THE EFFECTS OF WIND AND SALINITY UPON THE SEDIMENTATION RATES OF SOILS FROM DREDGING SITES IN ALBEMARLE SOUND, NORTH CAROLINA

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ABSTRACT

Clay, loam, silt, and sand soil samples collected from dredging sites in Albemarle Sound were suspended in solutions of sea water varying from 0 to 25 per cent sea strength. Sedimentation rates were obtained by measuring the amount of light transmission through each solution as described by Coggin, 1960. Test suspensions were placed in a wind tunnel to determine the effect of wind action on sedimentation rates.

Except for sand, no appreciable sedimentation of the suspended soils occurred in the zero concentrations of sea water during the entire test period. Rapid sedimentation of the other soil types tested occurred during the first 8 hours in all tests of all sea-water concentrations and no appreciable difference was noted between the various percentages of sea water.

A simulated wind velocity of 7 miles per hour had no appreciable effect on the sedimentation rates in 10 per cent sea water. A wind velocity of 14 miles per hour precluded any appreciable sedimentation of soils in the sea-water concentrations tested. The agitational effects of wind action on the material suspended in the solutions was greater than the accelerated rate of sedimentation provided by the sea-water concentrations tested.

INTRODUCTION

A temporary lease to mine the oyster shell deposits in eastern Albemarle Sound recently was issued to a North Carolina firm. An estimated 700 million cubic yards of oyster shells lie beneath varying depths of soil sediments and removal of these shell deposits necessitates considerable excavation of the overlying soil sediments which would be subject to being placed in suspension for unknown periods. The resulting detrimental effects of excessive turbidity and siltation on the habitat for fish and for waterfowl food plants made it desirable to determine the sedimentation rate of the various soil types which would be encountered during the dredging operations.

Any detrimental effects which might occur in Albemarle Sound could also extend into Currituck Sound, Kitty Hawk Bay, Collington Bay, North River, East Lake, South Lake, and Alligator River due to the encroachment of Albemarle Sound water into these adjacent areas during various wind tides. All of these waters, at present, support a good to excellent fresh-water fishery. The water depth in Currituck Sound, one of the best largemouth bass fisheries and waterfowl areas in the United States, is increased at times by as much as twelve inches in twenty-four hours by water being pushed from Albemarle Sound by southwesterly winds. A Cooperative Study of Back Bay-Currituck Sound, conducted by the Bureau of Sport Fisheries and Wildlife (U. S. Fish and Wildlife Service), Virginia Commission of Game and Inland Fisheries, and the North Carolina Wildlife Resources Commission has determined that excessive turbidity is the primary factor limiting the growth of waterfowl food plants in the Sound. Additional turbidity obviously would be very undesirable.

Coggin (1960) reported that sedimentation rates for various soils in suspension increased as the concentration of sea water increased. As the area of Albemarle Sound to be dredged contains varying concentrations of sea water, the persistence of turbidity induced by the dredging operations in the area was estimated by suspending the various types of soils overlying the shell deposits in varying concentrations of sea water and the rate of sedimentation obtained. It was also desired to obtain some measure of the effect of wind action on the sedimentation rates of the various soils because this might well be an important nautral factor maintaining the soils in suspension.

PROCEDURES

Soil samples were collected throughout the area and identified as to type based on previous soil classfications provided by the U. S. Soil Censervation Service, Plant Industry Station, Beltsville, Maryland. Soil samples were obtained from the dredging sites with a portable, combination soil auger and core sampler.

The portable, combination auger and core sampler, mounted on the chassis of a truck, was loaded onto a barge and towed to the desired sample site. The barge was anchored as sturdily as possible and the truck was backed to the edge of the barge to the extent that the auger mechanism extended over the edge. The auger was bored into the bottom to a 50-foot depth. It was pulled up, without turning the bit, and dismantled by five-foot sections. The soil remained on the auger at the depth at which it was encountered. The different soils recovered were recorded as to type and depth and the samples placed in labeled plastic containers for shipment to the laboratory. These constituted the soil types used in all tests.

