SATURATED HYDRAULIC CONDUCTIVITY ESTIMATES OF SOILS FOR THREE SITES IN THE GEORGIA SOUTHERN PIEDMONT

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REFERENCE: *Proceedings of the 2005 Georgia Water Resources Conference*, held April 25-27, 2005, at the University of Georgia. Kathryn J. Hatcher, editor, Institute Ecology, The University of Georgia, Athens, Georgia.

Abstract. For soils in the Southern Piedmont, clayey upper Bt horizons have typically been estimated to have low saturated hydraulic conductivity (K_s) relative to underlying less clayey horizons. However, data from a few sites suggest that the more clayey upper Bt horizons are more permeable than deeper horizons. The objective of this study was to evaluate K_s in major horizons of soils on various landscape positions in Piedmont landscapes and to associate those measurements with morphological and landscape properties to refine morphology-based estimates of K_s. For sites studied so far, mean field measured K_s of upper Bt horizons was 42.6 centimeters per day as compared to 12.3 cm d^{-1} for underlying horizons with less clay. High permeability of the upper Bt horizons is attributed to well developed pedogenic structure.

INTRODUCTION

Hydraulic properties of soils in the Southern Piedmont of Georgia are the main focus of this study (Figure 1). No single physical property appears to provide specific information of all hydraulic parameters, although aggregation or structure is clearly the predominant component for estimating macropore flow rate and hydraulic parameters dominated by macropore flow, such as saturated hydraulic conductivity. The K_s or "permeability" is one of the more often used properties for evaluating soil suitability. The growing interest regarding the hydraulic properties of soils and saprolite in the Georgia Piedmont is driven by concerns about the environmental impact of subsurface waste disposal, such as onsite wastewater management systems.

The objective of this study is to evaluate K_s for major horizons of common soils in the Piedmont of Georgia, to develop relationships between K_s and morphological properties of these horizons, and to suggest landscape and/or morphological features that can be used to better estimate K_s from disturbed soil (bucket auger) observations.

The evaluation of K_s for horizons was focus in well-drained soils on upper hillslope positions. Hillslopes were selected to have Typic Kanhapludults (Cecil, Pacolet, Madison, and similar soils) mapped on upper landscape components, but soils on lower landscapes including Oxyaquic Kanhapludults (Hard Labor and similar soils) and Aquic Hapludults (Helena and similar soils) were also evaluated.

Source: Bureau of Land Management (http://www.blm.gov/wildlife/pl_11sum.htm)

Figure 1. Southern Piedmont Major Land Resource Area

BACKGROUND

Cecil and related series comprise more than 50% of soils mapped in the Southern Piedmont. In these soils, the maximum clay content typically occurs in the upper Bt horizon and gradually decreases with depth to a minimum in C horizons (Perkins, 1987). Because of the reliance on clay content for estimates of K_s, upper Bt horizons have minimum estimated K_s in the profile, and lower Bt and BC horizons with less clay are considered to have higher K_s.

In contrast to these estimates, limited data for soils in the Piedmont indicate that clayey upper Bt horizons often have higher K_s than subjacent BC horizons (Bruce et al., 1983; O'Brien and Buol, 1984; Schoeneberger and Amoozegar, 1990; Schoeneberger et al., 1995; Vepraskas et al., 1996). Most of these studies have attributed rapid water movement through the clayey Bt horizons to dominance of kaolinitic clays and to a well-developed pedogenic structure that forms a network of macropores.

Underlying BC horizons with less clay have a more weakly developed structure and, consequently, fewer macropores available for water transmission. In addition, macropores that are present in BC horizons may be filled with translocated clay and iron oxides, which reduces the capacity to transmit water (Vepraskas et al., 1991). In sandy and loamy C horizons that are below the depth of clay and iron translocation, structural macropores are not present, but coarse packing pores are open and capable of rapid transmission of water under saturated conditions.

METHODS

Three hillslopes in the Georgia Piedmont were selected to represent a range of slopes and local relief. Slopes were selected to be within 3% and 15%.

On each hillslope, K_s of major horizons was measured at 7 equally-spaced locations along each of three transects that extend from summit to footslope positions. The K_s of major horizons (upper Bt, lower Bt, and BC or C) was evaluated with a constant head permeameter using a 0.02 M $CaCl_2$ solution to minimize clay dispersion (Amoozegar, 1989). Transects were located such that horizon K_s was evaluated at multiple locations within landscape components on the hillslope. If rock was encountered at a measurement location, depth of description and measurement were at the top of the rock. Sites with more than 20% of the locations with rock before 137 cm were excluded from the research.

At each measurement site, the landscape position was described, slope was measured, and location determined with globalpositioning system (GPS). The soil was described from bucket auger borings using standard terminology (Soil Survey Division Staff, 1993).

