# USE OF GROUND-PENETRATING RADAR TO CHARACTERIZE HYDROSTRATIGRAPHIC UNITS WITHIN A GEORGIA COASTAL PLAIN PROVINCE

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**Abstract.** The fate of pesticides/herbicides in a watershed depends upon important hydrologic pathways. In the Coastal Plain of Georgia, the presence and extent of semi-confining lithologic layers dictates the potential for contaminant movement into the local water table. This study used ground penetrating radar to characterize subsurface hydrostratigraphic units on a Coastal Plain study site.

Groundwater monitoring wells were installed at various locations at the site, and soil samples were collected and described. The site lithology is characterized by a fine grained quartz sand which is underlain by a clay-rich indurated sandy loam (CRISL). These soil samples are only point descriptions and do not describe the continuity of the layer. Therefore, ground penetrating radar was utilized to map the lithological features of the CRISL and determine the continuity of this layer.

Analysis of the ground penetrating radar data suggests the CRISL (semi-confining layer) is discontinuous, and the discontinuity is elongated at the region along the ephemeral stream that drains the watershed. This geometry may be used to accurately illustrate unsaturated/saturated flow in a contaminant transport model.

## INTRODUCTION

In a Coastal Plain geological setting, the lithological units consist of sub-horizontal unconsolidated clay, silt, and sand formations (layer cake geology). These alternating layers form a regional groundwater system consisting of aquifers and their confining/semi-confining units. Coastal Plain aquifers are usually comprised of highly permeable formations, whereas the confining units are formations of low permeability, primarily silts and clays, thus forming separate hydrostratigraphic units. These hydrostratigraphic units are regional in extent, with localized areas of recharge.

Aquifer recharge is dependent upon the hydrologic characteristics of the hydrostratigraphic units (permeability and hydraulic conductivity). Therefore, the transport of organic compounds such as pesticides/herbicides becomes dependent upon the hydrostratigraphic characteristics and their continuity.

Ground penetrating radar (GPR) was utilized as a means to map lithologies within approximately five meters of ground surface. GPR is a near surface exploration system that uses electromagnetic waves to obtain high-resolution profiles of the subsurface (a cross-sectional image). GPR measures differences in the dielectric potential of the porous media below ground surface and detects and graphically records the position and depth of interfaces between soil, sediment, and rock.

The objectives of the study were to:

1) Evaluate the hydrostratigraphic units within the study area.
2) Determine the continuity of these units using ground penetrating radar.
3) Determine the recharge pathways of these units within the watershed.

## MATERIALS AND METHODS

A first-year loblolly pine plantation near Downs, GA in Washington County in the Coastal Plain was selected for this study. The soil in this region is predominantly Orangeburg series with small areas of Ochlocknee series in the draws. Based on the analysis of split spoon soil samples that were collected during the installation of groundwater monitoring wells in the study area, three distinct soil lithologies were found to exist:

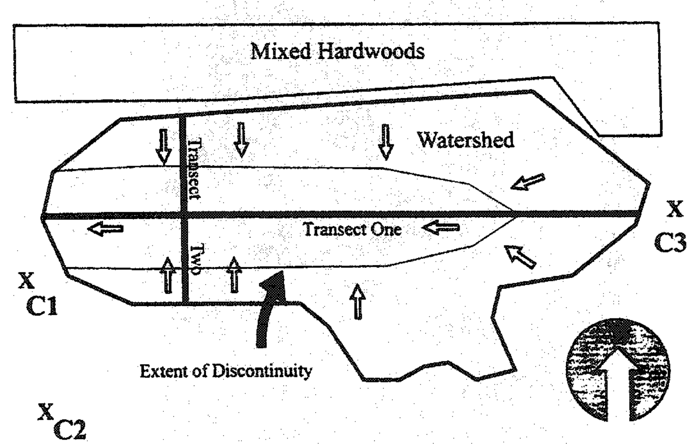


**Figure 1. Study site. Small white arrows indicate direction of downslope. Large white arrow indicates the limits of the discontinuous CRISL. X denotes monitoring wells.**

- the first lithology was a loamy sand that was approximately one meter thick;
- the second lithology was a CRISL from one to six meters below grade surface that was a sandy clay to sandy clay loam approximately 5 meters thick;
- the third lithology was a sandy soil and extended through the water table.

These three lithologies represented three separate hydro-stratigraphic units. The upper loamy sand behaves as a seasonal perched aquifer, the CRISL behaves as a semi-permeable confining layer, and the sandy soil beneath the CRISL is the unit in which the local water table is located. The study area is approximately 7.36 acres in size and contains slopes ranging from two to twenty percent (Figure 1).

