

**MAJOR SEDIMENTATION (EROSION) ISSUES AND ONGOING
RESEARCH AND DEVELOPMENTS AT THE USDA-ARS**

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Abstract: The U.S. Department of Agriculture, Agricultural Research Service (ARS) has research programs designed to produce technology with which to predict, measure, and control erosion and sedimentation associated with U.S. agriculture. Begun in the 1920s, the work now differs greatly from the beginning. This paper identifies key issues associated with the many facets of the program, describes what is currently being investigated, and enumerates some research issues for the future.

Introduction: Erosion and sedimentation research in ARS began in the Soil Erosion Service of the U.S. Department of Interior and transferred to the USDA Soil Conservation Service (SCS) in 1935 where it remained until ARS became a separate USDA agency in 1954. Water erosion and sedimentation research is being conducted at 13 locations in the U.S.: (Tifton and Watkinsville, GA; Oxford, MS; W. Lafayette, IN; Morris, MN; Temple, TX; Tucson, AZ; Boise, ID; State College, PA; Ft. Collins, CO; Beltsville, MD; Durant, OK; and Columbia, MO). Special laboratories, instrumented watersheds, and rainfall simulators are used to produce information for the research. The programs involve fundamental and applied research on erosion and sedimentation, and incorporation of research findings into practices for present-day agriculture. Research is coordinated with the needs of SCS, the Corps of Engineers, the Environmental Protection Agency, and other federal and state agencies. The general principles of erosion and sedimentation are formulated with a mixture of laboratory, watershed, and analytical experiments.

Erosion Prediction and Control (Models): Erosion prediction and control has long been an objective of the USDA, starting with the creation of 10 Regional Soil Erosion Centers in 1928. By 1935, 36 more centers were added in 23 states and Puerto Rico. These centers followed a

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standard procedure to formulate rainfall-runoff and sediment yield equations. In 1935 the 10 original centers were assigned to the newly formed SCS. Following their transfer to ARS in 1954, U.S. Senate Document #59 consolidated the watershed research into six Regional Research Centers at Boise, ID; Tucson, AZ; Chickasha, OK; Columbia, MO; University Park, PA and Tifton, GA. These centers remain intact today with the National Soil Erosion Research Laboratory at W. Lafayette, IN and the National Sedimentation Laboratory in Oxford, MS providing the remainder of the water erosion and sedimentation program.

Two major erosion prediction projects involving multidisciplinary efforts at multilocations are presently underway to improve the erosion prediction technology used in resource assessment and control on agricultural lands: the Revised Universal Soil Loss Equation (RUSLE) and the Water Erosion Prediction Project (WEPP). RUSLE technology involves preparation of computer based technology which replaces the Universal Soil Loss Equation (USLE) and includes new equations with which to provide estimates of the six factors needed to provide soil erosion estimates from a hillslope. WEPP technology, also a computer based approach, besides providing estimates for a hillslope (i.e. technology to replace the USLE), will have a version for application on a small watershed, and a grid version to estimate sediment yield from a moderate sized river basin. The model, based on fundamental hydrologic and erosion principles, has subroutines for climate, hydrology, plant growth, erosion/sediment transport, tillage and residue decomposition. The model simulates overland flow, rill and channel hydraulics, erosion, sediment transport, and deposition. It provides estimates of when and where erosion and deposition is occurring on the hillslope or watershed so that conservation measures can be designed to most effectively control soil loss and sediment yield. RUSLE is now available and WEPP (hillslope) should be in operation by 1992.

Channel Stability--Sediment Transport--Deposition: Runoff from watersheds carries sediment that must be conveyed by flows in downstream channels. Stream channel research has been one of the major efforts of ARS, and measurement of flow and sediment transport rates have been routine parts of research watershed measurement programs. Although the intent of channel measurements has been to determine the quantities of sediment eroded from the watersheds, the associations between the sediment load and channel stability have been identified. Defining the mechanics of sediment transport became a part of the National Sedimentation Laboratory mission, and the need for rectification of stream channel problems led to the interagency effort known as the DEC (Demonstration and Erosion Control) Project.