Pits were excavated in three representative areas on each hillslope at transect sites that represent a range in measured K_s (high, low, and intermediate K_s) on the hillslope. A detailed description of pedon structural characteristics and other morphological features were made from the pit. These pedons were sampled for physical and chemical laboratory characterization. Core samples were also collected for determination of water characteristic curves from horizons in which field K_s measures were made, and undisturbed clods were collected for micromorphological analysis.

The null hypotheses are: a) that pedogenic structure does not have a major influence on K_s in Piedmont soils and b) that morphological properties observable in disturbed samples cannot be used to infer K_s.

RESULTS

For sites evaluated thus far, overall mean values of K_s observed at the three sites were 43, 4, and 13 cm d^{-1} for the upper Bt, middle depth of measurement (lower Bt and BC horizons), and lowest measurement depth (BC and C horizons), respectively. Site 1 has the highest mean K_s of the three sites at all depths (Tables 1, 2, and 3). In the upper Bt horizons, mean K_s was lower at Site 2 than at Site 3. At the lowest depth of measurement (BC and C horizons) Site 2 had lower mean K_s than Site 3, but mean K_s was similar for Sites 2 and 3 at the middle measure depth (lower Bt and BC horizon) (Tables 1, 2, and 3).

Table 1. Saturated hydraulic conductivity for different positions in the landscape at three depths in Site 1 (values are the mean of three measurements).

Landscape position*	Depth**	Sat.hydr.conductivity (cm d^{-1})
A	1	83.6
	2	9.8
	3	44.8
B	1	49.3
	2	4.9
	3	47.8
C	1	70.9
	2	12.1
	3	39.4
D	1	105
	2	4
	3	6.4
E	1	89.4
	2	10.9
	3	11.4
F	1	91.7
	2	5.7
	3	12.5
G	1	95.6
	2	4.4
	3	4.1
Mean	1	83.6
	2	7.4
	3	23.8

*A=highest; G=lowest **1=shallowest; 3=deepest

Table 2. Saturated hydraulic conductivity for different positions in the landscape at three depths in Site 2 (values are the mean of three measurements).

Landscape position*	Depth**	Sat.hydr.conductivity ($cm\ d^{-1}$)
A	1	11.6
	2	2.5
	3	1.2
B	1	6.7
	2	5.5
	3	4.2
C	1	10.9
	2	2.3
	3	5.1
D	1	2.8
	2	3.1
	3	1.6
E	1	1.8
	2	1.9
	3	2.2
F	1	3.4
	2	2.4
	3	1
G	1	4.6
	2	2.3
	3	8.5
Mean	1	6
	2	2.9
	3	3.4

*A=highest; G=lowest **1=shallowest; 3=deepest

At all sites, mean K_s in the upper Bt horizon was higher than mean K_s of the underlying horizons although this difference was not large at Site 2 (Tables 1, 2, and 3). At sites 1 and 3, the lowest mean K_s was for horizons at the middle measurement depth (lower Bt or BC horizons), but mean K_s at the middle depth was similar to mean K_s for the lowest depth of measurement at Site 2. At all sites, these general relationships did not hold at all positions in the landscape, but there was no obvious relationship between K_s and landscape position at any of the measurement depths.

Table 3. Saturated hydraulic conductivity for different positions in the landscape at three depths in Site 3 (values are the mean of three measurements).

Landscape position*	Depth**	Sat.hydr.conductivity ($cm\ d^{-1}$)
A	1	10
	2	0.3
	3	1.3
B	1	6.2
	2	0.4
	3	1.4
C	1	6.3
	2	0.3
	3	29.3
D	1	39
	2	0.7
	3	30.6
E	1	29
	2	1.8
	3	7.3
F	1	80
	2	1.5
	3	4.3
G	1	95.6
	2	5.2
	3	7.1
Mean	1	38.1
	2	1.5
	3	11.6

*A=highest; G=lowest **1=shallowest; 3=deepest

DISCUSSION

Differences among horizons appear to be related to a combination of horizon texture and pedogenic structure. Even though upper Bt horizons present a high clay content, they have the best developed blocky structure of horizons evaluated. Clay contents of the lower Bt horizons are commonly similar to those of the upper Bt horizon, but less developed blocky structure and weakly developed platy structure apparently reduce water movement through these horizons. An increase in K_s at the lowest depth of measurement (BC and C horizons) appears to be caused by lower clay content even though these horizons have the weakest structure in the profiles. Lowest observed K_s at Site 2 may be due to greater shrink-swell potential at this site than at Sites 1 and 3.

ACKNOWLEDGEMENTS

The authors wish to acknowledge USDA-NRCS employees Jim Lathem, Curtis Marshall, Bob Evon, and Sherry Carlson for their assistance with field work.

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