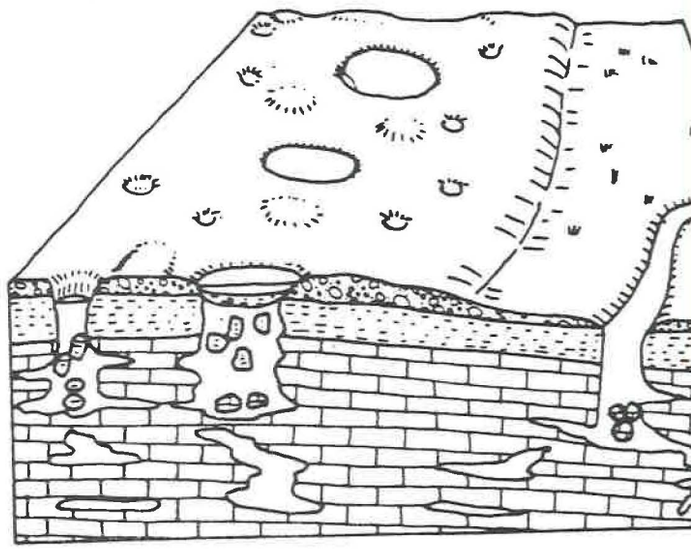
GROUND-WATER POLLUTION SUSCEPTIBILITY MAP OF GEORGIA

by

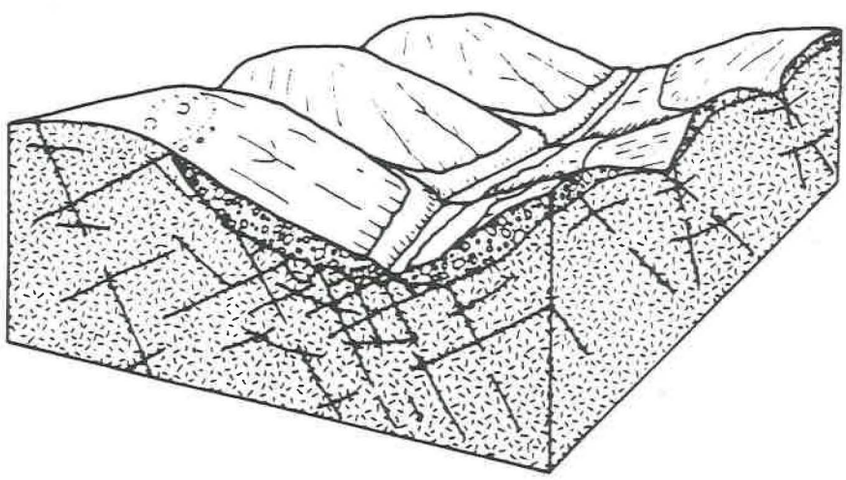
Victoria P. Trent

The preparation of this atlas was financed in part through a grant from the U.S. Environmental Protection Agency under the provisions of Section 106 of the Federal Water Pollution Control Act of 1972, as amended.



