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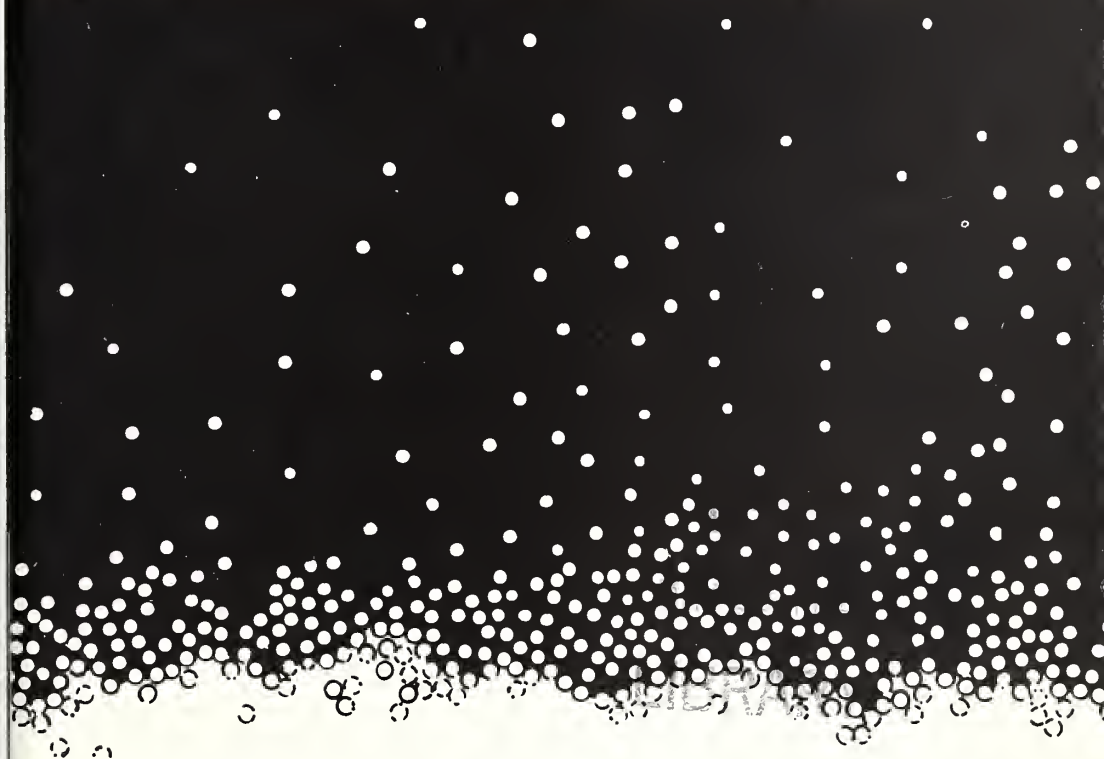

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Theoretical Settling Time for Suspended Sediment in Flooded Rice Fields

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Water-leveling techniques are used in reshaping the land surface for rice growing in areas in Louisiana. Lawson (1962) has described the water-leveling technique in Louisiana in detail. The technique involves flooding the area to be leveled, then stirring the flooded surface with a tractor or tractor-drawn implement. Soil material put in suspension by the stirring may be removed from the area if the impounded water is immediately drained. Delaying drainage allows settling and reduces the amount of suspended sediment removed in the drained water. Complete removal of suspended material by sedimentation is not practical due to the long settling times required for the smaller particles. Very small sediment particles may remain in suspension indefinitely due to movement of water molecules.

To the author's knowledge, no on-site field experiments have been conducted to evaluate actual settling times for suspended sediment after water leveling in flooded rice fields. Time periods involved in settling of suspended sediments are strongly dependent on factors, in addition to soil textures and depth of water, that can vary independently among locations and from one time to another. The most important of these factors are (1) the degree of soil dispersion, which largely depends on the kind and amounts of salts in the soil and the extent to which the soil has been stirred, and (2) the development of currents in the water caused by changes in water temperature, wind action, or other disturbances. However, theoretical settling times based on reasonable assumptions can be calculated and used as a reference for deciding the length of time to allow settling to proceed after water leveling flooded fields.

This bulletin will provide estimates of the amount of sediment that will have settled at specific times after stirring so that an adequate delay time can be determined to prevent removal of large quantities of sediment when the area is drained. Use of the tables requires only that the depth of the impounded water and texture of the surface soil be known.