The chlorinity and per cent sea water in all test solutions were determined by the Mohr method as outlined in Standard Methods for the Examination of Water, Sewage and Industrial Wastes (1955). A chlorinity content of 19,538 ppm (19.538 parts per thousand) was considered full-strength sea water (Sverdrup, Johnson, and Fleming, 1942).

De-ionized water was used as the zero per cent sea-water concentration in all experiments. Sea water, obtained 300 feet from shore at Nags Head, North Carolina, was mixed with de-ionized water to obtain the various percentages of sea water used.

Each experiment was terminated at the end of 24 hours. Foot-candles of light transmitted through the solutions and the temperature of the test solutions were recorded at two- or four-hour intervals—the time depending on the rate of increase of light transmitted. The foot-candles of light transmission were plotted against elapsed time to determine the sedimentation rates in terms of per cent sedimentation.

Light-tight box experiments:

Three light-tight boxes, each with five separate compartments, as developed by Coggin (1960), were constructed with a rheostat-controlled light bulb behind each compartment. A jar was placed in each compartment so that the light would shine through a hole in one side, through the center of each jar and through a hole on the side opposite the light source. The light transmitted through the test solutions was determined with a light meter, graduated in foot-candles, placed in the hole opposite the light source.

Sea-water solutions of 0. 5, 10, 15, and 25 per cent, were used for all soils tested in the light-tight boxes. The sea-water solutions were prepared and 1,500 ml poured into each jar. The light transmitted through each solution was then adjusted to 54 foot-candles by rheostat control.

Following the techniques used by Coggin (1960) in his Currituck Sound-Back Bay soil sedimentation studies, a suspension containing 5 grams of soil per liter was placed in each jar and stirred vigorously for ten seconds with a paddle shaft at 2,000 rpm.

The sedimentation tests in the light-tight boxes were conducted under static conditions.

Wind Tunnel Experiments:

To compare the sedimentation rates of various soil types under simulated wind action, a wind tunnel was constructed according to specifications outlined by the U. S. Weather Bureau, Raleigh, North Carolina. The U. S. Weather Bureau advised that the wind velocities on Albemarle Sound average approximately 15 miles per hour. Fourteen mile-per-hour winds were used in the wind tunnel experiments to simulate the average wind velocities. Since the 14 mile-per-hour wind precluded any appreciable sedimentation in silt, loam, and clay soil solutions, it was deemed desirable to conduct wind tunnel experiments with a lesser wind velocity.

Four trays, 24 inches long, 12 inches wide, and 3 inches deep were utilized in the wind experiments—two as quiet controls and two in the wind tunnel. The wind was directed horizontally over the surface of the trays and its velocity was determined with a Dwyer Wind Meter. The speed of the wind tunnel fan was adjusted to obtain the desired wind velocities of 7 and 14 miles per hour. The test solutions in the trays were mixed to the equivalent of 10 per cent sea water. Twelve liters of the solution were placed into each tray with 60 grams of soil and thoroughly mixed by hand.

To determine the sedimentation rates, 200 ml of the test solutions were carefully siphoned from each tray at two- or four-hour intervals, placed in jars in the light-tight boxes, and the foot-candles of light transmission recorded. The 200 ml of test solution were carefully replaced in such a manner that the sediment was not disturbed.

A question arose concerning the ability of average wind velocities to re-suspend soil particles after a significant amount of sedimentation had taken place. To investigate this aspect, silt and loam soil solutions in 15 per cent sea water were placed into the wind tunnel for 2- or 8-hour periods of no wind followed by a 2-hour period of average wind velocity.

DISCUSSION OF RESULTS

A total of 18 light-tight box and wind tunnel experiments were conducted on 12 soil samples obtained at varying depths from the dredging area of Albemarle Sound. Sand, silt, loam, and clay were the basic soil types encountered.

Sedimentation rates were determined by the progressive increase in the amount of light transmitted through solutions with initially equal turbidities. The sedimentation of heavier soil particles that occurred immediately after stirring could not be measured. This unmeasurable fraction was considered non-significant in determining the sedimentation over a 24-hour period.

