Drainage Properties of Some Soils in the Atlantic Coast Flatwoods

J. R. Carreker, F. Long, and J. M. Daniels
FELLOW ASAE

THE Atlantic Coast Flatwoods resource area ranges from 20 to 50 miles wide along the Atlantic Coast from Florida to Delmarva Peninsular (Fig. 1). The topography is level to gently rolling, and natural drainage is imperfect over much of the area. An estimated 70 percent of the soils require drainage for profitable and efficient agriculture.

The soils are sedimentary and range from sand on the low ridges to clay on the more level areas, with some organic soils in the lowest parts. The parent material consists of unconsolidated beds of sand, sandy clay, and clay. Internal drainage is extremely poor in the clays and rather poor in some of the more sandy soils.

The sandy soils are used primarily for truck crops. Pastures are highly productive on the heavier soils where surface drainage has been developed. A large percentage of the area is in poorly drained forest land.

The average annual rainfall is 52 in. along the Coast and about 45 in. along the inland boundary of the area (5)*. Normal monthly amounts range from about 2 in. in November to 7 in. in July. However, excessively heavy rains may occur at any time. Thunderstorms of high intensity occur most frequently in the summer, and sometimes cause severe flooding. The drainage problem may arise from a generally high water table or from excess rainfall on the soil surface. The low internal drainage of some soils causes water to remain on the soil surface an excessive length of time where surface disposal is not available.

Drought of serious proportions also occurs because the rainfall-distribution pattern often is erratic within a given season. Deficient moisture sometimes is a limiting factor in crop production because of the low-water-holding capacity of some soils, the low rate of percolation for some soils, and the excessive water losses from surface runoff after high-intensity rainstorms.

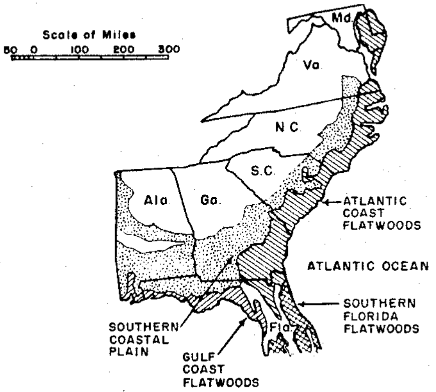

FIG. 1 Location of Atlantic Coast flatwoods land resource area.

An efficient drainage system should remove excess surface water to prevent prolonged waterlogging of the soil and to lower the water table. At the same time, it should permit entry of water into the soil profile when the soil moisture is depleted. Drainage increases the depth of the rooting zone. This hastens moisture depletion after rainfall, thereby improving water entry and storage capacity for the next rain.

DRAINAGE SYSTEM DESIGN

Drainage-system design should be based on the drainage requirement of crops and the physical properties of the soil being drained. Practically no research data are available on the drainage requirements of crops, and field experience must serve as a guide for this criterion. The function of drains then is to lower the water table. Design criteria should include some rate of fall of the water table. Several equations have been developed that base drain spacing on the rate of fall of the water table as well as soil properties.

Van Schilfgaarde (4) showed that the time required to lower the water table a given distance is a function of the equivalent depth to impervious layer beneath the drain as well as the spacing and depth of the drain and the porosity and hydraulic conductivity of the soil. These relationships are expressed by the formula

$$t = \frac{fS^2}{9Kd_e} \log n \frac{m_o(2dc + m)}{m(2dc + m_o)} \quad \ldots\ldots\ldots\ldots\ldots\ [1]$$

where

t = time in days
f = drainable pore space as volume fraction ($1>f>o$)
K = hydraulic conductivity in feet per day
S = spacing in feet
d_e = equivalent vertical distance of impervious layer beneath center of drain
m_o = initial water-table height above drain in feet
m = water table height in feet at time t

Formula [1] fails to give a solution when the drain is on the impervious layer and d_e is zero. In that case, the following formula applies:

$$t = \frac{S^2}{9} \; \frac{2f(m_o - m)}{K(m \times m_o)} \quad \ldots\ldots\ [2]$$

Curves based on formula [1] in Fig. 2 and on formula [2] in Fig. 3 show the relationship between the days required to lower the water-table prescribed depths (m_o to m) and porosity and hydraulic conductivity values, for selected drain spacings. The porosity and hydraulic conductivity are shown as f/K for simplicity of plotting. Similar curves could be made up in field practice for a practical range of values for S, m_o, m, and d_e. The drainage system design then could be simply a matter of selecting the right point on the curve for specific values of f/K applicable to the particular field conditions encountered. This, of course, requires a knowledge of porosity and hydraulic conductivity of the soil and the time required to lower the water table from one position to another to meet the drainage requirement of the crop.

