TR-14

Sediment Transport in Shallow Subcritical Flow Disturbed by Simulated Rainfall

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- Full Text

Studies were conducted in a closed system recirculating research flume to evaluate the relative effects of high intensity rainfall on von Karman's universal constant and the sediment transport capacity of shallow flow The tests in this study were conducted at flow depths of 0.3 ft and less, with discharges less than 0.5 cfs. The point velocities in the flow were determined with a Pace CD-25 pressure transducer and an inclined manometer connected in parallel to a Pitot-static tube of the standard Prandtl design. Regression analyses were performed on the velocity data to determine the best fit dimensionless velocity curve on semilogarithmic paper. Von Karman's universal constant was then evaluated from the slope of the regression line.

Point sediment samples were siphoned from the flow with a stainless steel-pipette sediment sampler. Sediment concentrations were found with a filtering technique. Sediment samples were taken with and without rainfall to evaluate the relative effect of the rainfall on the transport capacity of shallow flow.

Introduction

Many important pollution problems of today involve the movement of sediments by water. Although extensive research has been directed towards reducing or eliminating sediment at its source, less research has been directed towards understanding the mechanics of sediment transport between the origin and the point of deposition. Within the continental United States, an estimated one billion tons of sediment are transported to the sea each year (21). This sediment travels by various modes through a system of rivulets, channels, and gullies which enter major waterways. This sediment ultimately causes extensive damage by sedimentation of the streams and reservoirs and, in general, by polluting the water supplies. Much of this vast sediment load in the streams results from land erosion which occurs during the rain storms. Since the sediment is eroded during the high intensity rainfall period of the storm, the sediment is initially transported by shallow flowing water during the time rainfall is occurring.

This study involves transport of sediment, both as suspended load and bed-load in shallow subcritical flow when rainfall is occurring and thereby disturbing the physical processes in the sediment laden flow.

The primary objectives of this study were:

1. To determine the effect of simulated rainfall on sediment concentration, suspended load transport capacity, and bed-load transport capacity of shallow subcritical flow.
2. To determine the effect of suspended sediment and simulated rainfall on von Karman's universal constant, k.

The problem was divided into the following four major categories:

1. Pollution of Water by Sedimentation: One billion tons of sediment per year constitutes a heavy load of pollutants. The resulting turbidity in streams used for water supplies increases the cost of purifying the water for domestic, public, and industrial use. High turbidity is also detrimental to fish and wildlife and decreases any potential recreational value.
2. Sedimentation in Reservoirs: Sediment deposits reduce reservoir capacity while increasing the exposed water surface area for a given quantity in storage. Increased evaporation losses per unit volume of storage result and transpiration losses are increased by vegetation growing at the head of the reservoir. Sediment deposits decrease the life of the reservoir project thus depreciating the value of the storage development.
3. Sedimentation in Improved Waterways: Sediment deposits reduce the capacity and efficiency of waterways resulting in higher flood stages. Canals and pools in improved waterways must continually be dredged to maintain navigation depths. Increased maintenance costs are experienced in irrigation canals and ditches.
4. Sediment Deposits on Land Improvements and Habitats: Agricultural crops and lands are severely damaged by layers of infertile deposits. Homes, industries, and transportation facilities in urban areas experience water and sedimentation damage during flooding. Drainage of agricultural and urban land areas is impaired.

Summary

Studies were conducted in a closed system recirculating research flume to evaluate the relative effects of rainfall on von Karman's universal constant and the transport capacity of the flow. The tests conducted are outlined in Table II. Two different velocity head indicators were used with the Pitot-static tube to determine point velocities in the flow. A stainless steel-pipette sediment sampler was used to siphon point sediment concentrations from the flow. Regression analyses were performed on the velocity data to determine the best fit dimensionless velocity curve on semilogarithmic paper. Von Karman's universal constant was then evaluated from the slope of the regression line.

Sediment samples were taken at 45 second intervals from the beginning of simulated rainfall to determine the effect of rainfall on sediment transport.

Conclusions

1. Suspended sediment reduces the value of the von Karman's universal constant. A significant reduction in von Karman's universal constant is shown in Table IV where the values of K obtained in Test Series A, B and C

(clear water) are shown with those obtained in Test Series I, 2, 3 and 4 (with sediment). The reduction of K with suspended sediment indicates that the mixing is less effective and that the sediment tends to suppress or dampen out the turbulence.

2. Test Series 4 indicates that simulated rainfall and suspended sediment reduces the value of von Karman's universal constant of turbulent exchange which characterizes the effectiveness of the turbulence in transfering momentum. Reduction of K means that the mixing is less effective and the simulated rainfall and suspended sediment tend to suppress the turbulence.
3. The velocity distribution at the centerline of the flume for all test series (with and without rainfall) were of the logarithmic form (within the accuracy of the instrumentation) and followed the velocity defect law.
4. The suspended load transport capacity of the flow appears to be reduced under simulated rainfall conditions due to a reduction in von Karman's universal constant.

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