QUALITY OF WATER AND NATURE OF CONTAMINATION OF SHALLOW AQUIFERS IN THE GULF COASTAL PLAIN OF LOUISIANA AND MISSISSIPPI

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INTRODUCTION

The shallow aquifers of the Gulf Coastal Plain, represented by study areas in Louisiana and Mississippi, are underlain by southerly dipping strata of Pleistocene, Pliocene, and Miocene age. Although the shallow water-table aquifers (200 ft or less) are not used extensively, a trend in increased water use for domestic and irrigation water supplies is expected to result in increased development of these aquifers. The deeper confined sand aquifers are the major sources of water for public and industrial supplies.

A high potential for recharge into the shallow ground-water system through the surficial deposits in the study area is likely, owing to the hydraulic character of the deposits and the large annual rainfall in the sub- tropical southeastern United States. Because of this, the shallow aquifer systems of the Gulf Coastal Plain are particularly susceptible to contamination from some types of land uses.

This report is a preliminary assessment of data collected from October 1984 to May 1985 on the quality of ground water in shallow aquifers in study areas in Louisiana and Mississippi (fig. 1). The study was conducted as part of the U.S. Geological Survey Toxic Waste-Ground-Water Contamination program. Contaminants in shallow ground water are explained in terms of land-use activities. The results of the study provide data that are applicable to similar land-use areas of the Gulf Coastal Plain. A comprehensive study of the aquifer systems is needed to better understand the effects of land use on chemical quality of the shallow ground water.

Chemical-quality and water-level data were collected from wells constructed during the study and from existing wells at 16 sites in Louisiana and 18 sites in Mississippi (fig. 2). The wells are located at sites that are uniformly distributed within the study area and that offer the greatest potential to provide data that relates to water movement through subsurface materials in a particular type of land-use area.

Geohydrologic information was obtained from on-going studies, published reports, and the U.S. Geological Survey data base. This information was used to select data-collection sites and to determine the movement of shallow ground water.

Purpose and Scope

The purpose of the reconnaissance study was to make a preliminary assessment of the ambient water quality and changes in chemical quality of water that occur in shallow aquifers as a result of three types of land-use practices that are typical of the Gulf Coastal Plain. Emphasis was placed on obtaining data to determine the presence or absence of contaminants in shallow ground water.

Location

The study includes about 175 mi² in Louisiana and 150 mi² in Mississippi (fig. 1). The Louisiana study area includes the northern part of East Baton Rouge Parish and extends about 25 mi north into East Feliciana Parish. This area is known to be contaminated locally by surface disposal of hazardous wastes. The Mississippi area, mostly undeveloped, extends from about 6 mi north of the shore line of the Mississippi Gulf Coast to the Stone County line about 20 mi north of Gulfport.

