SHALLOW GROUNDWATER RESOURCES OF THE PROPOSED RED HILLS FACILITY AND MINE AREA

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A study was conducted in order to gather information on the nature of the water resources in the study area in Choctaw County, Mississippi, prior to the proposed development of a lignite mine within the study area. Within this area exist domestic and public supply wells, natural springs, and ponds. Samples taken from ponds, springs, and wells were collected for chemical analysis. On-sight measurements of pH, temperature, specific conductivity, and color were recorded at surface impoundments, springs, and wells. Water level measurements were taken in all accessible wells. Spring flow rates were estimated from velocity of the flow and cross sectional area.

Shallow groundwater data was provided by local citizenry, well measurements and well water sample collection. Springs that could be located using topographic maps, aerial photographs, and information from the population of the study area were sampled and tested. Water quantity has been sufficient to support area population. The only concerns with respect to water quality were eight wells and thirty-six springs that exhibited iron levels above potable drinking water standards.

INTRODUCTION

The study area in north-central Choctaw County is located in the North Central Hills of Mississippi. The lower and middle portion of the Wilcox Group is exposed at the surface in this area and extends to depths ranging from 400-850 feet (Newcombe and Bettandorf 1973). Topography in this area is a highly dissected hilly terrain (USDA 1986). Aquifers, ponds, and streams are all within the outcrop area of the Wilcox Group. (Figure 1 shows study area).

The Tennessee Valley Authority (TVA) has published data on pump tests conducted within Middle and Lower Wilcox sediments and groundwater samples analyzed from the proposed mining area.

Data were collected from local citizenry, testing of all accessible wells, use of existing Mississippi Office of Land and Water Resources data files, United States Geological Survey data, and location and testing of all springs and ponds using aerial photographs, topographic maps, and residents' knowledge. Wells that were not accessible for water level measurements or sampling, were included in the inventory, with all obtainable characteristics such as location, casing type and diameter, pump type, and date of drilling recorded. Latitude and longitude of each well, pond, and spring location was determined using a global positioning system (GPS). Aquifer transmissivity data were collected from previously-completed studies conducted by TVA, and included in the final report. Basic ground water characteristics such as pH, temperature, and color were recorded, and laboratory analysis of chemical constituents completed for some wells, ponds, and springs.

Ground water resource characteristics within the study area were recorded in order to establish baseline conditions prior to the development of a lignite mine within the study area. Establishing baseline conditions will enable the assessment of any changes in ground water due to lignite mining.

Geology and Hydrogeology

The study area in north-central Choctaw county lies entirely within the Paleocene-Eocene Wilcox Group (King and Beikman 1978). The study area lies within the Middle and Lower Wilcox strata (Hosman and Weiss 1991). The Wilcox Group is a fluvial-deltaic facies (Sharp et al. 1991 and Hosman 1996) with aggregate aquifer thicknesses of 200-500 feet, and dips to the west-southwest at 0. 15 to 0. 35 degrees (Newcombe and Bettandorf 1973) (see Figure 2 for general geology and dip of the region). Thin interbedded sands, clays, silts, and lignites compose the Wilcox, and the stratified clays, silts, and lignites retard the vertical movement of water throughout the entirety of the unit (Hosman and Weiss 1991). The wells and springs produce water from sand units interbedded with clay and coal layers. The depth of the sand units varies greatly and lateral extent of the units is largely unknown (Newcombe and Bettandorf 1973) and are regionally discontinuous (Sharp et al. 1991). The thickness of the sand units also varies greatly. Thicknesses of as little as twenty feet and as great as one hundred feet have been recorded (Mississippi Office of Land and Water Resources 1996). Lignite and clay layers may act to divert water flow laterally, and spring flow is due to dip of a sand layer overlying such a low permeability bed and intersection of the sand and low permeability bed with the surface, and is primarily not due to confined pressurization of the aquifer, with exception of the deeper lower Wilcox sands that are under some confining pressure (TVA 1998). The direction of groundwater flow is generally downdip from east to west except in the case of shallow sand aquifers that are at least partially driven by topography.