The two major problems in stream channels are erosion of the channel boundary and deposition of sediment within the channels. These are closely related to bed material transport (sand and gravel) and the meander tendency of alluvial streams with low gradients. Bank failures and headcuts are the most obvious features of local instability. The propagation of bank failures has been shown to be very sporadic and influenced by the temporal variability of extreme flow events and the spatial variability of bed and bank materials.

Watershed protection methods, channel straightening, spur dikes and other mechanical methods of alignment stabilization, and maintenance dredging are examples of rectification methods to control channel deposition. Channel erosion control includes bank shaping and mechanical or vegetative stabilization for localized erosion problems and grade control structures to reduce grade and transport capacity of channel flows.

Sediment transport is still poorly defined. Deviations of actual measurements of transport rates of sand from average trends are large with long time periods. Consequently, estimates of the sand load for unmeasured streams or for single events in even our most intensively observed channels can not be reliably made. Measurement of gravel fractions of bed material load is few, and evidence suggests the gravel accumulation in alternate bars that may deflect the flow and cause erosion of the opposite banks. Consequently, control design remains largely an art with almost no basis to define a failure probability. Rectification methods vary in cost, so means are needed to design rectifications to balance construction and maintenance costs with potential losses from failures. Development of new, more economical rectification methods may be feasible. Research is needed to define the relative effectiveness of various protective measure combinations not only in protecting local channel reaches but also in altering the sediment load delivered downstream. Development of a systems approach to channel rectification is needed.

Reservoir Deposition: Reservoir capacity reduction by sediment deposition was a major ARS concern. From surveys of over 1800 reservoirs, progress was made in defining the extent of the problem. Measurements of reservoir inflow and outflow were used to develop trap efficiency relationships. Novel means of surveying depositions were used including using radioactive tracer elements from nuclear weapon testing. A few rectification methods were investigated including sluicing and bypass. Since the extent of the problem was identified to be less than initial projections and since needed rectifications were identified to be reduction of the sediment supply to reservoirs, emphasis has been redirected upstream.

Instrumentation: Instrumentation for collecting model development data has not kept pace with computer computational capability. Although there are extensive networks of recording precipitation gages associated with ARS experimental watersheds, individual recordings associated with such equipment produce considerable timing uncertainty. Networks of precalibrated runoff measuring devices allow reliable runoff recordings (again timing uncertainty frequently creates problems), but associated sediment transport measuring devices are still difficult to calibrate and labor-intensive to operate. Also, the installation of runoff and sampling equipment in sequence along a channel system generally disturbs the natural channel dynamics in the vicinity of the equipment, and upsets the normal energy equilibrium.

Rainfall simulators used to define infiltration, soil erodibility, rill shear characteristics, and agronomic practice consequences have improved over the equipment used in earlier years. Laser technology has been developed that measures surface characteristics such as roughness and rill dimensions with minimal disturbance. Data collection has been automated for direct input to computer models. Equipment to quantify sediment particle sizes for the evaluation of transport in different size classes has been developed but is still not routinely used in laboratory work.

Remote Sensing and Reservoir Deposition: Earth observing satellites in the 1970's provided the opportunity for early ARS exploratory and developmental work on the application of aerospace technology to measure sediment and algal concentrations in surface waters. In the initial phase, portable spectroradiometers were used to determine the effects of sediment concentration on the spectra and amounts of energy reflected and scattered back from the water bodies. Despite major limitations, the use of remote sensing from aircraft or satellites to monitor water quality in large water bodies remains an attractive approach to determining spatial and temporal trends and variations in algal and sediment levels. Research is being pursued in both basic and applied aspects of this technology. Basic research is needed to isolate the separate contributions of algal and sediment concentrations to the spectral signal, and to improve our understanding of ways in which suspended particles modify the underwater and emerging light fields. Applied work is needed to correct the signal for atmospheric distortions, and to exploit more recent developments in satellite sensing capabilities.

