Distribution of Total Arsenic in Groundwater in the North Carolina Piedmont

October 3, 2003

Charles G. Pippin, PG*
Michele Butczynski
Jonathan Clayton

Department of Environment and Natural Resources
Groundwater Section
Resource Evaluation Program

Mooresville Regional Office

***contact information**
Chuck Pippin, NCDENR – Groundwater Section, 919 N. M ain Street, Mooresville, NC 28115
704-663-1699
chuck.pippin@ncmail.net

Table of Contents

INTRODUCTION

In 2000, the Groundwater Section received requests from the Lincoln and Stanly County Health Departments for assistance in investigating occurrences of arsenic in water supply wells. Both counties had identified geographic areas where total arsenic was present in groundwater at concentrations in excess of 0.05 mg/L, the former Environmental Protection Agency (EPA) National Primary Drinking Water Standard for arsenic. Another area with similar arsenic concentrations was discovered in Union County in 2001 (Figure 1). The Groundwater Section began compiling analytical results from these and other counties and discovered that wells in these counties had an anomalously high occurrence of detectable arsenic. In Union and Stanly counties the problem was geographically extensive. In Lincoln County, elevated arsenic concentrations appear to be limited to one community. Public water supply data was also analyzed. Detectable concentrations of arsenic have been recorded in historical data from several public water supply wells; the majority of these are in Gaston County.

Through the Groundwater Section's Resource Evaluation Program, a study was organized to address the distribution of total arsenic in the four counties mentioned above. In January 2002, the Groundwater Section held a meeting of interested parties to discuss the occurrence of arsenic in the groundwater resource. Representatives of the following organizations attended the meeting and expressed interest in working together to determine the geographic extent of the arsenic problem, the potential risk to users of the groundwater resource, the potential source (natural or anthropogenic), and potential corrective actions:

- North Carolina Division of Water Quality, Groundwater Section (Groundwater Section)
- Lincoln County Department of Health
- Gaston County Department of Health
- Stanly County Department of Health
- Union County Department of Health
- North Carolina Geological Survey (NCGS)
- United States Geological Survey (USGS)
- North Carolina Department of Health and Human Services – Occupational and Environmental Epidemiology Branch (NC DHHS – OEEB)
- University of North Carolina, Asheville
- Appalachian State University

The attendants of the meeting concluded that a study of the arsenic problem was warranted. Due to the limited resources available, a decision was made to target "hot spot" areas for study.

The purpose of this paper is to:

- Report the historical arsenic data that has been collected to date.
- Report the arsenic data collected during the summer of 2002.
- Identify the "hot spot" areas in the State.
- Make recommendations for further work.

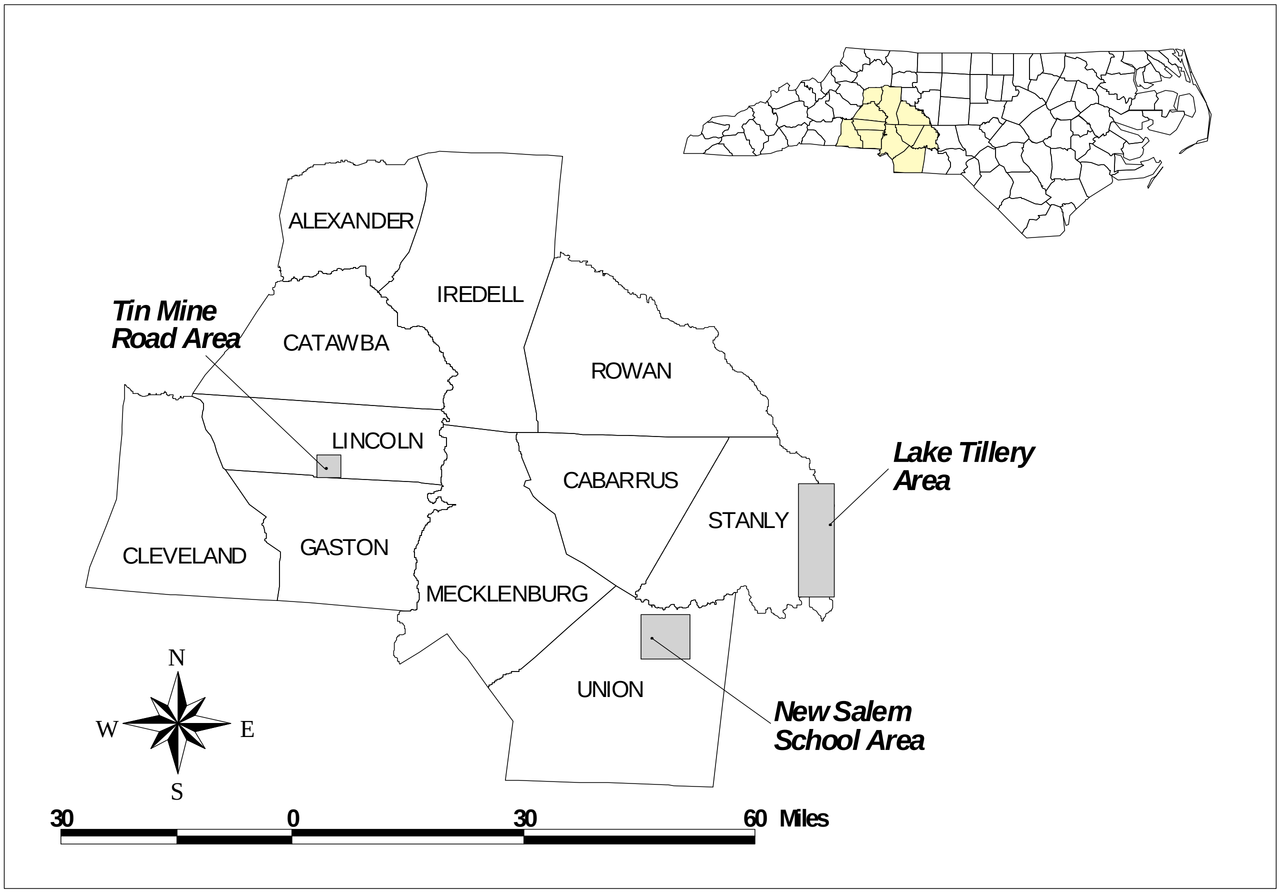

Figure 1. The Mooresville Region is made up of the eleven counties shown above. The initial areas of concern for elevated total arsenic concentrations are identified by gray shading and include the Tin Mine Road Area of Lincoln County, the Lake Tillery Area of Stanly County, the New Salem School Area of Union County and generally all of Gaston County.

STUDY GOALS

The main goals of the study include the following:

- Assess the distribution of arsenic in the groundwater resource.
- Assess the potential health risk associated with using arsenic contaminated groundwater.
- Increase our understanding of processes that contribute to arsenic concentrations in groundwater.
- Increase public knowledge on the issue.

The study will attempt to achieve these goals in three phases.

- Phase one "Hot Spot Identification" - systematic groundwater sampling in the areas previously identified and collection of historical analytical results for arsenic; analysis of all the results and identification of the "hot spot" areas.

- Phase two "Determination of Source" - thorough sampling of rock, soil, groundwater, surface water and stream sediment in the area of highest groundwater concentrations.
- Phase three "Health Surveillance" - involves the NCDHHS OEEB health surveillance of individuals identified as high risk. High risk individuals will be those whose domestic water supply well has tested positive for arsenic, who have used the contaminated well for a significant number of years, and have no other option for water. The NCDHHS OEEB will take the lead in health surveillance and it will be performed concurrently with the other phases of the study.

In the summer of 2002, the Groundwater Section initiated Phase One of the study. Groundwater Section activities in the summer of 2002 constituted a reconnaissance study designed to supplement historical data through systematic sampling in Lincoln, Gaston, Stanly and Union Counties and to define the "hot spot" areas through analysis of historical and newly collected arsenic data.

BACKGROUND

Previous Work on Arsenic in NC

Aside from the National Uranium Resource Evaluation (NURE) program, which collected groundwater, stream water, and lake water samples as well as lake and stream sediment samples between 1974 and 1980 (Smith 2001), there have been no other regional studies that provide data regarding the distribution of arsenic in North Carolina. The North Carolina portion of the NURE data only contains arsenic analyses from stream sediments and this data does not exist in all areas. Recent reports provide a nationwide overview of arsenic in the groundwater resources of the United States (Focazio ***et al.;*** 1999, Welch ***et al.;*** 2000, Welch 2001; and Welch ***et al.,*** 1999). In general, the data presented in these reports suggests that the potential health risk from arsenic in North Carolina is not significant with typical concentrations of less than 1 µg/L.

The data analyzed in the works cited above was extracted from the USGS National Water Information System and the EPA Safe Drinking Water Information System. To evaluate whether or not the data contained in these water information systems are applicable to the state of North Carolina, the Groundwater Section downloaded the data used in the Focazio ***et. al.,*** (1999), report. Based on a review of the data, the portion representing North Carolina includes 148 sample locations of which 40% are undesignated (blank entry field), 9% are domestic supply wells, 3% are public supply wells and 48% are monitoring wells. In addition, the data is not spatially representative of the state with much of the data occurring in a few local clusters. The review suggests that the data used by Focazzio ***et. al.,*** (1999), is not sufficient to evaluate the health risk potential across the state.

County Specific Data

Based on domestic water supply well data collected prior to 2002, arsenic had been identified as a potential health threat in three areas in the southwestern piedmont of North Carolina (Figure 1). Table 1 provides a statistical summary of the domestic water supply well data compiled by the Groundwater Section prior to 2002 from Lincoln, Stanly, and Union counties. The data were collected by state and county personnel to assess the geographic extent of dissolved arsenic in the areas of concern. Since the data was not collected randomly, the results likely are biased toward higher arsenic values.

Table 1 – Summary of Known Data Collected Prior to 2002

General Statistics for Arsenic Concentrations	Lincoln County Private Wells[1]	Stanly County Private Wells[2]	Union County Private Wells[3]	Combined Data for Lincoln, Stanly and Union Counties
Mean[4]	0.032	0.016	0.020	0.020
Std. Deviation	0.131	0.022	0.028	0.062
Minimum	<0.001	<0.001	<0.001	<0.001
Maximum	0.870	0.111	0.110	0.870
25th percentile	<0.001	0.002	<0.001	0.001
Median	<0.001	0.010	0.009	0.007
75th percentile	0.005	0.020	0.032	0.020
Geom. mean	0.001	0.006	0.005	0.004
Valid cases	57	192	31	280
No. Non Detects	30	25	9	64

Notes
1. Sampling conducted by Lincoln County and the Groundwater Section. Samples cover an approximate 1 square mile area along Tin Mine Road.
2. Sampling conducted by Stanly County. Samples are distributed over the entire county, with a concentration of samples collected near Lake Tillery.
3. Sampling conducted by Union County and the Groundwater Section.
4. Mean based on substitution of 0.00025 mg/L for sample results that were less than the method detection limit.
5. <0.001 - Method detection limit.

The following paragraphs describe the occurrence of arsenic in Lincoln, Stanly, Union and Gaston counties.

Lincoln County

In Lincoln County, the area of concern is located in the Tin Mine Road neighborhood south of Lincolnton (Figure 2). Fifty-seven groundwater samples from wells in the Tin Mine Road area returned analytical results that ranged from less than detection limits to a maximum value of 0.87 mg/L. Samples were also collected from soil, stream sediment and surface water in the drainage basin containing the Tin Mine Road area. A review of the collected data did not link the source for the elevated arsenic concentrations to the local geology or potential anthropomorphic sources. However, the Kings Mountain Shear Zone, a northeast-southwest trending fault zone, transects the neighborhood, along which are several mineralized zones (i.e. tin deposits). It is possible that sulfide mineralization along the fault may be a host for arsenic in the form of arsenopyrite and arsenic bearing pyrite. A statistical summary of the groundwater analytical results is presented in Table 1.

Stanly County

In Stanly County, the area of concern is located in a neighborhood adjacent to Lake Tillery, a reservoir of the Yadkin River that defines the Stanly County border to the east. Stanly County Health Department collected 192 samples from wells mostly in the Lake Tillery and surrounding area (Figure 3). The analytical results from these sampling efforts ranged from less than detection limits to 0.111 mg/L. The proximity of the wells of concern to the shore of Lake Tillery, suggest a possible relationship. It is possible that the formation of Lake Tillery affected the local oxidation/reduction conditions in the soils and groundwater surrounding the lake, resulting the mobilization of arsenic (Reid personal communication, 2002). A statistical summary of these groundwater analytical results is presented in Table 1.

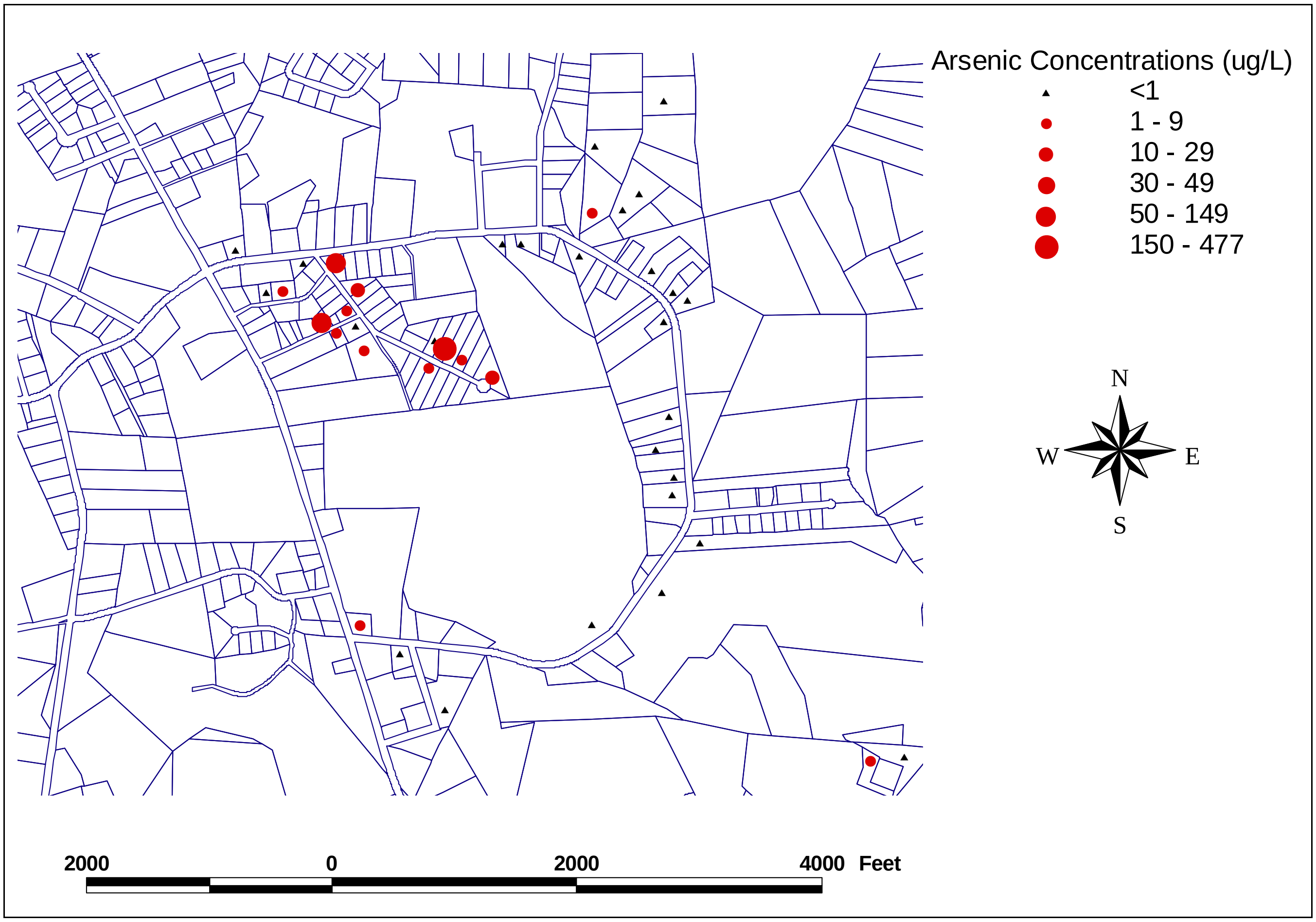

Figure 2. Arsenic concentrations in the Tin Mine Road area of Lincoln County. Lincolnton is located approximately 2 miles northwest.

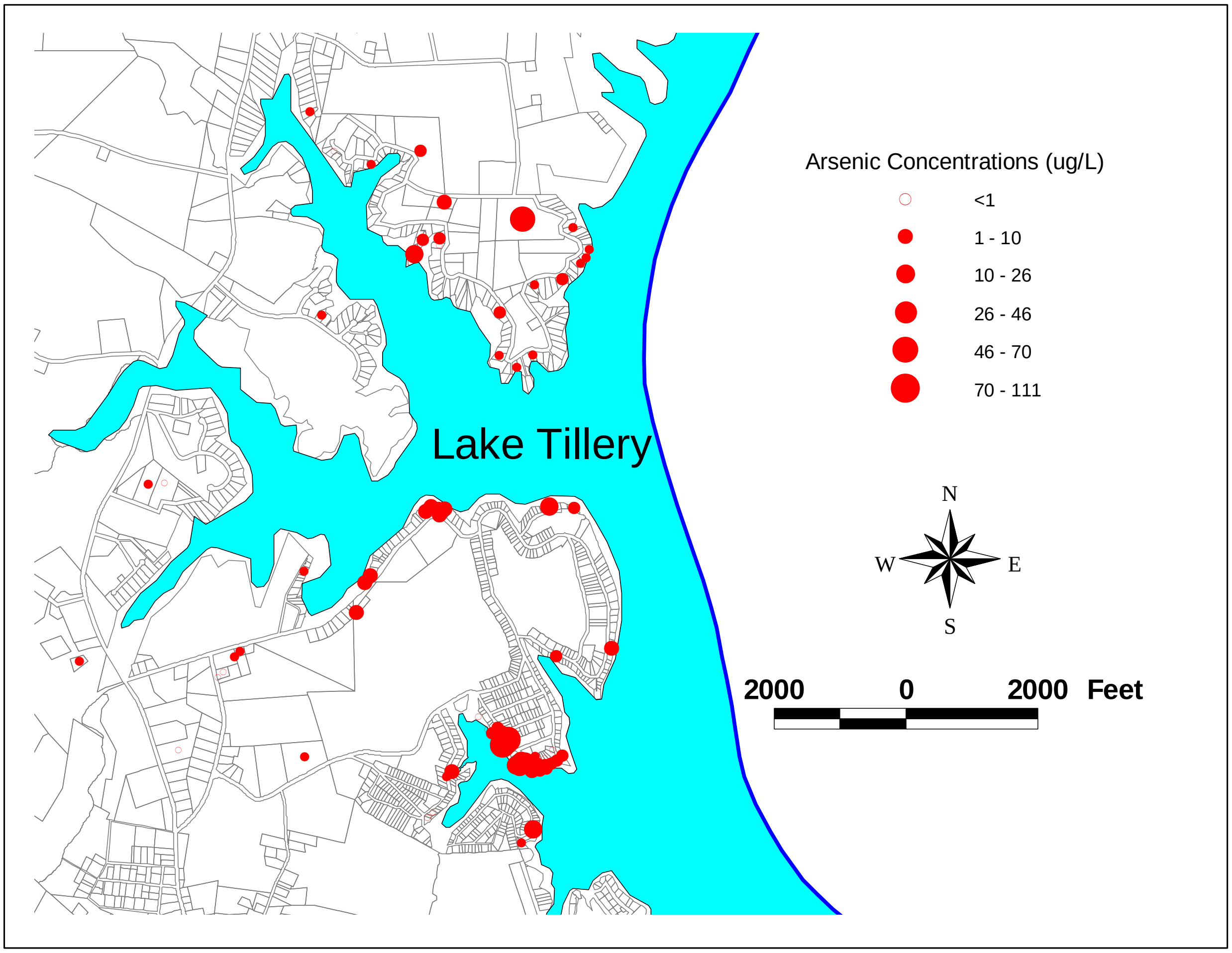

Figure 3. Arsenic concentration ranges in the Lake Tillery Area of Stanly County.

Union County

In Union County, no formal study has been performed. Newspaper coverage of dissolved arsenic detected in a public supply well that served New Salem Elementary School, prompted a heightened awareness of arsenic in the county and subsequently generated more requests for groundwater sampling at the local level. Analytical results from sampling of wells in Union County range from less than detection limits to 0.110 mg/L. A statistical summary of the groundwater analytical results is presented in Table 1.

Gaston County

In Gaston County, arsenic has been identified primarily in Public Water Supply (PWS) wells. Sampling of private wells does not appear to show a concern, looking at the data prior to 2002. Figure 4 shows the locations of PWS wells in Gaston County and distinguishes between those that have had a historical occurrence (i.e. any detectable amount over period of monitoring) of arsenic at concentrations that exceed 0.001 mg/L and those that have not. Several of these locations have had occurrences of arsenic that are greater than the current EPA standard of 0.01 mg/L for arsenic in drinking water. Typically, elevated arsenic concentrations in PWS wells attenuate over time, perhaps due to the volume of pumping they experience.

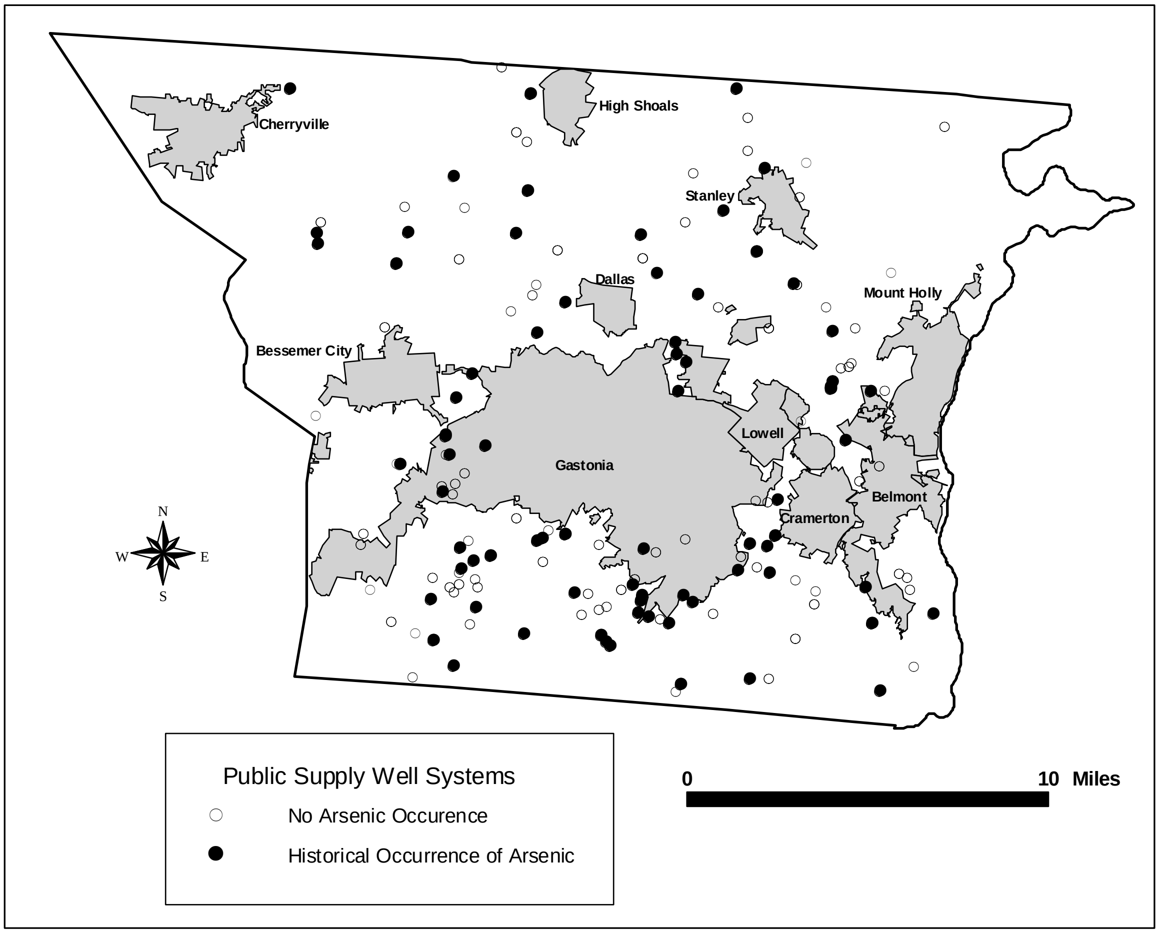

Figure 4. Locations of public water supply well systems in Gaston county with municipalities identified. Many of the wells have had historical occurrences of arsenic detected during water quality testing.

METHODS

Historical Data Configuration and Character

During the study four databases were acquired. The collected databases are listed in Table 2 with a brief description of their contents and any manipulations that were made to the original data set. All the data sets were reviewed to determine their usability. The data from the USGS was not used during data analysis for the State since relatively few samples from across North Carolina are present in it (Figure 5). Likewise the data from the Public Water Supply Section was not used further in data analysis for this report, because it was collected as part of a yearly monitoring program. Therefore, the bulk of the data consists of duplicate sample locations. The NC portion of the NURE database does not contain arsenic analyses for stream sediments or groundwater samples collected from the Charlotte $1^{o}x2^{o}$ Quadrangle, which comprises a large portion of the Piedmont. Therefore a large portion of the Piedmont is not represented. For this reason the NURE data was not analyzed in this report. The data from the NC DHHS Analytical Laboratory (DHHS Data) was used for the study due to its extensive coverage of the Piedmont portion of the State (Figure 5). The DHHS Data was analyzed using an ICP/MS and should be similar in quality to the data collected during the summer sampling event since the same laboratory was used. One limitation with the DHHS Data is that over the years the detection limits for arsenic have changed many times from 0.05 mg/L to 0.001 mg/L as technology has advanced.

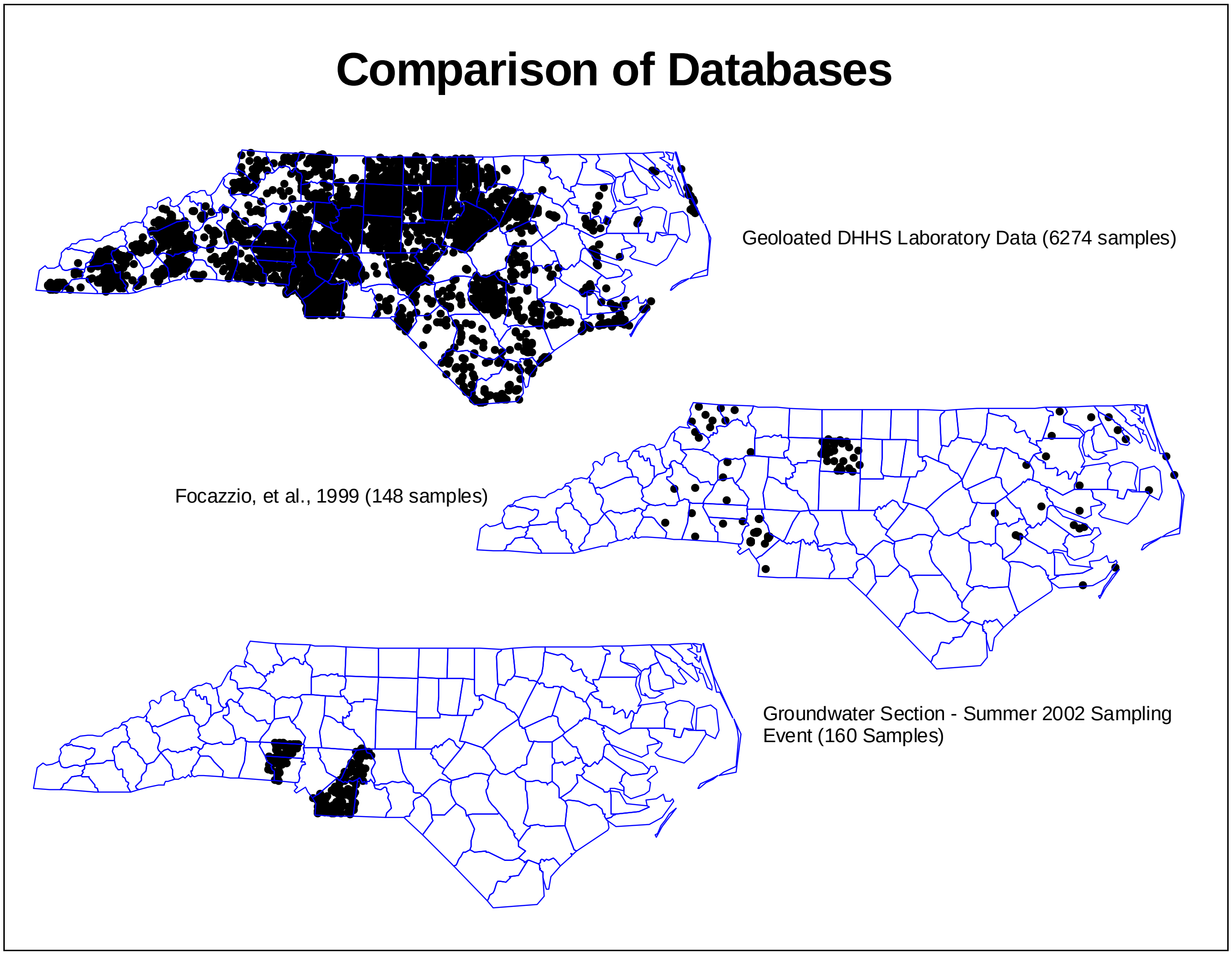

Figure 5. Comparison of the spatial distribution of data from the cited databases reveals the inadequacy of the Focazzio database for broad interpretations of arsenic distribution in North Carolina.

