017	4.79	10.53
Well #6 Site 2	May 30, 2012	*	*	*	22.88	6.17
Well #6 Site 2	Jun 11, 2012	*	*	*	18.94	5.23
Well #6 Site 2	Jun 25, 2012	*	*	0.020	14.52	3.23
Well #6 Site 2	Jul 9, 2012	0.065	0.040	0.062	2.03	5.92
Well #6 Site 2	Jul 25, 2012	0.035	*	0.057	3.81	6.34
Well #7 Site 1	May 30, 2012	*	0.027	0.022	10.51	5.36
Well #7 Site 1	Jun 11, 2012	*	0.049	*	20.14	4.85
Well #7 Site 1	Jun 25, 2012	*	0.034	*	15.65	5.08
Well #7 Site 1	Jul 9, 2012	0.057	0.047	0.027	11.07	4.84
Well #7 Site 1	Jul 25, 2012	0.032	0.155	*	4.59	5.83
Well #7 Site 2	May 30, 2012	*	*	0.177	18.24	6.51
Well #7 Site 2	Jun 11, 2012	0.015	*	*	17.08	10.81
Well #7 Site 2	Jun 25, 2012	0.030	*	0.022	10.94	5.02
Well #7 Site 2	Jul 9, 2012	0.040	*	0.027	3.03	4.87
Well #7 Site 2	Jul 25, 2012	0.091	*	*	3.34	4.97
Well #8 Site 1	May 30, 2012	*	0.078	0.024	10.58	5.14

Soil Collection Data Summer 2012

Site	Date	Chloride (mg/g Soil)	Nitrate (mg/g Soil)	Sulfate (mg/g Soil)	% Moisture	% Organic Matter
Well #8 Site 1	Jun 11, 2012	*	*	*	17.32	6.32
Well #8 Site 1	Jun 25, 2012	*	*	*	10.60	5.46
Well #8 Site 1	Jul 9, 2012	0.050	0.050	0.030	2.58	8.39
Well #8 Site 1	Jul 25, 2012	0.032	0.035	*	2.89	7.06
Well #8 Site 2	May 30, 2012	*	*	0.097	21.76	7.35
Well #8 Site 2	Jun 11, 2012	*	0.030	*	19.48	5.62
Well #8 Site 2	Jun 25, 2012	*	*	*	11.88	5.04
Well #8 Site 2	Jul 9, 2012	0.027	0.127	0.027	2.86	6.77
Well #8 Site 2	Jul 25, 2012	0.124	0.514	0.042	3.52	7.37
Well #11 Site 1	May 30, 2012	*	0.032	0.231	12.64	6.70
Well #11 Site 1	Jun 11, 2012	*	0.034	*	21.90	4.61
Well #11 Site 1	Jun 25, 2012	*	0.072	0.022	19.98	6.18
Well #11 Site 1	Jul 9, 2012	0.057	0.049	0.044	9.53	6.92
Well #11 Site 1	Jul 25, 2012	0.022	0.149	0.027	6.07	7.22
Well #11 Site 2	May 30, 2012	0.026	0.190	0.176	13.59	5.97
Well #11 Site 2	Jun 11, 2012	0.020	*	0.020	21.41	5.89
Well #11 Site 2	Jun 25, 2012	0.025	0.057	0.047	17.51	4.35
Well #11 Site 2	Jul 9, 2012	0.049	0.034	0.066	16.82	4.02
Well #11 Site 2	Jul 25, 2012	0.044	0.039	0.029	22.5	6.90

* = not detected