HYDROGEOLOGY OF THE PIEDMONT AND BLUE RIDGE

HYDROGEOLOGY OF THE SOUTHEASTERN COASTAL PLAIN



Department of Natural Resources
Lonice C. Barrett, Commissioner

Environmental Protection Division
Harold F. Reheis, Director

Georgia Geologic Survey
William H. McLemore, State Geologist

ATLANTA

1992

Reprinted 1999

GROUND-WATER POLLUTION SUSCEPTIBILITY MAP OF GEORGIA

by
Victoria P. Trent

Georgia Department of Natural Resources
Joe D. Tanner, Commissioner

Environmental Protection Division
Harold F. Reheis, Director

Georgia Geologic Survey
William H. McLemore, State Geologist

EXPLANATION

- HIGHER SUSCEPTIBILITY AREAS (DRASTIC RATING >181)
- AVERAGE SUSCEPTIBILITY AREAS (DRASTIC RATING OF 141–181)
- LOWER SUSCEPTIBILITY AREAS (DRASTIC RATING <141)
- MAJOR WATER BODIES
- MOST SIGNIFICANT GROUND-WATER RECHARGE AREAS OF GEORGIA, HYDROLOGIC ATLAS 18, 1989, SCALE 1:500,000
- STREAMS AND LAKES STATE OF GEORGIA HYDROLOGY BASE MAP, 1966. SOURCE: USGS, SCALE 1:500,000
- MAJOR HIGHWAYS AND ROADS STATE OF GEORGIA ROADS BASE MAP, 1974. SOURCE: NCIC, SCALE 1:2,000,000

Scale 1:500,000
1 inch represents approximately 8 miles

10 0 10 20 30 40 Miles
10 0 10 20 30 40 50 Kilometers

Base Map Data

Source: U.S. Dept of the Interior-Geologic Survey topographic maps
U.S. Dept of the Army-Corps of Engineers topographic maps

Compiled, edited, and published by the U.S. Geologic Survey
Compiled in 1963
Edition of 1970

Datum is mean sea level
1927 North American datum
Lambert conformal conic projection based on standard parallels 33° and 45°

Atlanta 1992

INTRODUCTION

The 1:500,000 scale map contained in this Hydrologic Atlas shows the relative susceptibility of the shallow unconfined aquifers in Georgia to pollution from man-made surface sources. Relative susceptibility was derived by generally following the DRASTIC method developed by the United States Environmental Protection Agency (EPA) (Aller and others, 1987). Areas within the state of Georgia are classified as having a relatively lower, average, or higher susceptibility to pollution (see Note No. 1).

All of Georgia, in some form or fashion, is susceptible to ground-water pollution. Some areas, however, are more susceptible than other areas. DRASTIC mapping demonstrates that the Fall Line Hills region of the Upper Coastal Plain, the Dougherty Plain and the limestone valleys of northwest Georgia are generally the areas in Georgia that are most susceptible to pollution of shallow, unconfined ground water. The massive crystalline rocks, with their overlying clayey residuum, of the Piedmont/Blue Ridge region are the least susceptible to pollution.

There have been a number of attempts to develop systems for assessing the susceptibility of shallow unconfined ground water to pollution. The most well known is DRASTIC, which is a qualitative guideline system for ground-water vulnerability assessments (LeGrand and Rosen, in press). According to LeGrand and Rosen:

> "DRASTIC has been found to have some statistical and descriptive properties that are very advantageous, but a problem is that to many users it is not clear what the final product, or DRASTIC-index, really means. Another problem is that such assessments tend to be regarded as monumental simplistic truths, which DRASTIC indices are certainly not, since they by necessity are associated with several kinds of uncertainties, due to system build up and geological heterogeneities. DRASTIC has been widely used by a number of states in the USA for planning purposes. We believe that the main reason for this is not that DRASTIC necessarily is that excellent a system, but that there is really no other standard technique available for vulnerability mapping in the United States."

The 1:500,000 scale map in this atlas is a generalized version of a series of 1:100,000 scale maps developed for Georgia's eighteen Regional Development Centers (RDC's) and is intended primarily for planning and educational purposes. The pollution susceptibility maps were developed by using a computer based geographic information system (GIS) to overlay different natural resource and demographic databases. Locational inaccuracies in these maps can result from the utilization of different scales of maps for the databases. Though published at a scale of 1:500,000, this derivative map is a compilation of data having scales ranging from 1:100,000 to 1:500,000. Because individual map layers are from different sources, a feature from one source may not coincide exactly with the same or related features from another source. Overlay accuracy appears to be about one mile or less in most cases. Areas having differentiation of pollution susceptibility of less than one square mile are not shown on the 1:500,000 map. They are present, however, in the 1:100,000 digital databases.