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Methods

Theoretical basis for the settling time calculations is given by Stokes' Law (Baver, 1965). Stokes' Law is also used in the laboratory determination of particle size distribution in soils. Certain assumptions are commonly made in either application. Those made in this study include the following: a constant temperature, assumed to be 86° F; rigid, smooth, spherical soil particles; constant soil particle density (2.65 grams per cubic centimeter); and that Stokes' Law is applicable to the particle size range represented in the soil.

Additional assumptions are necessary when application is made to settling of particles in water-leveled fields. It is assumed that the suspended soil particles are dispersed, that is they do not clump together, and that the particles are uniformly mixed throughout the water volume and are present in the same relative proportions as they occur in the soil surface horizon. It is also assumed that wind and diurnal temperature changes have no influence on settling and that water movement and agitation stop on completion of water leveling.

The form of Stokes' Law used in this study is:

$$U = \frac{2}{9} \frac{(dp - d)}{m} gr^2$$

where
U = particle fall velocity, centimeters per second
g = acceleration of gravity, 980 centimeters per second squared
dp = particle density, 2.65 grams per cubic centimeter
d = density of water, .99707 gram per cubic centimeter
r = mean particle radius, centimeters, and
m = absolute viscosity of water, .008904 poise.

The 12 soil texture classes recognized by soil scientists are defined in terms of definite allowed ranges in the content of sand-, silt-, and clay-size particles. The soil texture classes and size range of the clay-, silt-, and various sand-size particles are given in Figure 1.

A representative percent by weight of sand-, silt-, and clay-size particles was assigned to each texture class to calculate theoretical settling time for the suspended sediment. These values are given in Table 1 and plotted in Figure 1. The clay texture class was divided into two subclasses—heavy clay, with an assumed average of 65 percent clay; and light clay, with an assumed average of 45 percent clay. Theoretical settling times were calculated for each texture class even though water-leveling techniques are not normally used on soils with certain textures, for example, sands.

A computer program was developed to perform the necessary calculations and prepare graphs of the results. For calculation purposes, the clay

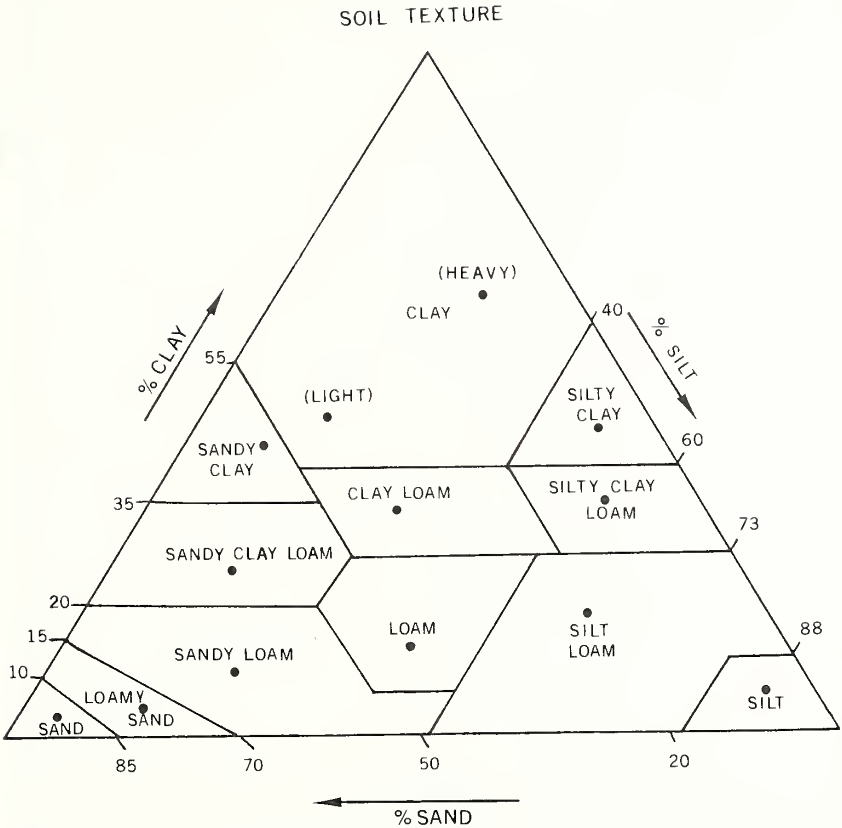

Figure 1.—The 12 soil texture classes and the size range of their particles.