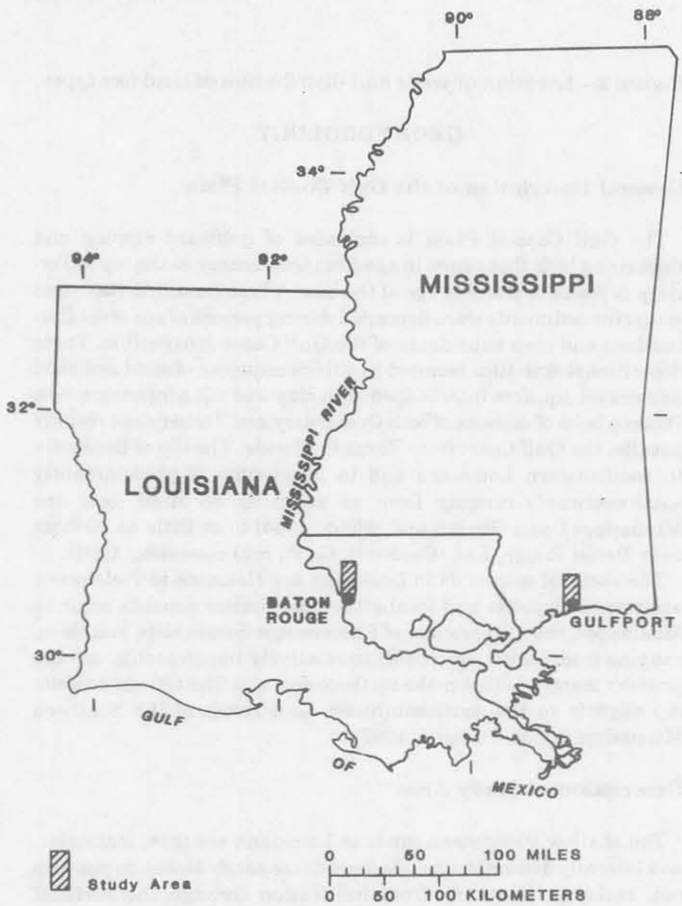

Figure 1.– Location of study areas

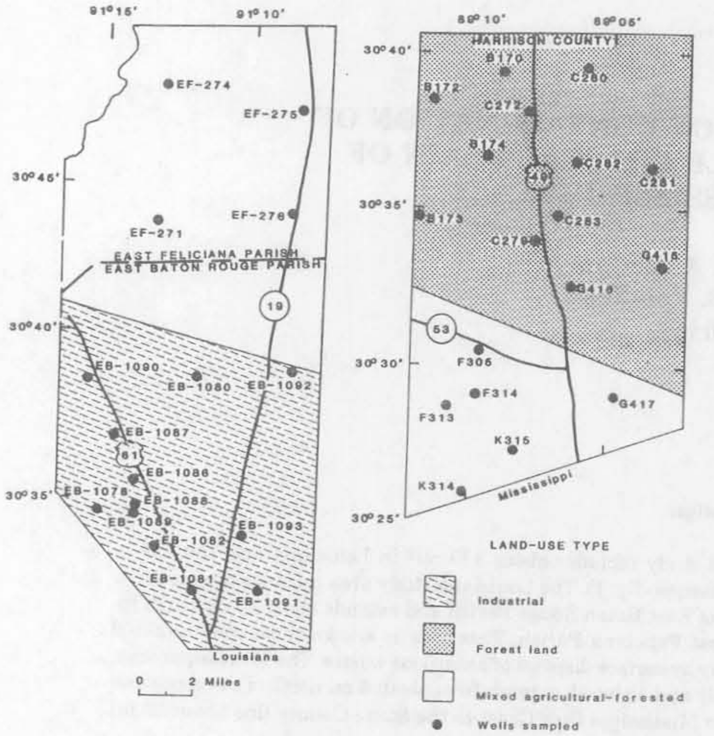

Figure 2.–Location of wells and distribution of land-use types.

GEOHYDROLOGY

General Description of the Gulf Coastal Plain

The Gulf Coastal Plain is composed of gulfward dipping and thickening beds that range in age from Quaternary at the top to Tertiary deposits of Miocene age at the base. These fluvial, deltaic, and estuarine sediments were deposited during periods of sea level fluctuations and slow subsidence of the Gulf Coast geosyncline. These depositional activities resulted in a thick sequence of sand and sand and gravel aquifers interbedded with clay and silt confining zones. Outcrop belts of deposits of both Quaternary and Tertiary age roughly parallel the Gulf Coast from Texas to Florida. The dip of the strata in southeastern Louisiana and in Mississippi is predominantly southwestward, ranging from as much as 85 ft/mi near the Mississippi Coast (Brown and others, 1944) to as little as 20 ft/mi near Baton Rouge, La., (Cardwell, G. T., oral commun., 1984).

The surficial materials in Louisiana are Holocene to Pleistocene age terrace deposits and local alluvium. Similar deposits occur in Mississippi, though some are of Pliocene age. Sands, silts, and clays, ranging from highly permeable to relatively impermeable, are the primary materials that make up these deposits. The terrace deposits dip slightly to the south-southwest as a result of the Southern Mississippi uplift (Parsons, 1967).

Description of Study Area

The shallow Pleistocene sands in Louisiana are thin, lenticular, and laterally discontinuous. Because these sandy lenses do not crop out, recharge is mainly from infiltration through the surficial deposits. The shallow sands may reach a thickness of nearly 80 ft and a depth of approximately 120 ft below land surface. The potentiometric surface of the shallow Pleistocene sands shows the predominant direction of ground-water movement to be south- southwest toward the Mississippi River. The "400-foot" and "600-foot" sands of the Baton Rouge area underlie the shallow Pleistocene sands. These sands merge north of the industrial land-use area near Zachary, La., to form one hydrologic unit. In East Feliciana Parish, this unit is known as the Upland Terrace aquifer. The "400-foot" sand consists of fine to very fine sand. Although materials in the "400-foot" sand are fine grained, permeabilities are relatively high because the materials are well sorted and uniform in size. Transmissivities in the "400-foot" sand range from about 4,000 to about 10,000 ft^2/d. As with the shallow Pleistocene Sands, the predominant flow direction is south-southwest toward the Mississippi River.