SOIL PHYSICAL PROPERTIES IN ATLANTIC COAST FLATWOODS LAND-RESOURCE AREA

Studies were initiated in 1961 at the Southeastern Tidewater Conservation Experiment Station at Fleming, Ga., to determine the hydraulic conductivity, porosity, moisture release characteristics, and other physical properties, plus chemical properties, of the dominant soil series in the Atlantic Coast Flatwoods land-resource area (3). Hydraulic conductivity was measured in situ above the water table by the double-tube method developed by Bouwer (4, 5).

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The authors—J. R. CARREKER, F. LONG and J. M. DANIELS—are research investigations leader for water management, research soil scientist, and civil engineering technician, USDA, ARS-SWC, at Athens, Ga., Florence, S. C. and Fleming, Ga., respectively.

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*Numbers in parentheses refer to the appended references.

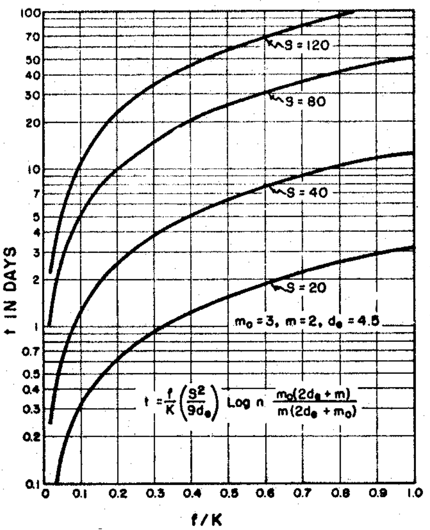

FIG. 2 Time in days to reduce water table from m_o to m with different drain spacings ($m_o = 3$; $m = 2$; $d_e = 4.5$).

The double-tube equipment used consisted of an 8-in. outer tube and a 5-in. inner tube, with the necessary fittings on top. There was an unavoidable slight compression of soil as these tubes were imbedded in the bottom of each hole. This action probably caused about 50 percent reduction in the hydraulic conductivity values obtained with the apparatus†.

Data are given in Table 1 on the hydraulic conductivity, pores drained at 60-cm tension, available moisture (moisture held between 1/10 and 15 atm tension), and the textural class by horizons for nine soil series, with duplicate sites for seven of the series. Pore space at 60-cm tension was obtained by extrapolation from the moisture removed at 1/10, 1/3, 1, 4, and 15 atmospheres tension. Moisture release characteristics were determined with disturbed samples. The values computed for pores drained at 60-cm tension ranged from negative readings (not listed) to more than 40 percent. These values probably are not indicative of the amount of air-filled space obtained under natural drainage conditions. An estimate of 10 percent of pores drained perhaps would be a more realistic upper limit to use for most soils.

Analyses by multiple regression of the data in Table 1 show there is no consistent relationship between hydraulic conductivity and any of the other properties listed. Similar analyses showed no consistent relationship between the hydraulic conductivity and clay, silt, or sand content, any sand fraction, percent moisture for any tension, bulk density, or organic matter. Therefore, hydraulic conductivity apparently is not correlated with any of the physical properties measured in these soils.