The DHHS Data were geolocated using the Arcview script "Locate Address", which can determine the spatial location of a specific address by using the street number and zip code. This information is cross-referenced with a street address database used by Arcview to determine the approximate location of data. Exact locations are not possible; however, the locations are in their approximate positions and are close enough to provide accurate information given the scale of the maps and grid used in analysis. The geolocated DHHS Data is referred to as GeoDHHS Data.

Table 2 – Summary of Arsenic Database Descriptions

Database	Media	Collection Dates	Description	Reference
NC/SC NURE Database	SS	June through December 1976	The NURE data available for North Carolina and South Carolina only contains arsenic analyses for sediments in a select number of 1^ox2^o quadrangles.	Smith, S.M., 2001[1]
USGS National Water Information System	GW	1983-1996 (NC Only)	20,043 arsenic samples from potable ground water, retrieved from the USGS National Water Information System in 2001. This dataset is a product of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program.	Focazio et al., 1999[2]
NC DHHS Public Water Supply Well System	GW	1976 to 2001	Contains arsenic analytical results from Public Water Supply Well System monitoring data. Database provides monitoring data from 1976 to 2001, though most systems have only 10 to 20 years worth of annual data.	NC DHHS Public Water Supply Section[3]
NC DHHS Analytical Laboratory	GW	1996 to 2002	Database contains analytical results from water samples collected from all over North Carolina. Through several iterations of filtering the data for separate parameters, cutting and pasting the filtered data, a new more concise database was created. The new database contains 13,976 records. Of these 13,976 records, 6,274 records had sufficient data to be spatially located.	NC DENR Groundwater Section, Mooresville Regional Office[4]

Notes:
1. http://pubs.usgs.gov/of/1997/ofr-97-0492/state/nure_nsc.htm.
2. http://co.water.usgs.gov/trace/data/arsenic_may2000.txt.
3. http://www.deh.enr.state.nc.us/pws/index.htm.
4. http://www.mro.enr.state.nc.us/gw/. Not available over internet
5. NC NURE database - the North Carolina portion of the National Uranium Resource Evaluation program.
6. USGS - United States Geological Survey.
7. NC DHHS - North Carolina Department of Health and Human Services.
8. NC DENR - North Carolina Department of Environment and Natural Resources.
9. Media - SS = Stream Sediments and GW = Groundwater.

Sampling Grid

The sampling effort initiated for Phase One of the Study generally adhered to the "Random Selection within Blocks" approach (Alley, 1993). The counties were divided into 5 minute latitude by 5 minute longitude cells (Figure 6). The number of samples collected from each cell was dependent on the number of samples previously collected from each cell. If 5 or more samples had been previously collected then no additional samples were collected from that cell. If less than 5 samples had been collected, enough samples were collected to achieve a density of 5 samples per cell. Sampling locations within the cell was dependent on existing water supplies, on proximity to roads and well owner permission. Efforts were made to spread out sample locations across each grid cell.

Sample Collection

During the summer of 2002, Groundwater Section temporary staff collected water samples from wells located in Gaston, Lincoln, Stanly and Union counties. The samples were collected following the Groundwater Section's Standard Operating Procedures (SOP) for collecting water samples from wells. After reviewing the data, it appears that insufficient time was allowed for purging at several locations. Each well location was recorded using a handheld Trimble Global Positioning System (GPS) unit in accordance with the Groundwater Section's SOP for GPS data collection. In addition, the well construction details were collected from the well tags or obtained through interviews with the well owners. All samples were submitted to the NC Department of Health and Human Services Laboratory for Standard Inorganic analysis, which uses an inductively coupled plasma mass spectrometer to determine the concentrations of selected metals. A total of 160 samples were collected and analyzed. To assess the quality of the collected data, duplicate samples and field blanks were collected periodically during the study. The data described above is presented in Appendix A.

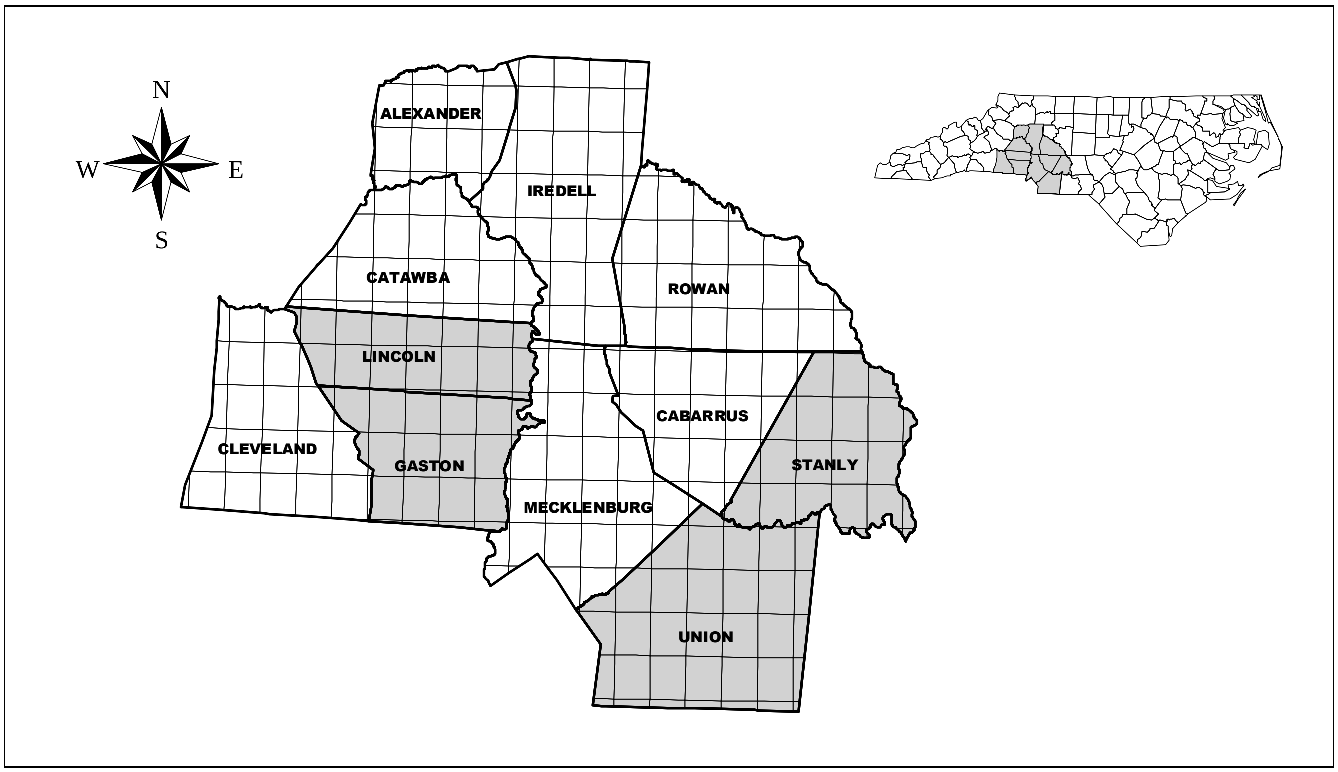

Figure 6. Map of counties that make up the Mooresville Region. Shaded counties were sampled during the summer of 2002. The grid is based on 5x5 minute quadrangles of latitude and longitude. A minimum of 5 sample were collected from the grid cells.

ANALYSIS

Summer 2002 Sampling

Field Data

A total of 160 samples was collected during the summer of 2002 from Gaston, Lincoln, Stanly and Union Counties. A certain degree of variability is inherent in the collected data due to the individual characteristics of the water supply wells sampled and the variable rock types that hosts the wells. The following statistics in Table 3 describe the wells sampled.

Table 3 – Summary of Summer 2002 Well Construction Data

Statistic	Depth (ft)	Year Installed	Casing Depth (ft)	Static Water Level (ft)	Yield (gpm)
Mean	191	1983	61	29	13
Standard Dev.	111	15 years	34	10	17
Minimum	48	1916	24	9	1
Maximum	600	2002	170	50	100
Median	180	1986	54	30	8
Valid Cases	90	136	30	23	59

Notes:
1. Valid Cases – 160 wells were sampled during the summer of 2002. The information above was obtained from interviews of well owners or was copied from well constructions tags located on the well head. The number of valid cases represents the data obtained.
2. ft – feet
3. gpm – gallons per minute

Based on the results in Table 3, well owners tend to not know very much about the construction of their wells and many wells lack well tags. Most know the year installed and the depth, but few know much else.

In addition to well construction information, a series of field parameters were collected for each sample location. Table 4 summarizes those data.

Table 4 – Summary of Summer 2002 Field Parameters

Statistic	pH	E_H (mV)	Conductivity (us/m)	Temperature (^oC)
Mean	6.7	357	262	18.8
Standard Dev.	0.7	174	281	2.9
Min	5.3	-103	26	15.4
Max	8.8	517	2058	29.8
Median	6.7	422.3	164.5	18
Valid Cases	160	88	160	160

Notes:
1. E_H – E_H measurements were collected for 88 samples due to the timing of instrument acquisition. The E_H data is suspect and should not be used for analysis.
2. pH – measured in standard units.
3. mV – millivolts.
4. us/M – microseimens per meter.
5. ^oC – Degrees Celsius.

As was stated previously, purge times appear to be insufficient, based on the temperature data (typical groundwater temperatures we observe in the areas sampled range between 15 and 17 degrees Celsius). Due to this, the field parameter data is suspect and should be used with caution. That said, these are domestic supply wells and we assume that within the 24 hours prior to sampling sufficient quantities of water have been pumped during domestic activities like bathing, dish washing, lawn watering, etc. As a result, we feel that the laboratory data from these well samples is representative of the groundwater conditions. In addition, the E_H collected in the field is apparently not reliable. At first glance the data appear reasonable; however, when plotted against pH a near perfect correlation is produced. Thus, the lack of variability in the data with respect to pH indicates instrument error.

Analytical Data

The samples were submitted to the DHHS Laboratory for standard inorganic analysis. The standard inorganic analysis includes the parameters listed in Table 5, which provides a statistical summary of the data collected during the summer.

Table 5 – Summary of Summer 2002 Inorganic Data

All in mg/L	Alk.	As	Ca	Cl	Cu	Fl	Fe	Hard.	Mg	Mn	Pb	Zn
Mean	88.10	0.0053	28.23	30.533	0.024	0.19	0.40	100.64	6.65	0.098	0.0017	0.056
Std. Deviation	78.94	0.014	31.84	65.62	0.061	0.71	1.22	118.47	9.28	0.27	0.0072	0.22
Minimum	4	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Maximum	370	0.11	161.1	515	0.44	5.38	8.96	690	72.9	1.43	0.08	2.2
Median	62	<MDL	14.8	6	<MDL	<MDL	<MDL	55.5	3.75	<MDL	<MDL	<MDL
75th percentile	127	0.0038	43	29.75	<MDL	0.2	0.17	142.75	7.35	0.023	<MDL	<MDL
No. Valid cases	148[1]	160	159	148[1]	160	148[1]	160	160	160	160	160	160
No. Non Detect	0	90	4	62	127	107	97	4	4	120	144	124

Notes:
1. The first 12 collected samples were not analyzed for Alkalinity, Chloride, or Fluoride.
2. Mean – based on substitution of 0.00025 for non detect values.
3. <MDL – less than method detection limit.
4. Alk. – Alkalinity
5. Hard. – Hardness
6. mg/L – milligrams per liter.

The data indicates that the average arsenic concentration based on the sampled wells is 0.0053 mg/L; however, the median concentration is less than the method detection limit. The data was collected from wells hosted by varying geology, which must be taken into account during data analysis.

Correlations between arsenic and other base metals are rather poor due to the highly censored nature of the dataset. Though in general, an inverse relationship seems to exist between arsenic and iron, manganese, copper, and zinc. When arsenic concentrations are high these base metal concentrations are low (Figure 7).

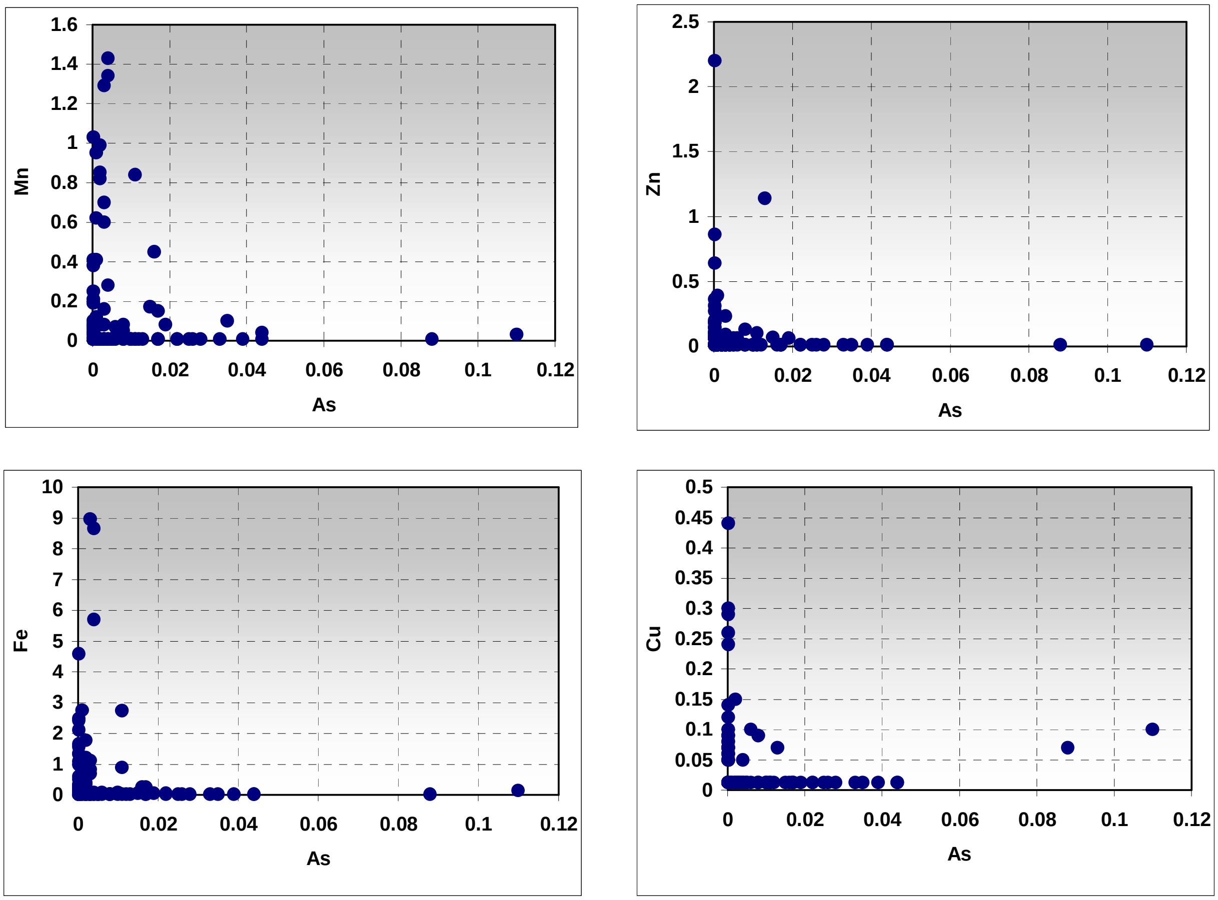

Figure 7. Examples of correlations between arsenic (mg/L) and other base metals (mg/L). In general when arsenic is high, other base metals are low.

Data Quality

The quality of the data can be assessed through analysis of the collected duplicate samples and field blank. The one field blank collected during the summer field activities returned analytical results reporting non detects for each parameter. Five duplicate samples were collected during the summer field activities. Percent differences were calculated between the duplicate and primary sample results using the following formula:

$$\%\text{Difference} = \frac{|x_1 - x_2|}{\frac{1}{2}\,|x_1 + x_2|}$$

Where: x_1 = primary sample
x_2 = duplicate sample

In general the duplicate samples were comparable to the primary samples (Appendix A). Differences in arsenic concentrations varied by only 0.001 mg/L. The calculated percent differences for arsenic ranged from 0% to 4.7%. Minimal differences were observed for most of the other parameters as well.

DHHS Laboratory Analytical Data

The arsenic results from a total of 6,274 analytical results from the GeoDHHS Database were reviewed. The data were sorted by county name so that county to county comparisons could be made and so the data could be compared to the data collected during the summer. Table 6 compares the available data for counties where a minimum of 100 samples had been collected.

TABLE 6 – Comparison of Data Between Counties

	General Statistics							Probabilities			
County	n	ND	Mean (mg/L)	Geom. Mean (mg/L)	Std. Dev. (mg/L)	Max. (mg/L)	Median (mg/L)	n_1	Prob. > 0.01 mg/l	n_2	Prob. > 0.001 mg/L
STANLY	176	60	0.0111	0.0023	0.0205	0.122	0.003	176	0.290	156	0.744
UNION	528	309	0.0093	0.0011	0.0238	0.303	<MDL	528	0.210	410	0.534
LINCOLN	187	160	0.005	0.0004	0.0376	0.477	<MDL	187	0.037	154	0.175
ROWAN	286	264	0.0018	0.0003	0.0186	0.309	<MDL	286	0.017	208	0.106
CABARRUS	135	115	0.0015	0.0004	0.0051	0.047	<MDL	135	0.052	82	0.244
DAVIDSON	251	217	0.0014	0.0004	0.0064	0.085	<MDL	251	0.036	174	0.195
WAKE	567	536	0.0013	0.0003	0.0111	0.22	<MDL	567	0.012	387	0.080
CHATHAM	239	181	0.0011	0.0004	0.0028	0.03	<MDL	239	0.017	139	0.424
MOORE	362	310	0.001	0.0004	0.0031	0.035	<MDL	362	0.030	247	0.211
PERSON	231	192	0.0009	0.0004	0.0024	0.02	<MDL	231	0.026	160	0.244
RANDOLPH	270	220	0.0009	0.0004	0.0019	0.013	<MDL	270	0.011	195	0.256
ORANGE	812	670	0.0008	0.0004	0.0033	0.086	<MDL	812	0.006	553	0.257
CLEVELAND	101	94	0.0007	0.0003	0.0031	0.029	<MDL	101	0.020	68	0.103
GASTON	131	113	0.0007	0.0003	0.0015	0.01	<MDL	131	0.008	96	0.188
CATAWBA	112	104	0.0006	0.0003	0.0017	0.014	<MDL	112	0.009	91	0.088
JOHNSTON	425	396	0.0005	0.0003	0.0017	0.023	<MDL	425	0.007	282	0.103
ROCKINGHAM	128	119	0.0005	0.0003	0.0011	0.009	<MDL	128	0.000	87	0.103
GRANVILLE	154	145	0.0004	0.0003	0.001	0.009	<MDL	154	0.000	95	0.095
ALAMANCE	368	339	0.0004	0.0003	0.0007	0.007	<MDL	368	0.000	274	0.106
NASH	202	194	0.0004	0.0003	0.0009	0.01	<MDL	202	0.005	131	0.061
DAVIE	132	124	0.0004	0.0003	0.0005	0.003	<MDL	132	0.000	73	0.110
IREDELL	194	188	0.0003	0.0003	0.0005	0.007	<MDL	194	0.000	141	0.043
MECKLENBURG	578	560	0.0003	0.0003	0.0005	0.006	<MDL	578	0.000	457	0.039
GUILFORD	745	723	0.0003	0.0003	0.0005	0.008	<MDL	745	0.000	512	0.043

NOTES:
1. n – number of analytical results.
2. ND – Non Detect, number of analytical results that reported values for arsenic as <0.001,< 0.003, <0.005, < 0.01, <0.05 mg/L.
3. n_1 – number of analytical results excluding those that returned non detect values or were less than 0.01 mg/L.
4. n_2 – number of analytical results excluding those that returned non detect values of <0.003, < 0.005, <0.01 or <0.05 mg/L.
5. General Statistics – A value of 0.00025 mg/L was substituted for all <MDL results; therefore, statistical values are likely biased toward lower values. Substitution also produces values that are less than the method detection limits.
6. Geom. Mean – Geometric mean.
7. Std. Dev. – Standard deviation.
8. Max. – Maximum value.
9. Prob. > 0.01 mg/L – Probability that a county will host water supply wells that produce groundwater with arsenic concentrations detectable at or above 0.01 mg/L.
10. Prob. > 0.001 mg/L - Probability that a county will host water supply wells that produce groundwater with arsenic concentrations detectable at or above 0.001 mg/L.
11. <MDL – less than method detection limit.

The data indicates that Union, Stanly and Lincoln counties have the highest mean values; however, those with the highest probability to exceed arsenic concentrations of 0.01 mg/L or

0.001 mg/L are Union, Stanly, and Chatham counties. The mean plus or minus the standard deviation provides a general idea of the range of arsenic concentrations that a well located in one of the counties listed above may produce. As will be discussed later in greater detail, probability analysis is better suited to data sets with significant percentages of censored data. The probability values in Table 6 provide an estimate on the chance a well will produce water with arsenic concentrations that are greater than a threshold value (0.01 mg/L or 0.001 mg/L). The significance of these values is better understood when the data can be observed spatially. Figure 8 shows the sample locations for the DHHS data and summer data combined. From the figure it is clear that sample density varies from county to county and it is apparent that some counties have very good coverage while others do not. The statistical variations from county to county may be partially controlled by different factors such as the varying geology underlying each county, population density, and historical land use. Correlations between geologic units and arsenic concentrations have been made and will be discussed later.

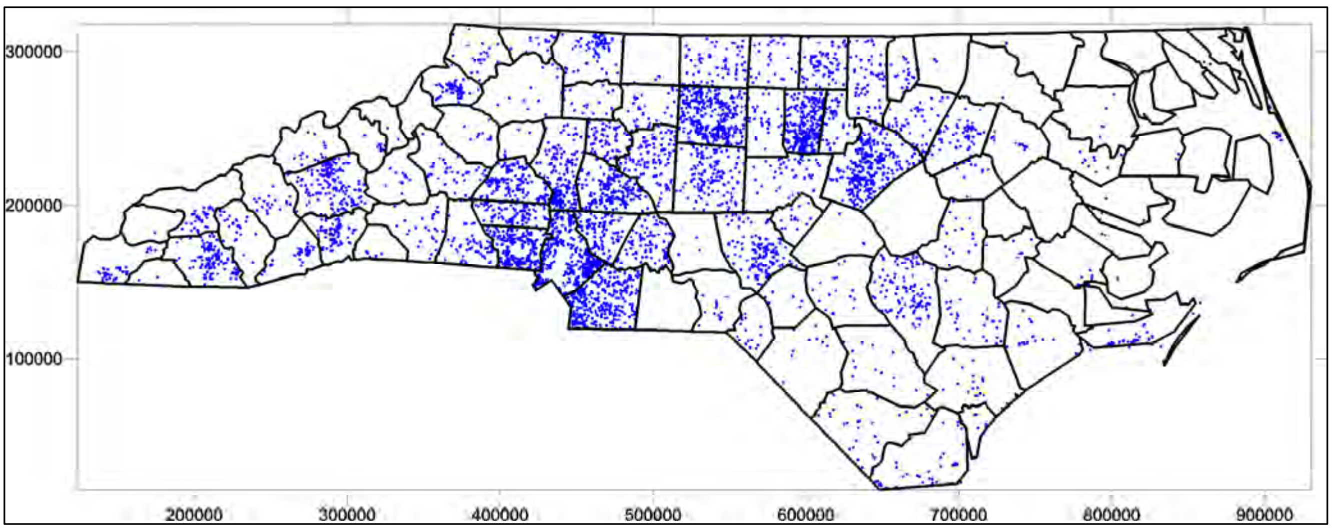

Figure 8. Sample locations. Data obtained from the geolocated DHHS Laboratory database and from the summer 2002 sampling event.

Data Comparisons

The DHHS data is a very useful database due to its statewide coverage, consistent analysis method and laboratory. However, the way the data was collected may bias the data set toward higher than expected values. For example, if a county is aware of a well with high arsenic concentrations, the county may sample several wells in the surrounding area. Such sampling is appropriate to assess the extent of dissolved arsenic in the groundwater resource in the area sampled; however, it may not be appropriate to use that data to characterize the whole county. The DHHS data was collected by county personnel responding to citizen requests, permit requirements, certificate of occupancy or special studies by the health departments.

The method of sample collection used for the summer study was described above and results in a more or less random sample.

The data collected during the summer study was sorted by county and compared to the individual county data from the GeoDHHS database. The following table summarizes the comparisons.

Table 7 – Frequency and Cumulative Percentage*

Concentration Ranges (mg/L)	Lincoln		Gaston		Stanly		Union	
	GeoDHHS	2002 Data	GeoDHHS	2002 Data	GeoDHHS	2002 Data	GeoDHHS	2002 Data
<0.001	115 - 78%	26 - 76%	49 - 27%	18 - 78%	51 - 37%	25 - 67%	152 - 46%	26 - 39%
0.001 to 0.005	19 - 91%	6 - 94%	65 - 62%	3 - 91%	25 - 55%	6 - 83%	64 - 65%	16 - 63%
0.005 to 0.01	6 - 95%	1 - 97%	38 - 83%	1 - 95%	24 - 72%	1 - 86%	32 - 75%	7 - 74%
0.01 to 0.015	2 - 96%	1 - 100%	20 - 93%	1 - 100%	10 - 80%	0 - 86%	22 - 81%	5 - 81%
0.015 to 0.02	1 - 97%		7 - 97%		11 - 88%	4 - 97%	6 - 83%	2 - 84%
0.02 to 0.025			3 - 99%		1 - 88%	0 - 97%	7 - 85%	1 - 86%
0.025 to 0.03					3 - 91%	1 - 100%	7 - 87%	2 - 89%
0.03 to 0.035	1 - 97%		2 - 100%		3 - 93%		9 - 90%	1 - 90%
0.035 to 0.04	0 - 97%						5 - 92%	2 - 93%
0.04 to 0.045	1 - 98%				2 - 94%		6 - 93%	2 - 96%
0.045 to 0.05							4 - 95%	
0.05 to 0.055							5 - 96%	
0.055 to 0.06	1 - 99%				1 - 95%		2 - 97%	
0.06 to 0.065							1 - 97%	
0.065 to 0.07					1 - 96%			
0.07 to 0.075					1 - 96%		2 - 98%	
0.075 to 0.08							1 - 98%	
0.08 to 0.085					1 - 97%		1 - 98%	
0.085 to 0.09					1 - 98%		3 - 99%	1 - 98%
0.09 to 0.095	1 - 99%				1 - 99%		2 - 99%	
0.095 to 0.1								
0.1 to 0.105								
0.105 to 0.11					1 - 99%			
0.11 to 0.115					1 - 100%		1 - 100%	1 - 100%
>0.115	1 - 100%							
Detects	33 – 22%	8 – 33%	135 – 73%	5 – 22%	87 – 63%	13 – 35%	180 – 54%	40 – 61%
N	147	34	184	23	138	37	332	66

Notes:
1. * - Frequency and cumulative percentage represented in the format of "121 – 78%".
2. GeoDHHS – Geolocated DHHS database with result values of "<0.003", "<0.005", "<0.01" and "<0.05" mg/L removed.
3. 2002 Data – Random sample based on grid cell sampling.
4. Detects – Number of detects followed by the percent detects.
5. N – number of samples

Table 7 shows the data frequency across different concentration ranges, the associated cumulative percentage and provides the ratio of detects to non detects (probability). The most obvious comparison between the two databases is the relative lack of outlying concentrations of arsenic in the summer 2002 data. This suggests that as the sampled population increases the probability for sampling a well with high arsenic concentrations increases too. The data for Union county is the most similar, showing similar cumulative percentages for consecutive concentration ranges.