Coggin (1960) found that a temperature range of 39° to 81°F had no appreciable effect on the sedimentation rates of clay during a 6-hour test period. The temperature range for the light-tight box and wind tunnel experiments was 44° to 73° F. Within this range, temperature appeared to have no appreciable effect on the sedimentation rates of the soils tested.

Light-tight box experiments:

Sedimentation rates obtained in the light-tight box experiments for representative sand, silt, loam, and clay soil types are presented in Figures 1, 2, 3, and 4, respectively. The per cent sea-water concentrations are presented with each soil type.

There was a 41 per cent sedimentation of the sand soils in the zero per cent sea-water solutions. Sedimentation of sand soil in the zero per cent sea-water solutions was expected because of the nature of the soil. For all remaining soil types, no measurable sedimentation occurred. These data indicate that in water with no salinity the turbidity apparently remained unaltered under quiescent conditions. Initially, some sedimentation does occur but no quantitative estimate was possible. An average of 67 per cent sedimentation occurred during the first 8 hours for all soils suspended in sea-water solutions (Figures 1 through 4).

After the initial rapid decline in turbidity, the sedimentation rate decreased sharply. An average of 86 per cent sedimentation occurred for all soils except sand during the 24-hour periods. Sedimentation of sand was complete, except in the 5 per cent sea-water solution, at the end of 24 hours.

The presence of any sea water, within the range tested, had a very significant effect on the sedimentation rates of all soils tested. There was, however, little difference in the sedimentation rates of soils in the various solutions of sea water (5 to 25 per cent).

Wind Tunnel Experiments:

To simulate natural conditions, a wind tunnel was constructed and the suspended soil samples were exposed to varying wind velocities directed horizontally across the water surface. Evaporation caused some increase in the sea-water concentration of all solutions in the wind tunnew experiments. The range of sea-water concentrations encountered are shown in each respective Figure. The quiescent control solutions in all wind velocity experiments decreased in turbidity similarly to the decrease found with the same sea-water concentrations in the light-tight box experiments.

Sedimentation rates obtained in the 14 mile-per-hour wind tunnel experiments for representative silt and loam soil types are presented in Figures 5 and 6, respectively. No decrease in turbidity occurred under a 14-mile-per-hour wind with an initial 10 per cent sea-water concentration for silt and loam soil. Clay soils suspended in a 10 per cent sea-water concentration showed no appreciable decrease in turbidity under a 14-mile-per-hour wind (Figue 7) and were relatively comparable to the sedimentation rates of loam and silt soils.

A comparison of the effects of wind velocities of 7 and 14 miles per hour showed that the results obtained in a 7 mile-per-hour wind test were not appreciably different from the quiescent control solution of the same salinity. In all cases where the 14 mile-per-hour wind was employed (Figures 6 and 7), the wind action precluded any appreciable sedimentation.

In 15 per cent sea water, with no wind over a two-hour period, a 7 per cent sedimentation occurred in both the silt and loam soil suspensions (Figure 8). A wind velocity of 14 miles per hour for two hours re-suspended the soil particles to the extent that light transmission was reduced to zero foot-candles. During a following eight-hour period with no wind, the sedimentation reached an average of 40 per cent for both the silt and loam soil solutions. A second two-hour period of 14 mile-per-hour wind velocity again re-suspended the soil particles to the extent that there was not light transmission. During a second eight-hour period with no wind, the sedimentation reached an average of 54 per cent. A third two-hour period of 14 mile-per-hour wind re-suspended the soil particles to the extent that light transmission was reduced to 4 per cent for both samples. It appears that a cessation of wind action permits a partial clearing of the water temporarily, but that a resumption of the wind quickly re-establishes the previous turbidity.

The sea-water concentrations naturally occurring in the eastern portion of Albemarle Sound are, in general, within the range of sea-water concentrations used during the soil sedimentation tests. Sedimentation did not occur to any extent during the 14-mile-per-hour induced wind action experiments made with the soils collected from the dredging area in eastern Albemarle Sound. On the basis of these experiments an average wind velocity of 14 miles per hour could be expected to keep sediments, disturbed by a dredging operation, in suspension for an indefinite period of time.