THE USE OF EPA'S "DRASTIC" METHODOLOGY FOR ENVIRONMENTAL MAPPING

DRASTIC mapping is intended to provide a standardized technical basis for environmental decision making. This map will assist planners, managers and administrators in evaluating the relative vulnerability of shallow aquifers in Georgia to ground-water pollution. The map does not address the pollution susceptibility of an area having undergone man-made modification; nor is the map appropriate for making site specific assessments.

DRASTIC is a methodology that allows the pollution potential of any hydrogeologic setting to be systematically evaluated with existing information anywhere in the United States (Aller and others, 1987). The system involves two major themes: The designation of mappable units, termed hydrogeologic settings, and the superposition of a relative ranking system on those settings.

The hydrogeologic settings (from Aller and others, 1987) generally correspond to Georgia physiographic provinces as follows:

(1) Setting 6: Nonglaciated Central Region, which corresponds to the Cumberland Plateau and Ridge and Valley.
(2) Setting 8: Piedmont and Blue Ridge.
(3) Setting 10: Atlantic and Gulf Coastal Plain, which generally correspond to the Fall Line Hills of the Upper Coastal Plain.
(4) Setting 11: Southeast Coastal Plain, which generally corresponds to the Dougherty Plain and the Lower Coastal Plain.

Within each of these settings, there are subsettings. For example, for the Atlantic and Gulf Coastal Plain, there are five subsettings (e.g., regional aquifers, unconsolidated and semi-consolidated shallow surficial aquifers, river alluvium without overbank deposits, and swamps). For each subsetting, general hydrogeologic features are delimited and DRASTIC indices are recommended.

The term DRASTIC is an acronym derived from the seven hydrogeologic parameters deemed most influential to pollution susceptibility. They are Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone, and hydraulic Conductivity of the aquifer. Each factor is incorporated into a relative ranking scheme that uses a combination of weights and ratings to produce a numerical value called the DRASTIC Index. The higher an area scores on the index, the more vulnerable or more susceptible the area is believed to be to ground-water pollution.

However, as Aller and others (1987) point out, DRASTIC is neither designed for, nor is it intended to replace on-site inspections, or site specific hydrogeologic investigations. DRASTIC mapping alone should not be used to specifically site any type of facility or practice. Rather, DRASTIC is intended to provide a basis for comparative evaluation of areas with respect to the potential for pollution of ground water.

DESCRIPTION OF DRASTIC PARAMETERS (from Aller and others, 1987)

Depth to water in an unconfined aquifer is defined as the depth from ground surface to the water table. Depth to water is important primarily because it determines the depth of earth materials through which a pollutant must travel before reaching the aquifer. Depth to water also is important because, in general, the greater the thickness of unsaturated material, the longer the travel time for a pollutant to reach the water table. Greater travel time would result in a greater opportunity for the pollutants to be adsorbed or degraded.

Net Recharge is defined as the total amount of water precipitated to the ground surface which infiltrates to reach the shallow unconfined aquifer. Recharge is important because it can transport a pollutant vertically into the water table and horizontally within the aquifer. Recharge is also an important factor for dispersion and dilution of a pollutant in the vadose zone.

Aquifer media refers to the earth materials which serve as an aquifer. An aquifer is defined as a subsurface lithologic unit which will yield sufficient quantities of water for use. Ground water in aquifers is contained within the pore spaces, fractures, and solution openings of the earth materials. The aquifer referred to in this atlas is the shallow unconfined aquifer, where the water table represents the uppermost elevation where the openings in the earth materials are filled (saturated) with water. The type of aquifer media affects the ground-water flow system, which in turn affects the amount of time for attenuation of pollutants.

Soil media refers to the uppermost portion of the vadose zone characterized by significant biological activity. For purposes of this study, soil is considered the upper weathered zone of the earth which averages a depth of six feet or less from the ground surface. Soil has a significant impact on the amount of recharge which can infiltrate to the ground and hence the ability of the pollutant to move vertically into the vadose zone.

Topography refers to the slope and slope variability of the land surface. Topography helps control the likelihood that a pollutant will run off over the surface or will remain on the surface in one area long enough to infiltrate. Topography also influences soil development and is an indicator of shallow ground-water flow direction.

