GROUND WATER PROBLEMS ASSOCIATED WITH A MUNICIPAL LANDFILL IN THE NASHVILLE DOME REGION OF ALABAMA

Kathleen M. Leonard, John A. Gilbert, William F. Kane

Civil Engineering Program
The University of Alabama in Huntsville
Huntsville, AL 35899

Department of Civil Engineering
The University of Tennessee
Knoxville, TN 37996-2010

Pollution of ground water supplies is one of the most pressing environmental concerns facing the nation today. Large numbers of municipalities are located in limestone areas and many of these cities pollute their own drinking water supplies with leachate from municipal landfills and other sources. For example, rapid development and growth in Huntsville, Alabama has forced the city to place some of its solid waste in an abandoned limestone quarry and surrounding environs. The large number of solution cavities and joints inherent in the karst geology of the region, along with the southward flow of ground water towards the Tennessee River, create a potentially hazardous situation.

This paper is a case study of ground water contamination in one area of Huntsville which includes a sanitary landfill situated above a large network of caverns. The extent of the problem is defined based on data gathered from various governmental agencies. Results of this investigation reveal that pollutants from the landfill are entering the ground water at an increasing and variable rate. The overall conclusions of the study are that the required six month testing interval is insufficient to adequately define environmental conditions, and that further studies should be undertaken to completely define and correct existing problems.

Introduction

There have been considerable problems with wastes contaminating ground water. In the past several years, at least one-fourth of all cities relying on ground water for drinking have experienced some contamination. [DeWalle, 1981] Methods for monitoring the most common pollutants such as chloride, nitrate, heavy metals and hydrocarbons, have been established. However, the sources of these pollutants are sometimes difficult to trace, especially when they are distributed throughout a large region. Landfills pose a specific threat to ground water since precipitation may permeate the fill to produce organic wastes and other toxic substances as leachate. The exact composition of this leachate (effluent) varies by geology, temperature, type of debris and location. This problem is even more pronounced in karst areas because solution features allow leachate to flow directly to the aquifer with little or no natural filtration.

Geology of the Huntsville Area

Huntsville, the county seat of Madison County, Alabama, is in the north-central part of the state. It lies 10 miles north of the Tennessee River and approximately 19 miles south of the Tennessee border. The city was settled in the early 1800's by John Hunt, who built a cabin at the top of a bluff above Big Spring. That spring and others nearby provided the area with plentiful water for generations. In fact, prior to 1950, all of the city's water supply was derived from limestone springs and wells which penetrated the underground fracture system in the limestones [Christensen, et al., 1975].

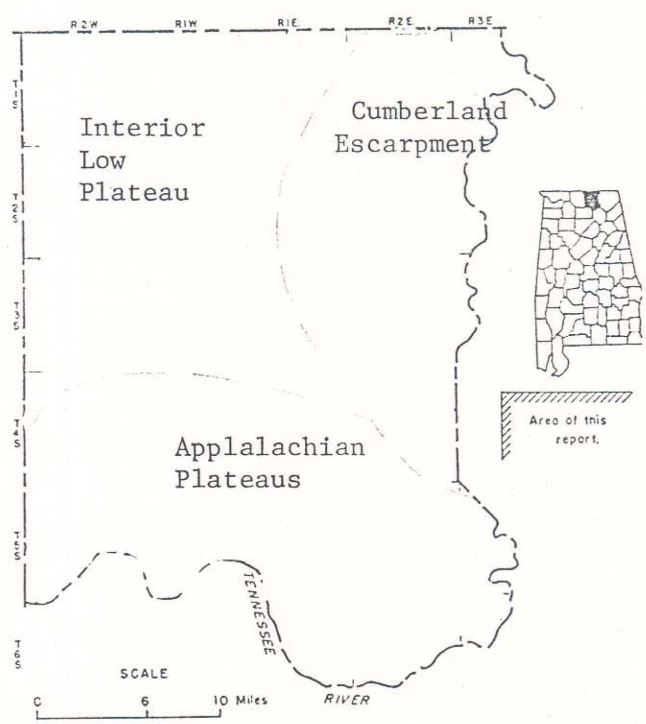

Figure 1. Index map of Madison County

Physiographically, Huntsville is located in Madison County, Alabama on the western edge of the Cumberland Plateau in the Highland Rim section of the Interior Lowland Plateaus [Johnston, 1930] (Figure 1). This corresponds to the southeastern portion of the Nashville dome, and is west of the folded and thrust-faulted Valley and Ridge province. The topography is characterized by a gentle rolling upland with a total relief of about 400 feet. There is a marked topographic break of approximately 900 feet between the Highland Rim and the Cumberland Plateau. Stream drainage is generally towards the Tennessee River to the south.