TABLE 1. PHYSICAL PROPERTIES OF SOILS IN THE ATLANTIC COAST FLATWOODS LAND RESOURCE AREA

Soil series and sample number	Horizon	Soil depth, in.	Textural class	Available moisture, in. per in.	Pores drained at 60 cm, percent	Hydraulic conductivity, feet per day
Lakeland	A_1	0-4	S	0.052	30.1	0.72
1A	C_1	4-16	S	0.021	32.5	1.32
	C_2	16-37	S	0.026	22.4	5.52
	D_1	37-51	FSL	0.035	11.8	0.10
1B	A	0-4	S	0.020	40.6	0.36
	C_1	4-40	S	0.011	39.1	0.84
Goldsboro	A_p	0-7	S	0.028	32.9	2.40
4A	A_2	7-13	S	0.066	32.8	0.60
	B_1	13-24	FSL	0.037	20.1	0.04
	B_2	24-36	SCL	0.053	6.3	0.05
	B_3	36-46	SCL	0.051	12.8	....
4C	A_p	0-8	LS	0.094	21.2	0.60
	A_2	8-11	FSL	0.090	0.6	0.02
	B_{21t}	11-18	SCL	0.091	6.3	....
	B_{22t}	18-36	SCL	0.109	....	0.36
	B_3	36-52+	SCL	0.117	....	....
Irvington	A_{11}	0-5	LFS	0.059	34.1	0.48
5B	A_{12}	5-9	LS	0.045	27.9	1.32
	A_2	9-16	LS	0.036	25.6	0.36
	B_1	16-20	LS	0.036	21.3	0.60
	B_2	20-27	FSL	0.036	13.0	1.44
	B_{3gx}	27-40	SCL	0.044	6.0	....
	C	40-50+	FSL	0.054	....	0.02
5C	A_1	0-10	S	0.036	31.3	0.48
	A_3	10-17	LS	0.031	23.2	0.12
	B_1	17-25	LS	0.045	17.2	5.52
	B_{2tcn}	25-32	FSL	0.066	6.0	0.12
	B_{3t}	32-44+	SCL	0.059	10.1	....
Kiawah	A_1	0-10	FS	0.027	41.5	0.36
6A	A_2	10-15	FS	0.029	33.0	0.05
	B_{21}	15-20	FS	0.031	30.5	3.60
	B_{22}	20-32	LFS	0.036	31.2	2.60
	C	32-40+	LFS	0.029	33.9	0.54
6B	A_p	0-9	FS	0.022	41.9	0.84
	A_3	9-18	LFS	0.028	27.0	....
	B_1	18-30	LFS	0.018	34.3	1.56
	B_2	30-40	LFS	0.021	26.2	....
Fairhope	A_1	0-1	FSL	0.080	....	....
10A	A_2	1-8	FSL	0.050	3.7	....
	B_{21}	8-10	SCL	0.084	0.7	0.01
	B_{22}	10-24	C	0.114	....	....
	B_3	24-30	SC	0.090	....	....
	C	30-40+	SCL	0.066	....	....
10C	A_1	0-4	LFS	0.071	39.5	1.08
	A_2	4-16	LFS	0.042	35.2	2.64
	B_1	16-19	FSL	0.072	16.8	....
	B_2	19-28	SCL	0.121	....	....
	B_3	28-36	SCL	0.119	....	....
	C	36-50+	SCL	0.106	....	....
Eulonia	A_1	0-4	LFS	0.048	32.0	0.48
14A	A_2	4-14	LFS	0.032	29.9	....
	B_{21}	14-18	FSL	0.044	15.0	1.20
	B_{22}	18-25	SCL	0.078	11.9	....
	IIC	25-36+	SCL	0.067	3.6	....
14B	A_p	0-8	LFS	0.035	36.4	1.68
	A_2	8-15	LFS	0.032	31.5	1.68
	B_{21}	15-21	SCL	0.078	....	....
	B_{22}	21-27	SCL	0.077	2.6	....
	C	27-44	SCL	0.086	0.9	....
Lynchburg	A_1	0-6	LFS	0.108	31.3	0.48
17A	A_2	6-10	LFS	0.101	21.4	0.48

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† Estimate by Dr. Herman Bouwer in personal correspondence.

TABLE 1. Continued

Soil series and sample number	Horizon	Soil depth, in.	Textural class	Available moisture in. per in.	Pores drained at 60 cm, percent	Hydraulic conductivity, feet per day
	B_1	10-13	LFS	0.059	20.2	0.60
	B_{21}	13-17	FSL	0.055	1.6	0.12
	B_{22g}	17-25	FSL	0.050	17.2	0.06
	B_{23g}	25-38	FSL	0.049	13.0	0.06
	B_{3g}	38-44+	FSL	0.054	4.3	....
Leon	A_1	0-4	FS	0.010	38.3	3.60
3A	A_2	4-14	FS	0.010	40.2	6.96
Klej	A_1	0-5	FS	0.026	34.8	0.36
2A	C_1	5-21	FS	0.029	35.5	0.24
	C_2	22-32	S	0.026	27.7	0.48
	D_1	32-45	LFS	0.031	20.8	0.07
Charleston	A_p	0-8	FS	0.033	*	0.12
9A	A_2	8-16	FLS	0.025	*	0.24
	B_2	16-24	FSL	0.047	*	0.01
	B_{31}	24-36	FSL	0.034	*	0.01
	B_{32}	36-44	FSL	0.043	*	0.002
	C	44-52+	FS	0.024	*	....
Charleston	A_p	0-9	LFS	0.037	*	1.20
9C	A_2	9-21	LFS	0.024	*	0.44
	B_{2t}	21-30	SCL	0.060	*	0.04
	B_3	30-43	FS	0.019	*	0.02
	C	43-52+	FS	0.032	*	0.72

* Not determined.

