SYNOPSIS

Soil erosion is of great concern alike to developed and developing countries of the world. The main hazards of erosion are removal of top soil rich in nutrients, water pollution and reservoir siltation. It has been estimated that out of the 326 million hectares of total geographical area in India, nearly 81 million hectares of land (25%) are prone to severe erosion. Out of the net cultivated area of 135.8 million hectares, 56.7 million hectares (41.7%) are affected by soil erosion. Several major multipurpose reservoirs like those of Bhakra, Panchet, Maithon, Mayurakshi, Tungabhadra and Chambal have been experiencing siltation at rates far in excess of their design values, thus seriously impairing their storage capacities.

Main causes for erosion by water are raindrop impact, overland flow and channel flow. Of these, overland flow is known to contribute the most by way of erosion and sedimentation. Rainfall in excess of infiltration and depression storage, after building up an adequate head to cause flow, runs off a land slope as a thin sheet. This is termed as overland flow with slightly varying thin depths of flow as a result of continuously changing bed configurations. Within a short distance, the flow may change from laminar to turbulent or vice-versa. The depth of overland flow is a variant due to the irregularities of the bed and its mobility. When it rains, falling raindrops bring in added turbulence creating turbulent flow in local regions at Reynolds' numbers that would ordinarily indicate laminar flow. The resulting overland flow is thus unsteady and is spatially varied.

Several investigators have studied soil loss and deposition phenomena in nature and attributed qualitatively the reasons for the same with certain degree of confidence. However, the interplay of various parameters causing soil loss has not been clearly established. Analytical approaches to the problem of overland flow and the resulting soil loss have not been practicable in view of the complexity of the phenomena. Thus, research workers have to adopt an essentially empirical approach. In the forties of this century, some investigators have suggested the study of soil erosion as a process of detachment and transportation of bed materials by erosive agents. This has led to a more rational approach towards erosion prediction and control by simulating the complex erosion-sedimentation process as a system.

This thesis embodies a report on the research work carried out to study the mechanics of erosion on non-cohesive soil bed by overland flow under simulated rainfall. An attempt is made to develop a coherent theory on transportability of soil by overland flow. The work is fundamental in nature and may be made to serve as a basis for future studies on mechanics of erosion and sedimentation on cohesive soil rather than for any direct prediction of field erosion.

The specific objectives of the present research are

i) to study the inter-relationships between hydraulic parameters and the resulting soil loss in case of a non-cohesive soil,

ii) to examine the applicability of bed-load theories to non-equilibrium erosion prevalent in overland flow with and without rainfall,

iii) to develop a relationship based on dimensional analysis identifying all the various physical parameters involved in the soil erosion problem,

and iv) to study the influence of raindrop impact on soil loss under varying flow depths.

Experiments were conducted under four major sets of conditions in order to establish the effects of intake, sedimented inflow and rainfall. Each set consisted of 80 experiments with combinations of two inflow rates, four slopes, and ten durations of runs. Relatively high inflow rates were chosen to maintain the flow regime turbulent, in order to verify the validity of bed-load theories in the case of overland flow. Runs were conducted in an indoor laboratory flume specially developed for this study. The set-up incorporated devices for intake, rainfall and total sediment collection. Measuring devices for inflow, intake, outflow discharges and depth and velocity of overland flow were also incorporated. A non-cohesive, uniform sized sand was used as bed material for all the experimental runs. After one hour of idle run, total samples of the transported sediment were collected. This was done to stabilize the bed and to allow the flow to attain near regime conditions. The levels for each of the other parameters were fixed on considerations such as capacity for handling the total sediment.

The data were processed on an IBM 1620 digital computer using Fortran - II. Statistical analyses included tests on the validity of known parametric relations, development of new relations, tests of significance, correlation and goodness of fit.

Six single parametric equations between soil loss and each of flow velocity, flow depth, slope, tractive force, Reynolds and Froude numbers were developed. Of these independent parameters, tractive force had the greatest effect on soil loss and Reynolds number the least. The power and second order-polynomial equations fitted to the data are in general agreement with the earlier researches. It is found that the parametric equations could be as well fitted through a linear relation of the form $Y = mX + c$ as compared to the power or quadratic forms.

It is found on statistical analysis that the functional form of Einstein-Brown, Kalinske-Brown, Du Boys, Yalin and Bagnold bed-load theories are applicable in varying degrees under the experimental conditions to the overland flow studied. The relationship between the dependent transportation function and the independent entrainment function is in closer agreement with those of the Einstein-Brown, and Kalinske-Brown followed by Du Boys. But, the original equations given by those investigators are not suitable to predict soil loss within 50 per cent confidence limit. Amongst the equations tested, Yalin's gave results closest to the soil losses found in the present study followed by those of Du Boys, Einstein-Brown and Bagnold.

The equation developed by dimensional analysis has been found to have a statistically significant relationship between the dependent and independent dimensionless groups. The predicted value of soil erosion from the equations fitted to each set of experimental results as well as the equation proposed to the test results of all the sets are found to be well within 50 per cent confidence limits due to the introduction of the sheet flow factor into the entrainment function accounting for bed configurations, rill formations and the excess turbulence created by raindrop impact.

The velocity of flow is found to be restricted due to rainfall impact while the bed particles are being transported by splash. A qualitative observation of the raindrop impact indicated that shallower the flow depth the higher is the turbulence in the vicinity of the bed. Therefore, the effects of the decreased velocity and the increased turbulence due to raindrop impact get nullified as far as sediment transportability is concerned.

Various bed-load theories based on tractive force, turbulence theory, dynamics and stochastic models or certain combinations of these have been found to be inapplicable in their original forms. The ratio of the particle size to the hydraulic mean radius could be a significant factor in transportability of sediment. A possible reason for the non-applicability is the neglect of this significant factor. Though certain critical parameters govern the initiation of bed load movement, these do not play any role in controlling transportability during flow. The effect of bed configurations, rill formations and the excess turbulence created by raindrop impact with low discharges on flat slopes is adequately covered by the sheet flow factor introduced in this study.