The vadose zone (I) is defined as that zone above the water table which is unsaturated or discontinuously saturated. The type of vadose zone media determines the attenuation characteristics of pollutants below the soil horizon and above the water table.

Hydraulic Conductivity refers to the ability of aquifer materials to transmit water, which in turn controls the rate at which ground water will flow under a given hydraulic gradient. The rate at which ground water flows controls the rate at which a pollutant moves away from the point at which it enters the aquifer.

METHODS

Overview

The seven DRASTIC parameters influencing the relative pollution susceptibility of the shallow ground water in Georgia were derived from three existing statewide natural resource digital databases: slope (1:250,000), soils (1:250,000), and geology (1:500,000). All databases underwent quality assurance and quality control procedures. A fourth database, average depth to the water table, was derived from the slope and soils databases. Ratings for aquifer media, impact of the vadose media, and hydraulic conductivity of the aquifer were derived from the geology database. Soil ratings were derived from soil-type descriptions assigned by the United States Soil Conservation Service to the soils database. Net recharge and topography ratings were derived from the slope database. All mapping was done utilizing the overlay process of a geographic information system using ARC/INFO software. ARC/INFO is a registered trademark of ESRI.

Development of the seven DRASTIC parameters and numerical values used for mapping the pollution susceptibility of Georgia is described in the following subsections. A DRASTIC value recommended by Aller and others (1987) was assigned to each DRASTIC parameter for each hydrogeologic subsetting. Once the DRASTIC ratings were assigned for the seven parameters, the pollution susceptibility for each hydrogeologic setting was estimated by calculating the DRASTIC Index. The equation for calculating the DRASTIC Index is:

$$D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w = \text{Pollution Potential}$$

where: $_r$ = rating
$_w$ = weight.

Depth to Water

Depth to the water table was estimated by using a combination of the slope and soils databases. Following the DRASTIC methodology, described by Aller and others, (1987), depth to water was assigned a weight of 5. Areas having a slope of greater than 6% were assumed to have a depth to water of 15 feet or more and were assigned the recommended DRASTIC rating of 7 (see Note 2 for discussion of the use of 6% slope as the measure of depth to water). For areas having slopes equal to or less than 6%, depth to water was estimated further by identifying which of such areas had soils associated with a shallow water table and which areas did not. This meant that if an area had a slope of 6% or less and soil associations not characterized by "shallow water table," then the depth to water was assumed to be 5 to 15 feet, and was assigned the recommended DRASTIC rating of 9. If an area had a slope of 6% or less and a soil association characterized by a "shallow water table" then the depth to water was assumed to be 5 feet or less and was assigned the recommended DRASTIC rating of 10. The ratings, in turn, were multiplied by a weight of five, resulting in DRASTIC numbers of 35, 45, and 50, respectively.

Recharge

The length, shape, and steepness of slope determine the rate of runoff of precipitation. Runoff generally is more rapid on steep slopes than on areas where the ground surface is level or nearly level. In flatter areas, more time is available for precipitation to penetrate into and percolate through the vadose zone down to the water table.

Aller and others (1987) estimated a net recharge of 4–7 inches for the residual soils overlying crystalline rocks of the Piedmont/Blue Ridge. For the Valley and Ridge and Cumberland Plateau, they reported a typical net recharge of 2–4 inches per year for folded sedimentary rocks of moderate slope (e.g., >6%) and a typical net recharge of 10+ inches per year for valleys of low slope in limestones. Shallow slope (<6%) Coastal Plain settings had a net recharge of 10+ inches (Aller and others, 1987). Based upon Aller and others (1987) use of the 6% slope to differentiate areas of higher and lesser recharge as well as their use of 10+ inches per year as a measure of higher and lower net recharge, those portions of Georgia having a slope of less than or equal to 6% were assumed to have a net recharge of 10+ inches per year and were assigned the recommended DRASTIC rating of 9. Areas having a slope of greater than 6% were assumed to have a net recharge of less than 10 inches per year and were assigned a net recharge rating of 8. These ratings when multiplied by the recommended DRASTIC weight of 4, result in DRASTIC numbers of 36 and 32, respectively, for net recharge.