Extent of groundwater movement and residence time within the sand units is largely unknown, but lateral movement is limited by the extent of relatively permeable sands. Groundwater recharge is primarily at points where sand layers intersect the surface in their updip areas.

Precipitation and infiltration is the sole source of recharge to the lower Wilcox aquifer in the study area. The majority of recharge occurs where highly permeable sand units are exposed at the surface. Infiltration at points of sand exposure and movement down gradient within the sand units allows aquifer recharge to occur. A minor amount of aquifer recharge occurs through clays and silts having low permeability, but the amount of recharge is negligible. Evapotranspiration, interflow to springs and streams, and ground water pumpage are the sources of aquifer discharge.

Previous Investigations

Several reports on the groundwater resources in north central Mississippi have been conducted, but a detailed inventory of this specific area had not been conducted.

Inventory, combined with exploration, development, and management are the four necessary stages of groundwater utilization (Domenico and Schwarz 1990). Development of groundwater as a resource has been adequate for domestic and agricultural needs within the study area, but industrial water supplies have not been developed. The effects of significant industrial development within the study area, specifically lignite mining, on ground water resources can only be assessed if the groundwater resources are quantified prior to any industrial development.

Sources of Data

All existing water wells, springs, and surface water bodies were located and inventoried. Data on all accessible wells, and all ponds and springs, were collected. Water levels, well depth, type and diameter of casing, well location, drilling date, and accounts of water quality by residents was recorded whenever possible at all wells. Mississippi Office of Land and Water Resources well driller's logs and United States Geological Survey data were obtained and used to gather any data that were not gathered at the well sites. Water temperature, pH, specific conductivity, and color was measured and recorded from operating and accessible wells and all ponds and springs. Water temperature, specific conductivity, color, and pH were measured. Water samples were taken from all operating and accessible wells, ponds, and all springs flowing over five gallons per minute, and analyzed.

All surface water bodies were identified from aerial photos and topographic maps. Field locations of surface water bodies were recorded using global positioning systems (GPS). All wells and springs were field located using GPS and plotted on topographic maps.

RESULTS

Within the study area exist 167 wells, 90 springs, and 110 surface impoundments or ponds. Of the 167 wells 30 are abandoned, 117 were not used at the time of the study, 12 were used for domestic purposes, two were used for stock or gardens, one was used at a hunting camp, one is used at Jeff Busby Park on the Natchez Trace Parkway for recreational purposes, and three were used for public water supply as part of the Reform Water Association (See figure 3 for location of all currently used wells). Wells varied in age and drilling methods. The oldest known well was reported to have been dug around 1850, although this is not verified in records. Wells are dug, bored, or drilled, with the oldest wells typically being dug and the newest wells drilled. The dug wells reach shallow sand units that are under water table conditions, while the rotary drilled wells reach much deeper sand units that are under some confining pressure.

Ninety springs exist within the study area. Five springs were used for domestic purposes, two were used for livestock, and one is used for recreational purposes at Jeff Busby Park. The springs are a product of down-gradient flow of water within a highly permeable sand unit that is confined on its bottom by an impermeable layer such as lignite, and which intersects the surface at the point of discharge (See figure 3 for the locations of selected springs). Spring discharges ranged from 110 gallons per minute to a mere seep. The average flow for all springs was 10. 7 gallons per minute. The average flow rate excluding the unusually large rate of 110 gallons per minute was 9. 3 gallons per minute. The most common flow rate range was five to ten gallons per minute, with twenty-one springs falling into this category.

Within the one hundred and ten surface impoundments located within the study area, one hundred and one were excavated embankments, four were excavations without embankments, and five were beaver ponds. Fifty seven surface impoundments had as sources surface runoff and springs, while fifty three were reported as only having surface runoff as a source. Surface areas ranged from as little as 375 square feet (ft^2) to as great as 200,000 ft^2 with an average of 22,514 ft^2 while volume ranged from 11,000 gallons to 15,000,000 gallons. None of the surface impoundments were reported as being used for domestic water supply.