Paleozoic rocks ranging from late Ordovician to Mississippian outcrop in Madison County (Table 1). From a hydrologic standpoint, the Chattanooga Shale represents the lowest confining strata to which wells are drilled. Huntsville itself, and most of the surrounding area, is located on the karstified Tuscumbia limestone which provides the plentiful ground water supply as well as the construction and evironmental problems associated with such areas. Figure 2 is a diagram of the stratigraphy of the Huntsville area as you ascend Monte Sano, the highest point in the city.

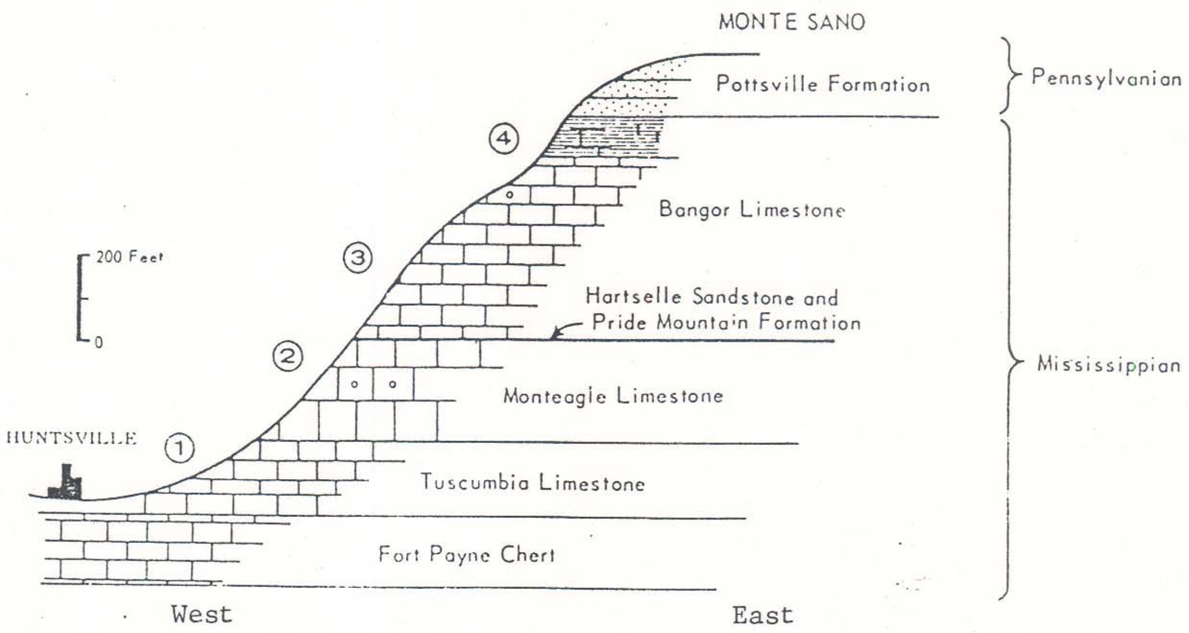

Figure 2. Map of exposed geologic layers in Huntsville area (LaMoreaux, 1975)

TABLE 1
Major Lithological Units Found in Madison County, Alabama (LaMoreax, 1975)

PENNSYLVANIAN

POTTSVILLE FORMATION: Light-gray and dark-gray crossbedded sandstone and light-gray, pale yelowish-brown and medium-gray shale with thin beds of coal. Caps ridges in eastern part of county comprising the Cumberland Plateau. Maximum thickness is approximately 200 feet. Fossiliferous throughout.

MISSISSIPPIAN

BANGOR LIMESTONE: Light-to medium-gray massive beds of fossilerous, crystalline and oolitic limestone. Thin beds of of grayish-green and moderate-red shale and light-gray dolomitic limestone are found in the uppper part. Found in southern and eastern parts of the county. Thickness ranges from 400-500 feet.