Actual net recharge in Georgia probably averages about 6 inches per year (Carter and Stiles, 1983). This means that by following Aller and others (1987) recommendations, actual net recharge is slightly overestimated presenting a slight overestimation of actual pollution susceptibility.

Aquifer Media, Impact of the Vadose Zone, and Hydraulic Conductivity

In the DRASTIC methodology, geologic outcroppings are used as surrogates for aquifers. As such, the Geologic Map of Georgia was used as an "aquifer media" map.

According to Aller and others (1987), the vadose zone encompasses those materials between the base of the soil profile and the water table. For unconfined aquifer systems, these would be the same as the "aquifer media." The DRASTIC methodology allows a standard geologic map, which depicts the distribution of lithologic units, to be used as a measure of the impact of the vadose zone.

General ranges of hydraulic conductivity have been established for a number of lithologic units (Freeze and Cherry, 1979). By knowing the lithology of the aquifer media, an estimate can be made of hydraulic conductivity.

All geologic units mapped at a scale of 1:500,000 on the Geologic Map of Georgia (1976) and the limestone units mapped on the Tertiary and Quaternary Formations of Georgia (1948) map (1:500,000 scale) were assigned a numerical rating for aquifer media, impact of the vadose zone, and hydraulic conductivity of the shallow aquifer. The DRASTIC ratings ranged from 1–10, according to the typical permeability of the lithologic unit. Following the DRASTIC methodology, ratings assigned to aquifer media and to the hydraulic conductivity of the aquifer were assigned a weight of 3, and the impact of the vadose zone media ratings were assigned a weight of 5. The numerical rating was multiplied by the weight factor to obtain a DRASTIC number for the particular lithologic unit, as follows:

Lithologic Unit	DRASTIC Rating	Aquifer Media (weight 3)	Impact of Vadose Zone (weight 5)
metamorphic/igneous rock	2	6	10
weathered metamorphic/igneous	3	9	15
bedded sedimentary	5	15	25
massive sandstone	6	18	30
sand/gravel	8	24	40
karstic limestone	10	30	50

Lithologic Unit	Hydraulic Conductivity (gpd/ft²)	DRASTIC Number (weight 3)
bedded sedimentary	1 – 100	3
metamorphic/igneous	101 – 300	6
weathered metamorphic/igneous	301 – 700	9
massive sandstone	701 –1000	18
sand/gravel	1000 –2000	24
karstic limestone	2000+	30

Soil Media

Soil media DRASTIC ratings ranging from 1 to 10 were assigned to the soils database according to soil types. The soils parameter was assigned a weight of 2 in conformity to DRASTIC methodology. The ratings were multiplied by the weight of 2, resulting in a DRASTIC soil index of 2–20, as follows:

Soil Media	DRASTIC Rating	Soil Number (weight 2)
Thin or absent	10	20
Gravel	10	20
Sand	9	18
Peat	8	16
Shrinking aggregated clay	7	14
Sandy loam	6	12
Loam	5	10
Silty loam	4	8
Clayey loam	3	6
Muck	2	4
Nonshrinking/Nonaggregated clay	1	2

Topography

As used in DRASTIC, "topography" means slope. Areas having a slope of less than or equal to 6% were assigned a topography DRASTIC rating of 10 (see Note 3 for use of 6% slope for assessing topography). Areas with a slope of greater than 6% were assigned a topography DRASTIC rating of 5. These ratings were multiplied by the weight of 5, resulting in DRASTIC numbers of 10 and 5, respectively, for topography.