The data from the summer 2002 study and the GeoDHHS Database were combined for statistical and spatial analysis (Appendix B). The data from the combined database can be described as nonparametric, positively skewed with significant percentages of censored data (i.e. less than detection limits) and many different method detection limits. Figures 9 and 10 provide a breakdown of how the data is distributed. To statistically account for analytical results that are below the detection limits, a value of 0.00025 mg/L was arbitrarily assigned to all results that were below the method detection limit. Although, according to Helsel (1990), substitution of values for non-detect results has no theoretical basis of support, it does produce a generalized description of the central tendencies of the data though biased toward lower values. For this reason statistical estimates via substitution should be used with caution. Substitution does not interfere with the median value or other percentile ranks (provided that the amount of censored data is less than 25% of the dataset); these statistical entities provide a much better estimation of the central tendencies of nonparametric data (Helsel, 1990; Helsel and Mirch 1992). Unfortunately, the combined database contains approximately 85% censored data, therefore, the median and percentile ranks are not applicable either. Since 85% of the data is censored, accurately describing the central tendencies is not possible. However, through logistic regression, the probability of exceeding certain threshold values tied to the method detection limits is possible and provides a very useful analysis of the spatial distribution of the data (Helsel, 1990; Saito and Goovaerts, 2000; Krivoruchko, 2001).

Arsenic Concentration Ranges	***Frequency***	***Relative %***
<MDL	5487	85.28
>MDL -0.001	159	2.47
>0.001-0.01	570	8.86
>0.01-0.1	211	3.28
>0.1-1	7	0.11
Totals	6434	100

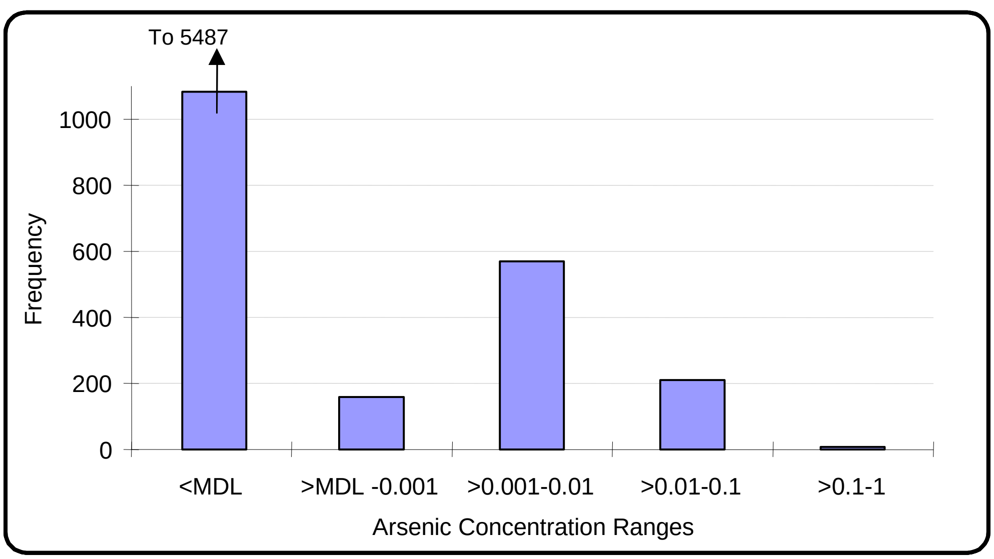

Figure 9. Histogram indicates the distribution of data in the geolocated DHHS Laboratory Data (n=6274) and the data from the Summer 2002 sampling event (n=160).

MDLs and Detects	*Frequency*	*Relative %*
<0.002	2	0.03
<0.05	3	0.05
<0.003	29	0.45
<0.005	299	4.65
Detects	937	14.56
<0.01	1836	28.54
<0.001	3328	51.73
Totals	6434	100.00

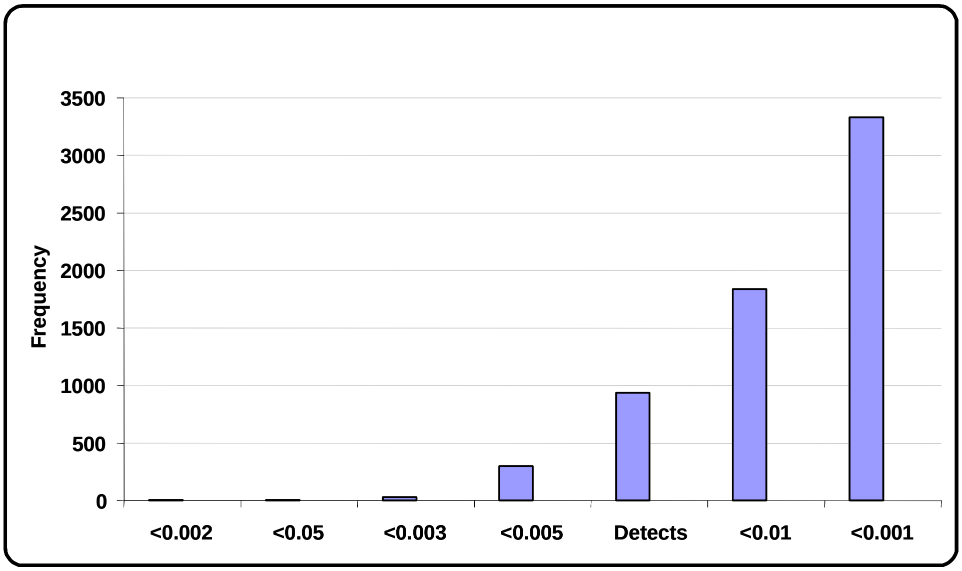

Figure 10. Histogram indicates the distribution of data types from the geolocated DHHS Laboratory data (n=6274) and from the summer 2002 sampling event (n=160).

SPATIAL ANALYSIS

Technique

The maps used for spatial analysis were all generated using the plotting and contouring capabilities of Surfer™ Contouring and 3D Surface Mapping for Scientists and Engineers, Version 7. Original x,y,z data sets, where x is equal to east-west coordinates, y is equal to north-south coordinates and z is equal to the contouring variable (i.e. concentration), are transformed into grid files using one of the gridding algorithm capabilities of Surfer™. The point kriging with linear drift algorithm was used for all the maps viewed in this report. Gridding densities were adjusted from Surfer's™ default values to achieve a better fit to the distribution of the data. The kriging algorithm transforms the data set into a grid file by assigning a weighted average to each grid node. The value assigned to each grid node is calculated based on the weighted average of the data found in a search ring that is centered on each grid node. The search ring is divided into four equal sectors. The six data points in each sector that are closest to the grid node are used to calculate the weighted average. A minimum of five data points must be present in the search ring, else the grid node is coded as a “blank node”.

Isoconcentration Maps

Isoconcentration maps of arsenic are shown in Figures 11 through 14 and provide a spatial summary of the Summer 2002 data and the combined GeoDHHS data and Summer 2002 data (Gridding Reports are available in Appendix C). Figure 11 shows the sample locations for the Summer 2002 Sampling event. The areas of highest concentration agree with those displayed in Figures 12 through 14. Figure 12a is a sample location and concentration map and Figure 12b is an isoconcentration map for the Mooresville Region. Figures 13 and 14 are isoconcentration maps of for the State. Figure 13 only displays the sample locations that returned analytical results greater than the method detection limit. Comparing the aerial extent of the 0.001 mg/L contour in Figures 13 and 14, it becomes apparent how the <MDL data affects the geographic extent of the area of concern. Removing the <MDL data from the kriging process produces grid node values that are biased toward higher concentrations. However, since ~85% of the data is <MDL data, substitution (<MDL set equal to 0.00025 mg/L) was used to represent the <MDL values. Therefore the results of the kriging process on the substituted data produces grid node values that are biased toward lower concentrations. Of the two maps, figure 14 is a more realistic representation of the data.

Because the datasets contain a large amount of censored data, the best approach for spatially describing the areas of concern is through probability mapping (“indicator kriging” or “logistic regression”). Spatial description of a dataset relies on estimating values between known data locations. Because ~85% of our dataset contains values that are unknown (<MDL), reliable estimates cannot be achieved. As seen in Figure 13, if we only use the data that was detected above the MDL the area of concern becomes over estimated toward higher values. By using the detection limit as a probability threshold (i.e. the probability of being greater than or equal to the threshold value), all of the collected data can be used to create a valid estimation of the probability that a sample will exceed a threshold value. The following section describes the techniques used for probability mapping with threshold values of 0.001 mg/L and 0.01 mg/L.

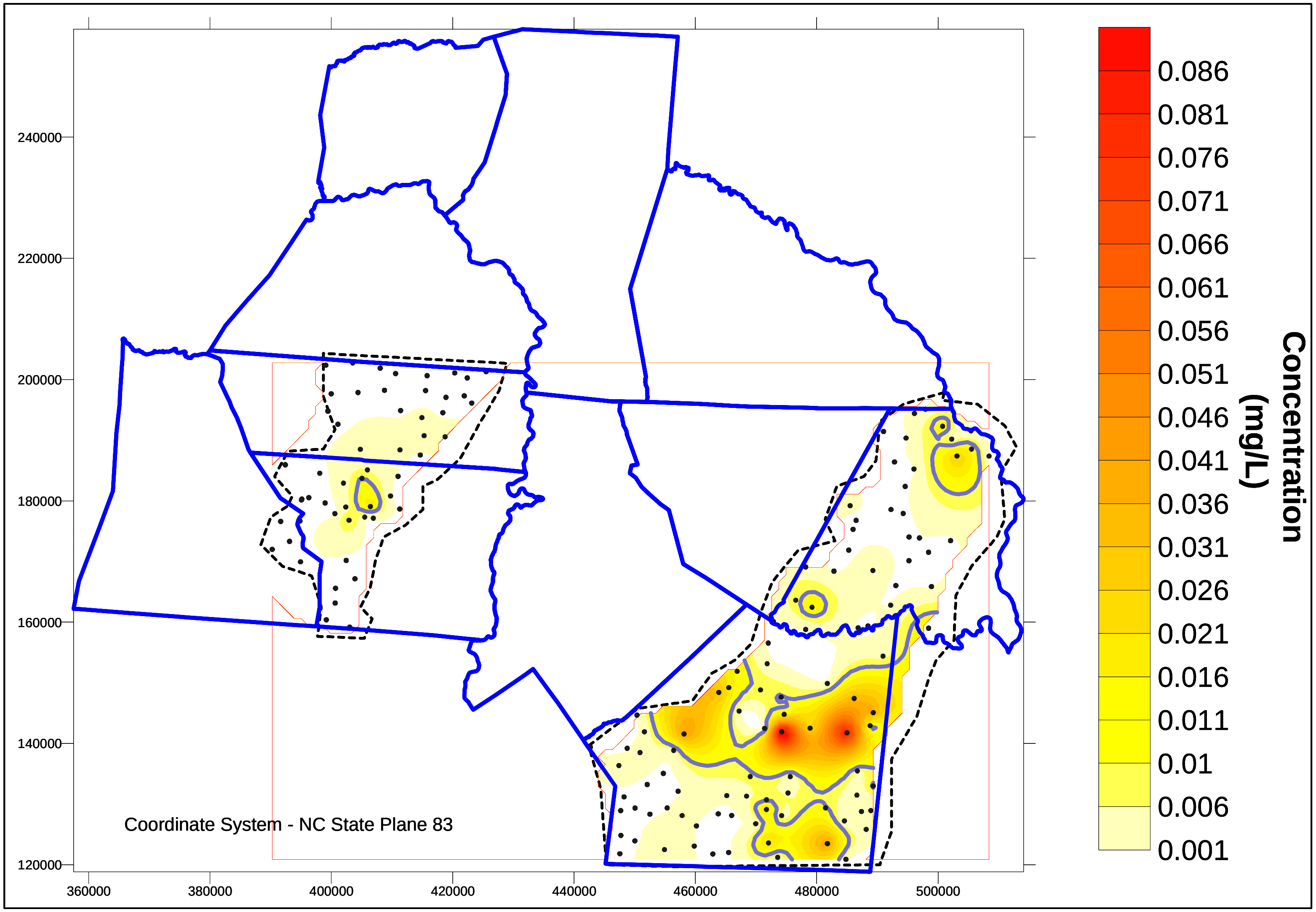

Figure 11. Samples collected during the summer of 2002 in Gaston, Lincoln, Stanly, and Union Counties are indicated by the black squares. Isoconcentration map developed by graticulating the data using point kriging. The 0.01 mg/L contour is indicated by the gray line. The dashed polygons indicate the sample collection areas.

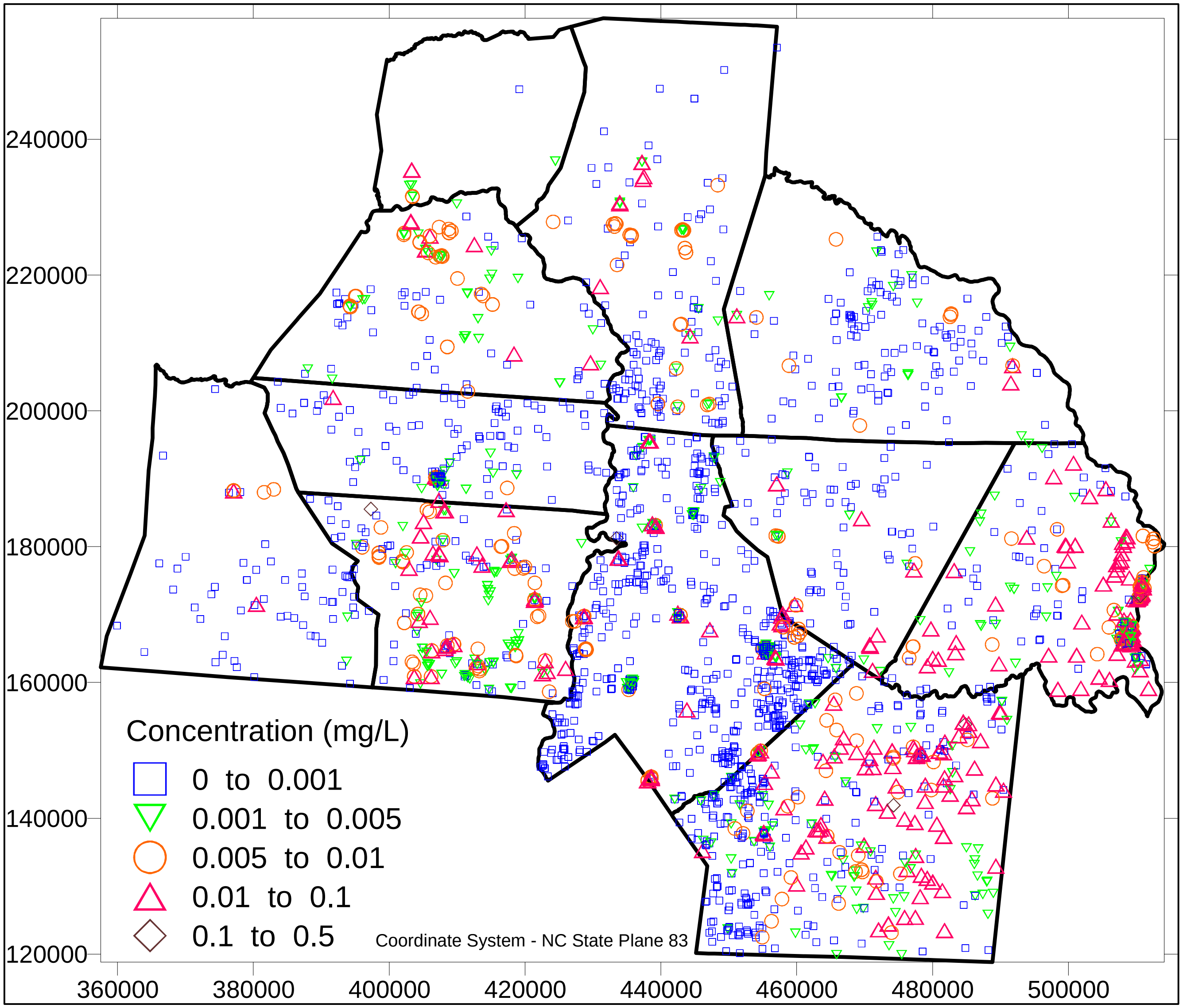

Figure 12a. Map of data compiled from the summer 2002 study and geolocated DHHS Laboratory data. The isoconcentration map (Figure 11b) was generated by graticulating the data using point kriging.

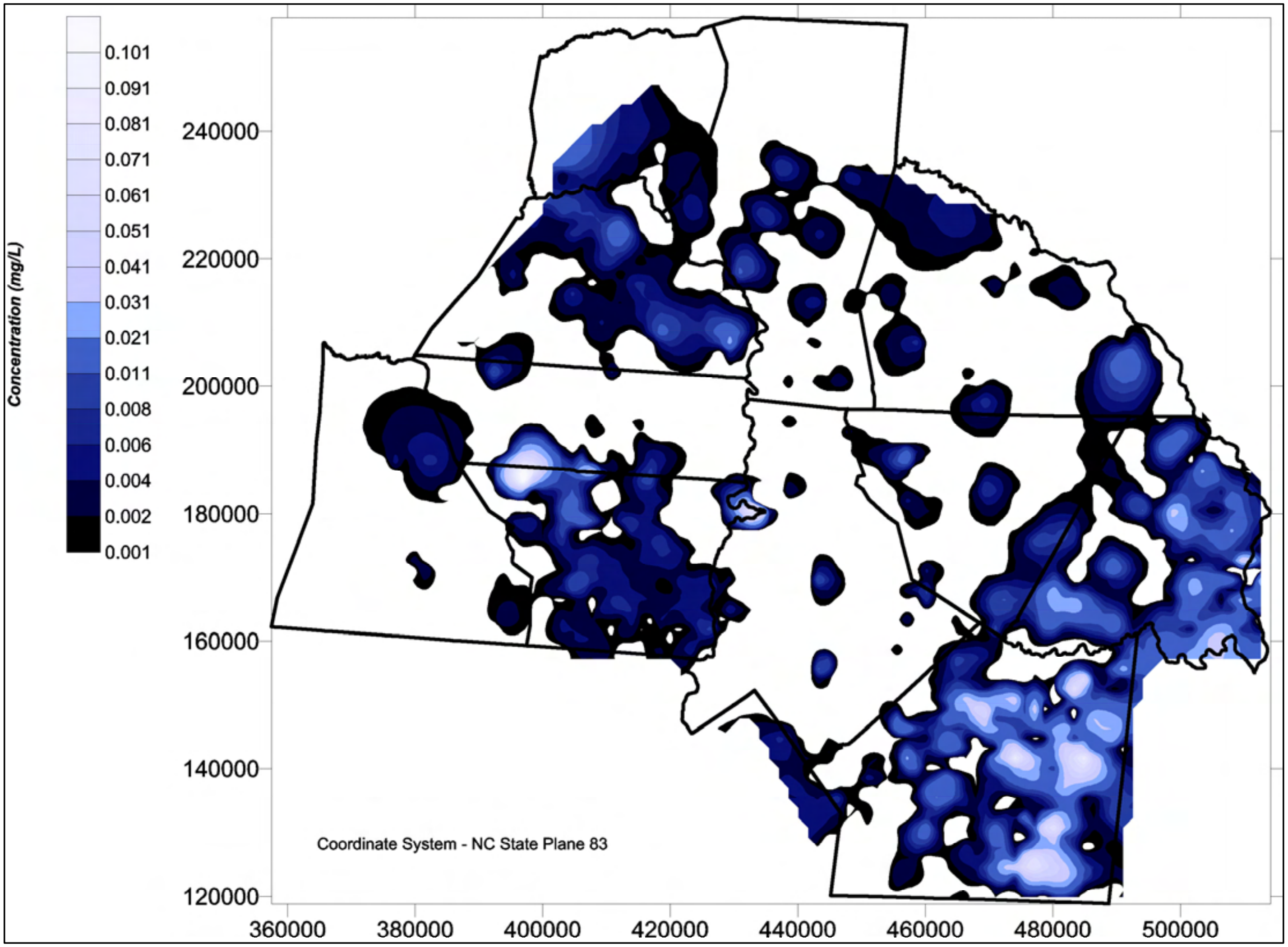

Figure 12b. Maps of data compiled from the summer 2002 study and geolocated DHHS Laboratory data. The isoconcentration map (left) was generated by graticulating the data using point kriging. The gray line indicates the 0.01 mg/L contour. The map to the right indicates the sample locations and their relative concentrations.

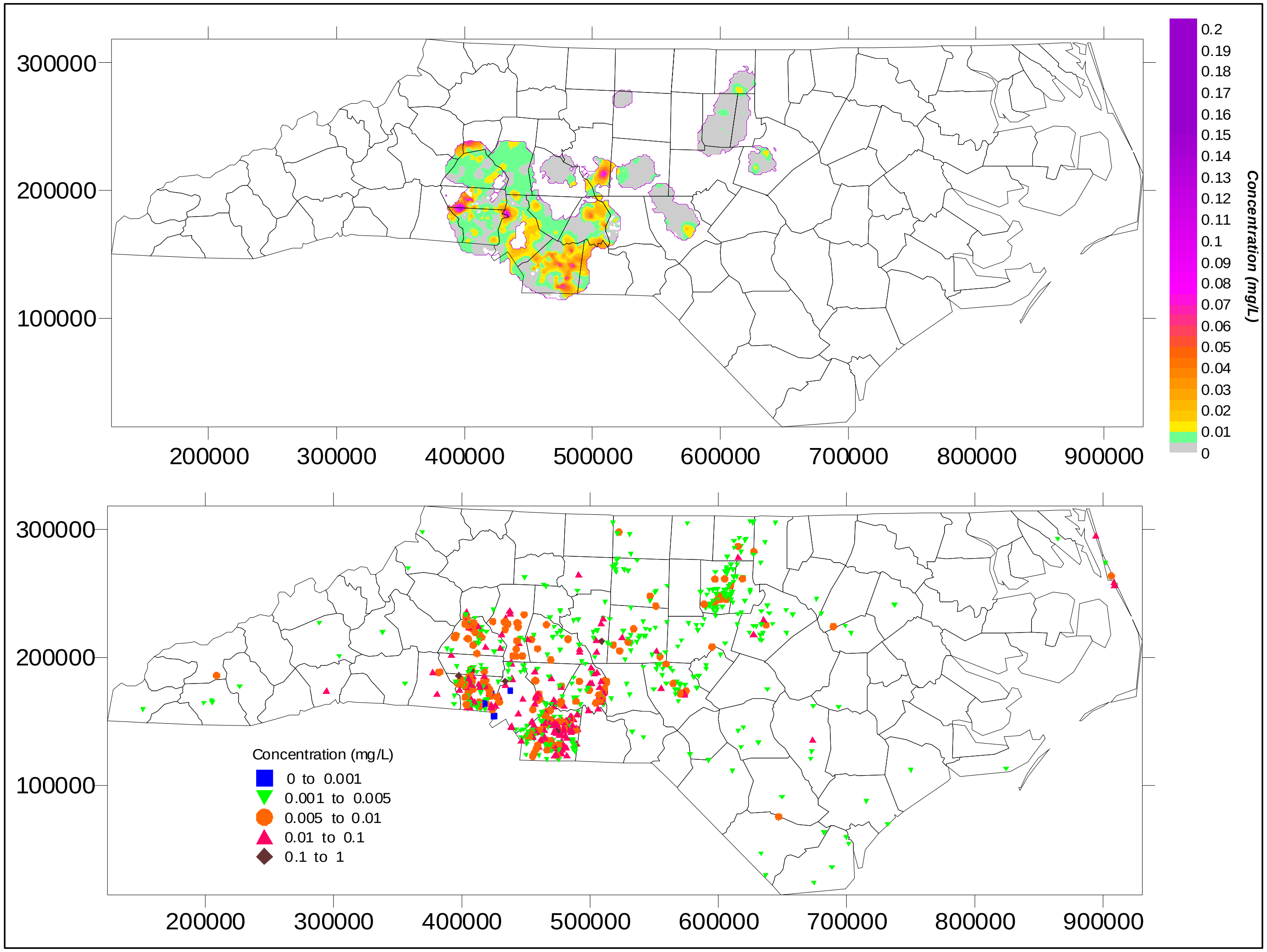

Figure 13. The upper map shows isoconcentrations of arsenic for sample locations where concentrations are greater than the method detection limits. The lower map displays the sample locations and relative concentrations.

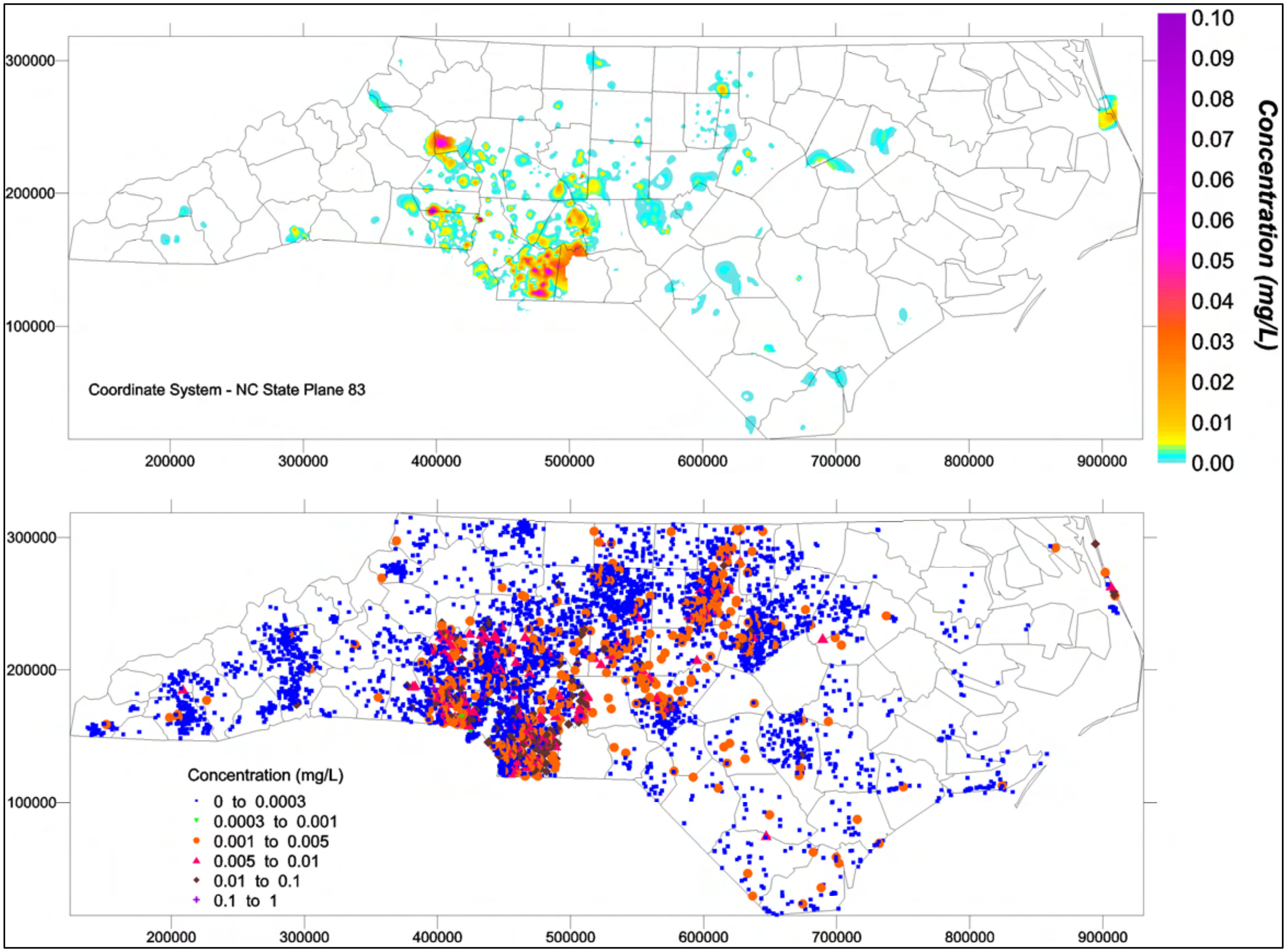

Figure 14. Arsenic sample locations and contours. Analytical results reported at "<" method detection limits were arbitrarily assigned a value of 0.00025 mg/L. The data were then contoured using Surfer's contouring capabilities to create the isoconcentration map (top). The sample locations and relative concentrations are displayed in the lower map.

Spatial Probability Mapping

In addition to the isoconcentration maps described above, the data was also used to construct probability maps. To generate the probability maps the data was sorted into two groups, those that are less than a threshold value and those that are greater than or equal to a threshold value. For example, values that are less than the threshold value of 0.001 mg/L are assigned a value of “0” and those equal to or greater than the threshold are assigned a value of “1”. Figures 9 and 10 describe the distribution of data; 28.54 % of the data is comprised of non detects where the detection limit is 0.01 mg/L. 51.73 % of the data is comprised of non detects where the detection limit is 0.001 mg/L. Only 14.56% of the 6434 data points are comprised of “detected” concentrations. The remaining 5.3% of the data is comprised of non detects where the detection limit ranges between 0.002 and 0.05 mg/L. In order to best represent the data, two probability maps were produced. If, for example, “0” is assigned to values <0.001 mg/L and “1” to those ≥ 0.001 mg/L, each <MDL data point where the detection limit was greater than “0.001” (i.e. an MDL of 0.01 mg/L) may be misrepresented by assigning it a zero. The real value is unknown below 0.01 mg/l and therefore must not be used in the analysis. Since the majority of the <MDL data is comprised of detection limits of 0.001 and 0.01, these where used as threshold values to produce the probability maps shown in Figures 15 and 16. The binary data was graticulated as described above. At each grid node, four quadrants are searched for data; the weighted average of the data surrounding each node is used to assign a value to the grid node. Therefore each grid node has a value that lies between 0 and 1, providing an estimate of the probability to exceed the threshold value. The maps of course have the greatest validity in the geographic areas where the spatial density of sample locations is greatest.