Water levels in ninety-seven domestic wells were measured. In addition, water levels from test wells were presented. The water levels vary throughout the study area. Similar water level elevations may be representative of a single sand unit. Clusters of water level elevations are shown by plotting the data and identifying the data point clusters. Plotting wells across elevation changes provides useful analysis of any trends in groundwater quality as depth changes. The most noted clustering of elevations are near 390 feet (AMSL) in the domestic well data, and 400 feet (AMSL) in the test well data. This water level elevation in the domestic data corresponds with the CD sand in the TVA data.

Ground Water Quality Characteristics

Groundwater interacts with the material through which it flows, and often gains dissolved solids and ions in the process (Keady 1970). Measuring specific conductance, chemical constituents, pH, temperature, and color will provide baseline data on the characteristics of the quality of the water for domestic and industrial use. Ion concentration is recognized as at its lowest levels at the outcrop areas of the Wilcox Group (Keady 1970), which includes the study area.

Although many residences use water associations as the primary source of drinking water, fourteen wells are still used for domestic purposes. In addition, the Reform Water Association has three wells in the study area that supply or offer the alternate supply to fifty-nine households. Acceptable water quality for drinking purposes from well water within the study area is in demand.

Nine of the nineteen wells sampled exhibited iron levels above the 0. 30 mg/l standard. The highest value for iron was 3. 8 mg/l. Three wells exhibited hardness approaching the potable drinking water standard of 110 mg/l. With respect to water quality, some residents reported a sulphur odor, and sulphur odor was noted in over half of the wells sampled.

Surface impoundment measurements of pH ranged from 5.15 to 9.45 with an average of 6.59. Conductivity ranged from 0.009 to 0.300 millions with an average of 0.040. In addition, one-hundred and one surface impoundments were sampled and analyzed for chemical constituents levels.

Spring water temperatures range from 13.89°C to 19. 91°C with an average temperature of 16. 67°C. This difference in temperature can be at least partially explained by variation in proximity of the data collection point from the spring itself. Measurements of pH ranged from 4.72 to 6.69 with an average of 5.61. Conductivity ranges from 0.009 to 0 .111 millimhos with an average of 0.038.

Well water temperatures ranged from 15.75°C to 20. 24°C with an average of 18.10°C. Conductivity ranged from 0.058 millimhos in well number to 0.349 millimhos with an average of 0.212 millimhos. Well water pH ranged from 5.16 to 8.16. Twenty-four wells were sampled and chemical analyses performed. An average value, high value, and low value is presented in Table 1 in order to provide a general description of the data.

Fifty springs were sampled and the samples analyzed. Springs that were not sampled did not have sufficient flow to allow the collection of a large enough sample. An average, high, and low value for each constituent is presented in Table 1 in order to provide a general description of the data.

Hydraulic Characteristics

Previous reports of hydraulic characteristics within Lower and Middle Wilcox aquifers reported transmissivity values ranging from 5,000 to 55,000 gallons per day per foot (gpd/ft), hydraulic conductivity values ranging from 250 to 1,000 gallons per day per square foot (gpd/ft^2) with an average of 460 gpd/ft^2 (Newcombe and Bettandorf 1973).

Fifteen aquifer tests were performed by Harden and Associates within the study area between November of 1996 and June of 1997. Tests were conducted in the thicker and coarser sand sediments that represent the areas of greatest permeability within the lower and middle Wilcox sediments. Transmissivity values ranged from 0.20 to16,600 gallons per day per foot, hydraulic conductivity ranged from . 03 gallons per day per foot to 233 gallons per day per foot. One hour specific capacity in gallons per minute per foot drawdown ranged from 0.01 to 1.74.