In some places in the industrial area, the shallow Pleistocene sands have been found to be vertically connected to the underlying "400-foot" sand. This presents the potential for downward migration of contaminants. Using an average of porosity and head differences between the shallow Pleistocene sands and the "400-foot" sand, the time of travel, due to vertical movement of water, is estimated to be 200 years. Locally, this downward movement may be more rapid due to head differences between the shallow Pleistocene sands and the "400-foot" sand, where water levels in the "400-foot" sand have been lowered by pumping in the industrial area to the south.

In Mississippi, the Citronelle Formation overlies the Graham Ferry Formation. The Citronelle has been reworked by erosive forces and is the source of many of the alluvial deposits in the vicinity of the larger streams. Isolated remnants of the original Citronelle Formation remain as ridges throughout the study area. The sands of the Citronelle are locally very thin and discontinuous, but may reach thicknesses of up to 100 ft in these ridge crests. In areas where the Citronelle crops out, it is identified by the brick-red color.

Rates and direction of ground-water movement in the Citronelle Formation are difficult to ascertain due to its limited distribution. The transmissivity of the formation is significantly higher than that of the Graham Ferry Formation; values are reported as high as 18,000 ft^2/d with the average being around 10,000 ft^2/d (Newcome, 1971). Downward percolation and lateral migration of the water is relatively rapid, and the Citronelle is an important source of streamflow and recharge to underlying, hydraulically connected aquifers. However, its limited areal distribution prevents large- scale development of the Citronelle as a water source.

The Graham Ferry Formation, the oldest of the shallow deposits, crops out over most of the study area in Mississippi. It consists predominantly of a series of deltaic sediments that range in thickness from about 200 ft to nearly 800 ft in the southern part of the study area. The sands of the Graham Ferry Formation are lenticular, varying in both bed thickness and grain size over short distances. The Graham Ferry does not contain consistently mappable sand beds. Discrete sand lenses are surrounded by silts and clays, resulting in a poorly defined hydraulic connection with each other and to sources of recharge. This condition has resulted in a network of water-bearing sands that differ in areal extent and depth. Most of the shallow water wells in the Mississippi study area are developed in the Graham Ferry.

Rates of ground-water movement in the Graham Ferry are quite variable due to rapid changes in lithology over short distances. The potentiometric surface indicates that the general direction of ground-water flow is to the southeast; however, ground-water movement locally toward streams and rivers in shallow (less than 200 ft) parts of the Graham Ferry is significant.

Transmissivities determined by Newcome (1971) from pumping tests were as low as 1,800 ft^2/d in some parts of the formation and as high as 6,100 ft^2/d in other parts. The average transmissivity of the Graham Ferry was about 3,500 ft^2/d. Increased pumpage in the coastal areas of Gulfport and Biloxi have resulted in local cones of depression within the Graham Ferry. At present, the effect on areas surrounding these cities is believed to be minimal.

The hydrology of the shallow sediments in both study areas is complex and poorly defined. Very little work has been done on these deposits due, in large part, to the limited use of the deposits as a ground-water source. Observations of water-level responses to rainfall during this study lead to the conclusion that the major source of recharge to the shallow aquifers is by vertical leakage through the surficial deposits. It was concluded that water quality in the shallow aquifers is young enough to reflect land-use activities in the past 50 years.

LAND USE

The land-use classifications developed for this reconnaissance study generally are applicable for the past 50 years; however, more detailed analyses of land-use activities will require more intensive investigations. Land-use information for the study was compiled from aerial photographs, land-use maps, and on-site mapping.

Land use is divided into seven classifications by the U.S. Geological Survey (1979). In this study, the level I land-use classifications were condensed or combined into industrial, mixed agricultural-forested, and forest to represent the land-use activities typical of the study area. Land use in the study area is about 24 percent industrial, 41 percent mixed agricultural-forested and 35 percent forest land. A fairly equal distribution of well sites are located in each land-use area to provide representative chemical- quality data. Twelve wells are located in the industrial area, 10 wells in the mixed agricultural-forested land, and 12 wells in the forest land (fig. 2).

Industrial land use is confined to the Louisiana study area. The major industries produce chemical, petrochemical, oil and gas, and wood and paper products. Most industrial growth within the area has been in the last 50 years. Several landfill and hazardous waste sites located in the study area are situated in areas where downward movement of water from shallow Pleistocene deposits to deeper aquifers is possible. The location of areas of potential ground-water contamination has been identified by the Louisiana Department of Environmental Quality (written commun., 1985).