County Probability Mapping

Approximately 13,000 analytical results exist in the raw NC DHHS Laboratory data (Appendix D). Not all of these samples were used for spatial analysis due to insufficient location information; however, these raw data do have county information. Additional maps were developed to show the probability of analytical results of samples collected from individual counties exceeding a threshold value of 0.001 mg/L (Figure 17). The probability assigned to each county was calculated by assigning a “0” or “1” to each data point based on the threshold value of 0.001mg/L. The binary data for each county was then averaged to produce the probability value assigned to the individual counties. Figure 18, breaks down the distribution of the data used to make Figure 16. Approximately 30% of the data were “<MDL” data where the MDL was greater than 0.001 mg/L; these data were not used in Figure 17. The counties with anomalously high probabilities for groundwater arsenic concentrations to exceed 0.001 mg/L are spatially correlative with the high probabilities area identified in Figure 16.

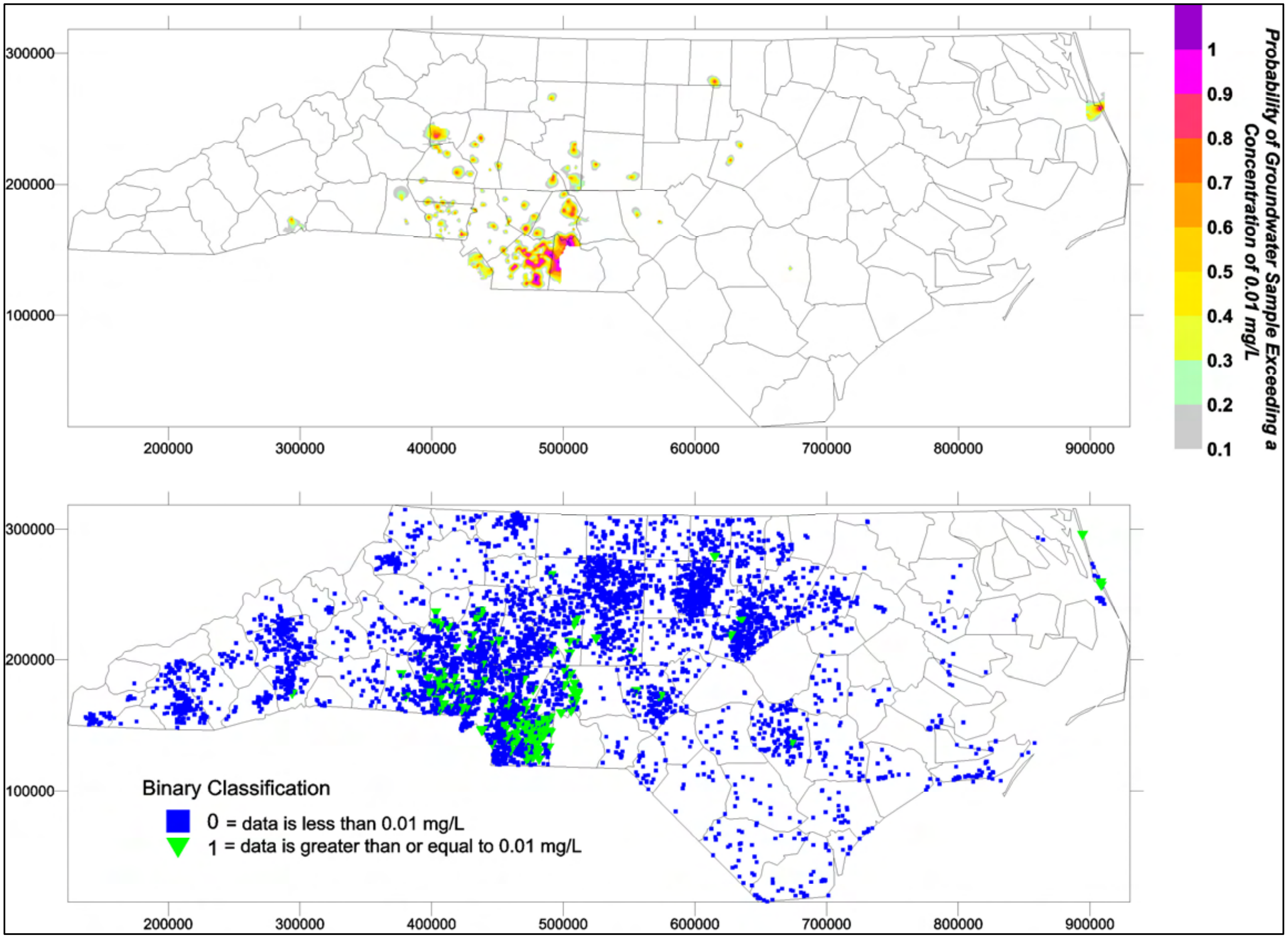

Figure 15. Probability mapping. The data used to create the probability map (upper map) is displayed in the lower map. If a sample location had an analytical result that is less than the threshold value of 0.01 mg/L then a "0" was assigned to that location, otherwise it was assigned a "1". This binary data was then graticulated into a 500 by 200 grid using point kriging. The kriging process calculates a weighted average of the closest data points to each grid node. These grid node weighted average values are between "0" and "1", thus creating an estimation of the probability at each grid node. These are then contoured to create the probability map above.

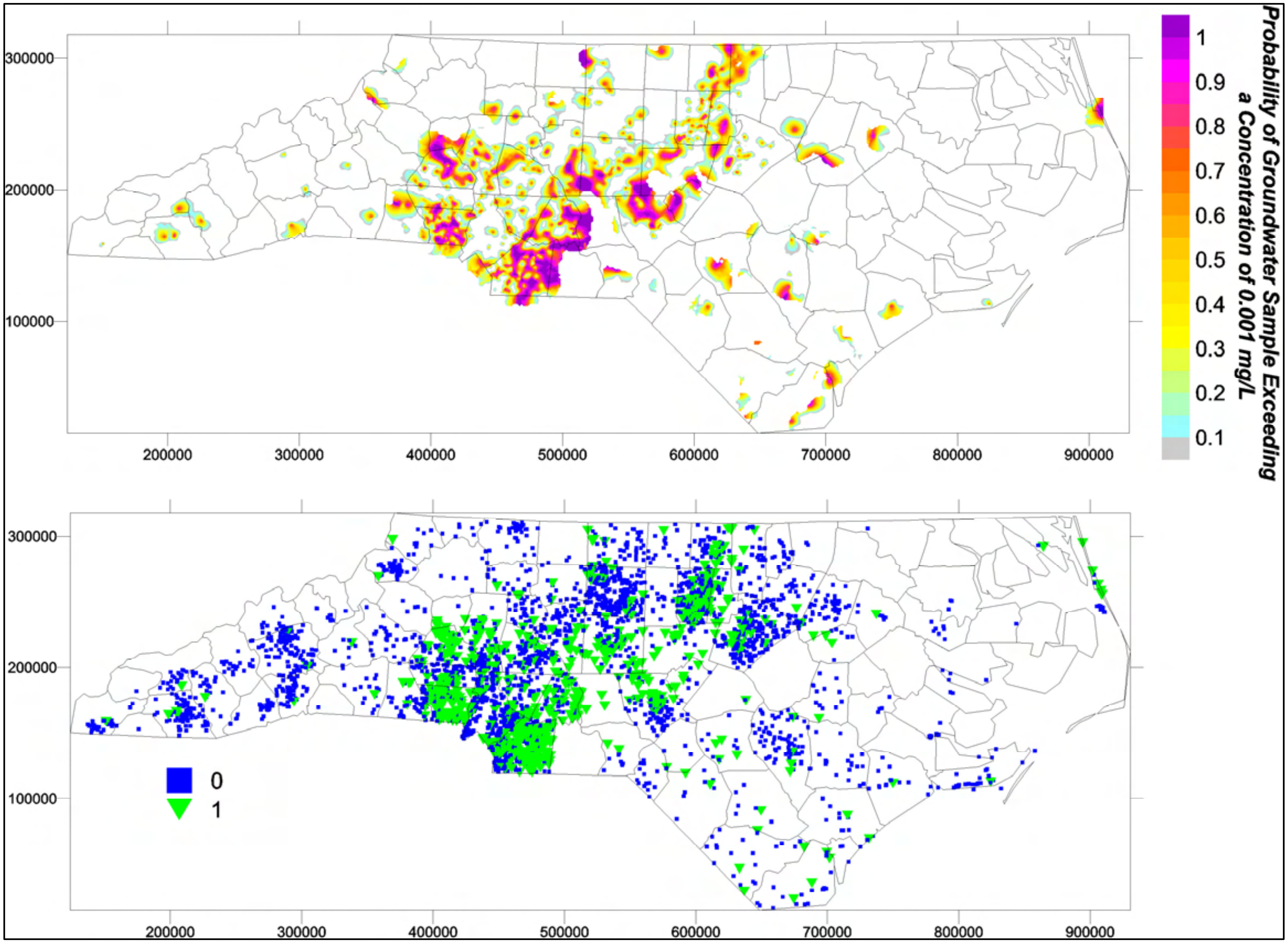

Figure 16. Probability map created using a threshold value of 0.001 mg/L. See figure 15 for additional details.

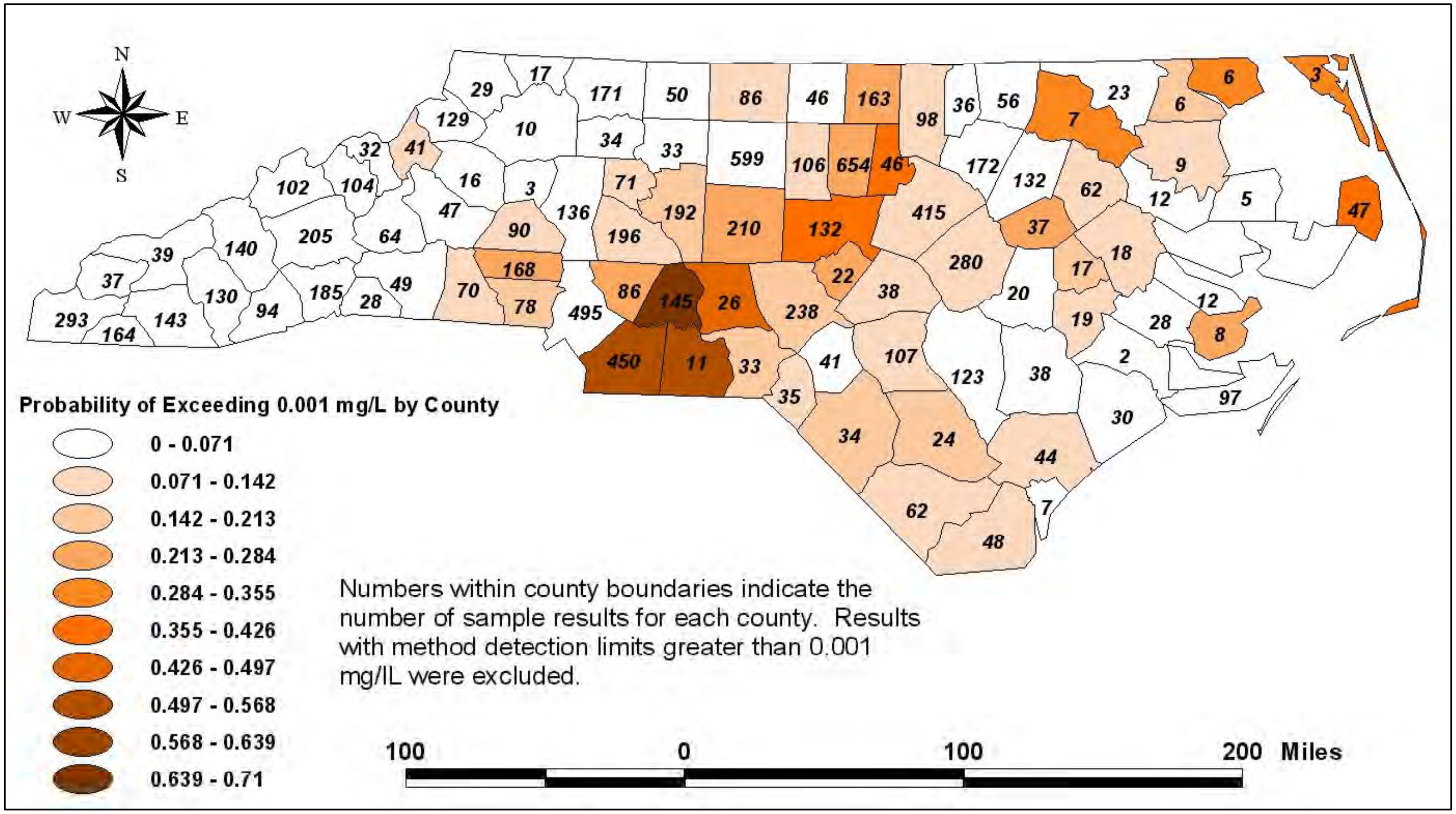

Figure 17. Map generated using the DHHS Laboratory Database. Counties with high probabilities generally agree with high probability locations in Figures 14 and 15. The numbers within the county boundaries indicate how many sample results were used to calculate the probabilities. Results that were less than method detection limits (MDL) were excluded when the MDL was greater than 0.001 mg/L. See figure 18 for a summary of how the data is distributed.

Data Catagories	Frequency	Relative %	Binary Assignment
MDL less than 0.001 mg/L	8106	60.78%	"0"
MDL greater than 0.001 mg/L	3994	29.95%	Not Used
Equal or greater than 0.001 mg/L	1237	9.27%	"1"
Totals	13337	100.00%	

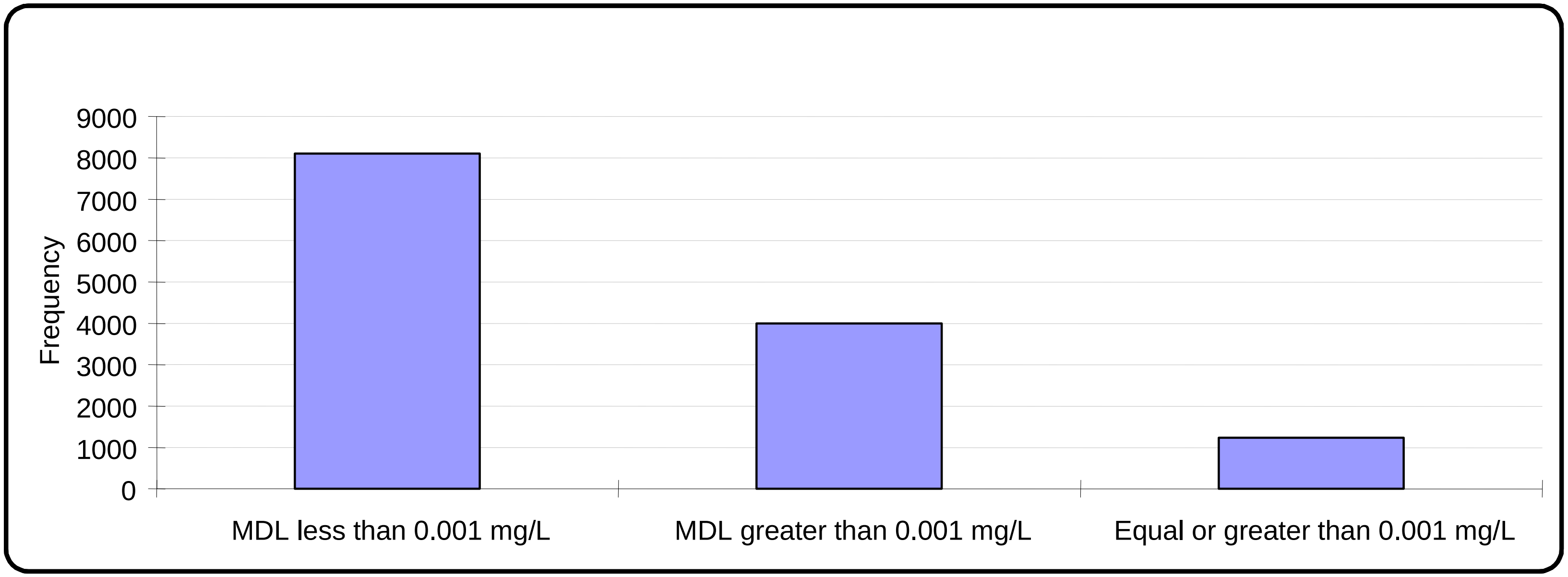

Figure 18. Histogram showing the distribution of data found in the DHHS Laboratory Database.

Analysis by Geologic Unit

The significance of the geologic host material was investigated by spatially joining the rock names from the 1985 NC Geologic Map (Brown ***et al***. 1985) to the combined database. The probability of each rock type to produce water with arsenic concentrations of 0.001 mg/L or more was calculated. Table 8 and Figure 19 show the results of the analysis. The rock types shown had a minimum probability of 0.25 based on a minimum of 10 samples per unit. Units that scored high probabilities but did not meet the minimum 10 samples were not included.

In general, the units of highest probability belong to rock types in the southern portion of the Carolina Slate Belt. Wells located in select areas of the Kings Mountain Belt, Charlotte Belt, and Inner Piedmont Belt also have higher chances to be affected by arsenic. A cursory review of the various rock types associated with areas of high probability suggests rocks of volcanic origin are of greatest concern.

Welch, ***et al***., (1988), summarizes the available literature and arsenic data for the western United States at that time and concludes that the natural occurrence of arsenic in groundwater at concentrations greater than 0.01 mg/L is generally linked to one of four geochemical environments:

- Basin-fill deposits of alluvial-lacustrine origin
- Volcanic deposits
- Geothermal systems
- Uranium and gold mining areas.

The Carolina Slate Belt is particularly representative of each of these four geochemical environments. In general, rocks of the Carolina Slate Belt were deposited in an island arc environment by deep-water sedimentation of fine-grained material interlayered with episodic large-scale deposition of volcanic material from nearby volcanoes (Goldsmith ***et. al.,*** 1988; Feiss ***et al***., 1993). The Carolina Slate Belt is also widely known for its association with gold and other sulfide deposits emplaced via geothermal activity related to island arc volcanism (i.e. Reed Gold Mine)(Feiss, ***et al.,*** 1993***)***. The high arsenic probabilities associated with rock units of the Slate Belt and the nature of formation of the Slate Belt rock units suggest a relationship and warrant the investigation of a hypothesis that links the two together.

The North Carolina Geological Survey has examined several cores collected from the Carolina Slate Belt in areas of Stanly and Montgomery counties. The cores can generally be described as fractured rhyolites and tuffs (Jeff Reid personal communication). Abundant iron oxide coatings are present on fracture surfaces and pyrite or other sulfides are present as veins or disseminated throughout the rocks (Jeff Reid personal communication). Arsenopyrite is one of the more common arsenic sulfides; however, arsenic can be present in other sulfide minerals such as pyrite. Arsenic also has an affinity for iron and manganese oxides (Hinkle and Polette, 1999; Welch, ***et al.,*** 2000; Bednar ***et al***. 2002). Therefore, the presence of sulfide minerals and iron oxides observed in core from the Carolina Slate Belt provide a possible source for the release of arsenic depending on the geochemistry of the groundwater system.

TABLE - 8

Geologic Unit	Map Area (km^2)	No. Samples	Samples/km^2	Prob. > 0.001 mg/L	Lithotectonic Belt	Detailed Description
CZab	844.619	74	0.088	0.55	Inner Piedmont	AMPHIBOLITE AND BIOTITE GNEISS - Interlayered; minor layers and lenses of hornblende gneiss, metagabbro, mica schist, and granitic rock
CZbg	1938.235	47	0.024	0.43	Inner Piedmont	BIOTITE GNEISS AND SCHIST - Inequigranular, locally abundant potassic feldspar and garnet; interlayered and gradational with calc-silicate rock, sillimanite-mica schist, mica schist, and amphibolite. Contains small masses of granitic rock
CZbg	765.424	15	0.020	0.33		
CZbl	212.229	78	0.368	0.26	Kings Mountain	BLACKSBURG FORMATION - Sericite schist, locally with graphite, phyllite with sericite quartzite, banded marble, amphibolite, and minor calc-silicate rock
CZfv	39.327	15	0.381	0.33	Slate Belt	FELSIC METAVOLCANIC ROCK - Metamorphosed dacitic to rhyolitic flows and tuffs, light gray to greenish gray; interbedded with mafic and intermediate metavolcanic rock, meta-argillite, and metamudstone
CZfv	1520.218	165	0.109	0.27		
CZfv1	1041.043	41	0.039	0.29		
CZfv2	247.696	12	0.048	0.50		
CZg	26.526	17	0.641	0.76	Slate Belt	METAMORPHOSED GRANITIC ROCK - Megacrystic, well foliated; locally contains hornblende
CZiv	35.308	11	0.312	0.45	Slate Belt	INTERMEDIATE METAVOLCANIC ROCK - Metamorphosed andesitic tuffs and flows, medium to dark grayish green; minor felsic and mafic metavolcanic rock
CZiv	49.111	15	0.305	0.40		
CZmd	452.457	14	0.031	0.79	Slate Belt	METAMUDSTONE AND META-ARGILLITE - Thin to thick bedded; bedding plane and axial-planar cleavage common; interbedded with metasandstone, metaconglomerate, and metavolcanic rock. CZmd3 - Floyd Church Formation CZmd2 - Cid Formation CZmd1 - Tillery Formation
CZmd1	650.981	83	0.127	0.76		
CZmd2	1267.878	164	0.129	0.77		
CZmd2	454.160	18	0.040	0.39		
CZmd3	210.330	13	0.062	1.00		
CZmd3	645.061	45	0.070	0.36		
CZms	300.860	60	0.199	0.45	Inner Piedmont	MICA SCHIST - Garnet, staurolite, kyanite. or sillimanite occur locally; lenses and layers of quartz schist, micaceous quartzite, calc-silicate rock, biotite gneiss, amphibolite, and phyllite
CZms	867.948	38	0.044	0.37		
CZph	359.226	59	0.164	0.68	Slate Belt	PHYLLITE AND SCHIST - Minor biotite and pyrite; includes phyllonite, sheared fine-grained metasediment, and metavolcanic rock
CZve	204.732	12	0.059	0.33	Slate Belt	METAVOLCANIC-EPICLASTIC ROCK - Metamorphosed argillite, mudstone, volcanic sandstone, conglomerate, and volcanic rock
CZve	729.349	28	0.038	0.29		
CZy	244.751	21	0.086	0.38	Slate Belt	YADKIN FORMATION - Metamorphosed graywacke, volcanic sandstone, and siltstone; interbedded with mafic and intermediate metavolcanic flows and tuffs
DOgb	47.437	11	0.232	0.27	Chlarlotte Belt	GABBRO OF CONCORD PLUTONIC SUITE - Barber, Concord, Farmington, Mecklenburg, and Weddington intrusives

TABLE - 8

Geologic Unit	Map Area (km^2)	No. Samples	Samples/km^2	Prob. > 0.001 mg/L	Lithotectonic Belt	Detailed Description
PPg	175.937	19	0.108	0.37	Chlarlotte Belt	GRANITIC ROCK - Megacrystic to equigranular. Churchland Plutonic Suite (Western group) - Churchland, Landis, and Mooresville intrusives
PPmg	358.539	67	0.187	0.60	Raleigh Belt	FOLIATED TO MASSIVE GRANITIC ROCK - Megacrystic to equigranular. Rolesville suite, Wise and Lemon Springs(?) intrusives
Zbt	273.209	59	0.216	0.71	Kings Mountain	BATTLEGROUND FORMATION - Quartz-sericite schist with metavolcanic rock, quartz-pebble metaconglomerate, kyanite-sillimanite quartzite, and garnet-quartz rock

Note - Probabilities were assigned to the geologic unit by spatially joining the point data representing the probability data to the polygon data representing the geologic units. Therefore if a geologic unit crops out in many different areas of the state, different probabilities will be assigned to it. These probabilities could be combined to represent the entire geologic unit; however, in order to better preserve the spatial probabilities for specific areas, probabilities were recorded for the individual polygons representing a specific geologic unit. Hence the multiple entries for geologic unit names.

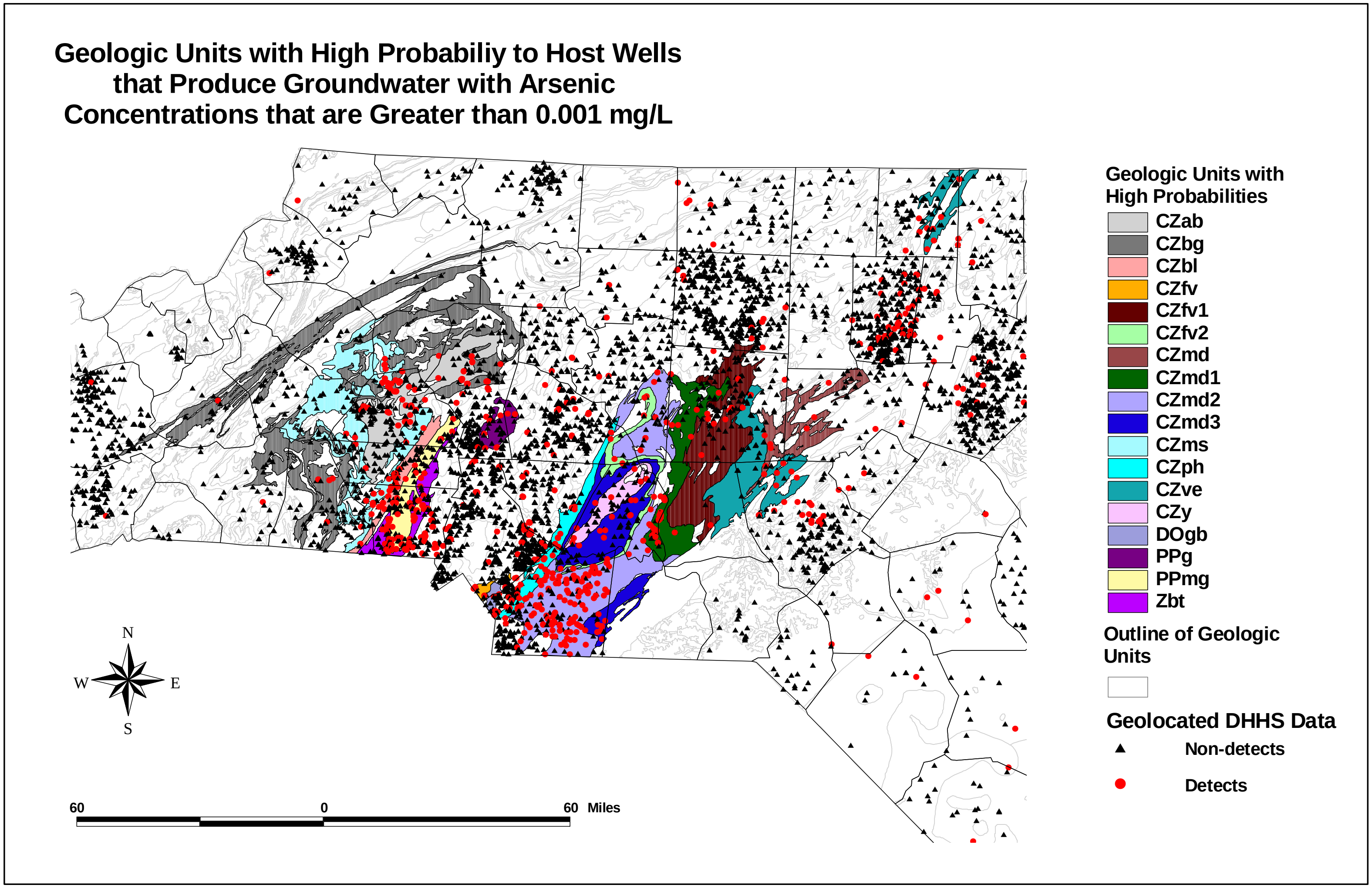

Figure 19. Map of geologic units that have a 25% chance or better to host wells that will produce water with arsenic concentrations of 0.001 mg/L or more. Table 8 provides the estimated probabilities for individual map units.