Three groundwater monitoring wells were installed within the watershed to determine the water table gradient and direction of groundwater flow. The wells were installed using the hollow stem auger method; split spoon soil samples were collected every two feet for soil classification. An ephemeral stream extending from east to west within the watershed flows during heavy rainfall events. The head of the stream is in the loamy sand lithology; as the stream flows west, it carves through the CRISL. Approaching the bottom of the watershed, it appears to erode through the CRISL, into the sand beneath. Two transects within the watershed were chosen for the collection of GPR data (Figure 1). Transect One extends longitudinally from monitoring well C3 west to the bottom of the watershed along the ephemeral stream.Transect Two extends east to west laterally within the bottom third of the watershed, perpendicular to Transect One. The transects were cleared of all debris and vegetation in order for the GPR antenna to maintain contact with the ground surface.

The GPR antenna transmits an electromagnetic pulse which is reflected at dielectrical boundaries. As the antenna is moved along the surface, the graphical recorder prints a continuous cross-sectional image of the subsurface. Strong signal reflections are recorded in black, weak signal reflections in white, and intermediate signal reflections such as noise between interface reflections, are printed in the gray range.

Interpretation of GPR data requires at least some knowledge of the subsurface composition of the surveyed area. Signal quality and depth of penetration depends on local soil, sedimentand rock characteristics. Highly conductive material (i.e clay) will produces a relatively poor record due to high absorbance which reduces penetration of the GPR signal. Less conductive material (i.e. sand) will produce a better record due to low absorbance and greater signal penetration.

The depth of penetration depends upon the frequency of the antenna. Using a 500 MHZ antenna, the depth of penetration

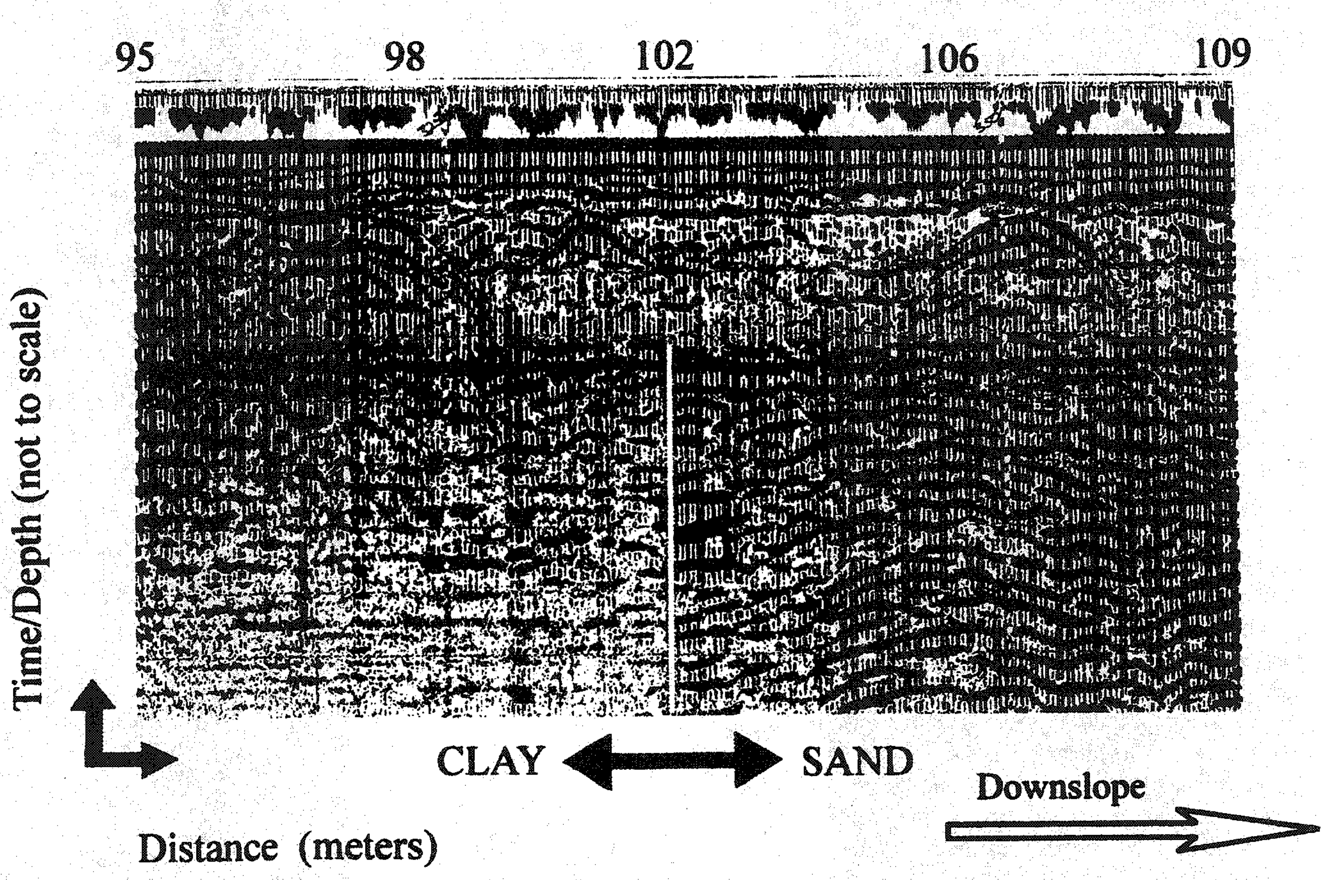


**Figure 2. GPR log. Section between 95 and 109 meters along Transect One. Figure shows discontinuity of clay at 102 meters along transect.**

extends to approximately five meters below ground surface. However, sacrificing accuracy for depth, the antenna can be tuned to yield data to a depth of thirty meters in silts and rock.

