Hydrologic and Hydraulic Research in the Soil Conservation Service

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Abstract
The U. S. Congress created the Soil Conservation Service (SCS) in 1935 in legislation that declared "the wastage of soil and moisture resources on farm, grazing, and forest lands of the Nation, resulting from soil erosion, is a menace to the national welfare and that it is hereby declared to be the policy of Congress to provide permanently for the control and prevention of soil erosion and thereby to preserve natural resources, control floods, prevent impairment of reservoirs, and maintain the navigability of rivers and harbors …" When the law was enacted, little hydraulic or hydrologic research had been done on the relationship of soil erosion to flood control, the impairment of streams and harbors, and the sedimentation of reservoirs. SCS undertook hydrologic and hydraulic research in order to design and implement effective conservation practices. The research developed basic principles that both aided the soil and water conservation Program and made pioneering contributions to science and technology related to land and water.

The National Soil Conservation Program

The Soil Erosion Service (SES) was established in U. S. Department of the Interior (USDI) on August 25, 1933. Hugh Hammond Bennett, a career soil scientist in the Bureau of Chemistry and Soil, U. S. Department of Agriculture (USDA), became director on September 19. Bennett became concerned about soil erosion while making soil surveys and supervising the work of other soil scientists. Eventually he succeeded in arousing national attention where others had failed. Among his writings of the 1920's, probably none was more influential than a USDA bulletin coauthored with William Ridgely Chapline titled *Soil Erosion*: *A National Menace* (1928). Bennett promoted research with immediate applicability to conservation problems on the farm. Largely in response to Bennett's campaign for soil conservation, Representative James P. Buchanan of Texas attached an amendment to the 1930 appropriations bill authorizing USDA to establish a series of soil erosion experiment stations. Bennett selected the sites for some ten stations and designed their research programs to develop conservation practices suited to the crops, climate, geography, and soils of the region.

Bennett had made himself the acknowledged expert in soil erosion by the time the Soil Erosion Service received $5 million in emergency employment funds. Bennett established demonstration projects on selected watersheds, often near the soil erosion experiment stations, so that the findings of each station could be utilized. The director of the experiment station also served as director of the demonstration project. Each project began hiring staff to work with the farmers in the watershed. Most demonstration projects had a Civil Conservation Corps camp in the demonstration area, as well as other workers hired with the emergency employment funds. The first generation of soil conservationists had high aspirations and a passion for their work. But the potential for their work was limited by the state of the scientific and technical knowledge for conservation application. Most of the early staff of specialists on the demonstration projects were college educated in agronomy, engineering, geology, soils, range, forestry, biology and other disciplines, but most of the land grant colleges had not made conservation a priority. A few of the state agricultural experiment stations had worked on conservation and Bennett cooperated with these stations or recruited the experienced staff from the stations. The work proved popular, and on April 27, 1935, Congress created the Soil Conservation Service in USDA.

The remainder of this paper will highlight contributions of the hydrologic and hydraulic research topically, rather than examining the subject chronologically. The Secretary of Agriculture transferred the soil conservation research to the Agricultural Research Service (ARS), effective Janaury 4, 1954. Much of the following discussion will focus on the pre-1954 era (See figure 1 for major locations of research activities).

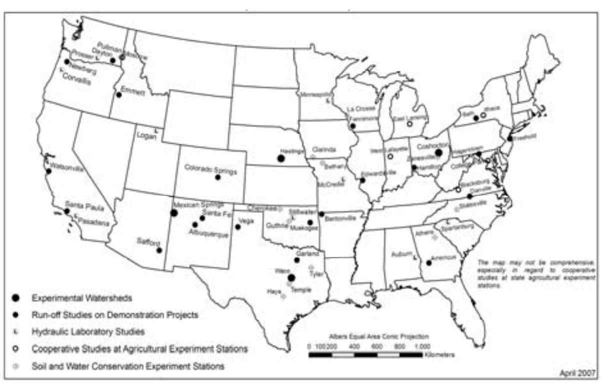

Figure 1. Hydrologic and hydraulic research conducted by the Soil Conservation Service (Cumulative 1933-1941). USDA-NRCS, Resource Economics & Social Sciences Division, Soil Survey Division.