HOT SPOT IDENTIFICATION

Hot spots have been identified as those geographic areas hosting wells that produce groundwater samples that have a 0.75 probability or greater of exceeding the 0.001 mg/L threshold value. The 0.001 mg/L threshold was chosen over the 0.01 mg/l threshold to be conservative and to attempt to align the study with the NCDHHS OEEB's recommended maximum contaminant level of 0.02 µg/L or parts per billion. Presently, five hot spot regions have been identified and are described below and in Figure 20. Within these hot spot regions, greater confidence in the estimated probability is obtained by observing the spatial density of the collected samples. Figure 21 displays probability maps for exceeding the 0.001 mg/L threshold and for exceeding 5 samples per five minute by five minute grid cell (each grid cell ≈ 13.5 mile^2). In addition, the bottom map in Figure 21 provides a data quality index; produced by creating a grid file that is the product of the grid node values generated during the kriging process used to create the two probability maps. Geographic areas where the data quality index is closest to 1 can be interpreted as areas that host wells that produce groundwater with a high probability of exceeding the 0.001 mg/L threshold and have sample densities of 5 samples per grid cell or more. The data quality index emphasizes the critical areas of these regions.

- Area 1 – generally consists of high probability areas located in Catawba and Alexander counties with areas of lesser concern in Alexander and Iredell counties.
- Area 2 – generally consists of high probability areas found in Gaston County. Area 3 – generally consists of high probability areas found in Union and Stanly counties predominately and with areas of lesser concern in Randolph and Davidson counties
- Area 4 – generally consists of high probability areas found in Orange and Person counties.
- Area 5 – generally consists of high probability areas found in Wake, Durham, and Chatham counties.

Of the five areas identified, by far the most critical is Area 3. Area 3 is almost entirely underlain by rocks of the Carolina Slate Belt and has a high data quality index.

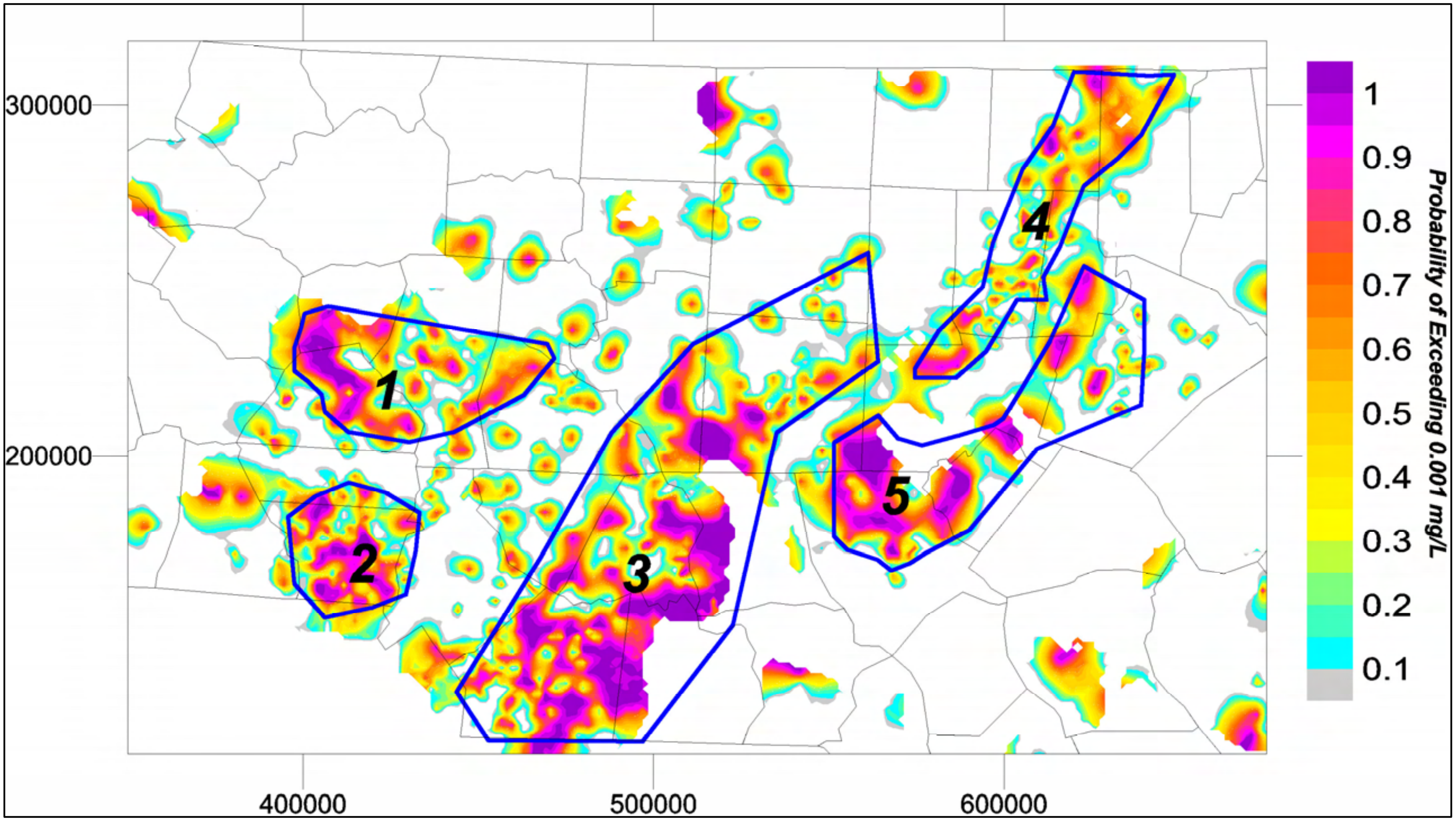

Figure 20. Hot spot regions 1 – 5.

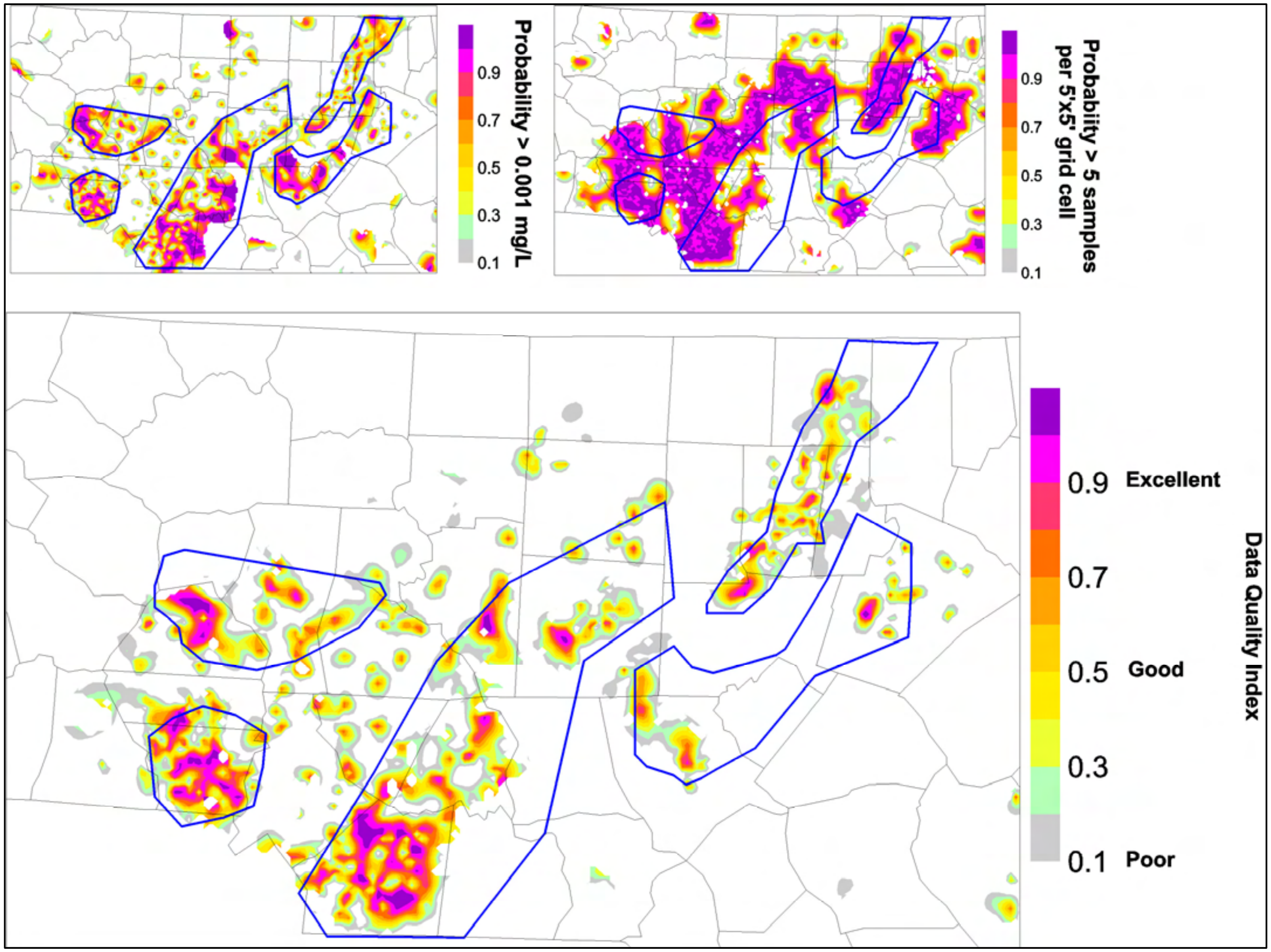

Figure 21. Data quality index. The smaller upper maps show the probability for a groundwater sample to exceed the threshold value of 0.001 mg/L (left) and the probability that the sample density is greater than 5 samples per 5x5 minute grid of latitude and longitude (fight). The lower map displays the product of the grid files for the smaller maps above and serves as a data quality index. The values closest to 1 indicate the overlap of the areas where it is more likely that a groundwater sample will exceed 0.001 mg/L and where there have been at least 5 samples collected per grid cell.

OVERVIEW OF NEGATIVE HEALTH AFFECTS FROM ARSENIC EXPOSURE

This report has focused on the distribution of arsenic in the North Carolina Piedmont Province and the identification of hot spot areas based on spatial probability analysis of the available data. It is important to identify these hot spot areas because arsenic is a known carcinogen in humans. The NC DHHS OEEB, (2001,) states that several studies have shown that exposure to arsenic in drinking water may cause skin, bladder and lung cancers. Based on the data presented in this report, several areas in the Piedmont Province of North Carolina have been identified as "at risk" for people to be exposed to arsenic through ingestion of groundwater. According to the data collected during the summer of 2002 (Tables 3 and 5):

- 70 out of 160 samples returned results that were ≥ 0.001 mg/L.
- The average arsenic concentration was 0.005 mg/L.
- The 75 percentile was 0.004 mg/L. So 25% of the data was between 0.004 and 0.011 mg/L.
- The average well age was 19 years, median well age is 16 years.

A conservative interpretation of the summer data implies that many people in the Piedmont may have already ingested low levels of arsenic over a significant amount of time. Of course, there is ongoing debate concerning the exposure to various arsenic concentrations and its associated risk.

In January 2001, the United States Environmental Protection Agency (US EPA) reduced the National Primary Drinking Water Standard for arsenic from 0.05 mg/L to 0.01 mg/L (US EPA, 2001). Likewise in August of 2002, the NC Division of Water Quality reduced the NC groundwater standard from 0.05 mg/L to 0.01 mg/L. These reductions are based primarily on the recognition of negative health affects from chronic exposure to low levels of arsenic (US EPA, 2001; National Research Council, 2001). According to the NCDHHS OEEB exposure to arsenic at levels commonly observed in the data presented in this report subjects one to an increased lifetime risk of developing cancer. Table 9 compares the National Research Council (2001) and the NCDHHS OEEB estimated cancer risks associated with ingestion of arsenic contaminated water.

Table 9 – Estimated Combined Lifetime Excess Risk of Lung and Bladder Cancer Following Lifetime Exposure to Arsenic in Drinking Water

Concentration	National Research Council[1]	NCDHHS OEEB[2]	Risk Category
0.05 mg/L[3]	Not Listed	1 in 30 persons (3.3%)	Very High
0.02 mg/L	1 in 143 persons (0.7 %)	1 in 75 persons (1.3%)	
0.01 mg/L[4]	1 in 333 persons (0.3%)	1 in 150 persons (0.6%)	High
0.005 mg/L	1 in 667 persons (0.15%)	Not Listed	
0.003 mg/L	1 in 1,000 persons (0.1%)	Not Listed	Moderate
0.001 mg/L[5]	Not Listed	1 in 1,500 persons (0.07%)	
0.00002 mg/L[6]	Not Listed	1 in 75,000 persons (0.001%)	Low

Notes:

1. Data from the National Research Council, (2001), Arsenic in Drinking Water: 2001 Update, Table 6-1. Assumes consumption of 1 liter of water per day. For a list of other assumptions see the National Research Council (2001) report, Table 6-2.
2. Minutes, May 21, 2003 Arsenic Study Groups Meeting, Mooresville Regional Office. Assumes consumption of 2 liters of water per day. In May 2003, the NCDHHS OEEB presented data at a meeting of State and County officials and other interested groups organized by the Groundwater Section's, Mooresville Regional Office to discuss the current issues surrounding arsenic in groundwater.
3. Former EPA Drinking Water Standard (prior to 2001).
4. New EPA Drinking Water Standard and current NC Groundwater Standard (effective 2001)
5. Method detection limit for NCDHHS Health Laboratory
6. Groundwater standard ***recommended*** by the NC DHHS. This standard is used by the NCDHHS OEEB to conduct all health risk evaluations related to arsenic in groundwater.
7. Risk Category – defined by the NCDHHS OEEB.

The NCDHHS OEEB risk estimates are a little more conservative than the National Research Council estimates. This is due to different assumptions used during the calculation, the main one being that the NCDHHS OEEB uses a water intake of 2 liters per day and the National Research Council (2001) used 1 liter of water per day.

It is important to understand that there are many assumptions made in the calculation of exposure risk estimates. Since people are different and have different habits, it is difficult to determine an individual's real risk to arsenic exposure. Of course, once arsenic is identified as being present in a water supply actions should be taken to minimize its use as a potable source of water.

There are also other non-carcinogenic diseases associated with the ingestion of arsenic. The National Research Council, (2001), summarizes the human health effects of exposure to arsenic. According to their report the effects listed in Table 10 may be observed following chronic exposure (continuous ingestion of very high doses) to arsenic.

Table 10 - Non-Carcinogenic Effects from Chronic Arsenic Exposure

Effected Biological System	Conditions	Chronic Exposure Duration
Gastrointestinal	Diarrhea Cramping	Weeks or months of high doses.
Hematological	Anemia Leukopenia	
Dermal	Hyperpigmentation	6 months to 3 years following exposure to high doses, 5 to 15 years at low doses
	Palmer-plantar hyperkeratosis	Within years of development of hyperpigmentation
Vascular	Peripheral vascular disease (Blackfoot Disease)	6 months to 3 years following exposure to high doses, 5 to 15 years at low doses

Notes:

1. Dose - Low - 0.01mg/kg/day, High - 0.04 mg/kg/day. "mg/kg/day" can be derived by arsenic concentration in water (mg/L) x water consumption 2 L/day ÷ mass of person (kg). Therefore, a 70 kg person drinking 2 liters of water per day would achieve the 0.01mg/kg/day dose if their water contained an arsenic concentration of 0.350 mg/L
2. Table based on data from the National Research Council, (2001), Arsenic in Drinking Water: 2001 Update.

Chronic exposure to doses of 0.01 mg/kg/day can cause non-carcinogenic effects; however, such a dose would be equivalent to a 70 kg or 154 pound person drinking 2 liters of water per day that contained an arsenic concentration of 0.350 mg/L or the same person drinking 70 liters (18 ½ gallons) of water per day with a concentration of 0.01 mg/L. These chronic doses are very high compared to the range of concentrations observed in the hot spot areas identified earlier. Many assumptions are also made in the calculation of the non-carcinogenic exposure risk estimates; therefore, specific risks for an individual are difficult to determine.

In the Piedmont, a well user's exposure to levels of arsenic that may present in them one or more of the non-cancer effects is limited based on the data collected so far. However, the body of evidence supporting the association between ingestion of low levels of arsenic and cancer incidence is well documented in the National Research Council (2001) report and by the US EPA (2001). The analysis of our summer data indicates that many people are at a moderate to very high risk for developing cancer from exposure to arsenic (Tables 5, 6, 7 and 9). Therefore, identification of hot spot areas, groundwater sampling, result notification and public education are important and will allow well owners to take responsibility for making choices that will address the potential risk associated with their use of groundwater. In addition, well users whose groundwater sample results have returned detectable concentrations of arsenic are encouraged to share the results and their exposure history with their personal physicians or they can contact the NCDHHS OEEB for further guidance.

ADDITIONAL WORK AND RECOMMENDATIONS

The hot spot regions host critical areas identified by high data quality index values. These critical areas are where the next phase of the study should focus. The following is a list of recommendations for future work:

1) Sampling and Monitoring
   a) Present findings to date to county health departments that are affected by the hot spot regions and encourage them to conduct systematic sampling in areas of their county lacking sufficient sample density.
   b) Conduct intensive sampling in areas with high data quality index value. Intensive sampling is to include analysis of sampled groundwater, surface water, soil, stream sediment and rocks.
   c) Monitor wells with high arsenic concentrations to establish temporal variations.
2) Source Determination
   a) Video log wells with highest arsenic concentrations.
   b) Collect rock cores from areas where wells with high arsenic concentrations.
   c) Collect historical land use information to provide insight to possible anthropogenic sources.
   d) Review geologic publications on areas identified with high arsenic.
   e) Search for arsenic bearing mineralogies in rocks associated with areas of high arsenic.
   f) Perform oxide analysis on ceramic tiles placed in wells with high arsenic concentrations.
3) Health Surveillance
   a) Conduct hair, blood, and urine analyses on well users identified as high risk.
   b) Continue to provide health risk evaluations for individuals with wells that produce groundwater with elevated arsenic concentrations.
   c) Educate the affected public about the best options for treatment of groundwater for drinking purposes.

Review of historical records along with additional sampling and monitoring is essential, especially since North Carolina recently adopted the lower 0.01 mg/L standard. Many wells have been sampled in the past when the former 0.05 mg/L standard was in place. Follow up sampling is needed for those wells that returned analytical results between detection levels and 0.05 mg/L. Addition sampling will also help to identify the areas to focus on for determining potential source materials.

Determining the source materials and the processes related to the mobilization of arsenic is very important. Performing the work describe above should provide the data needed to make a proper source determination. Once the source is identified or the processes contributing to arsenic mobilization is understood, safeguards can be emplaced to prevent installing wells in areas that are determined to be high risk.

REFERENCES

References

1. Alley, W.M., 1993, Regional Ground-Water Quality, Van Nostrand Reinhold, Eds. New York pp 63-107.
2. Arsenic Study Group, May 2003, Meeting Minutes.
3. Ayotte, J.D., ***et al***., 1999, Relation of Arsenic, Iron, and Manganese in Ground Water to Aquifer Type, Bedrock Lithogeochemistry, and Land Use in the New England Coastal Basis, U.S. Geological Survey ***Water Resources Investigations Report 99-4162,*** National Water-Quality Assessment Program, United States Geological Survey.
4. Bednar, A.J., 2002, Preserving the Distribution of Inorganic Arsenic Species in Groundwater and Acid Mine Drainage Samples, ***Environmental Science and Technology, 36, pp 2213-2218.***
5. Brown, P.B., ***et. al***., 1985, Geologic Map of North Carolina, NC Department of Natural Resources and Community Development, Division of Land Resources, North Carolina Geological Survey.
6. Carlson, R. A. and Osiensky, J. L., 1998, Geostatistical Analysis and Simulation of Nonpoint Source Groundwater Nitrate Contamination: A Case Study, ***Environmental Geosciences, vol. 5, no. 4. pp 177-186.***
7. Chen, S.L. ***et al.,*** 1994, Arsenic Species of the Blackfoot Disease Area, Taiwan, ***Environmental Science and Technology, vol. 28, pp 877-881.***
8. Clark, I. 1979, Practical Geostatistics.
9. Feiss, P.G., ***et al.,*** 1993, Volcanic Rock Hosted Gold and Base Metal Mineralization Associated with Neoproterozoic-Early Paleozoic Back Arc Extension in the Carolina Terrane, Southern Appalachian Piedmont, ***Geology, vol. 21, pp 439-442.***
10. Focazio, M.J., ***et al.,*** 1999, A Retrospective Analysis on the Occurrence of Arsenic in Ground-Water Resources of the United States and Limitations in Drinking-Water-Supply Characterizations: U.S. Geological Survey ***Water Resources Investigation Report*** 99-4279, 21 p.
11. Frey, M.M. and Edwards, M.A., ***Surveying*** Arsenic Occurrence, ***Journal of the American Water Works Association, vol. 89, no. 3.***
12. Goldsmith, R., ***et al.,*** 1988, Geologic Map of the Charlotte $1^{o}x2^{o}$ Quadrangle, North Carolina and South Carolina, United States Geological Survey, Miscellaneous Investigations Series, Map I-1252-E.
13. Helsel, D.R. and Hirsch, R.M., 1992, Statistical Methods in Water Resources, Elsevier Science Publishers, B.V., New York, pp 357-408.
14. Helsel, D.R., 1990, Less than Obvious; Statistical Treatment of Data Below the Detection Limit, ***Environmental Science Technology, vol. 24, no. 12.***
15. Hinkle, S. R. and Polette, D.J., 1999, Arsenic in Ground Water of the Willamette Basin, Oregon, ***Water Resources Investigations Report 98-4205,*** National Water-Quality Assessment Program, United States Geological Survey.
16. Jeff Reid, 2002, personal communication, North Carolina Geological Survey.
17. Krivoruchko, K., 2001, Using Linear and Non-Linear Kriging Interpolators to Produce Probability Maps, ***Annual Conference of the International Associations for Mathematical Geology,*** Cancun, Mexico.
18. National Research Council, 2001, Arsenic in Drinking Water: 2001 Update. National Academy Press, 2101 Constitution Avenue, NW, Lockbox 285, Washington, DC 20055

19. North Carolina Department of Health and Human Resources, Occupational and Environmental Epidemiology Branch, 2001, White Paper: Health Risk Assessment of Arsenic in Drinking Water.
20. Ryker, Sarah, 2001, Mapping Arsenic in Groundwater, Geotimes, November 2001.
21. Saito, H. and Goovaerts, P., 2000, Geostatistical Interpolation of Positively Skewed and Censored Data in a Dioxin-Contaminated Site, ***Environmental Science and Technology, vol. 34, no. 19.***
22. Smith, S.M., 2001, National Geochemical Database: Reformatted data from the National Uranium Resource Evaluation (NURE) Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) Program, Version 1.30: U.S. Geological Survey Open-File Report 97-492, WWW release only, URL: http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-97-0492/index.html, last accessed Nov. 1, 2001.
23. US EPA (United States Environmental Protection Agency), 2001, National Primary Drinking Water Regulations; Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring; Final Rule, Federal Register, Vol. 66, No. 14, p. 6976. EPA 815--Z-01-001, January 22, 2001.
24. Welch, A.H., ***et al.,*** 2000, Arsenic in Groundwater of the United States: Occurrence and Geochemistry, ***Ground Water***, vol. 38, no. 4, p. 589-604.
25. Welch, A.H. and Watkins, S.A., 1999, Arsenic in Ground Water Supplies of the United States, ***in:*** Arsenic Exposure and Health Effects, W. R. Chappell, C.O. Abernathy and R. L. Calderon, Eds., Elsevier Science, New York, pp 9-17.
26. Welch, A.H., 2001, Arsenic Cycling in Ground Water – Processes Leading to Widespread High Concentrations: ***In*** Arsenic in the Asia-Pacific Region, Adelaide, Australia, p 89-90.
27. Yu, D. 1999, A Probabilistic Assessment of Skin Cancer Rick from Inorganic Arsenic, ***International Journal of Environmental Studies, vol. 57, pp 93-108.***

APPENDICES

APPENDIX A - SUMMER 2002 SUMMARY TABLES

APPENDIX A - TABLE ONE

SAMPLE LOCATION INFORMATION

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	STREET	CITY, STATE	ZIP	POINT COLLECTED
Q72-1	-81.359498	35.259082	Cv	131 Old Home Place	Kings Mountain, NC	28086	House
Q72-2	-81.380389	35.289095	Cv	135 Green Meadows Drive	Kings Mountain, NC	28086	House
Q72-3	-81.397275	35.318431	Cv	336 Gary Beam Road	Kings Mountain, NC	28086	Well
Q72-5	-81.411441	35.276562	Cv	110 Woodbark Lane	Kings Mountain, NC	28086	House
P72-2	-81.391365	35.402763	Gs	249 Lee Black Road	Cherryville, NC	28021	House
Q70-1	-81.245156	35.327708	Gs	358 Joe Cloniger Road	Bessemer City, NC	28016	Well
Q70-2	-81.229456	35.326476	Gs	1131 White Jenkins Road	Bessemer City, NC	28016	Well
Q71-1	-81.276843	35.262848	Gs	516 Steele Road	Bessemer City, NC	28016	House
Q71-2	-81.273472	35.322591	Gs	1131 Bess Town Road	Bessemer City, NC	28016	House
Q71-3	-81.299332	35.331827	Gs	168 Kiser Street	Bessemer City, NC	28016	House
Q71-4	-81.325467	35.302242	Gs	PO Box 1034	Cherryville, NC	28021	House
Q72-4	-81.362310	35.319744	Gs	850 Sunnyside Shadyrest Road	Kings Mountain, NC	28086	Well
R71-1	-81.260307	35.235878	Gs	4333 Linwood Road	Gastonia, NC	28052	Well
R71-2	-81.295116	35.220949	Gs	725 Brevard Road	Kings Mountain, NC	28086	Well
R71-3	-81.267763	35.163601	Gs	2218 Crowder Creek Road	Gastonia, NC	28052	House
R71-4	-81.310355	35.173707	Gs	5131 Battleground Road	Kings Mountain, NC	28086	Well
R71-5	-81.295128	35.198976	Gs	143 Kings Drive	Kings Mountain, NC	28086	Well
P71-1	-81.317429	35.347395	Gs	330 Tryon School Road	Bessemer City, NC	28016	Well
P71-2	-81.279826	35.342164	Gs	1830 Bess Town Road	Bessemer City, NC	28016	House
P71-5	-81.285093	35.377564	Gs	1641 Hephzibah Church Road	Bessemer City, NC	28016	Well
P72-1	-81.347318	35.354766	Gs	309 Saint Marks Church Road	Cherryville, NC	28021	House
P72-3	-81.391365	35.402763	Gs	249 Lee Black Road	Cherryville, NC	28021	House
P72-3	-81.359816	35.352402	Gs	1071 Sellerstown Road	Cherryville, NC	28021	House
P72-4	-81.360492	35.351129	Gs	1052 Sellerstown Road	Cherryville, NC	28021	Well
N68-1	-81.064586	35.537988	Li	6604 King Wilkinson Road	Denver, NC	28037	House
N68-2	-81.069309	35.511309	Li	6297 Wingate Hill Road	Denver, NC	28037	House
N68-4	-81.055557	35.500657	Li	6590 Denver Heights Circle	Denver, NC	28037	Well
N68-5	-81.030493	35.547842	Li	6297 Burn Hurst Lane	Denver, NC	28037	Well
N69-1	-81.139886	35.517804	Li	2928 Jenkins Road	Lincolnton, NC	28092	Well
N69-2	-81.137671	35.540012	Li	3648 Goodson Road	Maiden, NC	28650	Well
N69-3	-81.102538	35.508459	Li	5287 Ray Ballard Street	Denver, NC	28037	House
N69-4	-81.087526	35.544960	Li	3846 Lee Moore Road	Maiden, NC	28650	Well
N69-5	-81.116550	35.529569	Li	4247 Majesty Court	Lincolnton, NC	28092	Well
N70-1	-81.223188	35.549576	Li	3152 Bank Street	Lincolnton, NC	28092	House