HARTSELLE SANDSTONE: Light-gray and very pale orange thin- to thick-bedded sandstone. Some cross-bedding. Interlayers of grayish-green and light-gray fossiliferous shale and occasional beds of sandy fossiliferous limestone. Thickness ranges from 0-80 feet.

PRIDE MOUNTAIN FORMATION: Light-greenish-gray and pale yellowish-brown fossiliferous shale with thin interbeds of clayey fossilerous limestone. Thickness ranges from 10 - 22 feet where exposed.

MONTEAGLE LIMESTONE: Light-gray massive and thin beds of fossilierous crystalline and oolitic limestone with thin interbeds of greenish-gray fossilerous shale. Some medium dark-gray chert. Occurs on hillsides and in valley floors in the southern part of county and on slopes of higher hills in the central and eastern sections. Thickness ranges from 200-220 feet.

TUSCUMBIA LIMESTONE: Light-gray to light-brownish-gray thin- to thick-bedded fossiliferous limestone containing abundant chert lenses and nodules. Thickness averages 150 feet.

FORT PAYNE CHERT: Very light gray to light-gray fossiliferous limestone, siliceous and dolmitic limestone and dolomite with thin beds of bluish-gray dense nodular chert. Averages from 155-185 feet thich and includes Maury Formation (shale).

DEVONIAN

CHATTANOOGA SHALE: Dark-gray to black fossiliferous, thinly bedded, partly fissile, partly pyritic shale with a discontinuous thin bed of medium gray fine grained sandstone at base. Locally 10 feet thick in outcrop.

SILURIAN

BRASSFIELD LIMESTONE: Medium-light gray cherty fossiliferous partly glauconitic limestone, dolomitic limestone, shale, and calcareous sandstone. Thickness varies from 10-40 feet.

ORDOVICIAN

SEQUATCHIE FORMATION: Moderate pink, moderate-red, medium-gray, and grayish-green coarse-grained fossiliferous limestone containing minor amounts of moderate-red to grayish-green shale, glauconite, hematit, pyrite, and phosphate. Exposed only in northern county and ranges from 0-45 feet thick.

Structurally, the regional dip displays the influence of the Nashville Dome. Except for minor folding, the strata dip very gently to the southeast at about 20 feet per mile. There is a north-trending synclinal trough about 2 miles wide with 90 feet of relief beneath the city [Malmberg and Downing, 1957]. Ground water movement is influenced by the underlying structure and moves down through the limestone by way of solution channels along joints and bedding planes. Upon reaching the Chattanooga shale, it is blocked from further downward movement and flows laterally along the regional dip to the south and southeast. The previously mentioned syncline also controls drainage as five large springs discharge along its axis. In addition, test wells drilled along the axis and flanks of the syncline have been very successful in encountering solution cavities [Malmberg and Downing, 1957].

Stringfield et al. [1974] suggest that karstification in the Nashville dome has been an almost continuous process since the Mesozoic, when erosion began removing clastic material and exposing the underlying limestone. Solution cavities are enlarged by water percolating through the residual soil in the level areas. These cavities are generally largest near to the surface and are plainly visible in roadcuts throughout the area. Along the flanks of the Cumberland Plateau, in east Huntsville, air-filled caves are often found beneath the clastic Pottsville cap rock.

Landfill Site

A sanitary landfill operation was begun in 1962 for the Huntsville area when countywide garbage collection began. Prior to this time, the locale was used as the city dump. The site has grown from 70 acres in 1972 to the present size of 240 acres. It is divided into 2 sections; trash and garbage fills. Trash is categorized as inert materials such as roofing, tree limbs, lumber, etc. This section is located in an old quarry which is at, or barely above, the water table level depending on the season. (See Figure 3) The garbage fill contains putrescible articles such as food and animal waste. This section is covered daily with approximately 6 inches of soil. Trash is covered and compacted on a weekly basis.

A data collection program was started in 1972 by the Geological Survey of Alabama to monitor surface and ground water. The locations of the landfill and four observation wells are shown in Figure 3. The land adjacent to this site on the south and west is part of the Redstone Arsenal. The federal government holds jurisdiction over this property; consequently, data is difficult to obtain.

Another study was conducted in Huntsville in 1972-1974 by the United States Geological Survey. In this study, wells and surface water were sampled for ion concentrations at different locations within the city. It was found that directly under the landfill site chloride type water appeared indicating that leachate was entering ground water at that time [Mustafa and Lloyd, 1977].