The variability in the hydraulic characteristics of the sediments reflects the variable nature of the underburden sands and the greater thickness and extent of the underburden sands. The higher hydraulic conductivity and transmissivity results of the tests run on the underburden wells (UB designation) is manifestation of the thicker and more laterally extensive sands. These underburden sands are part of the Lower Wilcox Aquifer, which exhibits water flow in the downdip direction from east to west and are under some confining pressure (TVA 1998). Other sands are less continuous and not as thick as the underburden sands.

DISCUSSION

Groundwater Quality

Groundwater in the study area in Choctaw county is currently uncontaminated. Due to the fact that this study serves as baseline data for the study area, comparison of water quality data with that from a study performed at a different time is impossible.

Well Water Quality

Well water is of acceptable quality for drinking standards. Iron (see Figure 3 for location) and pH are the only parameters that exceed potable drinking water standards. e sulfur odor present in many wells is not a health concern, but does present a difficulty in taste to some people. Bicarbonate levels are such that the water can be classified as a bicarbonate water.

Spring Water Quality

Spring water quality is very similar to well water with the exceptions of iron levels and pH. Iron levels average 1.31 mg/l, which is significantly higher than the 0.30 mg/l potable water standard and higher than the well water average of 0.80 mg/l The average for pH is 5.6. This is clearly more acidic than well water. Figure 4 shows the geographic relationship of springs having an iron content greater than the potable drinking water standard of 0.30 mg/l. (Hosman and Weiss 1991). The conductance of spring water is significantly lower than well water (averages of 0.030 mmhos for springs and 0.212 mmhos for wells). The average of dissolved solids for well water of 149 mg/l, and the average for springs of 31 mg/l correlates with the differences in conductance, as conductance is directly related to the level of total dissolved solids (Hem 1985). All of the other chemical constituent levels are well below potable drinking water standards.

Spring water is understood to be a shallow groundwater resource in the study area. Recharge of shallow sand units followed by discharge of water from these units at a spring downgradient of the recharge points should cause spring water characteristics to be similar to shallow well water characteristics.

Not all shallow wells exhibit the same groundwater characteristics. When compared with spring water, shallow wells (wells having depth to water less than 20 feet) exhibited higher average values of pH (6.9 vs. 5. 6), higher conductance (0.245 vs. 0.038), and slightly higher temperatures (18.35°C vs. 16.67°C). Spring water exhibited much higher acidity, slightly higher chloride and sulfate, and exhibited lower values for all other chemical constituents. Overall, the spring water was less mineralized than the shallow well water, suggesting that shallow well water exists in sand units that, although near the surface at the well site, have as sources water which has been recharged at a distant point, thus increasing residence time. Spring water is possibly recharged at relatively close locations, and does not have sufficient residence time prior to discharge to acquire similar chemical characteristics to the shallow well water.

Surface Impoundment Water Quality

Fifty-six surface impoundments were reported as having springs as sources. The average for surface impoundment water of 1.78 mg/l for iron levels is much higher than for springs (1.31 mg/l) and wells (0.80 mg/l). Total hardness of surface impoundment water (8.0 mg/l) is significantly lower than well or spring water. Surface impoundment water is composed of a significant portion of surface runoff, which has an aquifer residence time of zero and is therefore less mineralized. The characteristics of surface impoundment water in the study area do not present any problems. Surface impoundment water characteristics are as one would expect.

The value of pH is plotted in Figure 4, and the values of iron, conductance, total dissolved solids, and bicarbonate from selected wells were plotted in Figure 5 in order to represent the relationship, if any, that exists between groundwater elevation and mineral concentrations. The plot of pH against groundwater elevations suggests a trend of decreasing pH with increasing groundwater elevation. However, in the cases of total dissolved solids, iron, conductance, and bicarbonate, a relationship is not apparent.