It may be anticipated that the suspended material will settle during periods of low or no wind velocity. It can also be anticipated that the material may be re-suspended by winds of approximately 14 miles per hour (Figure 8). The re-suspension could create an "accumulated turbidity" which, during extended periods of average or greater wind velocities, could accentuate the detrimental effects to the aquatic habitat in Albemarle Sound and adjoining waters.

CONCLUSIONS

1. During quiescent conditions, suspensions of silt, loam, and clay in solutions of zero per cent sea water can be expected to remain in suspension for an indefinite period of time.
2. Sea-water concentrations from 5 to 25 per cent accelerated the rate of sedimentation for all soils tested with an average of 67 per cent sedimentation occurring the first 8 hours during periods of no wind.
3. A 7 mile-per-hour wind had no appreciable effect on the sedimentation rate of the soils tested.
4. A wind velocity of 14 miles per hour precluded any appreciable sedimentation provided by the sea-water concentrations and was sufficient to completely re-suspend sediment after a partial clearing of 40 per cent occurred during a preceding 8-hour period of no wind.
5. In areas with sea-water concentrations of 5 to 25 per cent, the sediments disturbed by a dredging operation can be expected to settle during periods of low or no wind veolcity and become re-suspended by winds of approximately 14 miles per hour or greater, thereby creating an "accumulated turbidity" which could detrimentally affect an aquatic habitat.

ACKNOWLEDGEMENTS

Appreciation is expressed to Dr. A. F. Chestnut and his staff for their assistance in obtaining the soil samples and to the North Carolina Highway Commission for providing the portable combination soil auger and core sampler and its operating crew.

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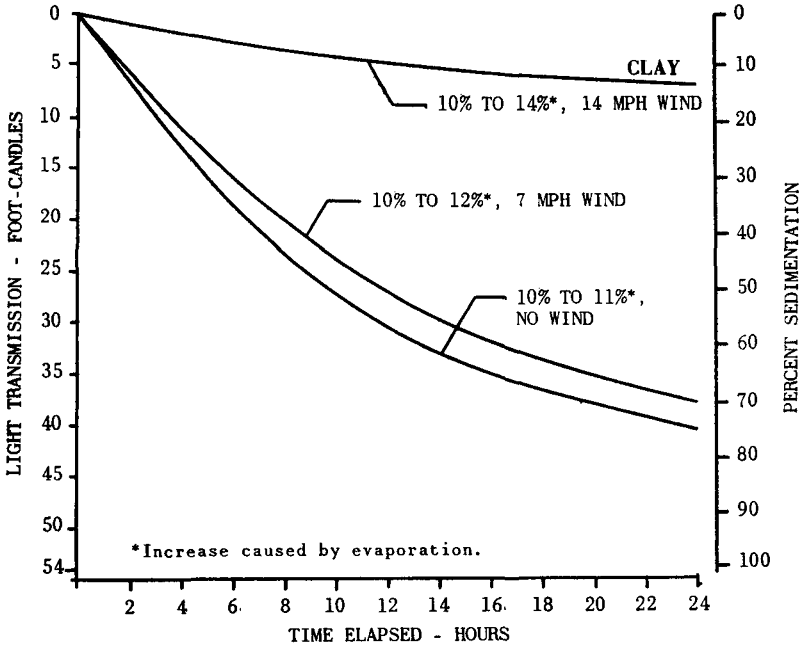

Figure 7. A Comparison of the Effect of 7 and 14 Mile-Per-Hour Winds on the Sedimentation Rates of Clay Suspended in 10 Percent Sea Water Solutions.