There is a gentle slope towards Huntsville Spring Branch to the west of the landfill. Consequently, the surface runoff for the garbage section of the landfill is towards Big Spring, which empties into the Tennessee River. The quarry retains precipitation since it is a topographic low.

Ground water movement is predominantly to the south and the Tennessee River. The general direction of this flow is shown in Figure 3. But, local variations exist since water moves through an intricate system of fracture and solution openings.

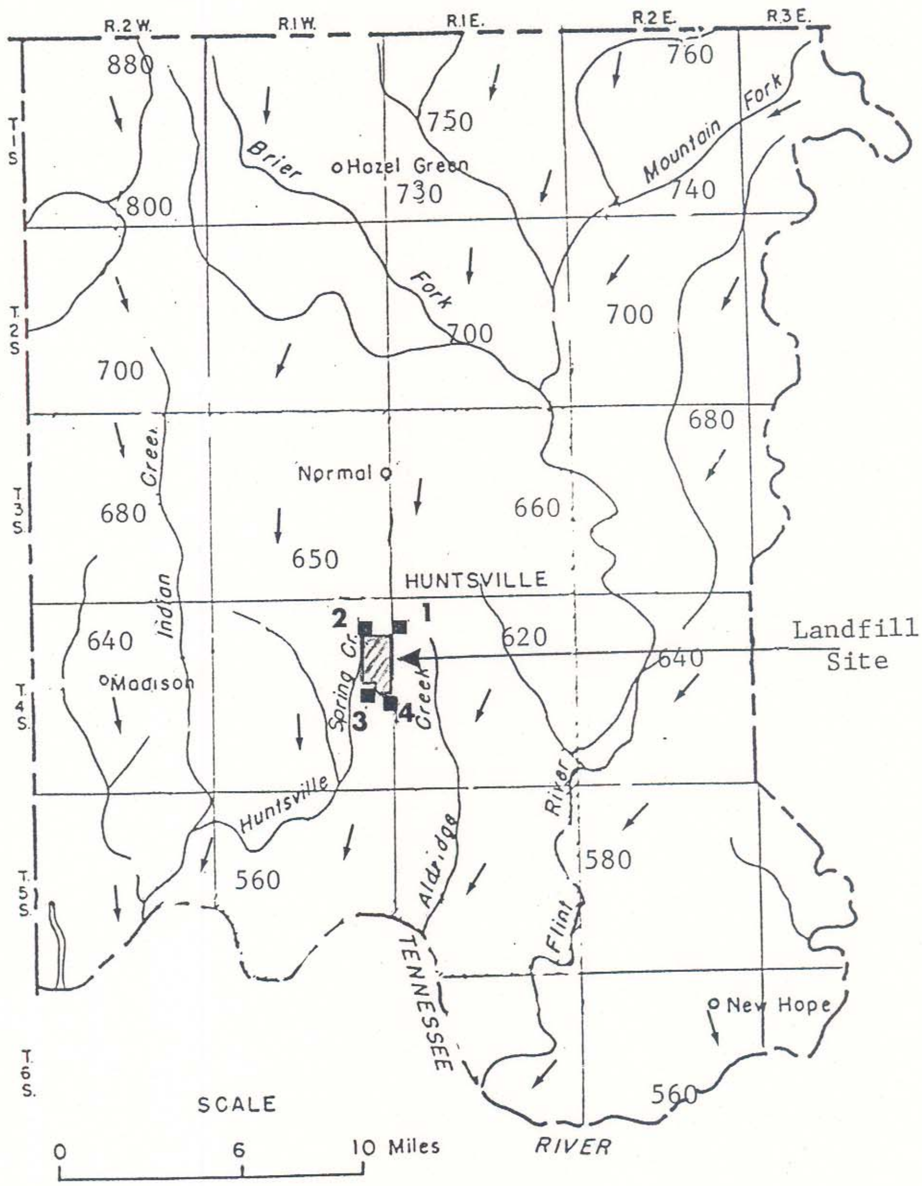

Figure 3. Direction of ground water flow, water table heights and location of monitoring wells

Data Analysis

The Alabama Department of Environmental Management (ADEM) follows the EPA guidelines for monitoring sanitary landfills at 6 month intervals. This involves the removal of a sample of groundwater for chemical analysis in a laboratory. The sampling is handled by the City of Huntsville for its municipal fill, and the results are sent to ADEM. Data from 4 monitoring wells adjacent to the Huntsville landfill site, for the period 1981 through 1985 is given in Table 2. In addition, public drinking wells are monitored at 4 year intervals, but since the wells were not critically located, the data was not analyzed in the present study.