CONCLUSIONS

Groundwater resources within the study area in Choctaw County exist within fluvial-deltaic Middle and Lower Wilcox aquifers. Water yielding sands are laterally and vertically limited. Water resource development has employed these sands, as wells for domestic use are developed in the sand units, and spring discharge is a result of the relationship of some sands to topography, creating gradient driven discharge. Surface impoundments are generally for livestock or recreational purposes, and are spring fed in some cases. Currently, the demands by the population of the study area have not exceeded the water resources.

Groundwater quality is generally good, as potable drinking water standards are exceeded only in the categories of pH and iron in some of the wells. In these wells, however, iron levels may cause staining of laundry and plumbing fixtures. Groundwater quality is not clearly related to groundwater elevation. In order to assess the relationship between groundwater chemistry and specific sands, information on the recharge areas of specific sands is necessary so that distance from the recharge area, and subsequent residence time can be calculated.

Hydraulic characteristics of the Middle and Lower Wilcox aquifers varies significantly. Hydraulic conductivities from lignite underburden sands within the proposed mining area are as high as 5.52×10^{-3} cm/s and as low as 1.36×10^{-6} cm/s in overburden sands. The Lower Wilcox sands are recognized as having the greatest vertical extent, transmissivity, and specific capacity (TVA 1998).

Inventory of wells, ponds, and springs in the study area prior to lignite mining enables the observation of any changes in groundwater resources due to lignite mining.

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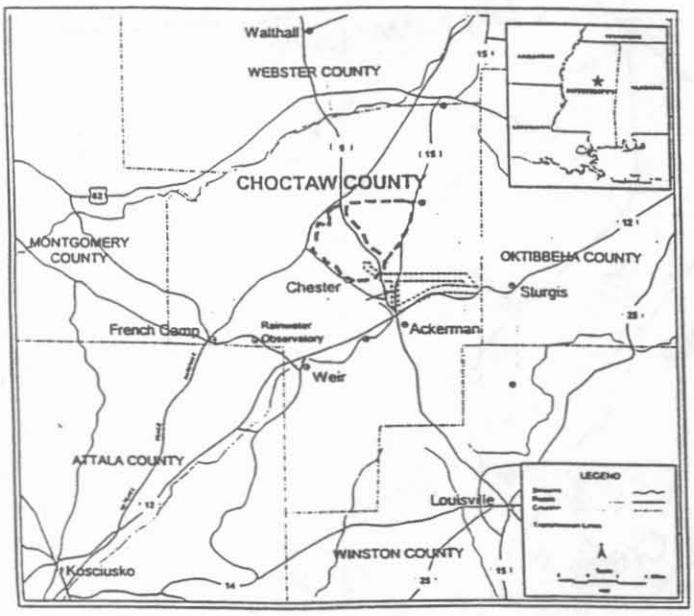

Figure 1: Study Area in Choctaw County, Mississippi (TVA, 1998)

