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The Cooperative Hydraulics Laboratory

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LABORATORY OBJECTIVE

The basic objective of the Cooperative Hydraulics Laboratory* is to investigate soil conservation problems involving hydraulics and to develop practical applications for field use. The major difference between normal and soil conservation hydraulics is that the former deals with clear water; whereas, the latter problems are complicated by sediment and debris. Therefore, much of the Laboratory's work has dealt with the interaction between flowing fluids and entrained sediment.

LABORATORY HISTORY

The Cooperative Hydraulics Laboratory was established in the spring of 1935. The concept of the Laboratory originated with Dr. W. C. Lowdermilk, then associate chief of the Soil Conservation Service in charge of research. As the name indicates, it is a joint activity of the Soil Conservation Service and the Institute. The laboratory staff members are SCS employees but they also are ranked as members of the Institute research staff. The Institute is represented directly through faculty members who are appointed "cooperative agents" by the Soil Conservation Service. These men participate in the formulation and direction of the research program of the Laboratory. Professor Theodore von Karman serves in this capacity on the wind-erosion aspects of the work and the writer on the hydraulic phases.

In its first years, the Laboratory was connected primarily with a single branch of the research organization of the Soil Conservation Service. Its scope has gradually broadened until now, under Dr. M. L. Nichols, chief of research, it has become a general hydraulics laboratory for the Soil Conservation Service Research Division as a whole.

The Laboratory was built in 1936. It was designed by the staff under Dr. V. A. Vanoni, who has been the Project Supervisor since the beginning. At first the Laboratory concentrated its activities on intensive studies of general soil conservation problems to secure sufficient knowledge to attack field problems. Intimate contact has always been maintained with the rapidly changing field problems of this young and fast-growing Service, and for the last few years much of its effort has gone to the solution of specific field problems. These studies have been in parallel with and complement the Laboratory's fundamental investigations. It is considered very important that the fundamental studies of sediment transportation be continued because much more knowledge will be required than is now available to meet the many difficult and complicated field problems.

EDITOR'S NOTE: In this issue of ENGINEERING AND SCIENCE is begun a series of two articles describing some of the work carried on at California Institute of Technology by the Soil Conservation Service and the application of the investigation. Drs. Vito A. Vanoni and Hans Albert Einstein have presented correlated material; Dr. Vanoni's article appearing in this issue; Dr. Einstein's to be published in August. To clarify the purpose and to outline the activities of the Soil Conservation Laboratory at California Institute of Technology, Dr. Robert T. Knapp has prepared these introductory remarks.

*Operated jointly by the U. S. Department of Agriculture Soil Conservation Service and California Institute of Technology.

LABORATORY ACTIVITIES

Among the first activities of the Laboratory was Vanoni's study of suspended load transportation. This, supplemented with investigations by H. Rouse, N. A. Christiansen, and E. R. Van Driest, and with observations from many field trips, formed the beginning of a good understanding of soil erosion mechanics.

Two other early activities were the studies of density currents as transporting agents for sediment by H. S. Bell and R. T. Knapp and wind erosion by F. Malina in consultation with Professor von Karman. Note that all have the same theme—the transportation of sediment by flowing fluids, which is, and probably always will be, the chief interest of this Laboratory.

The first field problem was the development of a standard design for a drop structure or small dam for use in controlling gully erosion. This was undertaken for the California-Nevada Region of the Soil Conservation Service. The resulting design has been adopted as standard by many operations regions of the Service. This was the first of a series of energy dissipation structures that have been studied. In addition, flow meters, samplers, and similar instrumental equipment have been developed.

During the first field study a practice originated which proved so successful that it became a fixed laboratory policy. It requested that a field engineer, acquainted with the problem, be detailed to work with the Laboratory. This practice has two principal benefits: the field representative brings to the Laboratory accurate knowledge of the problem details and takes back to the field

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Perhaps the most interesting fact concerns their relationship to living bears. It is now apparent that the short-faced bears are not nearly related to the living bears of North America, but have closest kinship with the diminutive spectacle bear of South America. The latter animal is found in the Andes from Colombia south to Chile. It is not often seen in zoological gardens in North America, although several living animals are the property of the Zoological Society of San Diego *(Fig. 2)*. The spectacle bear takes its name from the color pattern on the face, more particularly the marking about the eyes *(Fig. 3)*. In contrast to the black bear, the spectacle bear is a smaller animal, standing about 22 inches tall at the shoulders and weighing less than 100 pounds. Thus, in the lineage of the *tremarctothere* it may be said that not only did the occupants of what was once a great estate give way to a smaller breed, but also their territory became much more restricted in area.