Traditionally, soil loss has been measured from small runoff plots. As the size of the land area from which the soil loss is to be determined increases, soil redistribution, associated with sequences of erosion and

deposition during a series of runoff events, can no longer be ignored. Radioactive tracers, such as Cs-137 resulting from nuclear test fallout, are being used to estimate soil redistribution within a field. Early work established the potential for using tracers to estimate rates of sediment deposition in large water bodies. Several problems of data interpretation remain. Because cesium is strongly bound to the clay fraction, preferential erosion of soil clay fraction will result in over-estimates of actual erosion. Furthermore, estimates of total deposition will be distorted by higher rates of deposition for the coarser soil particles. Reliable methods for correcting the data and improving the accuracy and reliability of the technique are needed.

Physical and Chemical Characteristics of Sediment: Sediment and soil properties are important in ARS sedimentation research. Physical properties like particle density and size distribution control the sediment transport processes. Deposits of coarser sediments on the stream bed shield the underlying alluvium from erosion, modify the flow depths and velocities for a given flow rate, and serve as a sediment source or sink to compensate for short-term variations in the sediment supply rates. Chemical properties influence the stability of soil surfaces and channel banks, the density and stability of aggregates, flocculation, and binding of dissolved cations. Suspended fine sediments have been found to effectively remove agricultural nutrients and pesticides from solution in runoff. The chemical ions attached to sediment particles and dissolved in runoff have been used to determine the efficiency of different methods of agricultural chemical application as well as the fate and persistency of these chemicals.

Concerns related to physical characteristics of sediment include specification of selective transport and deposition of different size fractions of sand and gravel bed material and of lower-density aggregates in concentrated flows from farmland. More definitive information is needed about the effects of gravel fractions on sand transport rates and the growth of meander-type instabilities. Concerns related to the chemical associations of sedimentation include the exchange of chemicals with the flow, effects of chemicals in sediment deposits on benthic organisms and subsequent concentration in the food chain of aquatic and other organisms, and the potential for contamination of ground water by infiltration through chemical-laden sediment deposits.

Aquatic Ecology: The current ARS program is concerned with the effects of sediment inflow and concentrations on aquatic ecology of streams, ponds, and lakes. Although the research effort has been expanded during the past decade, it remains a small component of the total program

on erosion and sedimentation. Direct effects of sedimentation on water storage, and on the encroachment of emergent and woody vegetation receive only limited attention. Emphasis is given to improving our understanding of the factors and relationships associated with turbidity, quantifying the effects of turbidity on abiotic factors such as temperature and light adsorption, and evaluating the impacts of suspended sediments and sediment deposition on the survival and species diversity of aquatic organisms. Research on the management of water quality and the ecology of small impoundments includes an evaluation of the effectiveness of natural biological and chemical flocculants in reducing turbidity and suspended sediment concentrations. Factors being considered include sediment particle size, clay mineralogy, algal species and nutrient levels.

ARS is also providing research support for a major interagency project (ARS, SCS, and Army Corp of Engineers) to evaluate the economic and environmental consequences of watershed conservation strategies for reducing flooding and sedimentation in the Yazoo River Basin of Mississippi. A major component of this work includes evaluation of the effects of snag and debris removal, toe revetments, and scour pools downstream of grade stabilization structures on the survival, species composition and diversity of aquatic organisms.

Related work includes an evaluation of the toxicity of suspended sediments on freshwater invertebrates, and development and validation of biological indices of environmental stresses imposed by suspended and deposited sediments. This work is directed toward evaluating the effect of excessive sediment intrusion of freshwater gravel beds on salmonid habitat. Of primary interest is the decrease in concentration of dissolved oxygen and its consequences for embryo survival and fry emergence.

Summary: Erosion and sedimentation prediction and control research in ARS is designed to support action programs of USDA and other agencies involving sustaining production on agricultural lands and environmental protection. The research is also designed to prevent water pollution both on- and off-site, including transport of agricultural chemicals in both the adsorbed and dissolved phase. Brief summaries of the research have been presented and some information gaps have been identified. Space constraints preclude detail of most of the progress associated with the programs. It is suggested that persons requiring more detail write to the authors of this paper.