The mixed agricultural-forested land-use areas are similar in Louisiana and Mississippi and typify much of land use in the Gulf Coastal Plain. There are very few large farms in the area and less than half of the mixed land-use area is under cultivation. The trend in farming is toward raising beef and dairy cattle, and much of the open land is devoted to pasture and the growing of hay. A small amount of land is devoted to row crops, truck farms, and orchards. The use of agricultural chemicals is believed to be proportionately low and is not an important source for potential ground-water contamination; however, local problems may occur.

The forest land-use area in Mississippi is typical of many parts of the Gulf Coastal Plain. Forestry and wood products are important to the economy of the area. A large part of the forest land is devoted to tree farming. These forested areas are predominantly conifers. A limited amount of pesticides is used in forests for insect control and along roadsides for weed control.

RELATIONSHIP BETWEEN LAND USE AND GROUND-WATER QUALITY

Water samples were analyzed for common constituents, nutrients, trace elements, and organic compounds. In most cases, the presence of organic compounds was determined using gas chromographic/flame ionization detector (GC/FID) method of analysis. GC/FID scans can be used to screen samples for the presence of organics that can be positively identified by gas chromotographic/mass spectrometric (GC/MS) techniques. GC/FID scans are more informative than dissolved organic carbon (DOC) analyses, but less informative than GC/MS. Where peaks on the GC/FID were of sufficient magnitude, they were identified using GC/MS.

Non-parametric statistical procedures were used to test the hypothesis that a relationship exists between land use and chemical quality of shallow aquifers. As is often the case, the distribution of the concentrations of most of the constituents analyzed was not normal, and it was necessary to use the Kruskal-Wallis method (Conover, 1981) to test for variance in these constituents. In most instances, these non-normal data were transformed according to rank (the lowest value being assigned a rank of 1 and the highest value being assigned a rank of N, where N is the total number of samples). Differences in concentration of selected constituents were tested at the 0.05 significance level (P=0.05). A P-value of <0.05 indicates that there is a less than five percent chance of being wrong if it is assumed that there is a significant difference between land-use types with respect to a given chemical constituent. Only those chemical constituents that may show a relationship between land use and chemical quality of shallow ground water are discussed here.

Chemical quality of water in shallow aquifers in the industrial land-use area is significantly different from that in aquifers in the mixed agricultural-forested and forest land. Concentrations of chloride, barium, and perhaps manganese and DOC indicate that land use has had an effect on chemical quality in the industrial area.

Dissolved-solids concentrations, (sum of dissolved constituents) exceeded 300 milligrams per liter (mg/L) in water from 8 of 12 wells in the industrial land-use area. The highest concentrations were 1,300 and 1,600 mg/L in water from wells EB-1090 and EB- 1087, respectively. The median dissolved-solids concentration in water from the industrial land-use area was 370 mg/L, compared to 70 and 32 mg/L for water from the mixed agricultural-forested and forest lands, respectively. Bicarbonate concentrations were also proportionately higher in water in the industrial area, perhaps indicating that the increase in dissolved-solids may be naturally occurring. This is most likely the result of differences in chemical quality due to formation lithology. The same can be said for pH, which is higher in water in the industrial area. Median pH values were 6.6, 5.4, and 5.4 units in the industrial, mixed agricultural-forested, and forest land-use areas, respectively.

Chloride concentrations are significantly different from one another in all three land-use areas. Median chloride concentrations are 25, 6.4, and 5.2 mg/L for water in the industrial, mixed agricultural-forested, and forest land-use areas, respectively. Water from three wells in the industrial area had chloride concentrations of 250, 660, and 900 mg/L. This suggests contamination, either by oil-field brines or petrochemical activities. The difference observed between the mixed agricultural-forested and forest lands is somewhat misleading because water from four wells in the mixed land-use area had substantially higher chlorides . Two of the wells are located near the coastline and the higher chloride levels might be attributed to salt spray transported inland as precipitation by prevailing winds. Barium concentrations in water in the industrial area are much higher than in the other land-use areas. Mean concentrations of barium were 300, 19, and 38 μg/L for the industrial, mixed agricultural-forested, and forest land-use areas, respectively. This difference cannot be attributed to formation differences and may indicate some type of land-use effect in the industrial area. There has been a significant amount of oil exploration, in addition to the petroleum processing, in the area. Barium is a major constituent of drilling mud and the oil drilling that has been done in the area may be reflected by the high barium levels. The well that produced water having the highest barium concentration (2,000 μg/L) also had the highest chloride concentration. A well with a barium concentration of 800 μg/L is located less than a mile from an abandoned oil-test well. Manganese exhibits a trend similar to barium. Manganese concentrations are higher in the industrial area than the other two areas. Median manganese concentrations are 140, 25, and 27 μg/L for water in the industrial, mixed agricultural-forested, and forest lands, respectively. These differences are unlikely to be due to formational differences and a land-use activity that might account for this anomaly was not found. Also of note is that manganese concentrations exceeded iron concentrations in water from seven wells in the industrial area. This is an unusual condition (Hem, 1970).