APPENDIX A - TABLE ONE

SAMPLE LOCATION INFORMATION

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	STREET	CITY, STATE	ZIP	POINT COLLECTED
N70-2	-81.214610	35.516936	Li	1378 Meandering Lane	Lincolnton, NC	28092	House
N70-3	-81.194928	35.542121	Li	535 Springs East Road	Lincolnton, NC	28092	House
N71-1	-81.273304	35.556680	Li	5018 Ritchie Road	Lincolnton, NC	28092	House
N71-2	-81.262527	35.512740	Li	2085 Startown Road	Lincolnton, NC	28092	Well
N71-3	-81.311040	35.509933	Li	1692 Owlsden Road	Lincolnton, NC	28092	Well
N71-4	-81.322045	35.552186	Li	3830 Babe Lane	Vale, NC	28168	Well
O69-1	-81.145481	35.477547	Li	510 Camp Creek Road	Iron Station, NC	28080	Well
O69-2	-81.146862	35.421950	Li	2400 Hudson Poultry Road	Iron Station, NC	28080	House
O69-3	-81.102636	35.449825	Li	1615 Oak Park Court	Iron Station, NC	28080	Well
O69-4	-81.107613	35.485507	Li	5575 Stonebrook Drive	Iron Station, NC	28080	Well
O69-5	-81.140721	35.450773	Li	PO BOX 338	Iron Station, NC	28080	House
O70-1	-81.183925	35.428938	Li	1827 Will Schronce Road	Lincolnton, NC	28092	Well
O70-2	-81.184427	35.487334	Li	483 Sherril Farm Road	Lincolnton, NC	28092	House
O71-1	-81.316182	35.483930	Li	2575 Ellys Street	Lincolnton, NC	28092	Well
O71-2	-81.316415	35.484324	Li	2578 Ellys Street	Lincolnton, NC	28092	Well
O71-3	-81.297690	35.464811	Li	216 Gainsville Church Road	Lincolnton, NC	28092	House
O71-4	-81.255930	35.428453	Li	1322 Finger Merrsek Trails	Lincolnton, NC	28092	Well
P70-1	-81.186428	35.389385	Li	1131 Hardin Road	Dallas, NC	28034	House
P70-2	-81.199240	35.359974	Li	211 Springs Road	Dallas, NC	28034	House
P70-3	-81.181994	35.340956	Li	2405 Wilson Drive	Dallas, NC	28034	Well
P70-4	-81.235249	35.343716	Li	1232 Carpenter Springs Drive	Dallas, NC	28034	Well
P70-5	-81.235249	35.343716	Li	1232 Carpenter Springs Drive	Dallas, NC	28034	Well
P70-6	-81.242118	35.398099	Li	321 Rash Road	Lincolnton, NC	28092	Well
P71-3	-81.251906	35.385355	Li	1004 Long Shoals Road	Lincolnton, NC	28092	Well
P71-4	-81.328511	35.391464	Li	339 Anthony Grove Road	Crouse, NC	28033	House
O59-4	-80.286123	35.423710	St	24574 Rogers Road	New London, NC	28127	Well
P59-3	-80.269165	35.347286	St	27102 Burrelson Road	Albemarle, NC	28001	Well
Q58-3	-80.182648	35.307838	St	22601 Quail Ridge Road	Albemarle, NC	28001	Well
Q61-1	-80.444615	35.265609	St	17307 Meadow Creek	Locust, NC	28097	Well
R58-1	-80.216165	35.239112	St	32852 Chapel Road	Norwood, NC	28128	Well
R58-2	-80.220443	35.177231	St	4192 Old Davis Road	Norwood, NC	28128	Well
R59-1	-80.280797	35.239950	St	13328 Booger Hollar Road	Oakboro, NC	28129	Well
R59-2	-80.289698	35.210681	St	8424 Hillford Road	Oakboro, NC	28129	Well
R59-3	-80.330248	35.179256	St	20254 Old Sandbar Road	Oakboro, NC	28129	Well
R60-1	-80.348032	35.176414	St	4144 HWY 205	Oakboro, NC	28129	Well

APPENDIX A - TABLE ONE

SAMPLE LOCATION INFORMATION

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	STREET	CITY, STATE	ZIP	POINT COLLECTED
R61-2	-80.442924	35.173042	St	5009 Tite Road	Stanfield, NC	28163	Well
R61-3	-80.501777	35.184234	St	1101 Polk Ford Road	Stanfield, NC	28163	Well
057-3	-80.114870	35.434116	St	40373 Palmerville Road	New London, NC	28127	Well
O57-1	-80.147850	35.471312	St	46921 Tall Whit Road	New London, NC	28127	Well
O57-2	-80.146708	35.444288	St	42456 Moss Lane	New London, NC	28127	Well
O58-1	-80.231193	35.502620	St	49219 Willie Rd.	New London, NC	28127	Well
O58-2	-80.199669	35.477673	St	36216 Eudy Rd.	New London, NC	28127	Well
O58-4	-80.182702	35.458725	St	44655 Ledbetter Rd.	New London, NC	28127	Well
O58-5	-80.172862	35.433680	St	40150 Eagle Head Ct.	New London, NC	28127	Well
O59-1	-80.251058	35.496246	St	49922 Rider Rd.	Richfield, NC	28137	Well
O59-2	-80.306702	35.468869	St	24583 Mattors Grove Church Road	Gold Hill, NC	28071	Well
O59-3	-80.265527	35.459502	St	44368 Millingport Rd.	Richfield, NC	28137	Well
P59-1	-80.250513	35.413631	St	29531 Kendalls Church Road	New London, NC	28127	Well
p59-2	-80.266132	35.387594	St	28415 Austin Road	Albemarle, NC	28001	Well
P59-4	-80.291305	35.352996	St	29752-B Jay Road	Albemarle, NC	28001	Well
P60.1	-80.354424	35.336129	St	16574 Five Point Road	Locust, NC	28097	Well
P60-2	-80.365607	35.357913	St	28960 Pole Running Road	Mt. Pleasant, NC	28124	Well
Q58-1	-80.239130	35.311321	St	21053 St. Martin Road	Albemarle, NC	28001	Well
Q58-2	-80.222186	35.290115	St	20473 Old Aquadale Road	Albemarle, NC	28001	Well
Q59-1	-80.257518	35.277337	St	17156 St. Martins Road	Albemarle, NC	28001	Well
Q59-2	-80.322744	35.261879	St	16271 Mclester Road	Oakboro, NC	28129	Well
Q59-3	-80.257930	35.312431	St	24040 Carriker Road	Albemarle, NC	28001	Well
Q60-1	-80.393328	35.260116	St	16268 Barbee Road	Stanfield, NC	28163	Well
Q60-2	-80.393328	35.260116	St	16269 Barbee Road	Stanfield, NC	28164	Well
Q60-3	-80.366938	35.291731	St	16182 Austin Road	Locust, NC	28097	Well
Q60-4	-80.359714	35.322719	St	24921 Millingport Road	Locust, NC	28097	Well
R61-1	-80.432008	35.206109	St	8348 Love Mill Road	Stanfield, NC	28163	Well
R61-4	-80.461563	35.216213	St	5559 Thomas Lane	Stanfield, NC	28163	Well
S62-2	-80.511620	35.121168	Un	6714 Unionville Brief Road	Monroe, NC	28110	Well
U64-5	-80.738648	34.986000	Un	7112 New Town Road	Weddington, NC	28173	Well
U64-6	-80.738648	34.986000	Un	7112 New Town Road	Weddington, NC	28174	Well
U65-2	-80.776392	34.966051	Un	8409 Prince Valliant Drive	Marvin, NC	28173	House
U65-4	-80.828371	34.992627	Un	10515 new town road	Waxhaw, NC	28173	House
V61-1	-80.487358	34.833534	Un	5324 Dudley Road	Monroe, NC	28112	Well
V61-2	-80.481368	34.895736	Un	4309 Medlin Road	Monroe, NC	28112	Well

APPENDIX A - TABLE ONE

SAMPLE LOCATION INFORMATION

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	STREET	CITY, STATE	ZIP	POINT COLLECTED
V62-1	-80.575750	34.839621	Un	1720 Trinity Church Road	Monroe, NC	28112	Well
V62-2	-80.504343	34.854804	Un	6019 Rape Road	Monroe, NC	28112	Well
V62-4	-80.508969	34.904463	Un	1615 Stack Road	Monroe, NC	28112	House
S59-1	-80.302327	35.134818	Un	7052 Fish Road	Marshville, NC	28103	Well
S60-1	-80.402364	35.093098	Un	5817 Polk Mountain Drive	Marshville, NC	28103	Well
S62-1	-80.565668	35.109122	Un	1103 Lawyers Road West	Indian Trail, NC	28079	Well
S62-3	-80.510229	35.151835	Un	8316 Unionville Brief Road	Monroe, NC	28110	House
T59-1	-80.318669	35.050615	Un	3308 Marshville Olive Branch Road	Marshville, NC	28103	Well
T59-2	-80.323923	35.031280	Un	PO Box 591	Marshville, NC	28103	Well
T60-1	-80.365562	35.020179	Un	1718 Old Lawyers Road	Marshville, NC	28103	House
T60-2	-80.353595	35.071403	Un	5325 Old Gold Mine Road	Marshville, NC	28103	House
T61-1	-80.432423	35.026241	Un	1818 Ellis Griffin Road	Wingate, NC	28174	Well
T61-2	-80.483363	35.020192	Un	4107 Farm Wood Drive	Monroe, NC	28112	House
T61-3	-80.479610	35.046236	Un	2517 Old Camden Road	Monroe, NC	28110	House
T61-4	-80.485481	35.071725	Un	1608 Mill Creek Road	Monroe, NC	28110	House
T62-1	-80.523011	35.082073	Un	500 C J Thomas Road East	Monroe, NC	28110	Well
T62-2	-80.514463	35.024847	Un	1105 Deese Road	Monroe, NC	28110	Well
T62-3	-80.561059	35.050054	Un	1117 Roanoke Church Road	Monroe, NC	28110	House
T62-4	-80.580273	35.084805	Un	4802 Poplin Road	Indian Trail, NC	28079	House
T63-1	-80.659775	35.014750	Un	507 Jim Parker Road	Monroe, NC	28110	House
T63-2	-80.598266	35.077311	Un	6207 Kiker Brock Drive	Indian Trail, NC	28079	Well
T63-3	-80.597410	35.077735	Un	6208 Kiker Brock Drive	Indian Trail, NC	28080	Well
T64-1	-80.731405	35.016944	Un	1036 Fox Run Road	Weddington, NC	28104	House
T64-2	-80.745146	35.041528	Un	2249 Greenbrook Parkway	Weddington, NC	28104	Well
U59-1	-80.316975	34.941586	Un	6524 Gilboa Road	Marshville, NC	28103	Well
U60-1	-80.346213	34.927652	Un	4308 Camden road	Marshville, NC	28103	Well
U60-2	-80.345901	34.963714	Un	1225 JJ. Autrey Road	Marshville, NC	28103	Well
U61-1	-80.466845	34.953758	Un	3015 Old Monroe Marshville Road	Wingate, NC	28174	Well
U61-2	-80.470618	34.929443	Un	1913 Old Pageland Road	Monroe, NC	28112	Well
U62-1	-80.580836	34.924101	Un	1404 Augustus Road	Monroe, NC	28112	House
U62-2	-80.545157	34.923786	Un	3512 Wolf Pond Road	Monroe, NC	28112	Well
U62-3	-80.509249	34.918830	Un	3208 Hampton Road	Monroe, NC	28112	House
U62-4	-80.538999	34.953010	Un	215 Hillside Drive	Monroe, NC	28112	Well
U64-1	-80.695896	34.955602	Un	5801 Valley Stream Road	Waxhaw, NC	28173	Well
U64-2	-80.668677	34.929490	Un	3815 Potter Road	Monroe, NC	28112	Well

APPENDIX A - TABLE ONE

SAMPLE LOCATION INFORMATION

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	STREET	CITY, STATE	ZIP	POINT COLLECTED
U64-3	-80.724737	34.938590	Un	6808 High Gap Road	Waxhaw, NC	28173	Well
U64-4	-80.678079	34.989989	Un	813 Chambwood Road	Monroe, NC	28110	Well
U65-1	-80.766111	34.919692	Un	4615 Ferguson Circle	Waxhaw, NC	28173	House
U65-3	-80.761989	34.991914	Un	8002 New Town Road	Waxhaw, NC	28173	House
V59-1	-80.328549	34.877010	Un	4821 Leanor Morgan Road	Marshville, NC	28103	Well
V59-2	-80.320716	34.905075	Un	8224 White Store Road	Marshville, NC	28103	Well
V60-1	-80.364370	34.832118	Un	4821 Leonard Morgan Road	Marshville, NC	28103	Well
V60-2	-80.398226	34.855060	Un	4120 Canal Road	Marshville, NC	28103	Well
V60-3	-80.398226	34.855060	Un	4120 Canal Road	Marshville, NC	28103	Well
V60-4	-80.367997	34.889095	Un	3909 Philidephia Church Road	Marshville, NC	28103	Well
V60-5	-80.402499	34.908037	Un	5612 White Store Road	Wingate, NC	28174	Well
V60-6	-80.337487	34.903503	Un	7725 White Store Road	Marshville, NC	28103	Well
V62-3	-80.527895	34.883019	Un	524 Sandy Ridge Road East	Monroe, NC	28112	Well
V62-5	-80.571425	34.894713	Un	4023 Richardson Road	Monroe, NC	28112	Well
V63-1	-80.660755	34.893413	Un	4202 Nesbit Road	Monroe, NC	28112	Well
V63-2	-80.634851	34.878425	Un	5302 Old Highway Road	Waxhaw, NC	28173	Well
V63-3	-80.638161	34.848304	Un	3901 Tom Starns Road	Waxhaw, NC	28173	Well
V63-4	-80.604258	34.836901	Un	7118 Carl Belk Road	Monroe, NC	28112	Well
V63-5	-80.595757	34.896874	Un	4114 McManas Road	Monroe, NC	28112	Well
V63-fb	-80.595757	34.896874	Un	4114 McManas Road	Monroe, NC	28112	Well
V64-1	-80.745206	34.854561	Un	6807 Davis Road	Waxhaw, NC	28173	House
V64-2	-80.691465	34.842343	Un	5420 Harkey Road	Waxhaw, NC	28173	House
V64-3	-80.718931	34.894617	Un	6417 Providence Road	Waxhaw, NC	28173	Well
V64-4	-80.687870	34.904332	Un	5229 Parkwood School Road	Waxhaw, NC	28173	House
V64-5	-80.745962	34.903356	Un	7216 Sims Road	Waxhaw, NC	28173	Well
V65-1	-80.771817	34.835017	Un	9018 Minnie Ranch Road	Waxhaw, NC	28173	Well
V65-2	-80.770527	34.862265	Un	9020 Quail Roost Drive	Waxhaw, NC	28173	House
V65-3	-80.771658	34.899222	Un	5405 Argordon Road	Waxhaw, NC	28173	Well

Notes:

1. County - Cv = Cleveland, Gs = Gaston, Li = Lincoln , St = Stanley, Un = Union.
2. Sample Location – Well = spigot from well head, House = well water sampled at house

APPENDIX A - TABLE TWO

WELL CONSTRUCTION INFORMATION FROM SAMPLED WELLS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DRILLER	TYPE WELL	DEPTH (FEET)	YEAR	CASING DEPTH (FEET)	STATIC WATER LEVEL (FEET)	YIELD (GPD)
Q72-1	-81.359498	35.259082	Cv	NI	NI	NI	1970	NI	NI	NI
Q72-2	-81.380389	35.289095	Cv	NI	NI	NI	1983	NI	NI	NI
Q72-3	-81.397275	35.318431	Cv	NI	NI	NI	1970	NI	NI	NI
Q72-5	-81.411441	35.276562	Cv	NI	NI	NI	1973	NI	NI	NI
P72-2	-81.391365	35.402763	Gs	NI	Drilled (6")	NI	1987	NI	NI	NI
Q70-1	-81.245156	35.327708	Gs	NI	NI	NI	2001	NI	NI	NI
Q70-2	-81.229456	35.326476	Gs	NI	NI	NI	1960	NI	NI	NI
Q71-1	-81.276843	35.262848	Gs	NI	NI	NI	1972	NI	NI	NI
Q71-2	-81.273472	35.322591	Gs	NI	NI	NI	1973	NI	NI	NI
Q71-3	-81.299332	35.331827	Gs	NI	NI	NI	1974	NI	NI	NI
Q71-4	-81.325467	35.302242	Gs	NI	NI	NI	?	NI	NI	NI
Q72-4	-81.362310	35.319744	Gs	NI	NI	NI	1997	NI	NI	NI
R71-1	-81.260307	35.235878	Gs	NI	NI	NI	1972	NI	NI	NI
R71-2	-81.295116	35.220949	Gs	NI	NI	NI	1982	NI	NI	NI
R71-3	-81.267763	35.163601	Gs	NI	NI	NI	1985	NI	NI	NI
R71-4	-81.310355	35.173707	Gs	NI	NI	NI	2001	NI	NI	NI
R71-5	-81.295128	35.198976	Gs	NI	NI	NI	1972	NI	NI	NI
P71-1	-81.317429	35.347395	Gs	NI	Drilled (6")	55	1993	NI	30	50
P71-2	-81.279826	35.342164	Gs	NI	Drilled (6")	200	1992	NI	NI	NI
P71-5	-81.285093	35.377564	Gs	NI	Drilled (6")	520	1999	60	480	3
P72-1	-81.347318	35.354766	Gs	NI	Bored	50	1986	NI	NI	NI
P72-3	-81.391365	35.402763	Gs	NI	Drilled (6")	NI	1987	NI	NI	NI
P72-3	-81.359816	35.352402	Gs	DAVIS	Drilled (6")	54	2002	NI	25	16
P72-4	-81.360492	35.351129	Gs	FILLBECK	Drilled (6")	65	1991	NI	9	NI
N68-1	-81.064586	35.537988	Li	NI	Drilled (6")	NI	NI	NI	NI	NI
N68-2	-81.069309	35.511309	Li	DYSER	Drilled (6")	206	1998	NI	NI	7
N68-4	-81.055557	35.500657	Li	NI	Drilled (6")	145	2001	NI	30	NI
N68-5	-81.030493	35.547842	Li	KEITH	Drilled (6")	140	1997	NI	NI	7
N69-1	-81.139886	35.517804	Li	BLACKWELL	Drilled (6")	275	1989	NI	NI	75
N69-2	-81.137671	35.540012	Li	NI	Drilled (6")	NI	1977	NI	NI	NI
N69-3	-81.102538	35.508459	Li	NI	Drilled (6")	55	1987	NI	NI	15
N69-4	-81.087526	35.544960	Li	NI	Drilled (6")	245	1995	53	NI	5
N69-5	-81.116550	35.529569	Li	NI	NI	NI	2000	NI	NI	NI

APPENDIX A - TABLE TWO

WELL CONSTRUCTION INFORMATION FROM SAMPLED WELLS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DRILLER	TYPE WELL	DEPTH (FEET)	YEAR	CASING DEPTH (FEET)	STATIC WATER LEVEL (FEET)	YIELD (GPD)
N70-1	-81.223188	35.549576	Li	NI	Drilled (6")	NI	Fairly New	NI	NI	NI
N70-2	-81.214610	35.516936	Li	NI	Drilled (6")	NI	1982	NI	NI	NI
N70-3	-81.194928	35.542121	Li	NI	Drilled (6")	NI	NI	NI	NI	NI
N71-1	-81.273304	35.556680	Li	NI	Drilled (6")	263	2002	NI	NI	8
N71-2	-81.262527	35.512740	Li	NI	NI	NI	1978	NI	NI	NI
N71-3	-81.311040	35.509933	Li	DYSART	Drilled (6")	320	1987	NI	NI	3
N71-4	-81.322045	35.552186	Li	NI	Bored	48	2001	48	NI	5
O69-1	-81.145481	35.477547	Li	NI	Drilled (6")	600	1998	40	NI	1
O69-2	-81.146862	35.421950	Li	NI	Drilled (6")	NI	1972	NI	NI	NI
O69-3	-81.102636	35.449825	Li	NI	Drilled (6")	545	2002	24	50	1
O69-4	-81.107613	35.485507	Li	SOUTHEASTERN.	Drilled (6")	200	2000	70	40	7
O69-5	-81.140721	35.450773	Li	NI	Drilled (6")	100	1987	NI	NI	3
O70-1	-81.183925	35.428938	Li	NI	Drilled (6")	NI	1996	NI	NI	NI
O70-2	-81.184427	35.487334	Li	ADVANCED.PUMP	Drilled (6")	145	2002	NI	NI	100
O71-1	-81.316182	35.483930	Li	NI	Drilled (6")	160	2000	NI	NI	NI
O71-2	-81.316415	35.484324	Li	NI	Drilled (6")	280	2001	NI	NI	NI
O71-3	-81.297690	35.464811	Li	NI	NI	NI	1972	NI	NI	NI
O71-4	-81.255930	35.428453	Li	HENSLEY	Drilled (6")	NI	1990	NI	NI	NI
P70-1	-81.186428	35.389385	Li	NI	Drilled (6")	350	2002	NI	NI	30
P70-2	-81.199240	35.359974	Li	NI	Drilled (6")	NI	1965	NI	NI	NI
P70-3	-81.181994	35.340956	Li	NI	Drilled (6")	370	1975	NI	NI	5
P70-4	-81.235249	35.343716	Li	LEWIS	Drilled (6")	NI	1998	NI	NI	NI
P70-5	-81.235249	35.343716	Li	LEWIS	Drilled (6")	NI	1998	NI	NI	NI
P70-6	-81.242118	35.398099	Li	NI	NI	NI	1987	NI	NI	NI
P71-3	-81.251906	35.385355	Li	LEWIS	Drilled (6")	180	1977	NI	NI	8
P71-4	-81.328511	35.391464	Li	LOWELL	Drilled (6")	190	1996	NI	NI	NI
O58-1	-80.231193	35.502620	ST	NI	NI	NI	NI	NI	NI	NI
O58-5	-80.172862	35.433680	ST	NI	NI	NI	NI	NI	NI	NI
O59-4	-80.286123	35.423710	St	HERLOCKER	drilled (6")	400	NI	NI	NI	NI
P59-3	-80.269165	35.347286	St	NI	drilled (6")	NI	1992	NI	NI	NI
Q58-3	-80.182648	35.307838	St	NI	Drilled (6")	NI	1972	NI	NI	NI
Q61-1	-80.444615	35.265609	St	NI	Drilled (6")	NI	1974	NI	NI	NI
R58-1	-80.216165	35.239112	St	WHITLEY	Drilled (6")	120	1982	NI	NI	NI

APPENDIX A - TABLE TWO

WELL CONSTRUCTION INFORMATION FROM SAMPLED WELLS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DRILLER	TYPE WELL	DEPTH (FEET)	YEAR	CASING DEPTH (FEET)	STATIC WATER LEVEL (FEET)	YIELD (GPD)
R58-2	-80.220443	35.177231	St	NI	Drilled (6")	NI	1994	NI	NI	NI
R59-1	-80.280797	35.239950	St	HAYCOCK	Drilled (6")	0	1972	NI	NI	NI
R59-2	-80.289698	35.210681	St	NI	Dug	NI	1917	NI	NI	NI
R59-3	-80.330248	35.179256	St	HATHCOCK	Drilled (6")	214	2001	NI	NI	NI
R60-1	-80.348032	35.176414	St	NI	Drilled (6")	NI	NI	NI	NI	NI
R61-2	-80.442924	35.173042	St	NI	Drilled (6")	NI	NI	NI	NI	NI
R61-3	-80.501777	35.184234	St	NI	Drilled (6")	290	1997	45	NI	20
057-3	-80.114870	35.434116	St	WHITLEY	drilled (6")	NI	NI	NI	NI	NI
O57-1	-80.147850	35.471312	St	WHITLEY	drilled (6")	80	NI	NI	NI	NI
O57-2	-80.146708	35.444288	St	HATHCOCK	drilled (6")	NI	NI	NI	NI	NI
O58-2	-80.199669	35.477673	St	DERRY	drilled (6")	225	NI	NI	NI	NI
O58-4	-80.182702	35.458725	St	NI	drilled (6")	NI	NI	NI	NI	NI
O59-1	-80.251058	35.496246	St	WHITLEY	drilled (6")	101	NI	NI	NI	NI
O59-2	-80.306702	35.468869	St	HERLOCKER	drilled (6")	94	NI	NI	NI	NI
O59-3	-80.265527	35.459502	St	HERLOCKER	drilled (6")	NI	NI	NI	NI	NI
P59-1	-80.250513	35.413631	St	SIDES	drilled (6")	85	NI	NI	NI	NI
p59-2	-80.266132	35.387594	St	NI	drilled (6")	170	1940	NI	NI	10
P59-4	-80.291305	35.352996	St	NI	drilled (6")	NI	2001	NI	NI	NI
P60.1	-80.354424	35.336129	St	LOCUST.PUMP.WELL	drilled (6")	185	1990	60	NI	10
P60-2	-80.365607	35.357913	St	BOWERS	drilled (6")	80	1964	NI	NI	NI
Q58-1	-80.239130	35.311321	St	LOCUST	Drilled (6")	282	1996	NI	NI	10
Q58-2	-80.222186	35.290115	St	NI	Drilled (6")	85	1964	NI	NI	NI
Q59-1	-80.257518	35.277337	St	WHITLEY	Drilled (6")	98	19866	NI	NI	NI
Q59-2	-80.322744	35.261879	St	MORGAN	Drilled (6")	103	1966	NI	NI	NI
Q59-3	-80.257930	35.312431	St	NI	Drilled (6")	250	1972	NI	NI	NI
Q60-1	-80.393328	35.260116	St	NI	Drilled (6")	NI	1957	NI	NI	NI
Q60-2	-80.393328	35.260116	St	NI	Drilled (6")	NI	1954	NI	NI	NI
Q60-3	-80.366938	35.291731	St	NI	Drilled (6")	NI	1999	NI	NI	NI
Q60-4	-80.359714	35.322719	St	WHITLEY	Drilled (6")	197	1966	NI	NI	NI
R61-1	-80.432008	35.206109	St	NI	Drilled (6")	NI	NI	NI	NI	1
R61-4	-80.461563	35.216213	St	NI	Drilled (6")	285	2000	NI	NI	9
S62-2	-80.511620	35.121168	Un	NI	NI	NI	1997	NI	NI	NI
U64-5	-80.738648	34.986000	Un	NI	NI	NI	1970	NI	NI	NI
U64-6	-80.738648	34.986000	Un	NI	NI	NI	1970	NI	NI	NI

APPENDIX A - TABLE TWO

WELL CONSTRUCTION INFORMATION FROM SAMPLED WELLS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DRILLER	TYPE WELL	DEPTH (FEET)	YEAR	CASING DEPTH (FEET)	STATIC WATER LEVEL (FEET)	YIELD (GPD)
U65-2	-80.776392	34.966051	Un	MULLIS	Drilled (6")	270	1996	66	NI	5
U65-4	-80.828371	34.992627	Un	NI	Drilled (6")	110	1967	NI	NI	8
V61-1	-80.487358	34.833534	Un	NI	Drilled (6")	150	1945	NI	NI	2
V61-2	-80.481368	34.895736	Un	CAROLINA.WELL DRIL	Drilled (6")	230	1996	NI	20	3
V62-1	-80.575750	34.839621	Un	CATOE.+.SONS	Drilled (6")	125	1995	37	NI	8
V62-2	-80.504343	34.854804	Un	NI	NI	NI	1997	NI	NI	NI
V62-4	-80.508969	34.904463	Un	NI	Drilled (6")	200	1982	NI	NI	NI
S59-1	-80.302327	35.134818	Un	NI	Drilled (6")	NI	NI	NI	NI	NI
S60-1	-80.402364	35.093098	Un	HATHCOCK	Drilled (6")	305	1996	38	NI	10
S62-1	-80.565668	35.109122	Un	NI	Drilled (6")	NI	1957	NI	NI	NI
S62-3	-80.510229	35.151835	Un	BALCOM	Drilled (6")	200	1982	NI	NI	2
T59-1	-80.318669	35.050615	Un	NI	Drilled (6")	NI	NI	NI	NI	NI
T59-2	-80.323923	35.031280	Un	NI	Drilled (6")	174	1984	NI	NI	7
T60-1	-80.365562	35.020179	Un	GEROME.WELL.DRILL	Drilled (6")	210	1977	NI	NI	NI
T60-2	-80.353595	35.071403	Un	CATOE	Drilled (6")	205	1978	35	32	8
T61-1	-80.432423	35.026241	Un	NI	Drilled (6")	NI	1952	NI	NI	NI
T61-2	-80.483363	35.020192	Un	NI	Drilled (6")	220	1975	NI	NI	15
T61-3	-80.479610	35.046236	Un	NI	Drilled (6")	NI	1989	NI	NI	NI
T61-4	-80.485481	35.071725	Un	NI	Drilled (6")	NI	NI	170	NI	NI
T62-1	-80.523011	35.082073	Un	NI	Drilled (6")	220	1991	55	20	NI
T62-2	-80.514463	35.024847	Un	NI	Drilled (6")	NI	1988	NI	NI	NI
T62-3	-80.561059	35.050054	Un	NI	Drilled (6")	NI	1986	NI	NI	NI
T62-4	-80.580273	35.084805	Un	CATOE	Drilled (6")	78	1969	NI	NI	3
T63-1	-80.659775	35.014750	Un	NI	Drilled (6")	360	1994	40	NI	3
T63-2	-80.598266	35.077311	Un	NI	Drilled (6")	NI	1967	NI	NI	NI
T63-3	-80.597410	35.077735	Un	NI	Drilled (6")	NI	1967	NI	NI	NI
T64-1	-80.731405	35.016944	Un	NI	Drilled (6")	NI	NI	NI	NI	NI
T64-2	-80.745146	35.041528	Un	NI	Drilled (6")	NI	1985	NI	NI	NI
U59-1	-80.316975	34.941586	Un	NI	Drilled (6")	68	NI	NI	NI	NI
U60-1	-80.346213	34.927652	Un	NI	Drilled (6")	135	2000	35	NI	20
U60-2	-80.345901	34.963714	Un	GEROME.WELL.DRILL	Drilled (6")	180	1980	NI	NI	NI
U61-1	-80.466845	34.953758	Un	MYERS	Drilled (6")	NI	1971	NI	NI	NI
U61-2	-80.470618	34.929443	Un	NI	Drilled (6")	380	1958	NI	NI	2
U62-1	-80.580836	34.924101	Un	CATOE	Drilled (6")	150	1992	NI	NI	NI