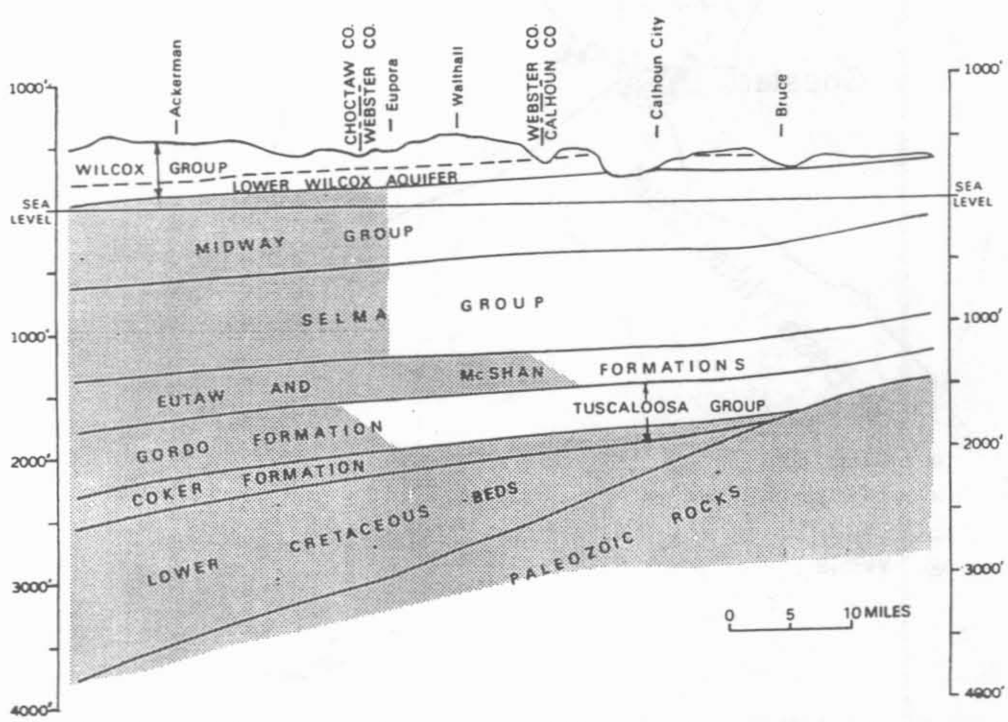

Figure 2: General Dip to the Southwest, of Strata Within the Study Area: Vertical Exaggeration Approximately 40x (Newcombe and Bettandorf, 1973).