The history of the short-faced bears can be traced back still farther in geologic time. Some of the evidence of their more ancient existence is furnished by fossil teeth and jaw fragments that have been collected in the Mt. Eden formation, Riverside County. These strata accumulated during the Pliocene, or the epoch immediately preceding the Pleistocene. The earliest record of the group leads back into the Miocene epoch, for in the famous Barstow deposits of the Mojave Desert are found curious animals showing relationship to the *tremarctothere* and to the dogs. *Hemicyon*, or half dog, as this carnivore is appropriately called, is a connecting link suggesting the derivation of this group of bears from one branch of the great and diversified family of dogs during the middle of the Age of Mammals.

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a thorough understanding of the advantages and limitations of the Laboratory solution.

PRESENT ACTIVITIES

Because of the war, work on basic research projects has been reduced in order to concentrate on problems of more immediate assistance to the war effort. Wind erosion studies have been discontinued and density current and sediment transportation studies retarded.

During 1943, hydraulic model studies of six large spillways were made by the Laboratory. The first four studies were for existing structures which had proved unsatisfactory and unsafe in operation because their designs were based on faulty hydraulic assumptions. One of these structures is in Oklahoma, one in Louisiana, and two in Texas. By means of the model studies, simple and economical methods of reconstruction were developed for these Southern structures, which will provide them with adequate hydraulic design for the spillways and their stilling basins. Incidentally, the damage loss, plus the cost of reconstructing these four large structures, will exceed the cost of operating this Laboratory for several decades. The other two spillway studies were for structures to be located in Utah and California. In both of these cases the designs were submitted in advance of actual construction, thus giving the Laboratory an opportunity to make constructive suggestions.

During 1943, a standard design for baffle type energy dissipators for pipe outlets was developed as a sequel to the standardized drop structure design. The development of such standardized designs is an effective Laboratory activity because the results apply to innumerable structures instead of to one. Another recent development in this category is a flow meter for pipe line irrigation outlets.

An interesting new density current development arose through the Southern California Edison Company. The company observed that in the spring at their Shaver Lake reservoir the cold heavy snow water entering from the stream would flow underneath the warmer, light water of the lake without mixing with it. Valuable field measurements have already been secured and the investigation is being continued this spring.

The sediment transportation studies have been accelerated by the addition of H. A. Einstein to the staff. He has been studying this particular problem for several years at one of the Soil Conservation Service research stations in the East.

At the request of the Navy, this Laboratory and the Hydraulics Structures Laboratory are studying an important problem of the Los Angeles Harbor. Although this project consumes most of the energies of both staffs, the effort seems justified since it appears that the study is assisting the Navy in more satisfactory operation of this important base.

Sediment Transportation

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on a straight line must not be taken as evidence that the theory is in complete agreement with experiment since as mentioned previously, the exponent z was determined so that the curve would fit the experimental data.

Fig. 8 shows velocity profile curves on the center of the flume for two flows of the same depth, one with clear water and the other with a suspended load of 0.15 per cent by weight, distributed according to the curve at the right of the figure. The shaded area between the velocity curves represents the increase in velocity due to the presence of the sediment. It will be seen that this increase is almost 10 per cent. The effect of the sediment is to reduce the apparent friction resistance of the channel. This results from a modification of the turbulence by the suspended sediment. The turbulence must support the sediment against the action of gravity which causes it to settle. This requires energy which must be supplied by the turbulence thus reducing its intensity. Since the turbulence also transmits the resistance of the channel to the entire cross section of the flow, when its intensity is reduced it is less effective in transferring this resistance and a higher velocity is necessary to establish equilibrium conditions.

The action of sediment in increasing the velocity of flow was observed in all laboratory tests; however, the concentrations used in the laboratory were rather low so there is no evidence available on the variation of this effect with extremely high sediment loads. The action of sediment in reducing the intensity of turbulence indicates that the maximum load that a stream can carry is determined by some kind of equilibrium between the supporting power of the turbulence and the settling tendency of the sediment.

SUMMARY

The experimental work on the transportation of suspended sediment described briefly in this paper has shown that the theoretical relationships which were based on analysis of turbulent flow give approximate results for the distribution of sediment. They have also clarified the inter-action of the sediment and the turbulence and suggested the mechanism by which the maximum load that a stream can carry is determined. Further experimental work and research on the subject is needed and promises to yield results that are necessary to enable engineers to handle sediment-laden flows.