APPENDIX A - TABLE TWO

WELL CONSTRUCTION INFORMATION FROM SAMPLED WELLS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DRILLER	TYPE WELL	DEPTH (FEET)	YEAR	CASING DEPTH (FEET)	STATIC WATER LEVEL (FEET)	YIELD (GPD)
U62-2	-80.545157	34.923786	Un	CAROLINA.WELL	Drilled (6")	355	2000	35	30	1
U62-3	-80.509249	34.918830	Un	CAROLINA.WELL	Drilled (6")	225	1977	NI	NI	3
U62-4	-80.538999	34.953010	Un	CATOE	Drilled (6")	275	1986	NI	NI	10
U64-1	-80.695896	34.955602	Un	CATOE	Drilled (6")	185	1999	101	32	15
U64-2	-80.668677	34.929490	Un	CAROLINA.WELL	Drilled (6")	280	1979	NI	NI	NI
U64-3	-80.724737	34.938590	Un	NI	Drilled (6")	115	1985	84	25	30
U64-4	-80.678079	34.989989	Un	DS.MULLIS	Drilled (6")	150	2000	61	30	15
U65-1	-80.766111	34.919692	Un	CAROLINA.WELL	Drilled (6")	180	2001	138	30	8
U65-3	-80.761989	34.991914	Un	NI	Drilled (6")	NI	2000	NI	NI	NI
V59-1	-80.328549	34.877010	Un	BAKER	Drilled (6")	80	1989	NI	15	8
V59-2	-80.320716	34.905075	Un	NI	Drilled (6")	70	1972	NI	NI	NI
V60-1	-80.364370	34.832118	Un	ANSON	Drilled (6")	125	1986	33	15	8
V60-2	-80.398226	34.855060	Un	CAROLINA	Drilled (6")	180	2000	35	30	5
V60-3	-80.398226	34.855060	Un	CAROLINA	Drilled (6")	180	2000	35	30	5
V60-4	-80.367997	34.889095	Un	CAR.WELL.DRILL	Drilled (6")	105	1994	35	20	25
V60-5	-80.402499	34.908037	Un	NI	Drilled (6")	NI	1952	NI	NI	NI
V60-6	-80.337487	34.903503	Un	NI	Drilled (6")	75	1957	NI	NI	30
V62-3	-80.527895	34.883019	Un	DARBY	Drilled (6")	65	1990	55	NI	20
V62-5	-80.571425	34.894713	Un	CAROLINA.WELL.DRIL	Drilled (6")	105	1993	65	20	25
V63-1	-80.660755	34.893413	Un	LOVE	Drilled (6")	140	1987	NI	NI	40
V63-2	-80.634851	34.878425	Un	NI	Drilled (6")	141	1961	128	25	NI
V63-3	-80.638161	34.848304	Un	NI	Drilled (6")	NI	1963	NI	NI	NI
V63-4	-80.604258	34.836901	Un	NI	Drilled (6")	300	2001	40	NI	8
V63-5	-80.595757	34.896874	Un	NI	Drilled (6")	NI	1970	NI	NI	NI
V63-fb	-80.595757	34.896874	Un	NI	NI	NI	NI	NI	NI	NI
V64-1	-80.745206	34.854561	Un	NI	Drilled (6")	NI	1974	NI	NI	NI
V64-2	-80.691465	34.842343	Un	NI	Drilled (6")	150	1977	NI	NI	NI
V64-3	-80.718931	34.894617	Un	KATO	Drilled (6")	113	1970	NI	NI	NI
V64-4	-80.687870	34.904332	Un	NI	Drilled (6")	NI	1995	NI	NI	7
V64-5	-80.745962	34.903356	Un	NI	Drilled (6")	80	1972	NI	NI	20
V65-1	-80.771817	34.835017	Un	CAROLINA	Drilled (6")	280	1977	75	40	2
V65-2	-80.770527	34.862265	Un	CATOE	Drilled (6")	245	1998	62	42	NI
V65-3	-80.771658	34.899222	Un	NI	Drilled (6")	102	1969	NI	NI	3

APPENDIX A - TABLE TWO

WELL CONSTRUCTION INFORMATION FROM SAMPLED WELLS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DRILLER	TYPE WELL	DEPTH (FEET)	YEAR	CASING DEPTH (FEET)	STATIC WATER LEVEL (FEET)	YIELD (GPD)

Notes:

1. NI – No information
2. County – Cv=Cleveland (sample collected near border with Gaston County), Gs=Gaston, Li=Lincoln, St=Stanly, Un=Union.
3. GPD – Gallons per day.
4. Drilled 6" – Well constructed by drilling a borehole through unconsolidated regolith to the bedrock surface, installing a 6 inch diameter PVC or steel casing and grouting in place, followed by further advancement of the borehole into consolidated bedrock until sufficient water bearing fractures are intersected.

APPENDIX A - TABLE THREE

SUMMARY OF ANALYTICAL RESULTS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DATE COLL.	LAB ID NUMBER	pH	E_H	COND	TEMP	APP	ALK	As (0.010)	Ca (NE)	Chloride (250)	Cu (1)	F (2)	Fe (0.3)	HARD (NE)	Mg (NE)	Mn (0.05)	Pb (0.015)	Zn (2.1)
Q72-1	-81.359498	35.259082	Cv	8/7/02	aa80750	5.9	484.4	41.4	18	NA	10	<0.001	3.3	<5	0.07	<0.20	<0.05	11	0.6	<0.03	<0.005	<0.05
Q72-2	-81.380389	35.289095	Cv	8/7/02	aa80751	6	478.5	39	23.7	NA	10	<0.001	3.6	<5	0.05	<0.20	<0.05	10	0.2	<0.03	<0.005	<0.05
Q72-3	-81.397275	35.318431	Cv	8/7/02	aa80752	6.2	465.2	60.3	17.4	NA	22	<0.001	5.7	<5	<0.05	<0.20	<0.05	19	1.1	<0.03	<0.005	<0.05
Q72-5	-81.411441	35.276562	Cv	8/7/02	aa80754	6	480.1	57	18.7	NA	16	<0.001	4.9	<5	0.07	<0.20	<0.05	16	0.8	<0.03	0.022	<0.05
P72-2	-81.391365	35.402763	Gs	8/20/02	aa81449	5.6	NA	43	17.7	Clear	12	<0.001	2.8	<5	0.1	<0.20	<0.05	9	0.4	<0.03	<0.005	0.1
Q70-1	-81.245156	35.327708	Gs	8/5/02	aa80632	5.3	516.6	31.9	16.9	NA	6	<0.001	1.4	<5	<0.05	<0.20	<0.05	7	0.8	<0.03	<0.005	0.06
Q70-2	-81.229456	35.326476	Gs	8/6/02	aa80691	5.9	485.9	58.6	16.5	NA	14	<0.001	3.3	<5	<0.05	<0.20	<0.05	11	0.06	<0.03	<0.005	<0.05
Q71-1	-81.276843	35.262848	Gs	8/6/02	aa80692	5.9	486.6	35.9	18.2	NA	8	<0.001	3	<5	0.08	<0.20	<0.05	11	0.9	<0.03	<0.005	<0.05
Q71-2	-81.273472	35.322591	Gs	8/6/02	aa80693	7	421.4	134.5	17.8	NA	60	0.013	13	<5	0.07	<0.20	<0.05	542	4.7	<0.03	<0.005	1.14
Q71-3	-81.299332	35.331827	Gs	8/6/02	aa80690	5.6	500.7	75.5	16.8	NA	20	<0.001	4.3	<5	0.09	<0.20	<0.05	21	2.4	<0.03	<0.005	<0.05
Q71-4	-81.325467	35.302242	Gs	8/6/02	aa80689	6.8	437.7	231.9	24.3	NA	90	0.01	28.4	6	<0.05	0.24	0.07	92	5	<0.03	<0.005	<0.05
Q72-4	-81.362310	35.319744	Gs	8/7/02	aa80753	6.3	458.6	80.1	16.9	NA	34	<0.001	6	<5	<0.05	<0.20	<0.05	26	2.6	<0.03	0.009	0.06
R71-1	-81.260307	35.235878	Gs	8/5/02	aa80621	6.1	473	174.3	17.8	NA	43	<0.001	14.3	19	0.09	<0.20	<0.05	59	5.7	<0.03	0.006	<0.05
R71-2	-81.295116	35.220949	Gs	8/5/02	aa80622	5.6	499.3	73.2	17.3	NA	8	<0.001	4.5	8	<0.05	<0.20	<0.05	15	0.8	0.1	<0.005	<0.05
R71-3	-81.267763	35.163601	Gs	8/5/02	aa80624	6.1	470.5	68.2	18.2	NA	22	<0.001	3.3	<5	<0.05	<0.20	0.07	15	1.7	<0.03	<0.005	<0.05
R71-4	-81.310355	35.173707	Gs	8/5/02	aa80627	6.2	439.7	128.7	18.2	NA	58	<0.001	13	<5	<0.05	<0.20	<0.05	48	3.8	<0.03	<0.005	0.06
R71-5	-81.295128	35.198976	Gs	8/5/02	aa80629	6.1	475	489.9	23.8	NA	20	<0.001	5.5	<5	<0.05	<0.20	0.26	20	1.5	<0.03	<0.005	0.64
P71-1	-81.317429	35.347395	Gs	8/19/02	aa81346	6.1	60	53	15.8	Clear	20	<0.001	5.1	<5	<0.05	<0.20	0.16	18	1.4	<0.03	<0.005	<0.05
P71-2	-81.279826	35.342164	Gs	8/19/02	aa81347	7.2	-11.8	76	19.5	Clear	64	0.003	14.2	<5	<0.05	<0.20	<0.05	58	5.5	<0.03	<0.005	0.23
P71-5	-81.285093	35.377564	Gs	8/20/02	aa81447	7.4	NA	159	17	Clear	66	0.003	20.5	<5	<0.05	0.29	0.68	66	3.5	0.08	<0.005	0.09
P72-1	-81.347318	35.354766	Gs	8/20/02	aa81450	5.8	NA	48	18.6	Clear	10	<0.001	3.5	<5	<0.05	<0.20	<0.05	10	0.4	<0.03	<0.005	<0.05
P72-3	-81.391365	35.402763	Gs	8/20/02	aa81448	5.6	NA	43	17.7	Clear	12	<0.001	2.8	<5	0.1	<0.20	<0.05	9	0.4	<0.03	<0.005	0.09
P72-3	-81.359816	35.352402	Gs	8/21/02	aa81492	6.8	NA	313	24.1	Clear	104	0.001	39.8	15	<0.05	0.29	0.82	106	1.7	0.12	0.026	0.39
P72-4	-81.360492	35.351129	Gs	8/21/02	aa81493	5.6	NA	71	17.5	Clear	14	<0.001	3.7	5	0.05	<0.20	0.06	10	0.2	<0.03	<0.005	<0.05
N68-1	-81.064586	35.537988	Li	8/12/02	aa80925	6.6	442	64	19	Clear	26	<0.001	4.5	<5	0.07	0.27	0.06	15	1	<0.03	<0.005	<0.05
N68-2	-81.069309	35.511309	Li	8/14/02	aa81143	6.2	48	67	25.4	Clear	24	<0.001	4.3	<5	<0.05	<0.20	<0.05	13	0.6	<0.03	<0.005	0.11
N68-4	-81.055557	35.500657	Li	8/21/02	aa81491	6.5	NA	127	17.2	Clear	210	<0.001	10.4	<5	<0.05	<0.20	0.97	37	2.8	<0.03	<0.005	0.18
N68-5	-81.030493	35.547842	Li	8/21/02	aa81490	6.2	NA	71	15.4	Clear	30	<0.001	5	<5	<0.05	<0.20	<0.05	19	1.5	<0.03	<0.005	<0.05

APPENDIX A - TABLE THREE

SUMMARY OF ANALYTICAL RESULTS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DATE COLL.	LAB ID NUMBER	pH	E_H	COND	TEMP	APP	ALK	As (0.010)	Ca (NE)	Chloride (250)	Cu (1)	F (2)	Fe (0.3)	HARD (NE)	Mg (NE)	Mn (0.05)	Pb (0.015)	Zn (2.1)
N69-1	-81.139886	35.517804	Li	8/2/02	aa80677	6.5	452	88	16.5	Clear	40	<0.001	6.2	<5	<0.05	<0.20	<0.05	29	3.3	<0.03	<0.005	<0.05
N69-2	-81.137671	35.540012	Li	8/2/02	aa80678	6.1	473	63	16.3	Clear	24	<0.001	6.6	<5	<0.05	<0.20	<0.05	24	1.8	<0.03	<0.005	<0.05
N69-3	-81.102538	35.508459	Li	8/2/02	aa80679	5.6	504	60	19.4	Clear	8	<0.001	2.1	<5	<0.05	<0.20	<0.05	10	1.1	<0.03	<0.005	0.07
N69-4	-81.087526	35.544960	Li	8/2/02	aa80680	6.8	433	103	16.9	Clear	44	<0.001	7.1	<5	<0.05	0.36	<0.05	33	3.6	<0.03	<0.005	<0.05
N69-5	-81.116550	35.529569	Li	8/6/02	aa80688	6.3	460.2	57.3	16.1	NA	20	<0.001	3.1	<5	<0.05	<0.20	<0.05	11	0.9	<0.03	<0.005	<0.05
N70-1	-81.223188	35.549576	Li	8/2/02	aa80681	7.2	406	93	19.1	Clear	40	<0.001	5.7	<5	<0.05	<0.20	0.16	33	4.6	<0.03	<0.005	0.86
N70-2	-81.214610	35.516936	Li	8/2/02	aa80682	5.7	497	59	19.7	Clear	10	<0.001	4.1	<5	0.05	<0.20	<0.05	14	1	<0.03	<0.005	<0.05
N70-3	-81.194928	35.542121	Li	8/2/02	aa80684	5.5	507	81	21	Clear	10	<0.001	3.7	5	<0.05	<0.20	<0.05	17	1.8	<0.03	<0.005	<0.05
N71-1	-81.273304	35.556680	Li	7/31/02	aa80366	7.8	377	155	25.5	Clear	64	<0.001	17.4	<5	<0.05	<0.20	<0.05	57	3.4	<0.03	<0.005	0.14
N71-2	-81.262527	35.512740	Li	7/31/02	aa80367	7.8	377.2	154.8	25.5	NA	4	<0.001	4.5	8	<0.05	<0.20	<0.05	21	2.4	<0.03	<0.005	<0.05
N71-3	-81.311040	35.509933	Li	7/31/02	aa80368	7	420	82	17.2	Clear	34	<0.001	6.5	<5	<0.05	<0.20	<0.05	26	2.3	<0.03	<0.005	0.2
N71-4	-81.322045	35.552186	Li	7/31/02	aa80369	7.3	404	132	17.6	Clear	56	<0.001	20.4	<5	0.06	<0.20	<0.05	57	1.5	<0.03	<0.005	<0.05
O69-1	-81.145481	35.477547	Li	8/13/02	aa81150	8.8	-103	162	17.7	Clear	49	0.002	12.3	<5	<0.05	4.84	<0.05	33	0.5	<0.03	<0.005	<0.05
O69-2	-81.146862	35.421950	Li	8/13/02	aa81151	6.5	33	280	20.3	Clear	66	<0.001	33.3	7	<0.05	1.23	<0.05	105	5.4	<0.03	<0.005	<0.05
O69-3	-81.102636	35.449825	Li	8/14/02	aa81146	7.3	-16.9	221	15.6	Clear	98	0.003	25.5	<5	<0.05	1.12	0.07	83	4.8	0.16	0.008	0.07
O69-4	-81.107613	35.485507	Li	8/14/02	aa81145	6.6	27	91	15.9	Clear	34	<0.001	6.1	<5	<0.05	0.34	<0.05	25	2.4	<0.03	<0.005	<0.05
O69-5	-81.140721	35.450773	Li	8/14/02	aa81144	8.1	-58.3	358	18	Clear	58	0.004	55.5	<5	<0.05	3.19	<0.05	145	1.6	<0.03	<0.005	<0.05
O70-1	-81.183925	35.428938	Li	8/13/02	aa81148	6.6	28	283	19.8	Clear	74	0.003	36.8	11	<0.05	0.33	<0.05	113	5.2	<0.03	<0.005	<0.05
O70-2	-81.184427	35.487334	Li	8/13/02	aa81149	7.1	-2	142	18.1	Clear	66	<0.001	16.9	<5	<0.05	<0.20	<0.05	69	6.6	<0.032	<0.005	<0.05
O71-1	-81.316182	35.483930	Li	8/8/02	aa80786	7	420	86	16.7	Clear	37	<0.001	7.4	<5	<0.05	<0.20	1.56	31	3	<0.03	0.014	<0.05
O71-2	-81.316415	35.484324	Li	8/8/02	aa80785	7	422.6	87	17.1	Clear	38	<0.001	6.9	<5	0.29	<0.20	1.65	30	3	<0.03	0.018	0.27
O71-3	-81.297690	35.464811	Li	8/8/02	aa80784	5.9	484	50	18.3	Clear	36	<0.001	3.1	<5	0.3	<0.20	0.05	12	1	<0.03	0.006	<0.05
O71-4	-81.255930	35.428453	Li	8/13/02	aa81147	6.6	445	89	16.8	Clear	32	0.003	7.3	<5	<0.05	<0.20	<0.05	30	2.9	<0.03	<0.005	<0.05
P70-1	-81.186428	35.389385	Li	8/15/02	aa81300	6.2	50	144	19.1	Clear	42	<0.001	13.7	8	0.06	0.28	<0.05	42	1.8	<0.03	<0.005	<0.05
P70-2	-81.199240	35.359974	Li	8/15/02	aa81301	6	63	84	19.1	Cloudy	24	<0.001	5.6	<5	0.05	<0.20	1.33	19	1.1	<0.03	<0.005	<0.05
P70-3	-81.181994	35.340956	Li	8/15/02	aa81296	7.5	-28.8	200	16.6	Clear	82	<0.001	20.1	<5	<0.05	3.28	0.17	54	0.8	<0.03	<0.005	<0.05
P70-4	-81.235249	35.343716	Li	8/15/02	aa81297	7.2	-8.9	138	16.6	Clear	58	0.022	17	<5	<0.05	0.25	<0.05	61	4.5	<0.03	<0.005	<0.05
P70-5	-81.235249	35.343716	Li	8/15/02	aa81298	7.2	-8.9	138	16.6	Clear	60	0.021	16.4	<5	<0.05	0.21	<0.05	58	4.2	<0.03	0.022	<0.05
P70-6	-81.242118	35.398099	Li	8/15/02	aa81299	6	62	79	16.7	Clear	14	0.005	3.7	<5	<0.05	<0.20	<0.05	14	1.2	<0.03	0.006	<0.05

APPENDIX A - TABLE THREE

SUMMARY OF ANALYTICAL RESULTS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DATE COLL.	LAB ID NUMBER	pH	E_H	COND	TEMP	APP	ALK	As (0.010)	Ca (NE)	Chloride (250)	Cu (1)	F (2)	Fe (0.3)	HARD (NE)	Mg (NE)	Mn (0.05)	Pb (0.015)	Zn (2.1)
P71-3	-81.251906	35.385355	Li	8/19/02	aa81348	6.6	26	44	17.3	Clear	30	0.011	4.7	<5	<0.05	<0.20	0.89	27	3.8	<0.03	<0.005	<0.05
P71-4	-81.328511	35.391464	Li	8/19/02	aa81349	6.1	56	116	23.8	Clear	42	<0.001	7.6	<5	<0.05	<0.20	<0.05	28	2.2	0.04	<0.005	<0.05
O58-1	-80.231193	35.502620	ST	6/20/02	aa78559	6.5	NA	139.5	20.3	NA	Na	<0.001	14.4	NA	<0.05	NA	1.33	44	2	0.08	<0.005	<0.05
O58-5	-80.172862	35.433680	ST	6/20/02	aa78563	7.4	NA	203.5	17.6	NA	Na	0.028	25.8	NA	<0.05	NA	<0.05	71	1.7	<0.03	<0.005	<0.05
O59-4	-80.286123	35.423710	St	6/19/02	aa78454	5.9	NA	168.8	19.1	NA	Na	<0.001	17.6	NA	<0.05	NA	<0.05	64	4.8	<0.03	<0.005	0.07
P59-3	-80.269165	35.347286	St	6/25/02	aa78596	6.2	NA	85.1	19.7	NA	26	<0.001	7.2	5	<0.05	<0.20	<0.05	31	3.2	<0.03	<0.005	<0.05
Q58-3	-80.182648	35.307838	St	7/1/02	aa78922	6.7	NA	224	16.07	Clear	78	<0.001	<0.5	25	<0.05	<0.20	0.18	<2	<0.10	<0.03	<0.005	<0.005
Q61-1	-80.444615	35.265609	St	6/26/02	aa78595	7.6	NA	204	16.2	Clear	114	0.003	35.1	6	<0.05	0.21	<0.05	107	4.8	<0.03	<0.005	<0.05
R58-1	-80.216165	35.239112	St	7/1/02	aa78923	6.5	NA	252	19.1	Clear	88	<0.001	0.5	19	<0.05	0.24	0.22	2	0.1	<0.03	<0.005	<0.05
R58-2	-80.220443	35.177231	St	7/1/02	aa78924	7.1	NA	584	17.01	Clear	186	0.017	69.6	138	<0.05	0.26	0.25	274	24.3	<0.03	<0.005	<0.05
R59-1	-80.280797	35.239950	St	7/2/02	aa79003	6.5	NA	189	18.04	Clear	42	<0.001	22.5	14	0.09	<0.20	<0.05	65	2.1	<0.03	<0.005	<0.05
R59-2	-80.289698	35.210681	St	7/2/02	aa79002	7.3	NA	238	20.01	Clear	94	0.001	40.6	9	<0.05	<0.20	<0.05	113	2.8	<0.03	<0.005	<0.05
R59-3	-80.330248	35.179256	St	7/2/02	aa79001	7.3	NA	283	17.8	Clear	112	<0.001	43.5	10	<0.05	<0.20	0.29	136	6.6	0.19	<0.005	<0.05
R60-1	-80.348032	35.176414	St	7/2/02	aa79000	7.1	NA	472	18.06	Clear	116	<0.001	58.8	33	<0.05	0.23	4.58	193	11.3	1.03	<0.005	0.15
R61-2	-80.442924	35.173042	St	7/3/02	aa79050	6	NA	337	17.05	Clear	80	<0.001	42.2	36	<0.05	<0.20	<0.05	142	8.8	<0.03	<0.005	0.07
R61-3	-80.501777	35.184234	St	7/3/02	aa79051	6	NA	269	17	Clear	80	<0.001	30.5	14	<0.05	<0.20	<0.05	94	4.3	0.06	<0.005	<0.05
057-3	-80.114870	35.434116	St	6/24/02	aa78602	7.6	NA	205	19.1	NA	Na	<0.001	33.8	NA	<0.05	NA	0.17	101	4	0.04	<0.005	<0.05
O57-1	-80.147850	35.471312	St	6/24/02	aa78600	5.9	NA	75.8	17.7	NA	Na	<0.001	5.2	NA	<0.05	NA	0.15	20	1.8	<0.03	<0.005	<0.05
O57-2	-80.146708	35.444288	St	6/24/02	aa78601	6.6	NA	144.4	24.2	NA	Na	0.016	18.2	NA	<0.05	NA	0.24	51	1.3	0.45	<0.005	<0.05
O58-2	-80.199669	35.477673	St	6/20/02	aa78560	7.5	NA	280.8	18.8	NA	Na	0.017	38.1	NA	<0.05	NA	<0.05	124	6.9	0.15	<0.005	<0.05
O58-4	-80.182702	35.458725	St	6/20/02	aa78562	6.7	NA	143.7	19.2	NA	Na	<0.001	9	NA	0.24	NA	<0.05	47	6	<0.03	<0.005	0.06
O59-1	-80.251058	35.496246	St	6/19/02	aa78457	7.8	NA	179.1	16.4	NA	Na	0.002	27.7	NA	<0.05	NA	0.33	91	5.3	0.08	<0.005	<0.05
O59-2	-80.306702	35.468869	St	6/19/02	aa78456	5.4	NA	175.8	17.1	NA	Na	<0.001	7.5	NA	<0.05	NA	0.06	45	6.4	0.03	<0.005	<0.05
O59-3	-80.265527	35.459502	St	6/19/02	aa78455	7.1	NA	283.6	17.7	NA	Na	<0.001	53.6	NA	<0.05	NA	0.26	152	4.5	<0.03	0.005	0.07
P59-1	-80.250513	35.413631	St	6/24/02	aa78603	6.6	NA	104	19.2	NA	Na	<0.001	8.1	NA	<0.05	NA	<0.05	35	3.6	<0.03	<0.005	<0.05
p59-2	-80.266132	35.387594	St	6/25/02	aa78595	6.5	NA	118.5	19	NA	18	<0.001	11	8	0.12	<0.20	<0.05	46	4.4	<0.03	<0.005	<0.05
P59-4	-80.291305	35.352996	St	6/25/02	aa78597	6.9	NA	127.6	18.9	NA	58	<0.001	15.4	5	<0.05	<0.20	<0.05	60	5.3	<0.03	<0.005	<0.05
P60.1	-80.354424	35.336129	St	6/25/02	aa78599	6.3	NA	115.2	20.7	NA	36	<0.001	9.2	7	0.44	<0.20	0.09	40	4.2	<0.03	<0.005	<0.05
P60-2	-80.365607	35.357913	St	6/25/02	aa78598	6.8	NA	169.7	16.7	NA	60	0.002	31.5	8	<0.05	<0.20	1.77	98	4.6	0.99	<0.005	<0.05