Interpretation

Following the calculation of the DRASTIC Index for individual hydrogeologic settings, the range of index scores in Georgia was divided into three parts (see Note 1). Those areas having a DRASTIC Index of less than 141 were considered to have a relatively low pollution susceptibility for Georgia and were mapped accordingly. Areas having an index between 141 and 181 were considered to have average pollution susceptibility and hydrogeologic settings with DRASTIC index values greater than 181 were considered to have relatively high pollution susceptibility. Subdividing the range of index values found in Georgia into three pollution susceptibility categories is relative, and for that reason, is meaningful only for the state of Georgia. For example, a hydrogeologic setting with a DRASTIC Index of 135 might be considered to have relatively low pollution susceptibility in Georgia, but might be one of the highest values measured in another state. Alternatively, a hydrogeologic setting with an index value of 182 is considered relatively susceptible to pollution in Georgia, but 182 may be considered a low or medium value in another state where pollution susceptible hydrogeologic settings are widespread.

RESULTS

Hydrogeologic settings in Georgia having higher DRASTIC index values are most common where karst topography is developed in limestones. Karst topography is characterized by sinkholes, swallow holes and underground caverns and is caused by the dissolution of underlying beds of limestone or dolostone. Karst areas are widely recognized by hydrogeologists as being extremely susceptible to ground-water pollution. Areas of karst are common in southwestern Georgia and in the valleys of the Valley and Ridge Physiographic Province of northwestern Georgia.

Areas where highly porous sandy soils occur, such as the Fall Line Hills, also are generally highly susceptible to pollution. In contrast, areas in Georgia where the shallow aquifers are clayey or where slope is greater than 6%, such as the Piedmont and Blue Ridge Physiographic Provinces, have relatively low pollution susceptibility.

The shallow ground water underlying most of Georgia's Coastal Plain is highly to moderately susceptible to pollution due to the presence of thin limestones, sandy soils, and the relatively flat lying topography common in the region. In contrast, areas in the Piedmont and Blue Ridge Physiographic Provinces of northern Georgia have susceptibility indices that are lower than those in the Coastal Plain. This is due to the presence of clayey saprolite which typically overlies the igneous and metamorphic rocks that characterize the region and to the relatively greater slope of the land. The relatively lower pollution susceptibility in the Piedmont and Blue Ridge, however, does not mean that the region is not susceptible to ground-water pollution. The region is susceptible no pollution, just relatively less so than most areas in the Coastal Plain. The Valley and Ridge Physiographic Province of northwestern Georgia has pollution susceptibility ratings ranging from higher to lower, depending on the geology and slope of the area. Most of the higher susceptibility areas are in valleys underlain by karstic limestone aquifers.

RECHARGE AREAS PROTECTION

The Georgia Planning Act of 1989 requires that land-use ordinances, which would be made in an attempt to protect ground water, be passed and enforced by local governments having jurisdiction over significant ground-water recharge areas shown on the map in Hydrologic Atlas 18 (Davis and others, 1989). Within significant recharge areas, the relative degree of protection required is further defined on the basis of whether the area has a high pollution susceptibility. For example, the Rules for Recharge Area Protection require that local governments enforce a 150% larger lot size requirement for septic systems that are within a significant ground-water recharge area as well as being in an area of higher pollution susceptibility as shown on the 1:100,000 scale versions of the pollution susceptibility maps provided to the RDC's. Larger lot sizes may be recommended, but not necessarily required, if the area has a higher pollution susceptibility but is not within a significant recharge area.

ACKNOWLEDGEMENTS

Funding for pollution susceptibility mapping was partially provided by the United States Environmental Protection Agency.

REFERENCES

Aller, L., Bennett, T., Lehr, J.H., Petty, R.J., and Hackett, G., 1987. DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings: U.S. Environmental Protection Agency, (EPA-600/2-87-035), 455 pp.

Carter, Robert F. and Stiles, Harold R., 1983. Average Annual Rainfall and Runoff in Georgia, 1941–1970: Georgia Geologic Survey Hydrologic Atlas 9, 1 sheet.