Reservoir Studies

Henry M. Eakin, Head, Sedimentation Studies, initiated the reservoir surveys in July 1934. After a review of the previous work in the field, Eakin, L. M. Glymph, Thomas L. Kesler, Fred E. Tardy, Raymond C. Becker, D. Hoye Eargle, and Carl B. Brown made a reconnaissance of 87 reservoirs in the southern regions and selected city reservoirs at High Point and Greensboro, North Carolina; Spartanburg, South Carolina; and Rogers, Texas, for reservoir sedimentation surveys. In this initial effort they developed the methods and equipment to be used in future studies. Brown became project supervisor for the Reservoir Investigations. Over a five-year period, 1934-1939, the group made 76 sedimentation surveys of which 67 were original and three were resurveys. They established permanent ranges for future sedimentation surveys on six reservoirs before they were filled with water (Eakin & Brown 1939, p. 2). The flood control surveys made in response to the Flood Control Act of 1936 expanded the program. By 1947, the Soil Conservation Service had made detailed sedimentation surveys on 150 reservoirs and another 300 reconnaissance investigations (Brown 1948, p. 4). Under the Watershed Protection and Flood Prevention Act of 1954, SCS built numerous flood protection structures with sediment storage. The agency surveyed a number of these.

SCS cooperated with the Bureau of Reclamation on surveys of two large reservoirs, Elephant Butte and Lake Mead. The mapping of the reservoir area of Lake Mead before it filled with water proved to be one of the more unusual studies. The map would facilitate future measurement of reservoir capacity loss, as well as provide information on sediment delivery from the Colorado River watershed. The Bureau of Reclamation called on the Soil Erosion Service (SES) for assistance as the Boulder Dam gates were being closed. As soon as SES received approval and funding, bids were solicited by telegraph on February 21, 1935. SES notified the Fairchild Aerial Survey at 8 a. m. (Pacific Time), February 23, accepting their bid; and five hours later the aerial mapping had been completed on the critical area, and completed on the whole area by February 27. Under contract with SES, the U. S. Coast and Geodetic Survey established more than 100 miles of first-order leveling to establish horizontal and vertical control. Completing the map occupied some 758 triangulation stations to control the 400-odd stereoscopic models covering 417 square miles. (Brown 1941, pp. 385-405).

Bedload Studies

SCS also carried out research on suspended- and bed-load sediment transportation at field locations and in cooperation with the California Institute of Technology in Pasadena. Walter Lowdermilk, head of the research program in SCS, and Robert Knapp developed the SCS-Caltech contract and program. Vito Vanoni, a recent Caltech graduate supervised the project, and SCS employed Hunter Rouse among others during the course of the cooperation. Arthur Ippen, Rouse, and other SCS researchers formulated an equation for the vertical distribution of suspended bed sediment throughout the depth of the flow. Vito Vanoni, head of the SCS effort, further refined the equation. The equation, which was generally termed the Rouse equation, proved to be one of the most successful formulations of sediment transport (Ettema & Mutel 2004, p. 482; Rouse 1976, pp. 132-133).

