

SOME FUNDAMENTAL PRINCIPLES OF EROSION*

IT has so far proved impossible to express the problems of erosion in terms of known physical laws. Hydraulic engineers have evolved certain empirical rules for its prediction, but these do not appear to have universal application. According to Dr. E. G. Richardson of King's College, Newcastle, England, the chief factors deciding the amount of stream erosion are :—

- (a) the degree of turbulence of the water,
- (b) the magnitude of the " gradient of velocity " over the soil surface,
- (c) the size, shape and density of the soil particles,
- (d) the compactness of the soil.

The gradient of velocity of a stream or runnel is determined by the change in velocity at increasing distances from the bed ; it is a fundamental factor in the modern theory of stream erosion, and is a more useful conception than mere surface velocity. For a given gradient of velocity, provided a stream is sufficiently turbulent to cause adequate mixing, erosion varies inversely as the size of soil particles having the same density. At increasing distances vertically above the bed within the turbulent stream, the concentration of soil particles (" silt ") diminishes exponentially with the magnitude of the height ; hence the slope of the straight-line graph obtained by plotting heights against logarithms of silt concentrations, furnishes a measure of what may be termed the " coefficient of erosion". Silt concentrations were measured by Dr. Richardson by a photo-electric method applied to graded sands moving under the action of water down glass-sided wooden channels. In this way, experimental evidence was obtained which proved the exponential or logarithmic law.

It has often been reported by hydraulic engineers that *colloidal* particles are less easily eroded than particles of larger magnitude. For soil comprising grains of heterogeneous size, a maximum rate of erosion seems to obtain for diameters around 0.1 millimetre (the " fine sand " grade in soil texture analysis). This apparent anomaly is now explained by the fact that the velocity gradient is not the same in moving water carrying colloidal material as in a homogeneous fluid, or in a stream containing sparsely-distributed particles of relatively large dimensions.

The permeability of a soil to water as determined by its natural structure is the first factor to operate erosion. A highly permeable soil allows water to penetrate easily and so to gain intimate contact with the structure units. If these are unstable or incoherent, readily disintegrating into small discrete grains, then the particles are floated apart, and those lying near the surface

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may be lifted bodily into the stream and rapidly removed. Soils having single-grain structure are thus very prone to erosion, especially if the size of the grain is uniform and small (around 0.1 mm.). If, however, the structure is crumbly and the aggregates are large and stable in water, or if it is coarse and the particles are heavy, then a greater velocity gradient is required to disturb the grains; and the soil strongly resists erosion.

A very deep permeable soil may absorb all the rain that falls on the ground, and eroding streams may fail to develop, but a permeable *shallow* soil, underlain by an impervious bed, readily becomes waterlogged and either slowly moves bodily down hill ("hill-creep"), or rapidly fills with water so that runnels develop over its surface. On the other hand, a fine-textured soil having *low* permeability may permit only the surface layer to become saturated, and streams may develop before downward penetration has proceeded very far. Slow penetration may greatly alter the distribution of velocity near the bed through the successive floating off of soil particles, so that a quasi-solid layer is formed at the surface, and this may diminish the load that can be carried in suspension.

Application to Customary Methods of Erosion Control.—One of the chief methods advocated for controlling erosion is to reduce the overall slope of the land by constructing terraces, or by creating barriers of vegetation. These procedures would seem to be merely palliatives. Although a reduction in the angle of slope over the surface of a terrace may be very effective in minimizing erosion, the water-level may rise rapidly during rains, so that, unless the soil is very permeable and deep, the land may become waterlogged and de-aerated. In extreme cases, the waterlogged soil may slip and break down the terrace, spilling water onto the lower grounds. Hence, *in regions of heavy rainfall, terracing should be practised with great caution*, and in all cases provision should be made for the adequate drainage of the tiers, especially when the soil is not very absorptive. Such modification of the terracing system, namely, the provision of drainage and run-off from the backs of the terraces, greatly complicates their construction, and necessitates careful planning over large areas within which outlet channels for the terrace drains must be accommodated.

As Dr. Richardson points out, a much more satisfactory procedure would be the provision of barriers which *reduce velocity gradients while not unduly impeding the run-off*. In the case of large rivers, this object has been achieved by constructing a series of transverse check-dams or shallow weirs placed at short intervals over the bed. These reduce water-movement over the bed almost to a standstill, yet do not retard the main flow. Application of the same principle to the control of sheet erosion on agricultural lands suggests the close sowing of low-growing herbage which will impede the immediate flow of surface water within, say, an inch of the surface while not hindering the run-off of the bulk of the water. In stony land, a similar result might be attained by placing small boulders in rows at intervals across the slopes, and in land being cleared of forest for agricultural utilization, thin logs of wood or stems of bamboo might be used for providing shallow barriers, at least until the slopes have been stabilized by the establishment of some permanent system of agriculture.