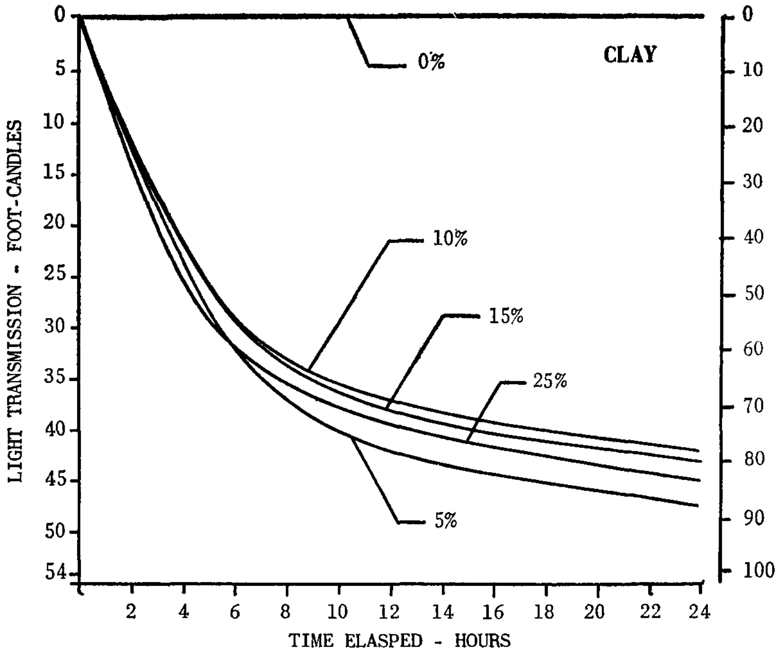

Figure 4. Percent Sedimentation and Foot-Candles of Light Transmission Through Solutions of Clay Induced Into Varying Percentages of Sea Water.

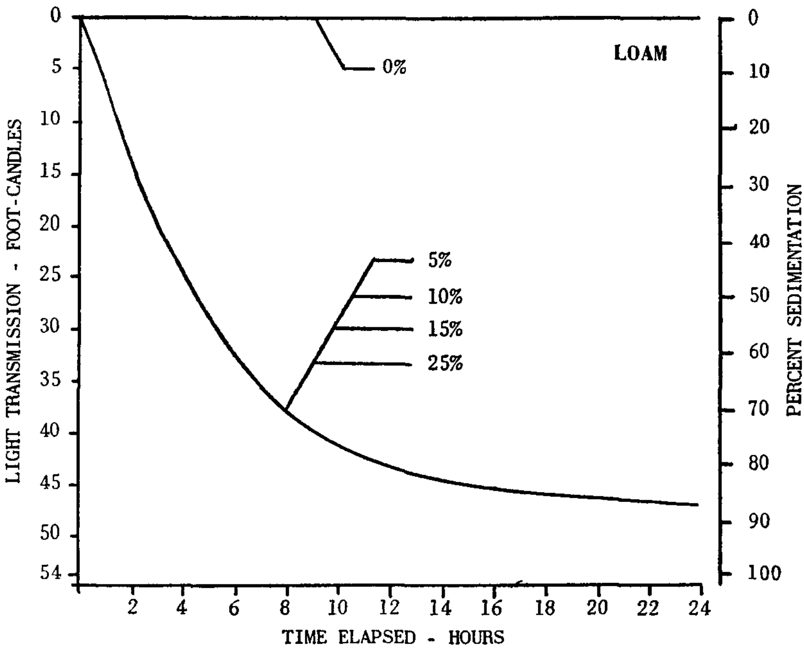

Figure 3. Percent Sedimentation and Foot-Candles of Light Transmission Through Solutions of Loam Induced Into Varying Percentages of Sea Water.