Davis, K.R., Donahue, J.C., Hutcheson, R.H., and Waldrop, D.L., 1989. Most Significant Ground Water Recharge Areas of Georgia. Georgia Geologic Survey Hydrologic Atlas 18, one sheet.

Freeze, R.A. and Cherry, J.A., 1979. Groundwater, Prentice-Hall, 604 pp.

Georgia Department of Natural Resources, 1975. Resource Assessment Program: Soils, 70 pp.

_____ 1976, Geologic Map of Georgia: Georgia Geologic Survey, one sheet.

LeGrand, Harry E. and Rosen, Lars (in press). Common Sense in Ground-Water Protection and Management in the United States; Ground Water.

Nees, Monica and Salmons, Cynthia, 1987. National Survey of Pesticides in Drinking Water Wells, A Review of the Planning Process and Data Quality Objectives, Research Triangle Institute/7801/08/01F

DATABASES USED

1976, Geologic Map of Georgia: Georgia Geologic Survey, one sheet. Scale 1:500,000.
1948, Geologic Map of the Tertiary and Quaternary Formations of Georgia: Georgia Geologic Survey, one sheet. Scale 1:500,000.
1974, Major Highways and Roads: National Geographic Information Center. Scale 1:2,000,000.
Slope Map of Georgia Developed from Analysis of TIN Processed Digital Elevation Model Data (60 meter intervals). U.S. Geological Survey. Scale 1:250,000.
Soils Map of Georgia Developed from Soil Conservation Service County Soils Series Maps (STATSGO). U.S. Department of Agriculture Soil Conservation Service. Scale 1:250,000.
Rivers and Lakes, State of Georgia Hydrology Base Map. U.S. Geological Survey. Scale 1:500,000.

NOTES

Note 1: In 1986, the Research Triangle Institute (Nees and Salmons, 1987) informally developed a DRASTIC rating for every county in the United States as part of EPA's National Survey of Pesticides in Drinking Water Wells. In Georgia, these rating values range from 128 to 219. Approximately one third of Georgia counties had an assigned DRASTIC rating of more than 181, approximately one third had a DRASTIC rating of 141 to 181, and approximately one third had a DRASTIC rating of less than 141. Based on this precedent, ratings below 141 in Georgia were classified as "lower," ratings of 141–181 were classified as "average," and ratings above 181 were classified as "higher."

Note 2: In unconfined aquifers, the water table generally is a subdued replica of the surface topography. Typically the depth to water is greatest at hill tops and hill slopes and is least at valleys, flood plains, and other relatively flat low lying areas. In 1975, the Georgia Department of Natural Resources (DNR) published an assessment of all the U.S. Soil Conservation Service's 43 soil associations in Georgia. DNR's assessment indicated that soils characterized as having a shallow water table rarely occurred on slopes in excess of 6%. Soils characterized as having either a deep or a shallow water table, however, occur on slopes of less than 6%. By identifying which areas had both slopes of less than 6% (from the slope data base) as well as soils characterized by shallow water table (from the soils data base) the depth to water could be further estimated. For the four Georgia hydrogeologic settings (Aller and others, 1987, pg. 21), seven depth to water ranges are recommended. Of these seven, 0–5 feet, 5–15 feet, and greater than 15 feet are the most appropriate ranges for Georgia. Monitoring well data from solid waste landfills indicate that the 0–5 feet, 5–15 feet, and greater than 15 feet are typical depth to water ranges throughout most of Georgia (McLemore, W.H., 1992, personal communication). Aller and others (1987) as well as U.S. Department of Agriculture, Soil Conservation Service also use the 6% slope as a common break generally separating upland areas with a deeper water table from lowland areas with a shallow water table.

Note 3: Aller and others (1987) present a graph (their figure 7, pg. 30) of ranges of DRASTIC ratings plotted against percent slope. The curve is S-shaped with the inflection point generally corresponding to a slope of 6% and a rating of 5. Therefore, the maximum rating for a slope of 6% or less would be 5 and the maximum rating for a slope of greater than 6% would be 10. These values were selected for use.