Dissolved organic carbon concentrations in water in the industrial and forest land-use areas were generally higher than that in the mixed agricultural-forested land-use area; however, statistically significant differences did not occur. Only five DOC analyses were performed on water from wells in the mixed land-use area and more data are necessary to evaluate DOC concentrations. The median DOC values were 2.2, 1.1, and 1.5 mg/L in water from the industrial, mixed agricultural-forested and forest land-use areas respectively. GC/FID scans had a significantly higher number of organic compound peaks for water in the industrial area than in the forest land, but there was not a significant difference in the number of peaks in the mixed agricultural-forested area and the other two. This could be due to the presence of organic materials generated by industrial activities; however, such an inference is speculative without a greater number of samples and positive identification of the peaks.

Organic compounds on the EPA (Environmental Protection Agency) priority pollutant list (1979) were detected in water from two wells in the industrial land-use area and one well in the mixed agricultural-forested land-use area. The compounds were identified as di-n-butyl phthalate and bis (2-ethylhexyl) phthalate. Organics not on the priority pollutant list also were found in water from two wells at depths of 22 and 36 ft in the industrial area. These included 2 (ethoxyethoxy) ethanol, a solvent for cellulose esters, found in concentrations of 3 to 5 μg/L. Also found were 10 μg/L of 1-methyl - 2 cyclopentencarbonic acid, 3 μg/L of 1-bromo-2chlorociscylo-hexane, 22 μg/L of 2, 5-diethy-tetrahydro furan, and 14 μg/L of 2 bis-cyclohexene. These organics or their derivatives are used as industrial type solvents. Caprolactam, a high molecular weight solvent used in the manufacture of synthetic fibers of the polyamide type, was found at a concentration of 73 μg/L and a depth of 230 ft in the "400-foot" sand. No other positive identification by GC/MS were made in the mixed agricultural-forested area or the forest lands.

Selected wells in all three land-use areas were sampled for purgeable organic compounds, arochlors, insecticides, and herbicides. These compounds were below the lower levels of detection with three exceptions. The insecticide, diazinon, was found at a concentration of 0.02 μg/L in water from one well in the industrial area.

The herbicide, dicamba, and the purgeable organic compound, trichloroethylene were found at concentrations of 0.02 and 6.4 μg/L, respectively, in different wells in the mixed agricultural-forested land-use area. While the source of the dicamba is unknown, it is suspected that the trichloroethylene was present due to the proximity of the well to a septic tank. Trichloroethylene is often used as a degreasing agent in septic tanks.

SUMMARY

Water samples collected from 34 wells in three land-use areas were used to determine if a relationship exists between land use and concentrations of inorganic and organic constituents. In most cases the presence of organic constituents was determined by chromatographic scans using a GC/FID method of analysis. Some organic compounds were identified and quantified using a GC/MS method of analyses. The inorganic constituents include common constituents, nutrients, and trace elements.

Land use in the study area is divided into three major categories that are based on classifications believed to represent land-use activities during the past 50 years. Twenty-four percent of the study area is industrial, all of which is in Louisiana, 41 percent is mixed agricultural-forested, and 35 percent is forest land, all of which is in Mississippi.

Water-quality data indicates that land use has had a significant effect on water quality in the industrial land-use area. Chloride and barium contamination are evident in several wells. This is apparently the result of industrial activity by the many petrochemical processing plants in the area; oil production in the area, or a combination of both. There are no significant changes in water quality in aquifers in the mixed agricultural- forested and forest land-use areas that can be attributed to land-use practices. Comparisons of chemical quality of water between the three land- use areas show the mixed agricultural-forested and forest lands to be very similar in chemical quality. Water from the industrial land-use area is unlike the other two with respect to DOC, dissolved solids, pH, and manganese, in addition to chloride and barium. Some of these differences, particularly dissolved solids and pH, may be attributable to changes in the water quality of the aquifer due to changes in the lithology of the formations involved. DOC's were noticeably higher in water from the industrial land-use area. This may indicate the presence of organic compounds that are not naturally occurring.

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