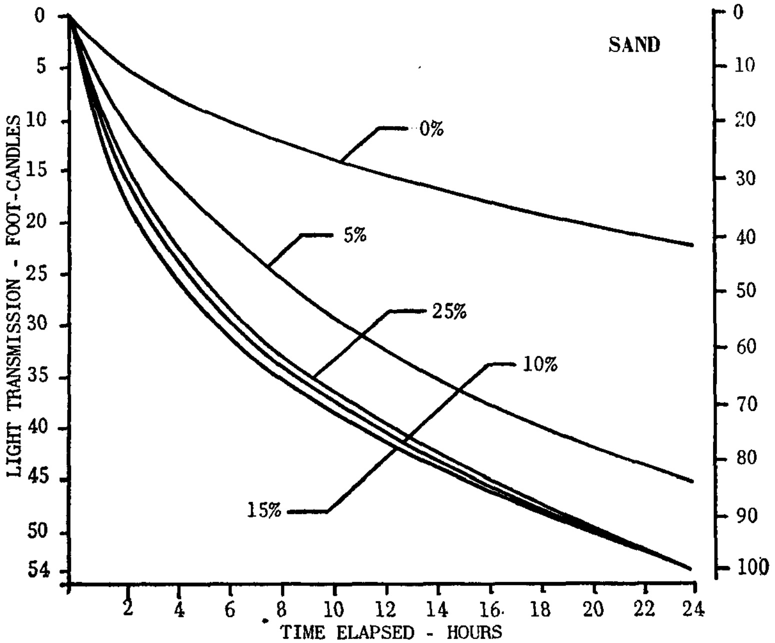

Figure 1. Percent Sedimentation and Foot-Candles of Light Transmission Through Solutions of Sand Induced Into Varying Percentages of Sea Water.

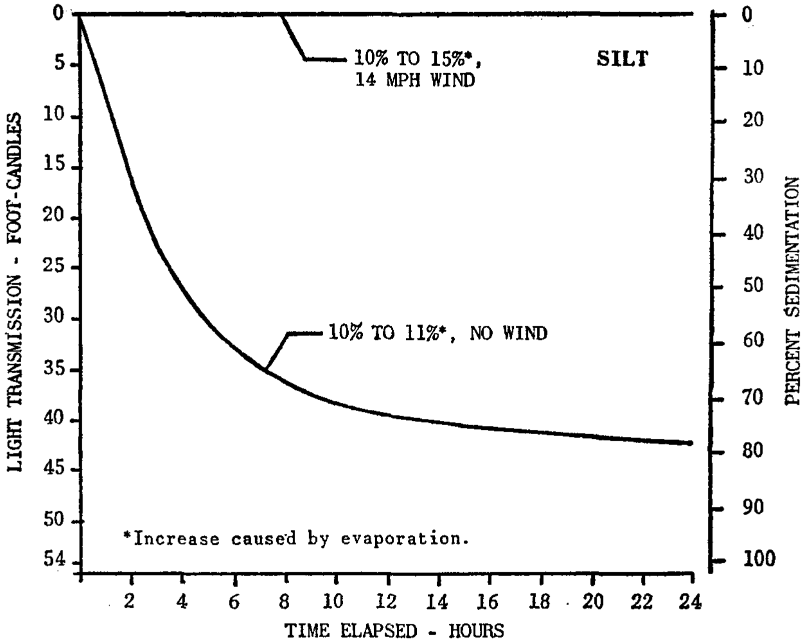

Figure 5. The Effect of a 14 Mile-Per-Hour Wind on the Sedimentation Rates of Silt Suspended in 10 Percent Sea Water Solutions.

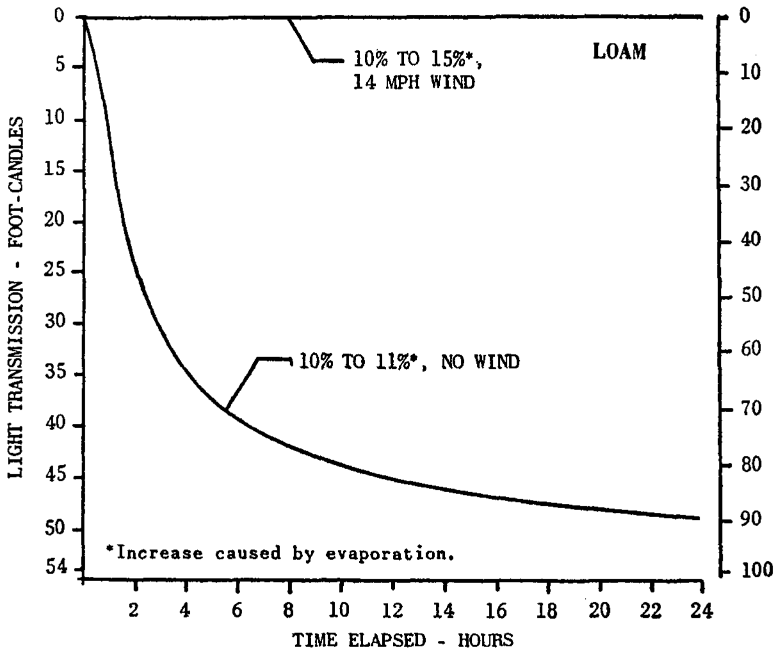

Figure 6. The Effect of a 14 Mile-Per-Hour Wind on the Sedimentation Rates of Loam Suspended in 10 Percent Sea Water Solutions.