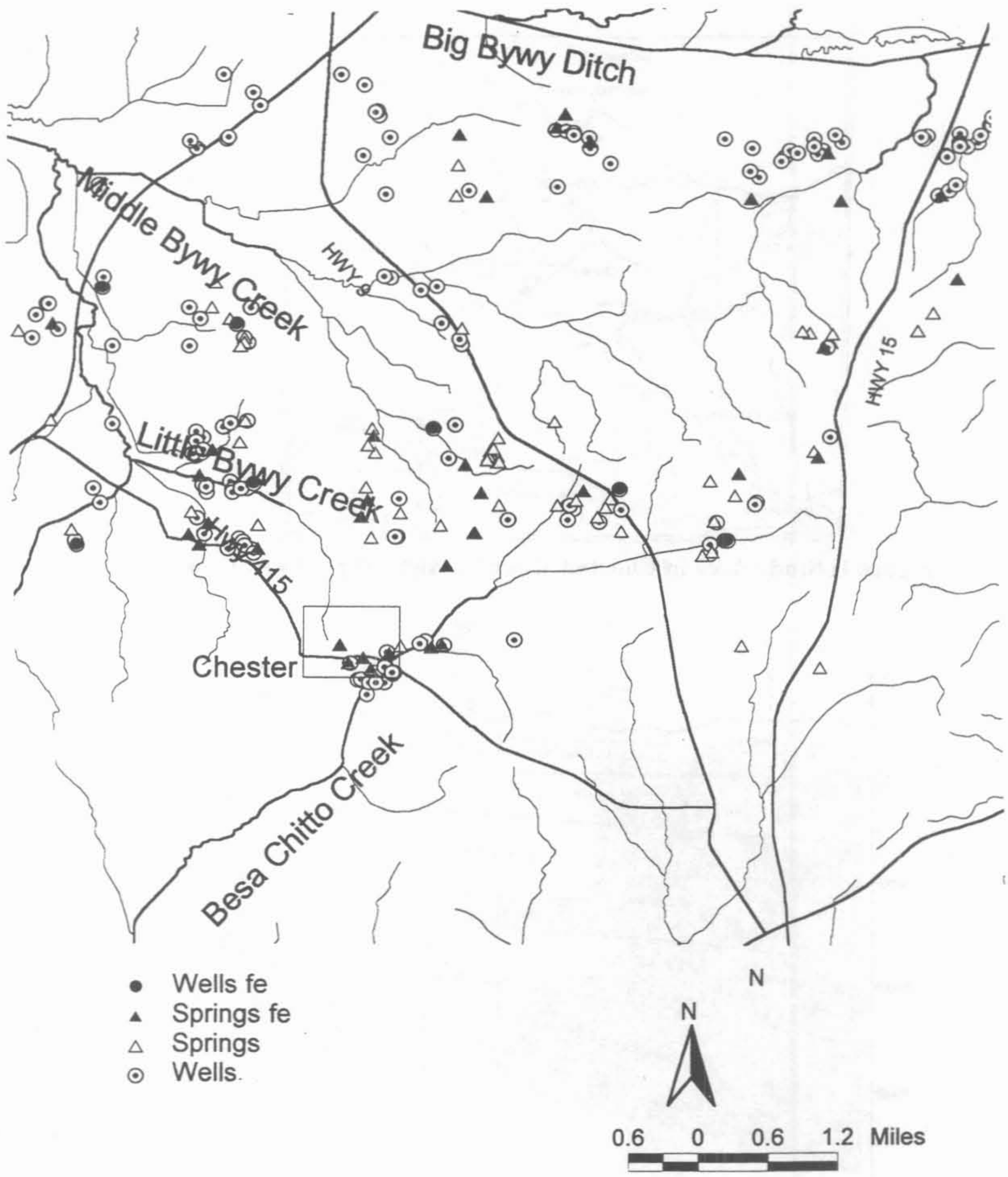

Figure 3: Location of wells, springs, and wells and springs containing greater than 0.30 mg/l Fe.

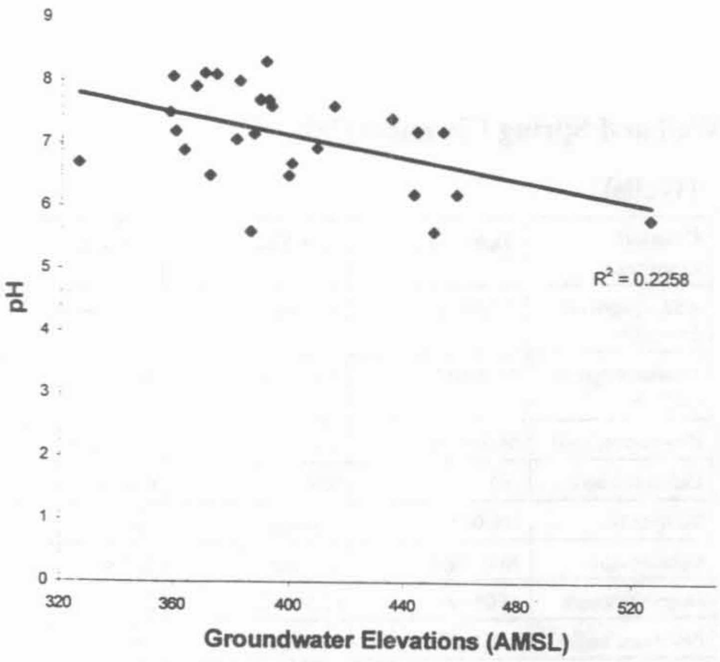

Figure 4: Plot of pH against Water Level Elevation (AMSL)