TABLE 2
Huntsville Landfill Monitoring Well Data

Date	pH	Conductivity	Chloride	COD	Phenol	Iron
WELL NO 1						
6/81	8.0	0.0	0.0	0.0	0.00	2.95
9/81	7.5	340.0	1.0	10.7	0.03	0.91
5/82	6.9	330.0	5.0	5.0	0.02	0.10
9/82	6.3	210.0	3.5	5.0	0.05	0.55
3/83	6.1	160.0	3.9	5.0	0.05	0.43
9/83	6.3	155.0	3.4	10.4	0.05	0.52
3/84	6.3	155.0	2.9	10.5	0.05	0.17
9/84	6.1	200.0	3.7	7.1	0.05	1.20
3/85	6.1	230.0	3.8	1.1	0.05	0.15
9/85	5.6	130.0	3.4	54.7	0.00	0.20
WELL NO 2						
6/81	8.0	0.0	0.0	0.0	0.0o	7.52
9/81	6.9	320.0	6.5	10.4	0.02	0.36
5/82	5.8	290.0	10.0	2.0	0.55	0.10
9/82	6.4	383.0	4.7	5.0	0.05	0.50
3/83	5.9	320.0	4.4	5.0	0.05	0.06
9/83	6.0	295.0	5.1	13.8	0.05	0.15
3/84	5.9	276.0	5.7	20.0	0.05	0.46
9/84	5.9	460.0	6.8	8.3	0.05	1.03
3/85	5.7	500.0	5.7	1.1	0.05	0.57
9/85	5.3	220.0	6.0	18.2	0.00	0.13
WELL NO 3						
6/81	7.9	0.0	0.0	0.0	0.00	4.00
9/81	6.9	170.0	5.0	30.0	0.02	0.12
5/82	7.1	200.0	6.0	2.0	0.02	0.10
9/82	6.3	213.0	6.7	5.0	0.05	0.78
3/83	6.5	290.0	9.7	5.0	0.05	0.10
9/83	6.7	275.0	13.6	13.2	0.05	0.42
3/84	6.6	276.0	17.2	5.0	0.05	0.17
9/84	6.6	440.0	15.3	4.8	0.05	0.92
3/85	6.4	575.0	24.9	9.0	0.26	1.42
9/85	5.9	320.0	30.0	18.2	0.00	0.45
WELL NO 4						
6/81	8.1	0.0	0.0	0.0	0.00	3.44
9/81	6.6	100.0	1.0	5.6	0.02	0.59
5/82	6.3	90.0	2.0	2.0	0.02	0.03
9/82	6.1	130.0	2.1	5.0	0.05	1.70
3/83	6.4	150.0	5.8	5.0	0.05	0.08
9/83	6.6	194.0	6.5	17.3	0.05	0.77
3/84	6.5	155.0	9.5	5.0	0.05	0.20
9/84	6.4	225.0	6.5	2.4	0.05	0.29
3/85	6.2	290.0	14.4	9.0	0.05	0.10
9.85	6.0	240.0	14.0	54.7	0.00	0.21

Data in Table 2 was statistically analyzed. The plots for chemical oxygen demand (COD) in Figure 4, show an unusually large increase for the last reading at 2 well locations. If these readings are correct, this indicates that a dramatic increase in organic pollutants has occurred.

Chloride is an indicator of both chemical and organic pollution in groundwater. Median chloride values of 2.7 mg/l were recorded for wells in this region [LaMoreaux, 1972]. More recent data, plotted in Figure 5, shows an alarming increase in chloride levels. The latest samples, taken in the fall of 1985, show an increase of 500% this amount for the two wells south of the landfill, monitoring well numbers three and four. The fact that this trend is increasing with time at these locations indicates that some sort of leachate is entering the ground water and moving in a southerly direction.

pH is a measure of the concentration of free hydrogen ion in water. Values were plotted for each location versus time in Figure 6. The data shows a specific downward trend in all four wells, which is indicative of increasing acidity. However, since all locations are involved, the acid source is not the landfill leachate.