On the GPR record (Figure 2), the horizontal axis depends upon: 1) the transportation velocity of the antenna over the ground surface; 2) the paper feed rate of the graphical recorder. The vertical axis provides a time-scale which records the travel time of the electromagnetic pulses. Knowing the velocity of the wave propagation through the media being analyzed, travel time (nanoseconds) can be converted into depth measurements. Conversely, if the depth of a specific anomaly is known, its location on the record can be determined and its depth can be correlated with time in nanoseconds.

## RESULTS

Analysis of the GPR record from Transect One (longitudinal along the ephemeral stream) showed the presence of the CRISL from the head of the watershed (monitoring well C3) to a point approximately 102 meters along Transect Two. This was demonstrated by the strong signal reflection as seen in black on the GPR log (Figure 2). From 102 meters along Transect One to the bottom of the watershed (328 meters), the signal penetrated to the limits of the antenna (approximately five meters). This indicated that the CRISL had been eroded from the center of the watershed by the ephemeral stream.

Erosion of the CRISL was further supported by analysis of the GPR log for Transect Two. The CRISL was absent near the center of the watershed, at the intersection of Transects One and Two. The GPR recorder did not receive a strong reflected signal between 38 and 71 meters along Transect Two, indicating that the CRISL was discontinuous for at least 33 meters near the ephemeral stream. The distances from the GPR logs were transferred to the map of the watershed (Figure 1). The elongated area of erosion due to the ephemeral stream became apparent.

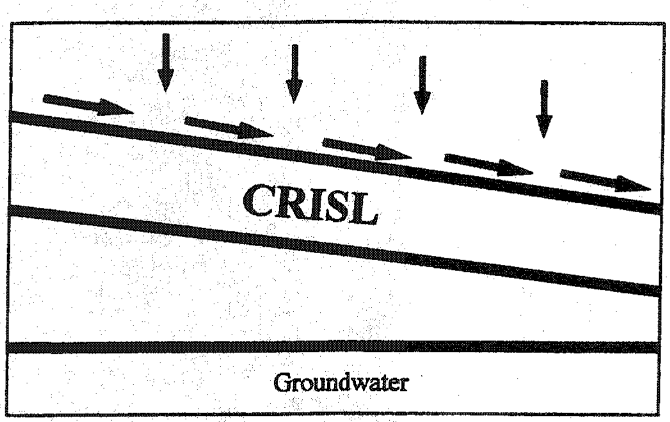


**Figure 3. Movement of recharge water and contaminants on continuous CRISL.**

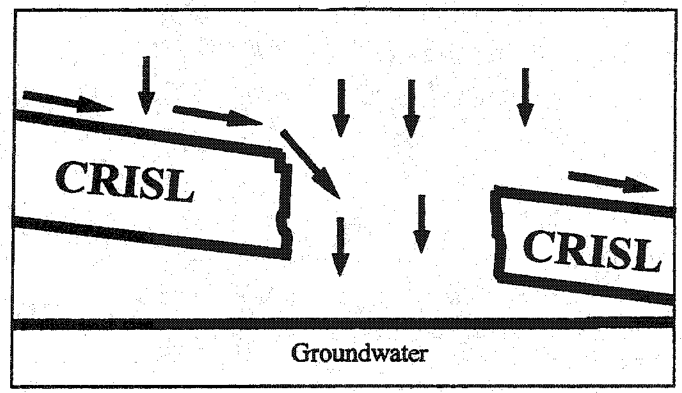


**Figure 4. Movement of recharge water and contaminants on discontinuous CRISL.**

## CONCLUSIONS

From the analysis of the GPR data it is apparent that the CRISL is discontinuous due to erosion by the ephemeral stream. The implications of this discontinuity are important when the possible pathways for the migration of organic compounds are considered. A continuous CRISL will provide a barrier to vertical migration of recharge water and possible contaminants (Figure 3). The absence of the CRISL in the area of the ephemeral stream provides a more direct pathway for the recharge of the water table and transfer of possible contaminants (Figure 4). The GPR data indicates that the area of discontinuity within the CRISL provides the most likely pathway for water movement beyond one to two meters below ground surface.

The use of GPR on the study site is an invaluable tool to be used when modeling unsaturated/saturated flow and contaminant transport. Assuming the confining layer (CRISL) was continuous, vertical migration of a target compound would be retarded. Travel time and resultant concentration of the target compound in the groundwater would have been underestimated. Without the GPR data, all possible pathways for the migration of contaminants would not have been considered.

## ACKNOWLEDGMENTS

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