Table 1.—Percent sand-, silt-, and clay-size particles assigned each soil texture class for calculating time and cumulative percent of soil particle sedimentation

Soil texture class	Clay	Silt	Sand
		%	
Heavy clay	65	25	10
Light clay	45	25	30
Silty clay	45	50	5
Sandy clay	45	10	45
Silty clay loam	35	55	10
Clay loam	35	30	35
Sandy clay loam	25	15	60
Silt loam	18	62	20
Loam	15	45	40
Sandy loam	15	25	60
Silt	8	87	5
Loamy sand	7	15	78
Sand	4	8	88

fraction was divided into four size groups, the silt particles into six size groups, and the sand into 13 size groups (Table 2). The percentage by weight of sand, silt, and clay in each texture class was subdivided equally among each of the groups in that particular size fraction. The median particle size of each group was used in the Stokes' Law equation to determine velocity of fall. Particle fall velocity and different water depths (6, 12, 18, and 24 inches) were then used to calculate the percent of that group that settles in a given time from the different water depths. Settling times in 3-hour increments in 336 hours (14 days) were used. The product of the percentage of a given group of particles that falls at a given time and the percentage of the total weight that group represents gives the weight of sediment in that group that has settled during that time period. The sum of all settled group weights in a given time period is the total weight settled for that texture class.

Table 2.—Subdivisions of clay-, silt-, and sand-size fractions used in calculations of time and cumulative sediment percentages

Particle size fraction	Size range mm
Clay	0.0000-0.0005
	0.0005-0.0010
	0.0010-0.0015
	0.0015-0.0020
Silt	0.0020-0.0100
	0.0100-0.0180
	0.0180-0.0260
	0.0260-0.0340
	0.0340-0.0420
	0.0420-0.0500
Sand	0.0500-0.2125
	0.2125-0.3750
	0.3750-0.5375
	0.5375-0.7000
	0.7000-0.8625
	0.8625-1.0250
	1.0250-1.1875
	1.1875-1.3500
	1.3500-1.5125
	1.5125-1.6750
	1.6750-1.8375
	1.8375-2.0000

Results

The results are presented as cumulative percent by weight of soil particles that settled versus settling time for a given soil texture class (Tables 3 to 5). The soil texture class represented is identified in the table. The values are the percent of the soil particles initially in suspension that have settled after given periods of time where depths are 6, 12, 18, and 24 inches. For example, 89.5 percent of the particles in the silt loam texture class (Table 3) will have settled in 24 hours where the water depth is 12 inches. Thus, the tables can be used to obtain a theoretical estimate of the percent by weight of particles in suspension that will have settled after a given time provided the soil texture class and depth of water are known.

Estimates other than those for 6-, 12-, 18-, and 24-inch water depths may be obtained by interpolation. Estimates can be useful in determining the settling times required to minimize soil losses resulting from drainage of water-leveled areas. Sources of information concerning the surface horizon texture of specific soil areas include Soil Survey reports, USDA-Soil Conservation Service, Louisiana Cooperative Extension Service, and private agricultural consultants.

The major areas of rice production in Louisiana are on soils having either silt loam, silty clay loam, silty clay, or clay surface horizon textures. Crowley, Mowata, Kinder, Acadia, Caddo, and Calhoun are examples of soils that, in most areas, have silt loam textures. Clay or silty clay surface horizon textures are common in the Sharkey, Alligator, Moreland, Perry, Portland, and Judice soils. Silty clay loam textures occur in some areas of soils such as the Morey and Mowata. In places, small areas of soils with loam or very fine sandy loam surface horizon textures are used for rice production. Soil with clay loam, sandy clay, sandy clay loam, loamy sand, or sand textures are rarely, if ever, used for growing rice in Louisiana.

The cumulative percentages in Tables 3 to 5 are theoretical values based on Stokes' Law and the assumptions already indicated. In using the estimates in these tables, it may be necessary to consider the effects of some of the main factors that affect the actual settling of soil particles in water-leveled fields.