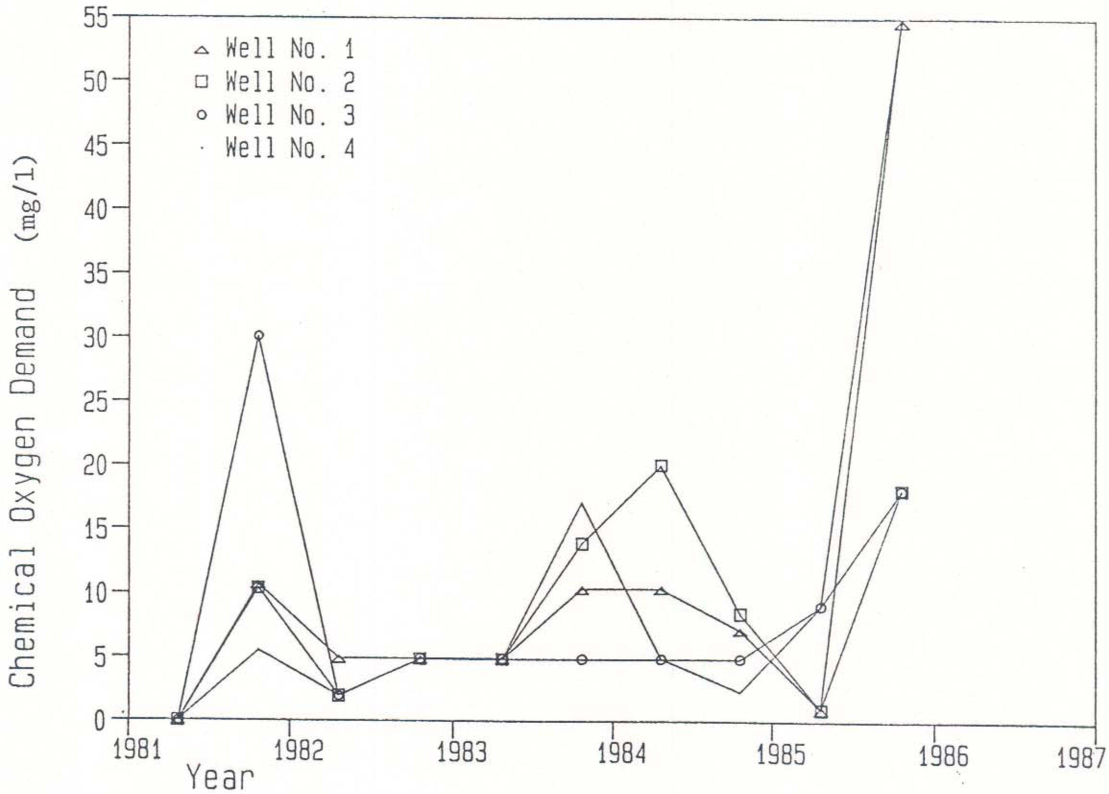

Figure 4. Plots of chemical oxygen demand measured at monitoring wells

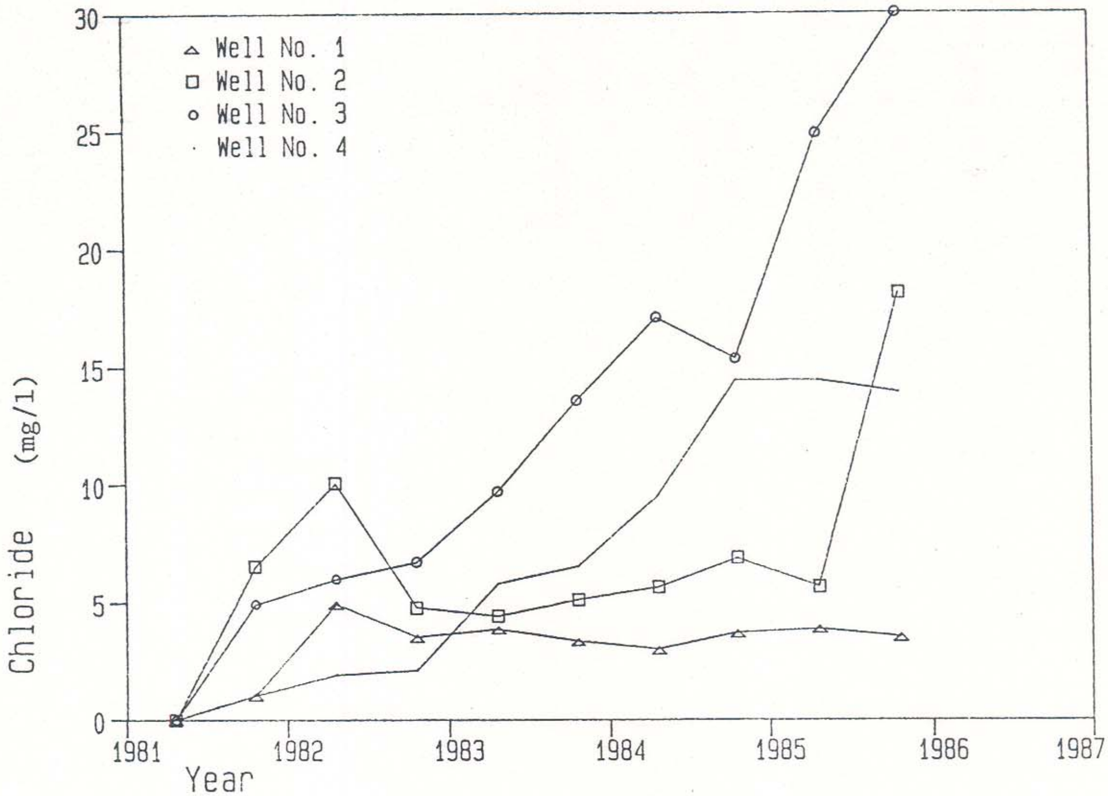

Figure 5. Plots of chloride ion concentrations measured at monitoring wells

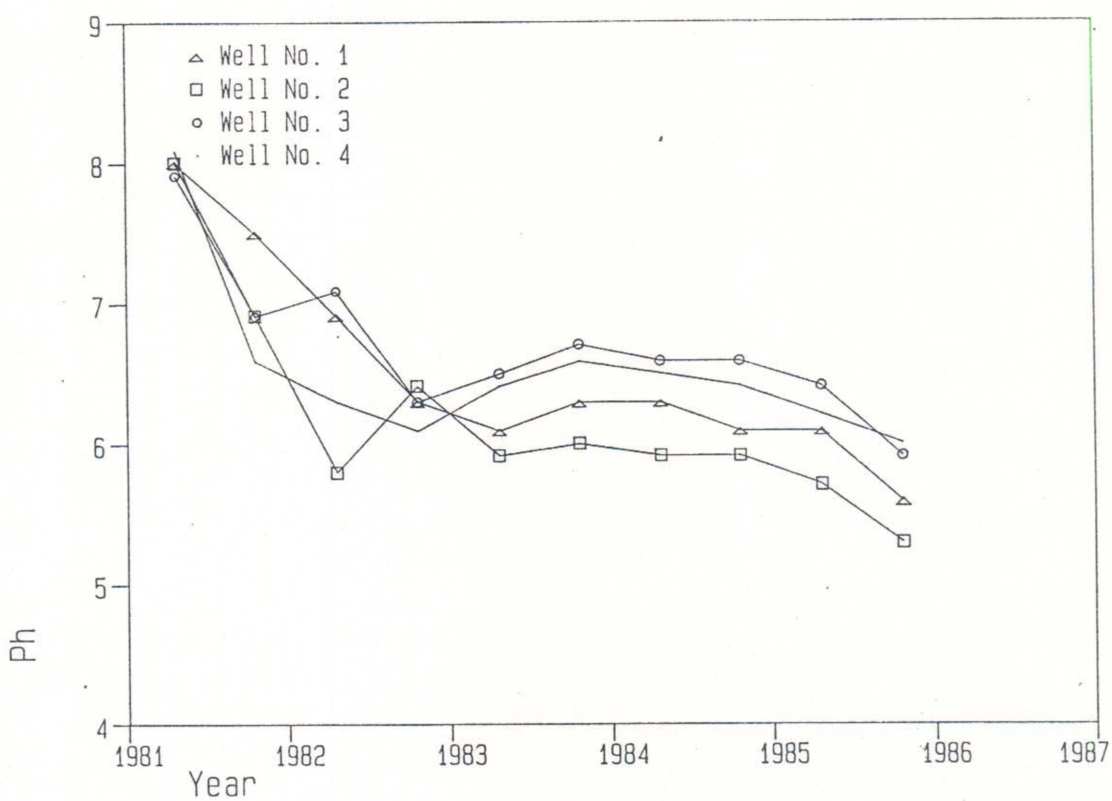

Figure 6. Plots of pH levels measured at monitoring wells

Numerical correlation techniques were used to analyze relationships between precipitation and values of chloride and COD, to determine the lag time for precipitation to affect the monitoring wells. The large sampling interval, coupled with the small sample population, precludes drawing any specific inferences.

Spatial correlations were generated to determine the interrelationship between the wells. Monitoring well number one was used as the relative location for the other three wells. The computer output is given in Appendix 1. It is apparent that the strongest correlation is for a zero lag time and for wells one to two. This is logical since they are in close proximity. The high correlation calculated for COD in wells one to four is apparent in the graphs of COD shown in Figure 4. This may be related to the recent filling of the region north of the landfill to make way for an industrial park.

Conclusion

The data for the Huntsville landfill exhibits an upward trend in chloride levels and COD. In addition, pH has been shown to be decreasing with time. These findings indicate that pollution is reaching the aquifer to the south of the landfill site. The problem is compounded by the the