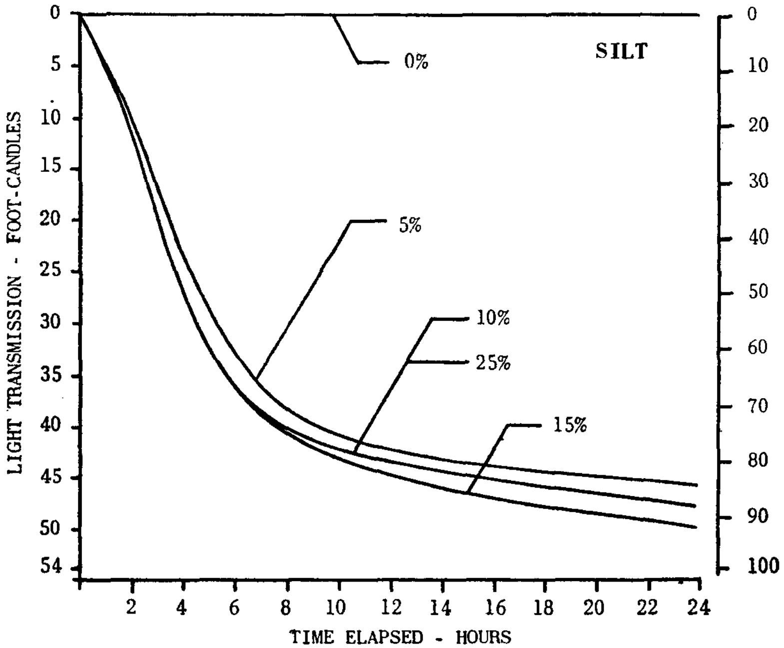

Figure 2. Percent Sedimentation and Foot-Candles of Light Transmission Through Solutions of Silt Induced Into Varying Percentages of Sea Water.

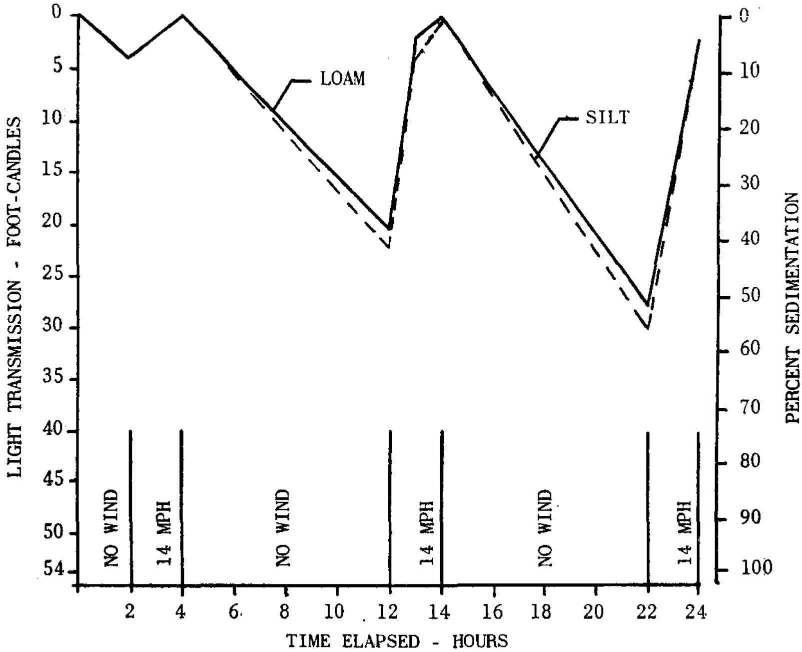

Figure 8. A Comparison of the Effect of Periods of No Wind and Periods of 14 Mile-Per-Hour Winds on the Sedimentation Rates of Silt and Loam Suspended in 15 Percent Sea Water Solutions.