It is assumed that water motion stops when water-leveling activity ceases. Strong winds or other factors that agitate the water can result in longer periods being required for sedimentation than indicated by the tables. Soil particles in suspension initially are assumed to be representative of the surface soil horizon. The actual amount of soil in suspension initially can have a wide range but is only a small fraction of the total soil surface horizon.

The cumulative percentages given in Table 3 to 5 do not assume a certain amount of soil initially in suspension. The values in Tables 3 to 5 reflect the theoretical percent settled of whatever quantity of soil in that

Table 3.—Theoretical percentage of suspended sediment that has settled after the given times by water depth for specific textures (see Table 1 or Figure 1)

	Soil texture															
	Sandy clay				Loam				Clay loam				Silt loam			
Time (days)	Water depth (inches)															
	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24
	% sediment settled															
.25	64.2	59.5	58.0	57.2	88.0	86.4	85.9	85.6	72.2	68.5	67.3	66.7	85.7	83.8	83.2	82.9
.50	73.6	64.2	61.1	59.5	91.1	88.0	86.9	86.4	79.5	72.2	69.7	68.5	89.5	85.7	84.4	83.8
.75	77.8	68.9	64.2	61.9	92.5	89.5	88.0	87.2	82.8	75.8	72.2	70.4	91.1	87.6	85.7	84.8
1.0	81.7	73.6	67.4	64.2	93.8	91.1	89.0	88.0	85.8	79.5	74.6	72.2	92.7	89.5	86.9	85.7
1.5	84.0	77.8	73.6	68.9	94.6	92.5	91.1	89.5	87.6	82.8	79.5	75.8	93.6	91.1	89.5	87.6
2	86.3	81.7	76.5	73.6	95.3	93.8	92.1	91.1	89.3	85.8	81.7	79.5	94.5	92.7	90.6	89.5
3	89.9	84.0	81.7	77.8	96.5	94.6	93.8	92.5	92.2	87.6	85.8	82.8	96.0	93.6	92.7	91.1
4	90.4	86.3	83.3	81.7	96.7	95.3	94.3	93.8	92.5	89.3	87.0	85.8	96.1	94.5	93.3	92.7
5	90.8	88.5	84.8	82.9	96.8	96.1	94.8	94.2	92.9	91.1	88.2	86.7	96.3	95.4	93.9	93.2
6	91.3	89.9	86.3	84.0	97.0	96.5	95.3	94.6	93.2	92.2	89.3	87.6	96.5	96.0	94.5	93.6
7	91.7	90.1	87.8	85.2	97.0	96.6	95.8	95.0	93.6	92.3	90.5	88.5	96.7	96.1	95.1	94.1
8	92.2	90.4	89.3	86.3	97.3	96.7	96.3	95.3	93.9	92.5	91.7	89.3	96.9	96.1	95.7	94.5
9	92.6	90.6	89.9	87.4	97.4	96.8	96.5	95.7	94.2	92.7	92.2	90.2	97.0	96.2	96.0	95.0
10	93.0	90.8	90.1	88.5	97.6	96.8	96.6	96.1	94.6	92.9	92.3	91.1	97.2	96.3	96.0	95.4
11	93.5	91.0	90.2	89.6	97.7	96.9	96.6	96.5	94.9	93.0	92.4	91.9	97.4	96.4	96.1	95.9
12	93.9	91.3	90.4	89.9	97.9	97.0	96.7	96.5	95.3	93.2	92.5	92.2	97.6	96.5	96.1	96.0
13	94.4	91.5	90.5	90.0	98.0	97.1	96.7	96.6	95.6	93.4	92.6	92.2	97.8	96.6	96.2	96.0
14	94.8	91.7	90.7	90.1	98.2	97.1	96.8	96.6	96.0	93.6	92.7	92.3	97.9	96.7	96.3	96.1

Table 4.—Theoretical percentage of suspended sediment that has settled after the given times by water depth for specific textures (see Table 1 or Figure 1)