fact that the Huntsville landfill is situated in a karst area containing a large interconnected network of solution features. The section located in an abandoned quarry acts as a trap for surface runoff. The other section directs runoff towards nearby Spring Branch. This water makes its way to the Tennessee River which supplies potable water to Huntsville and other cities downstream.

The testing interval required by the EPA (6 months) for groundwater monitoring near Huntsville's landfill does not appear to be sufficient for this karst area. The large fluctuations in amounts of pollutants, coupled with the fact that a large amount of drinking water comes from wells in this area, underlines the need for more field research. If this site is to be continued to be used for landfill purposes, the use of a clay liner in the quarry, careful leveling of backfill to control runoff, and more frequent monitoring of wells should be considered.

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Biographical Sketches

KATHLEEN M. LEONARD holds a lecturer position in the civil engineering program at the University of Alabama in Huntsville, where she is also working on her doctorate. Ms. Leonard received her B.S. and M.S. degrees from the University of Wisconsin/ Milwaukee in the field of water resource engineering. Her past research work has been in numerical modeling of both surface and ground water systems. Present interest is in the field of remote sensing of ground water contamination.

Civil Engineering Program
University of Alabama in Huntsville
Huntsville, AL 35803

JOHN A. GILBERT is currently a professor of mechanical engineering at the University of Alabama in Huntsville. He received B.S. (aerospace) and M.S. (applied mechanics) degrees from the Polytechnic Institute of Brooklyn. He holds a Ph.D. in applied mechanics from the Illinois Institute of Technology. Professor Gilbert specializes in experimental stress analysis and applied optics, with principal expertise concentrated in the areas of remote sensing through fiber optic systems.

Department of Mechanical Engineering
University of Alabama in Huntsville
Huntsville, AL 35803

WILLIAM F. KANE is currently an assistant professor of civil engineering at the University of Tennessee in Knoxville. He holds a B.S. degree in geology from James Madison University, as well as a M.S. and Ph.D. from Virginia Polytechnic Institute and State University in civil engineering. Professor Kane has done research in denudation rates and limestone cavern genesis in addition to examining the geomechanical aspects of coal mine ground control.

Department of Civil Engineering
University of Tennessee in Knoxville
Knoxville, TN 37996-2010

APPENDIX
Spatial Correlations

SPATIAL CORRELATIONS FOR COD

LAG TIME (MONTHS)	WELL NUMBER 1 TO 2	1 TO 3	1 TO 4
0	.66	.47	.96
12	-.31	.00	.06
24	-.06	-.15	-.08
36	.51	-.21	-.08
48	.33	.22	.19

SPATIAL CORRELATIONS FOR CHLORIDE

LAG TIME (MONTHS)	WELL NUMBER 1 TO 2	1 TO 3	1 TO 4
0	.71	.43	.41
12	.47	.09	.04
24	-.19	-.25	-.24
36	-.02	-.11	-.10
48	-.20	-.15	-.13