TABLE 2. COMPUTED TIME (4) REQUIRED TO LOWER THE WATER TABLE IN THE DIFFERENT HORIZONS OF LAKELAND SAND, SITE 1A, WITH THE DRAINS 40 FEET APART, PLACED ON THE IMPERVIOUS LAYER AT 37 INCHES DEPTH*

Horizon		Height above drain		Hydraulic conductivity,† feet per day	Time to lower water table		
No.	Depth, ft	m_0, ft	m, ft		In each horizon, days	Accumulated time	
						Days	Hours
A_1	0.33	3.08	2.75	1.44	0.023	0.023	0.5
C_1	1.00	2.75	1.75	2.64 } 6.84	1.08	1.1	27.0
C_2	1.75	1.75	0	11.04 } 6.84		..	..

* Pore space is assumed to be 0.10 of total soil volume.
† Measured rate times 2 (estimate by Dr. Herman Bouwer in personal correspondence).

The time required to lower the water table is a function of the hydraulic conductivity, pore space of the several layers drained, and dimensions of the drainage system (4). Computation of the time required to lower the water table from the surface through horizons A_1 and C_1 in the Lakeland sand on site 1A with a drain spacing of 40 feet is illustrated in Table 2. It is assumed the drain is placed at 37 inches depth on top of the D_1 horizontal that has such a low hydraulic conductivity rate it presents essentially an impervious layer beneath the drain, and formula [2] applies. The further assumption is made that the higher conductivities of horizons C_1 and C_2 in effect cause a unit gradient for drainage out of the A_1 horizon. The time to drain the A_1 horizon then becomes $0.33 \text{ ft} \times 0.10/1.44 \text{ ft/day} = 0.023$ day, or 0.5 hour.

It is assumed further that the effective hydraulic conductivity of horizons C_1 and C_2 will be the average of the values shown for these two horizons, or 6.84 ft per day. Application of the appropriate values from Table 2 in formula 2 gives 1.08 days required to drain the 1.00-foot depth of the C_1 horizon with a drain spacing of 40 feet. The total time to lower the water table from the surface to 1.33 feet below the surface then is 27 hours.

Similar computations for drain spacings of 80 and 120 feet give 4.3 and 9.6 days to lower the water table through the 1.0-foot depth of the C_1 horizon.

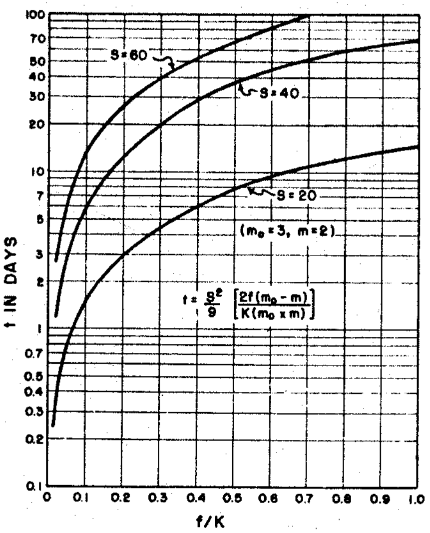

FIG. 3 Time in days to reduce water table from m_0 to m with different drain spacings ($m_0 = 3$; $m = 2$; $d_e = 0$).

The foregoing values indicate that adequate drainage can be obtained with fairly closely spaced drains on soils with physical properties like those of Lakeland 1A. Since the drainage rate throughout the profile would be controlled by a low rate in an underlying horizon, such as in Goldsboro 4A and Lynchburg 17A, it is doubtful that any of these soils can be drained successfully for crop production by subsurface methods. This poor internal drainage, together with the high rainfall rates during the crop-growing season, suggest that surface water disposal is the most practical answer to the control of excess water on these soils.

A drainage system in the Atlantic Coast Flatwoods should include major outlets, field drains, and land grading to insure free flow of surface water to the field drains. This type of system might be augmented with subsurface drainage in the soils with better drainage properties to permit wider spacing of the field drains.

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