Time (days)	Sand				Loamy sand				Sandy loam				Sandy clay loam			
	Water depth (inches)															
	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24
	%sediment settled															
.25	96.5	96.1	95.9	95.9	94.2	93.4	93.2	93.1	87.9	86.3	85.8	85.5	80.0	77.4	76.5	76.1
.50	97.3	96.5	96.2	96.1	95.6	94.2	93.7	93.4	91.0	87.9	86.9	86.3	85.2	80.0	78.2	77.4
.75	97.7	96.9	96.5	96.3	96.3	94.9	94.2	93.8	92.4	89.5	87.9	87.1	87.5	82.6	80.0	78.7
1.0	98.0	97.3	96.8	96.5	96.9	95.6	94.6	94.2	93.7	91.0	88.9	87.9	89.7	85.2	81.7	80.0
1.5	98.2	97.7	97.3	96.9	97.2	96.3	95.6	94.9	94.5	92.4	91.0	89.5	91.0	87.5	85.2	82.6
2	98.4	98.0	97.6	97.3	97.6	96.9	96.1	95.6	95.2	93.7	92.0	91.0	92.2	89.7	86.8	85.2
3	98.8	98.2	98.0	97.7	98.1	97.2	96.9	96.3	96.5	94.5	93.7	92.4	94.3	91.0	89.7	87.5
4	98.8	98.4	98.2	98.0	98.2	97.6	97.1	96.9	96.6	95.2	94.3	93.7	94.5	92.2	90.6	89.7
5	98.8	98.6	98.3	98.1	98.3	97.9	97.4	97.1	96.8	96.0	94.8	94.1	94.8	93.5	91.4	90.4
6	98.9	98.8	98.4	98.2	98.4	98.1	97.6	97.2	96.9	96.5	95.2	94.5	95.0	94.3	92.2	91.0
7	98.9	98.8	98.6	98.3	98.4	98.2	97.8	97.4	97.1	96.5	95.7	94.9	95.3	94.4	93.1	91.6
8	99.0	98.8	98.7	98.4	98.5	98.2	98.0	97.6	97.2	96.6	96.2	95.2	95.5	94.5	93.9	92.2
9	99.0	98.8	98.8	98.5	98.6	98.3	98.1	97.8	97.4	96.7	96.5	95.6	95.8	94.6	94.3	92.9
10	99.0	98.8	98.8	98.6	98.6	98.3	98.2	97.9	97.5	96.8	96.5	96.0	96.0	94.8	94.3	93.5
11	99.1	98.9	98.8	98.7	98.7	98.3	98.2	98.1	97.7	96.8	96.6	96.4	96.2	94.9	94.4	94.1
12	99.1	98.9	98.8	98.8	98.8	98.4	98.2	98.1	97.8	96.9	96.6	96.5	96.5	95.0	94.5	94.3
13	99.2	98.9	98.8	98.8	98.8	98.4	98.2	98.2	98.0	97.0	96.7	96.5	96.7	95.1	94.6	94.3
14	99.2	98.9	98.9	98.8	98.9	98.4	98.3	98.2	98.1	97.1	96.7	96.5	97.0	95.3	94.7	94.4

Table 5.—Theoretical percentage of suspended sediment that has settled after the given times by water depth for specific textures (see Table 1 or Figure 1)