APPENDIX A - TABLE THREE
SUMMARY OF ANALYTICAL RESULTS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DATE COLL.	LAB ID NUMBER	pH	E_H	COND	TEMP	APP	ALK	As (0.010)	Ca (NE)	Chloride (250)	Cu (1)	F (2)	Fe (0.3)	HARD (NE)	Mg (NE)	Mn (0.05)	Pb (0.015)	Zn (2.1)
Q58-1	-80.239130	35.311321	St	6/27/02	aa7882	7.4	NA	321	18.02	Clear	140	0.001	<0.05	27	<0.05	<0.20	0.15	<1	<0.10	<0.03	<0.005	<0.05
Q58-2	-80.222186	35.290115	St	7/1/02	aa78921	7.7	NA	211	16.04	Cloudy	112	<0.001	<0.5	6	<0.05	0.2	2.11	<2	<0.10	<0.03	<0.005	0.11
Q59-1	-80.257518	35.277337	St	6/27/02	aa78878	6.5	NA	314.1	16.9	Clear	80	<0.001	55.4	45	<0.05	0.23	0.51	171	8	0.38	<0.005	<0.05
Q59-2	-80.322744	35.261879	St	6/27/02	aa78879	7	NA	306	20.02	Clear	148	0.004	43	22	0.05	0.21	0.07	153	11.1	<0.03	0.007	0.05
Q59-3	-80.257930	35.312431	St	6/27/02	aa78880	7.2	NA	430	17.8	Clear	192	<0.001	82.6	60	<0.05	<0.20	0.6	257	12.2	0.41	<0.005	0.18
Q60-1	-80.393328	35.260116	St	6/26/02	aa78884	6.5	NA	105	18.3	Clear	50	<0.001	<0.5	5	<0.05	<0.20	<0.05	<1	<0.10	<0.03	<0.005	<0.05
Q60-2	-80.393328	35.260116	St	6/27/02	aa78885	6.5	NA	105	18.3	Clear	50	<0.001	<0.5	5	<0.05	<0.20	<0.05	<1	<0.10	<0.03	<0.005	<0.05
Q60-3	-80.366938	35.291731	St	6/26/02	aa78886	5.3	NA	26	17.07	Clear	12	<0.001	0.7	<5	0.26	<0.20	<0.05	6	1.1	<0.03	<0.005	<0.05
Q60-4	-80.359714	35.322719	St	6/26/02	aa78887	5.9	NA	85	17.04	Clear	30	<0.001	6.8	6	<0.05	<0.20	<0.05	27	2.5	<0.03	<0.005	<0.05
R61-1	-80.432008	35.206109	St	7/3/02	aa79048	6.5	NA	354	18.01	Clear	134	0.017	52.2	27	<0.05	<0.20	<0.05	162	7.6	<0.03	<0.005	<0.05
R61-4	-80.461563	35.216213	St	7/3/02	aa79049	6	NA	164	20.05	Clear	62	0.008	19.5	6	<0.05	0.2	<0.05	61	3	0.05	<0.005	<0.05
S62-2	-80.511620	35.121168	Un	7/30/02		7.4	400.3	300.1	17.4	Clear	134	0.002	51.4	7	<0.05	<0.20	0.39	143	3.6	0.85	<0.005	<0.05
U64-5	-80.738648	34.986000	Un	7/18/02	aa79823	7.2	409.1	491.6	17.9	NA	194	0.005	4.4	30	<0.05	<0.20	<0.05	24	3.2	<0.03	<0.005	<0.05
U64-6	-80.738648	34.986000	Un	7/18/02	aa79824	7.2	409.1	491.6	17.9	NA	117	0.004	37.8	26	<0.05	0.22	<0.05	129	8.5	<0.03	<0.005	0.05
U65-2	-80.776392	34.966051	Un	7/25/02	aa80032	6.9	425	627	18.1	Clear	174	0.003	84.8	64	<0.05	<0.20	0.82	255	10.4	0.6	<0.005	<0.05
U65-4	-80.828371	34.992627	Un	7/25/02	aa80034	6	478	61	17.7	Clear	24	<0.001	3.7	<5	0.14	<0.20	<0.05	13	1	<0.03	<0.005	<0.05
V61-1	-80.487358	34.833534	Un	7/15/02	aa79580	6.8	NA	1153	17.4	Clear	370	0.001	95.8	245	<0.05	<0.20	<.05	398	38.7	<.03	<0.005	<0.05
V61-2	-80.481368	34.895736	Un	7/15/02	aa79579	7.5	NA	530	16.9	Clear	196	0.002	42	67	<0.05	0.21	0.05	174	16.8	<0.03	<0.005	<0.05
V62-1	-80.575750	34.839621	Un	7/10/02	aa79259	6.3	NA	114	17.3	Clear	30	<0.001	9.3	8	<0.05	<0.20	<0.05	36	3.2	<0.03	<0.005	<0.05
V62-2	-80.504343	34.854804	Un	7/10/02	aa79258	7.4	NA	624	19.2	Clear	190	0.026	45.1	92	<0.05	0.2	<0.05	196	20.3	<0.03	<0.005	<0.05
V62-4	-80.508969	34.904463	Un	7/10/02	aa79256	7	NA	730	26.3	Clear	182	0.025	109.9	48	<0.05	<0.20	<0.05	337	15.2	<0.03	<0.005	<0.05
S59-1	-80.302327	35.134818	Un	7/8/02	aa79164	6.6	NA	131	17.8	Clear	360	0.004	161.1	175	<0.05	0.24	5.7	550	35.9	1.34	<0.005	<0.05
S60-1	-80.402364	35.093098	Un	7/24/02	aa80014	7.2	410	135	16.5	Clear	56	<0.001	20.4	<5	<0.05	<0.20	<0.05	63	2.9	<0.03	<0.005	<0.05
S62-1	-80.565668	35.109122	Un	7/30/02	aa80293	7.1	417	2058	19.3	Cloudy	360	0.015	156.3	515	<0.05	0.21	0.05	690	72.9	0.17	<0.005	0.07
S62-3	-80.510229	35.151835	Un	7/30/02	aa80295	7	423	747	29.8	Clear	300	<0.001	26.1	33	<0.05	<0.20	0.34	93	6.7	0.21	<0.005	<0.05
T59-1	-80.318669	35.050615	Un	7/8/02	aa79163	6.9	NA	95	19.9	Clear	280	0.039	106.7	201	<0.05	<0.20	<0.05	357	22	<0.03	<0.005	<0.05
T59-2	-80.323923	35.031280	Un	7/8/02	aa79161	7.2	NA	63	18	Clear	192	0.006	90.1	138	0.1	<0.20	0.07	281	13.7	0.07	<0.005	0.06
T60-1	-80.365562	35.020179	Un	7/15/02	aa79582	7.4	NA	348	16.9	Clear	156	0.088	52.5	21	0.07	<0.20	<0.5	161	7.2	<0.03	<0.005	<0.05
T60-2	-80.353595	35.071403	Un	7/24/02	aa80012	7.1	413	928	20.1	Clear	178	0.035	95.5	181	<0.05	<0.20	<0.05	367	31.3	0.1	<0.005	<0.05

APPENDIX A - TABLE THREE
SUMMARY OF ANALYTICAL RESULTS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DATE COLL.	LAB ID NUMBER	pH	E_H	COND	TEMP	APP	ALK	As (0.010)	Ca (NE)	Chloride (250)	Cu (1)	F (2)	Fe (0.3)	HARD (NE)	Mg (NE)	Mn (0.05)	Pb (0.015)	Zn (2.1)
T61-1	-80.432423	35.026241	Un	7/24/02	aa80013	7.3	404	366	18.2	Clear	118	0.022	51.7	34	<0.05	<0.20	0.05	166	8.9	<0.03	<0.005	<0.05
T61-2	-80.483363	35.020192	Un	7/24/02	aa80015	7.6	388	399	17.5	Clear	154	0.11	60.8	36	0.1	<0.20	0.14	181	7	0.03	0.005	<0.05
T61-3	-80.479610	35.046236	Un	7/24/02	aa80016	6.7	438	238	21.3	Clear	74	0.01	30.3	14	<0.05	<0.20	0.06	99	5.6	<0.03	<0.005	<0.05
T61-4	-80.485481	35.071725	Un	7/24/02	aa80017	7.4	401	415	18.1	Clear	110	0.012	62.4	52	<0.05	<0.20	<0.05	192	8.8	<0.03	<0.005	<0.05
T62-1	-80.523011	35.082073	Un	7/28/02	aa80209	6.9	425	314	17.4	Clear	90	0.01	40.7	29	<0.05	<0.20	<0.05	126	5.8	<0.03	<0.005	<0.05
T62-2	-80.514463	35.024847	Un	7/29/02	aa80210	6.8	433	276	17.8	Clear	94	<0.001	37.1	15	<0.05	0.36	2.48	117	6	0.25	<0.005	<0.05
T62-3	-80.561059	35.050054	Un	7/29/02	aa80211	7.3	401	597	18	Clear	140	0.001	57.4	87	<0.05	<0.20	0.78	183	9.7	0.95	<0.005	<0.05
T62-4	-80.580273	35.084805	Un	7/29/02	aa80208	7.1	416	1486	19.6	Clear	370	0.019	112.6	266	<0.05	0.37	0.05	451	41.3	0.08	<0.005	0.06
T63-1	-80.659775	35.014750	Un	7/30/02	aa80290	7.7	382	349	17.9	Clear	160	0.044	51.3	9	<0.05	0.22	<0.05	164	8.6	<0.03	<0.005	<0.05
T63-2	-80.598266	35.077311	Un	7/30/02	aa80291	7.6	387	738	19.8	Clear	166	0.033	61.1	133	<0.05	0.33	<0.05	238	20.8	<0.03	<0.005	<0.05
T63-3	-80.597410	35.077735	Un	7/30/02	aa80292	7.6	387	738	19.8	Clear	168	0.034	63.8	133	<0.05	0.33	<0.05	246	21.1	0.03	<0.005	<0.05
T64-1	-80.731405	35.016944	Un	7/25/02	aa80035	7.3	402	321	19.7	Clear	150	0.002	43	8	0.15	0.25	<0.05	137	7.2	<0.03	<0.005	<0.05
T64-2	-80.745146	35.041528	Un	7/25/02	aa80036	5.6	501	83	18.8	Clear	12	<0.001	4.8	5	0.07	<0.20	<0.05	16	1	<0.03	<0.005	<0.05
U59-1	-80.316975	34.941586	Un	7/8/02	aa79160	6.7	NA	373	22.6	Clear	108	0.011	54.8	43	<0.05	0.2	2.74	185	11.7	0.84	0.008	<0.05
U60-1	-80.346213	34.927652	Un	7/15/02	aa79578	7.1	NA	647	17.9	Clear	142	0.002	56.6	56	<0.05	0.21	1.21	212	17.1	0.82	<0.005	<0.05
U60-2	-80.345901	34.963714	Un	7/15/02	aa79581	6.9	NA	1101	18.7	Clear	280	0.003	151.6	191	<0.05	<0.20	1.11	477	23.8	1.29	<0.005	<0.05
U61-1	-80.466845	34.953758	Un	7/15/02	aa79584	6.3	NA	276	18	Clear	62	<0.001	22	32	<0.05	<0.20	<0.05	98	10.5	<0.03	<0.005	<0.05
U61-2	-80.470618	34.929443	Un	7/15/02	aa79583	7.4	NA	489	23.2	Clear	178	0.006	5.4	47	<0.05	0.23	<0.05	23	2.3	<0.03	<0.005	<0.05
U62-1	-80.580836	34.924101	Un	7/26/02	aa80204	7	422	211	18	Clear	74	0.002	23.8	9	<0.05	<0.20	<0.05	77	4.3	<0.03	<0.005	<0.05
U62-2	-80.545157	34.923786	Un	7/26/02	aa80205	7.4	395	671	19.1	Cloudy	190	0.004	67	92	<0.05	0.31	<0.05	254	21.2	0.28	<0.005	<0.05
U62-3	-80.509249	34.918830	Un	7/26/02	aa80206	7.3	402	426	22	Clear	128	0.008	56.6	42	0.09	<0.20	<0.05	176	8.4	<0.03	<0.005	<0.05
U62-4	-80.538999	34.953010	Un	7/26/02	aa80207	6.6	442	327	21.4	Clear	90	0.008	43.5	25	<0.05	<0.20	<0.05	132	5.7	<0.03	<0.005	<0.05
U64-1	-80.695896	34.955602	Un	7/16/02	aa79588	6.8	430	128	16.3	Clear	58	<0.001	10.2	<5	<0.05	<0.20	<0.05	47	5.2	<0.03	<0.005	<0.05
U64-2	-80.668677	34.929490	Un	7/18/02	aa79819	7.6	384	337	17.7	Clear	142	<0.001	44.6	16	<0.05	<0.20	0.1	148	9	<0.03	<0.005	<0.05
U64-3	-80.724737	34.938590	Un	7/18/02	aa79820	6.3	461	78	16.3	Clear	30	<0.001	5.4	<5	<0.05	<0.20	<0.05	20	1.6	<0.03	0.08	<0.05
U64-4	-80.678079	34.989989	Un	7/18/02	aa79822	6.7	434	273	16.5	Clear	124	0.002	33.6	9	<0.05	<0.20	<0.05	116	7.7	<0.03	<0.005	<0.05
U65-1	-80.766111	34.919692	Un	7/25/02	aa80033	7.2	410	138	17.3	Clear	62	<0.001	14.8	<5	<0.05	<0.20	<0.05	51	3.4	<0.03	<0.005	2.2
U65-3	-80.761989	34.991914	Un	7/25/02	aa80031	6.1	472	180	40	Clear	60	<0.001	13.4	10	0.08	<0.20	<0.05	51	4.3	<0.03	<0.005	0.09
V59-1	-80.328549	34.877010	Un	7/8/02	aa79159	6.7	NA	444	18.01	Clear	90	0.004	65.9	40	<0.05	0.2	8.66	261	23.4	1.43	<0.005	<0.05

APPENDIX A - TABLE THREE
SUMMARY OF ANALYTICAL RESULTS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DATE COLL.	LAB ID NUMBER	pH	E_H	COND	TEMP	APP	ALK	As (0.010)	Ca (NE)	Chloride (250)	Cu (1)	F (2)	Fe (0.3)	HARD (NE)	Mg (NE)	Mn (0.05)	Pb (0.015)	Zn (2.1)
V59-2	-80.320716	34.905075	Un	7/8/02	aa79162	6.9	NA	292	16.05	Cloudy	109	0.001	35.5	24	<0.05	0.3	2.75	134	11	0.41	<0.005	<0.05
V60-1	-80.364370	34.832118	Un	7/9/02	aa79153	8.4	NA	437	21.9	Clear	180	<0.001	6.5	21	0.07	5.38	<0.05	24	2	<0.03	0.017	<0.05
V60-2	-80.398226	34.855060	Un	7/9/02	aa79154	7.7	NA	752	17.1	Cloudy	176	0.044	76.2	172	<0.05	<0.20	<0.05	310	29.1	0.04	<0.005	<0.05
V60-3	-80.398226	34.855060	Un	7/10/02	aa79155	7.7	NA	752	17.1	Cloudy	178	0.044	73.8	173	<0.05	<0.20	<0.05	301	28.4	0.04	<0.005	<0.05
V60-4	-80.367997	34.889095	Un	7/9/02	aa79156	6.9	NA	982	21.08	Clear	118	<0.001	0.7	100	<0.05	0.24	1.09	2	0.1	<0.03	<0.005	<0.05
V60-5	-80.402499	34.908037	Un	7/9/02	aa79157	6.6	NA	330	18.01	Clear	78	0.011	43.4	42	<0.05	<0.20	<0.05	147	9.3	<0.03	<0.005	0.1
V60-6	-80.337487	34.903503	Un	7/9/02	aa79158	6.2	NA	241	17.1	Clear	56	0.003	15	25	<0.05	0.22	8.96	74	8.9	0.7	<0.005	<0.05
V62-3	-80.527895	34.883019	Un	7/10/02	aa79257	5.5	NA	47	18.2	Clear	20	<0.001	1.4	<5	<0.05	<0.20	<0.05	6	0.5	<0.03	<0.005	<0.05
V62-5	-80.571425	34.894713	Un	7/10/02	aa79255	6.2	NA	87	18.1	Clear	29	<0.001	6.6	<5	<0.05	<0.20	<0.05	26	2.3	<0.03	<0.005	<0.05
V63-1	-80.660755	34.893413	Un	7/11/02	aa79291	7.1	NA	326	17.6	Clear	144	0.008	48.2	17	<0.05	<0.20	<0.05	151	7.4	0.08	<0.005	0.13
V63-2	-80.634851	34.878425	Un	7/11/02	aa79292	6.5	NA	128	18.3	Cloudy	56	<0.001	9,2	5	<0.05	<0.20	2.41	41	4.5	<0.03	<0.005	<0.05
V63-3	-80.638161	34.848304	Un	7/11/02	aa79293	6.8	NA	910	23.8	Cloudy	130	0.001	109.9	242	<0.05	<0.20	1.19	365	22.1	0.62	<0.005	<0.05
V63-4	-80.604258	34.836901	Un	7/11/02	aa79294	6.7	NA	234	24	Clear	110	<0.001	33.6	5	0.07	<0.20	0.28	96	2.9	<0.03	<0.005	0.31
V63-5	-80.595757	34.896874	Un	7/11/02	aa79295	6	NA	253	17.4	Clear	46	<0.001	19.2	31	<0.05	<0.20	0.07	84	8.9	<0.03	<0.005	<0.05
V63-fb	-80.595757	34.896874	Un	7/11/02	aa79296	NA	NA	NA	NA	NA	2	<0.001	<0.5	<5	<0.05	<0.20	<0.05	<2	<0.10	<0.03	<0.005	<0.05
V64-1	-80.745206	34.854561	Un	7/16/02	aa79585	6.7	435	121	18	Clear	32	<0.001	8.4	<5	0.06	<0.20	0.3	41	4.9	<0.03	<0.005	<0.05
V64-2	-80.691465	34.842343	Un	7/16/02	aa79586	7.1	412	702	21.2	Clear	270	0.005	59.2	77	<0.05	<0.20	<0.05	262	27.9	<0.03	<0.005	0.06
V64-3	-80.718931	34.894617	Un	7/16/02	aa79587	6.7	433	114	21.2	Clear	48	<0.001	9.1	<5	<0.05	<0.20	<0.05	35	3.1	<0.03	<0.005	0.36
V64-4	-80.687870	34.904332	Un	7/16/02	aa79589	6.3	457	133	17.8	Clear	58	<0.001	12.2	<5	<0.05	0.48	<0.05	43	3	<0.03	0.005	<0.05
V64-5	-80.745962	34.903356	Un	7/17/02	aa79806	5.9	483	49	17.7	Clear	10	<0.001	1	<5	<0.05	<0.20	<0.05	4	0.3	<0.03	<0.005	<0.05
V65-1	-80.771817	34.835017	Un	7/17/02	aa79808	7	418	115	17.4	Clear	44	<0.001	9.2	<5	<0.05	<0.20	<0.05	38	3.7	<0.03	<0.005	<0.05
V65-2	-80.770527	34.862265	Un	7/17/02	aa79807	6.5	451	165	20.8	Clear	74	<0.001	13.7	<5	<0.05	<0.20	0.1	54	4.7	0.07	<0.005	<0.05
V65-3	-80.771658	34.899222	Un	7/17/02	aa79809	6	478	74	19	Clear	16	<0.001	2.4	<5	<0.05	<0.20	<0.05	9	0.7	<0.03	<0.005	0.06

APPENDIX A - TABLE THREE
SUMMARY OF ANALYTICAL RESULTS

SAMPLE ID	LONGITUDE	LATITUDE	COUNTY	DATE COLL.	LAB ID NUMBER	pH	E_H	COND	TEMP	APP	ALK	As (0.010)	Ca (NE)	Chloride (250)	Cu (1)	F (2)	Fe (0.3)	HARD (NE)	Mg (NE)	Mn (0.05)	Pb (0.015)	Zn (2.1)

Notes:

1. All analytical results measured in milligrams per liter (mg/L) except where noted. NCAC 2L standards are provided in parentheses under specific parameters.
2. NI - No information
3. NA - Not Analyzed
4. NE – NCAC 2L groundwater standard not established.
5. Latitude and longitude determined using a Trimble 2000 handheld GPS unit. A minimum of 180 points was collected at each well location.
6. Samples were collected at a spatial frequency of 5 samples per 5 minutes of latitude and longitude.
7. gpd - gallons per minute
8. Well construction information obtained from well tags or from owner interviews.
9. pH - measured in standard units
10. EH - millivolts
11. Cond. - Specific conductivity measured in microseimens per second.
12. Temp. - Temperature measured in degrees Celsius
13. "<" - indicates that the analytical result is less than the laboratories practical quantification limit.
14. Shaded cells indicate results that equal or exceed the State's groundwater standards.

APPENDIX A - TABLE FOUR

QUALITY CONTROL/ASSURANCE SAMPLES

Sample ID	Type Sample	Date Collected	LAB ID NUMBER	Alk.	As	Ca	Cl	Cu	Fl	Fe	Hard.	Mg	Mn	Pb	Zn
P72-2	Primary	8/20/2002	aa81449	12	<0.001	2.8	<5	0.1	<0.20	<0.05	9	0.4	<0.03	<0.005	0.10
P72-3	Duplicate	8/20/2002	aa81448	12	<0.001	2.8	<5	0.1	<0.20	<0.05	9	0.4	<0.03	<0.005	0.09
P70-4	Primary	8/15/2002	aa81297	58	0.022	17	<5	<0.05	0.25	<0.05	61	4.5	<0.03	<0.005	<0.05
P70-5	Duplicate	8/15/2002	aa81298	60	0.021	16.4	<5	<0.05	0.21	<0.05	58	4.2	<0.03	0.022	<0.05
T63-2	Primary	7/30/2002	aa80291	166	0.033	61.1	133	<0.05	0.33	<0.05	238	20.8	<0.03	<0.005	<0.05
T63-3	Duplicate	7/30/2002	aa80292	168	0.034	63.8	133	<0.05	0.33	<0.05	246	21.1	0.03	<0.005	<0.05
V63-fb	Field Blank	7/11/2002	aa79296	2	<0.001	<0.5	<5	<0.05	<0.20	<0.05	<2	<0.10	<0.03	<0.005	<0.05
V60-2	Primary	7/9/2002	aa79154	176	0.044	76.2	172	<0.05	<0.20	<0.05	310	29.1	0.04	<0.005	<0.05
V60-3	Duplicate	7/10/2002	aa79155	178	0.044	73.8	173	<0.05	<0.20	<0.05	301	28.4	0.04	<0.005	<0.05
Q60-1	Primary	6/26/2002	aa78884	50	<0.001	<0.5	5	<0.05	<0.20	<0.05	<1	<0.10	<0.03	<0.005	<0.05
Q60-2	Duplicate	6/27/2002	aa78885	50	<0.001	<0.5	5	<0.05	<0.20	<0.05	<1	<0.10	<0.03	<0.005	<0.05

Notes

1. < - Indicates that the parameter results were not detected at or above the detectable limit.
2. Duplicate sample represents a separate "grab" sample and was collected immediately following collection of the primary sample.
3. Alk. - Alkalinity
4. Hard. - Hardness
5. Percent Difference - calculated by dividing the difference by the average of the two numbers.
6. ND - non-determinable due to the parameter not being detected.

APPENDIX A - TABLE FIVE

PERCENT DIFFERENCE BETWEEN COLLECTED SAMPLES AND DUPLICATE SAMPLES.

Sample ID's	Alk.	As	Ca	Cl	Cu	Fl	Fe	Hard.	Mg	Mn	Pb	Zn
P72-2/P72-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5
P70-4/P70-5	3.4	4.7	3.6	0.0	0.0	17.4	0.0	5.0	6.9	0.0	ND	0.0
T63-2/T63-3	1.2	3.0	4.3	0.0	0.0	0.0	0.0	3.3	1.4	ND	0.0	0.0
V60-2/V60-3	1.1	0.0	3.2	0.6	0.0	0.0	0.0	2.9	2.4	0.0	0.0	0.0
Q60-1/Q60-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes

1. Sample ID's - The first number represents the sample and the second the duplicate sample
2. Duplicate sample represents a separate "grab" sample and was collected immediately following collection of the primary sample.
3. Alk. – Alkalinity.
4. Hard. – Hardness.
5. Percent Difference - calculated by dividing the difference by the average of the two numbers.
6. ND - non-determinable due to the parameter not being detected.

APPENDIX B - NC GEOLOCATED DEPARTMENT OF HEALTH AND HUMAN SERVICES LABORATORY DATA COMBINED WITH THE SUMMER 2002 DATA

Request database from author by email (chuck.pippin@ncmail.net).

APPENDIX C - GRID REPORTS

Grid report for probability analysis using a threshold value of 0.01 mg/L.

Data Filter Report

Source Data File Name:	**H:\REP\Arsenic Study\DATA\Statistic Data\All useable AS Data.xls**
X Column:	**C**
Y Column:	**D**
Z Column:	**I**

Data Counts

Number of Active Data:	**6431**
Number of Original Data:	**6431**
Number of Excluded Data:	**0**
Number of Deleted Duplicates:	**0**
Number of Retained Duplicates:	**0**
Number of Artificial Data:	**0**

Filter Rules

Duplicate Points to Keep:	**First**
X Duplicate Tolerance:	**0**
Y Duplicate Tolerance:	**0**
Exclusion Filter String:	**Not In Use**

Data Statistics Report

Data Counts

Number of Active Data:	**6431**
Number of Original Data:	**6431**
Number of Excluded Data:	**0**
Number of Deleted Duplicates:	**0**
Number of Retained Duplicates:	**0**
Number of Artificial Data:	**0**

X Variable Statistics

X Range:	**773904**
X Midrange:	**524153**
X Minimum:	**137201**
X 25%-tile:	**427347**
X Median:	**480037**
X 75%-tile:	**597722**
X Maximum:	**911105**
X Average:	**499509**
X Standard Deviation:	**129069**
X Variance:	**1.66588E+010**

Y Variable Statistics

Y Range:	**299514**
Y Midrange:	**165023**
Y Minimum:	**15265.9**
Y 25%-tile:	**165865**
Y Median:	**204646**
Y 75%-tile:	**242564**
Y Maximum:	**314780**
Y Average:	**203157**
Y Standard Deviation:	**50910.1**
Y Variance:	**2.59184E+009**

Z Variable Statistics

Z Range:	**1**
Z Midrange:	**0.5**
Z Minimum:	**0**
Z 25%-tile:	**0**
Z Median:	**0**
Z 75%-tile:	**0**
Z Maximum:	**1**
Z Average:	**0.0384077**
Z Standard Deviation:	**0.192178**
Z Variance:	**0.0369326**
Z Coef. of Variation:	**5.00364**
Z Coef. of Skewness:	**4.80379**

Inter-Variable Correlation

	X	Y	Z
X:	1	0.0995726	-0.0461224
Y:		1	-0.130336
Z:			1

Inter-Variable Covariance

	X	Y	Z
X:	1.66588E+010	6.54284E+008	-1144.03
Y:		2.59184E+009	-1275.19
Z:			0.0369326

Gridding Report

Search Rules

Number of Sectors: 4
Maximum Data Per Sector: 6
Minimum Number of Data: 5
Maximum Number of Empty Sectors: 4
Search Ellipse Radius #1: 12000
Search Ellipse Radius #2: 12000
Search Ellipse Angle: 0

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point

Semi-Variogram Model

Component Type: Linear
Variogram Slope: 1
Anisotropy Angle: 0
Anisotropy Ratio: 1

Polynomial Drift Order: 0
Kriging standard deviation grid: no

Grid Summary

Grid File Name:	**H:\REP\Arsenic Study\DATA\Statistic Data\2-19-03 500x200 grid 12x12 ellips prob 0.01.grd**
Minimum X:	**137201**
Maximum X:	**911105**
Minimum Y:	**15265.9**
Maximum Y:	**314780**
Minimum Z:	**-0.368009**
Maximum Z:	**1.07498**
Number of Rows:	**200**
Number of Columns:	**500**
Number of Filled Nodes:	**34390**
Number of Blanked Nodes:	**65610**
Total Number of Nodes:	**100000**

Grid report for probability analysis using a threshold value of 0.001 mg/L.

Data Filter Report

Source Data File Name:	**H:\REP\Arsenic Study\DATA\Statistic Data\All useable AS Data.xls**
X Column:	**C**
Y Column:	**D**
Z Column:	**J**

Data Counts

Number of Active Data:	**4265**
Number of Original Data:	**4265**
Number of Excluded Data:	**0**
Number of Deleted Duplicates:	**0**
Number of Retained Duplicates:	**0**
Number of Artificial Data:	**0**

Filter Rules

Duplicate Points to Keep:	**First**
X Duplicate Tolerance:	**0**
Y Duplicate Tolerance:	**0**
Exclusion Filter String:	**Not In Use**

Data Statistics Report

Data Counts

Number of Active Data:	**4265**
Number of Original Data:	**4265**
Number of Excluded Data:	**0**
Number of Deleted Duplicates:	**0**
Number of Retained Duplicates:	**0**
Number of Artificial Data:	**0**

X Variable Statistics

X Range:	**773904**
X Midrange:	**524153**
X Minimum:	**137201**
X 25%-tile:	**427414**
X Median:	**482964**
X 75%-tile:	**597303**
X Maximum:	**911105**
X Average:	**499806**
X Standard Deviation:	**130008**
X Variance:	**1.69022E+010**

Y Variable Statistics

Y Range:	**294476**
Y Midrange:	**163922**
Y Minimum:	**16683.8**
Y 25%-tile:	**164906**
Y Median:	**202059**
Y 75%-tile:	**242370**
Y Maximum:	**311160**
Y Average:	**202061**
Y Standard Deviation:	**50537.8**
Y Variance:	**2.55407E+009**

Z Variable Statistics

Z Range:	**1**
Z Midrange:	**0.5**
Z Minimum:	**0**
Z 25%-tile:	**0**
Z Median:	**0**
Z 75%-tile:	**0**
Z Maximum:	**1**
Z Average:	**0.219695**
Z Standard Deviation:	**0.41404**
Z Variance:	**0.171429**
Z Coef. of Variation:	**1.88461**
Z Coef. of Skewness:	**1.354**

Inter-Variable Correlation

	X	Y	Z
X:	1	0.123576	-0.0394322
Y:		1	-0.147432
Z:			1

Inter-Variable Covariance

	X	Y	Z
X:	1.69022E+010	8.11937E+008	-2122.59
Y:		2.55407E+009	-3084.97
Z:			0.171429

Gridding Report

Search Rules

Number of Sectors: 4
Maximum Data Per Sector: 6
Minimum Number of Data: 5
Maximum Number of Empty Sectors: 4
Search Ellipse Radius #1: 12000
Search Ellipse Radius #2: 12000
Search Ellipse Angle: 0

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point

Semi-Variogram Model

Component Type: Linear
Variogram Slope: 1
Anisotropy Angle: 0
Anisotropy Ratio: 1

Polynomial Drift Order: 0
Kriging standard deviation grid: no

Grid Summary

Grid File Name:	**H:\REP\Arsenic Study\DATA\Statistic Data\2-19-03 500x200 grid 12x12 ellipse prob 0.001.grd**
Minimum X:	**137201**
Maximum X:	**911105**
Minimum Y:	**16683.8**
Maximum Y:	**311160**
Minimum Z:	**-0.396358**
Maximum Z:	**1.36175**
Number of Rows:	**200**
Number of Columns:	**500**
Number of Filled Nodes:	**28939**
Number of Blanked Nodes:	**71061**
Total Number of Nodes:	**100000**

APPENDIX D - NC DEPARTMENT OF HEALTH AND HUMAN SERVICES LABORATORY DATA

Request database from author by email (chuck.pippin@ncmail.net).

***Page left intentionally blank*.**