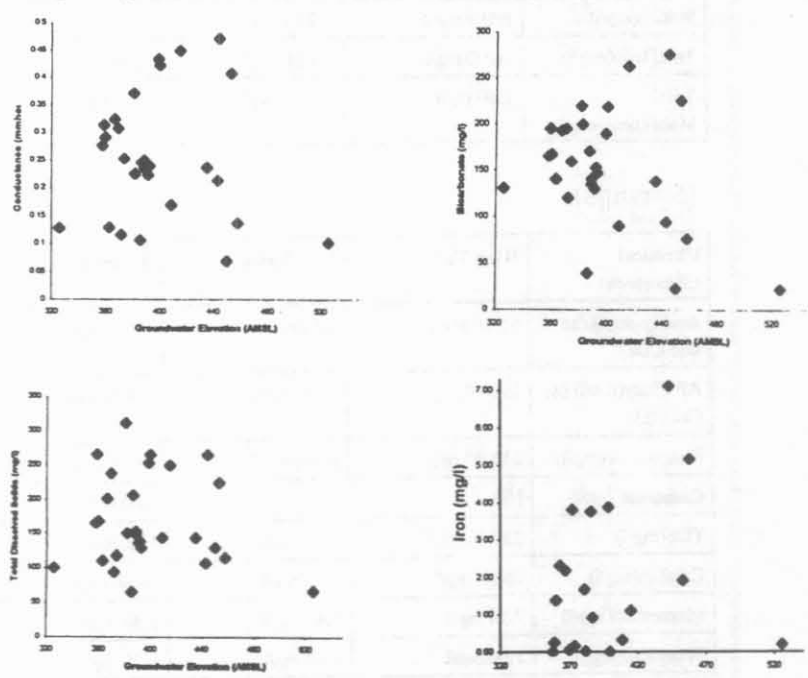

Figure 5: a) plot of Conductance against WL (AMSL) b) plot of Bicarbonate against WL(AMSL) c)plot of TDS against WL (AMSL) d) plot of Fe against WL (AMSL).

Table 1: Well and Spring Chemical Data.

(Wells)

Chemical Constituent	High Value	Low Value	Average
Acidity(mg/l) (as free CO2)	100.00 mg/l	4.00 mg/l	22.10 mg/l
Alkalinity(mg/l) (as CaCO3)	36.00mg/l	4.00 mg/l	9.20 mg/l
Bicarbonate(mg/l)	44.00 mg/l	2.40 mg/l	11.21 mg/l
Carbonate(mg/l)	ND	0.00	0.00,ND
TDS(mg/l)	300.00 mg/l	8.00 mg/l	30.50 mg/l
Calcium(mg/l)	36.00 mg/l	0.20 mg/l	2.40 mg/l
Magnesium(mg/l)	41.00 mg/l	0.25 mg/l	2.11 mg/l
Potassium(mg/l)	2.50 mg/l	0.30 mg/l	0.80 mg/l
Sodium(mg/l)	26.00 mg/l	1.00 mg/l	4.30 mg/l
Chloride(mg/l)	40.0 mg/l	1.2 mg/l	5.3 mg/l
Sulfate(mg/l)	190.0 mg/l	0.25 mg/l	8.50 mg/l
Total Iron(mg/l)	16.00 mg/l	<0.01 mg/l	0.09 mg/l
Total Manganese(mg/l)	1.40 mg/l	<0.01 mg/l	0.09 mg/l

(Springs)

Chemical Constituent	High Value	Low Value	Average
Acidity(mg/l) (as free CO2)	61.00 mg/l	3.00 mg/l	19.00 mg/l
Alkalinity(mg/l) (as CaCO3)	190.00 mg/l	12.00 mg/l	119.00 mg/l
Bicarbonate(mg/l)	232.00 mg/l	15.00 mg/l	145.10 mg/l
Carbonate(mg/l)	ND	0.00	0.00,ND
TDS(mg/l)	230.00 mg/l	67.00 mg/l	148.60 mg/l
Calcium(mg/l)	28.00 mg/l	1.60 mg/l	14.00 mg/l
Magnesium(mg/l)	7.30 mg/l	0.42 mg/l	3.30 mg/l
Potassium(mg/l)	3.80 mg/l	1.10 mg/l	2.30 mg/l
Sodium(mg/l)	76.00 mg/l	3.60 mg/l	38.00 mg/l
Chloride(mg/l)	13.00 mg/l	1.30 mg/l	3.60 mg/l
Sulfate(mg/l)	5.20 mg/l	<0.10 mg/l	2.37 mg/l
Total Iron(mg/l)	2.50 mg/l	0.014 mg/l	0.80 mg/l
Total Manganese(mg/l)	0.27 mg/l	<0.01 mg/l	0.09 mg/l