Time	Soil texture: Silty clay loam				Silt				Silty clay				Clay (light)				Clay (heavy)			
	Water depth (inches)																			
(days)	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24
	% sediment settled																			
.25	72.3	68.8	67.4	66.8	93.7	92.8	92.6	92.4	64.4	59.7	58.1	57.3	64.3	59.6	58.0	57.2	48.5	41.8	39.5	38.4
.50	79.6	72.3	69.8	68.6	95.3	93.7	93.1	92.8	73.8	64.4	61.3	59.7	73.7	64.3	61.2	59.6	62.1	48.5	44.0	41.8
.75	82.9	75.9	72.3	70.5	96.1	94.5	93.7	93.3	78.0	69.1	64.4	62.0	77.9	69.0	64.3	61.9	68.2	55.3	48.5	45.1
1.0	85.9	79.6	74.7	72.3	96.8	95.3	94.2	93.7	81.9	73.8	67.5	64.4	81.8	73.7	67.4	64.3	73.8	62.1	53.1	48.5
1.5	87.7	82.9	79.6	75.9	97.2	96.1	95.3	94.5	84.2	78.0	73.8	69.1	84.1	77.9	73.7	69.0	77.2	68.2	62.1	55.3
2	89.4	85.9	81.8	79.6	97.6	96.8	95.9	95.3	86.4	81.9	76.7	73.8	86.3	81.8	76.6	73.7	80.4	73.8	66.3	62.1
3	92.3	87.7	85.9	82.9	98.2	97.2	96.8	96.1	90.1	84.2	81.9	78.0	90.0	84.1	81.8	77.9	85.7	77.2	73.8	68.2
4	92.6	89.4	87.1	85.9	98.3	97.6	97.1	96.8	90.5	86.4	83.5	81.9	90.4	86.3	83.4	81.8	86.3	80.4	76.1	73.8
5	93.0	91.2	88.3	86.8	98.4	98.0	97.3	97.0	91.0	88.7	85.0	83.1	90.9	88.6	84.8	83.0	86.9	83.6	78.2	75.5
6	93.3	92.3	89.4	87.7	98.5	98.2	97.6	97.2	91.4	90.1	86.4	84.2	91.3	90.0	86.3	84.1	87.6	85.7	80.4	77.2
7	93.7	92.4	90.6	88.6	98.6	98.3	97.9	97.4	91.9	90.3	87.9	85.3	91.8	90.2	87.8	85.2	88.2	86.0	82.6	78.8
8	94.0	92.6	91.8	89.4	98.6	98.3	98.1	97.6	92.3	90.5	89.4	86.4	92.2	90.4	89.6	86.3	88.9	86.3	84.7	80.4
9	94.4	92.8	92.3	90.3	98.7	98.4	98.2	97.8	92.8	90.8	90.1	87.6	92.7	90.6	90.0	87.5	89.5	86.6	85.7	82.0
10	94.7	93.0	92.4	91.2	98.8	98.4	98.3	98.0	93.2	91.0	90.2	88.7	93.1	90.9	90.1	88.6	90.2	86.9	85.9	83.6
11	95.1	93.1	92.5	92.0	98.9	98.4	98.3	98.2	93.7	91.2	90.4	89.8	93.6	91.1	90.3	89.7	90.8	87.3	86.1	85.2
12	95.4	93.3	92.6	92.3	99.0	98.5	98.3	98.2	94.1	91.4	90.5	90.1	94.0	91.3	90.4	90.0	91.5	87.6	86.3	85.7
13	95.7	93.5	92.7	92.4	99.0	98.5	98.3	98.3	94.6	91.6	90.7	90.2	94.5	91.5	90.6	90.1	92.1	87.9	86.5	85.8
14	96.1	93.7	92.8	92.4	99.1	98.6	98.4	98.3	95.0	91.9	90.8	90.3	94.9	91.8	90.7	90.2	92.8	88.2	86.7	86.0

texture class was initially in suspension.

The percent by weight of particles in suspension is not indicative of relative degree of turbidity or vice versa. For example, a small percentage of clay-size particles in suspension can result in high turbidity. Particle size distributions within a soil texture class that differ from those used in the calculations can result in expected sedimentation times that differ slightly from the calculated. In comparison with the assigned particle size distributions (Table 1, Figure 1), a larger percentage of sand and/or silt and smaller percentages of clay result in sedimentation times slightly less than the calculated periods. Conversely, a greater percentage of clay will result in slightly greater sedimentation times. Finally, few if any soil surface horizons are completely dispersed. This undispersed condition results in clumping together (flocculation) of smaller particles so that they settle at a faster rate than if they are dispersed. This can result in shorter time periods for a given percent to settle than in shown.

In conclusion, the theoretical settling times in Table 3 to 5 can serve as a guide for decision-making regarding the length of time to allow for settling in order to prevent removal of large quantities of sediment when draining fields after they have been water-leveled. Changes in temperature and winds, or other disturbances that result in currents in the water, will result in a lower percent settling out at a given time than is indicated in Tables 3 to 5. Conversely, the flocculation characteristic of essentially all soils will result in a larger percent settling out at a given time than is indicated in the tables.

The methods applied in obtaining estimates of settling time have other applications. For example, settling ponds used to allow deposition of sediment are used in strip mine reclamation to remove potential pollutants from runoff water. The estimation of deposition in coastal wetlands could also be approached by methods used in this paper.

References

Baver, L. D. *Soil Physics* (third edition). 1965. John Wiley and Sons, Inc.: New York. Chapter 3, pp. 48-80.

Lawson, L. F. ''Water Leveling on Ricelands.'' 1962. Transactions of the American Society of Agricultural Engineers. Col. 43, No. 4, pp. 202-203.

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