In 1938, SCS hired Hans Albert Einstein, son of the physicist Albert Einstein, shortly after he had completed his doctoral studies in Zurich, Switzerland. Henry M. Eakin, first head of sedimentation studies in SCS, had established the Greenville Bedload Experiment Station on the Enoree River in South Carolina. For the first time sediment transport would be studied directly in the river itself, not in a flume. SCS selected the southern Piedmont because of the severe erosion associated with years of growing cotton in a rolling landscape. When flows proved insufficient to study suspended sediment, Einstein shifted to studying bedload. He decided to study small streams and developed a sampler that could be transported from stream to steam. Robert Ettema and Cornelia Mutel, authorities on Einstein's contributions, assessed the significance of this line of study. "The heartening—and milestone—finding of the Mountain Creek work was that it suggested the possibility of predicting the rate of bedload transport in an alluvial channel, provided that the values of flow resistance characteristics of the channel and the composition of the bed sediment were known." (Ettema & Mutel 2006, p. 757) SCS transferred Einstein to Caltech in 1943 and he joined the faculty at the University of California in 1947. In 1950, USDA published his technical bulletin "The Bed-Load Function for Sediment Transportation in Open Channel Flows." Einstein hoped the formula was "sufficiently general to apply to a large number of such problems" (Einstein, 1950). He had converted his empirical transport formula to an analytical one. Einstein also attempted to combine the Rouse equation for suspended load with his bedload equation. By Rouse's reckoning the attempt was less than successful (Rouse 1976, pp. 155-156). Ettema and Mutel judged Einstein's career to mirror that of less well-known researchers who had "mixed success and frustrations" when trying "to describe the complicated behavior of alluvial rivers in terms of rationally based equations" (Ettema & Mutel 2004, pp. 486).

Stream and Valley Sedimentation Surveys

Stafford C. Happ supervised more than 20 stream and valley sedimentation studies consisting of range and valley cross sections. Among the general principles discovered was the fact that most of the sediment was deposited near the point of origin and that sand caused more sediment damages than silt. The studies helped illuminate the relationship of erosion to sediment delivery (Happ, Rittenhoue & Dobson 1940, pp. 114-116). The studies established base lines for future study. Historical geographer Stanley W. Trimble has probably made the most use of these surveys having twice resurveyed Coon Creek, Wisconsin (Trimble & Lund 1982, pp. 1-35).

Runoff Studies

Runoff studies had several objectives. The information was needed for planning conservation practices and structures. The data were also valuable in the flood control surveys particularly in judging the impact of concentrated conservation practices in small watersheds on runoff. Partly spurred on by needs of the flood control program, SCS directed the soil conservation experiment stations to compile the data that they had been collecting since establishment of the stations. Several of the stations published summary bulletins. USGS had collected data on eight of the demonstration areas. Runoff was correlated to soil types, vegetative cover, management practices, conservation practices and other watershed conditions. Soil scientists in the Bureau of Chemistry and Soils began studying erodibility based on soil properties to support the work of the conservation experiment stations. By 1940 SCS had collected runoff data on some 113 small watersheds in 26 locations. Walter Wischmeier utilized runoff and other data collected at the conservation experiment stations in formulation of the Universal Soil Loss Equation. Victor Mockus also used the information in developing the SCS hydrology program for small watersheds. It was eventually released as "Project Formulation Program – Hydrology," Technical Release 20, in 1965 (Woodward, 2002).

Experimental Watersheds

SCS also established experimental watersheds near Reisel, Texas, Coshocton, Ohio, and at Mexican Springs on the Navajo Reservation. Investigators could control and manipulate watershed conditions to study runoff and other factors. Many studies utilized paired watersheds of similar geographic and climatic settings. In this manner conservation land treatments could be tested against the untreated condition. Both the North Appalachian Experimental Watershed and the Backlands Experimental Watershed remain active facilities in the Agricultural Research Service. The stations have accumulated more than 70 years of continuous data that are valuable for long-term agricultural, hydrologic, and environmental studies. A unique feature is the weighing lysimeters, blocks of undisturbed soil 2.4 meters deep, 2 meters wide, and 4 meters long on three distinct soil types. At least one lysimeter at each site measures evapotranspiration at one minute intervals. This level of specificity allowed for very detailed studies in agricultural hydrology (Harrold 1951, pp. 1-133).

Hydraulic Studies

Nineteenth-century farmers in the South had developed indigenous means to stop erosion, among which were the hillside ditch and the Mangum Terrace. But concentrated water flow from terraces could create a gully. Gullies also developed in draws in clean-tilled fields. W. O. Ree undertook studies at the outdoor hydraulic laboratory near Spartanburg, South Carolina, on channels protected by vegetative linings. His data established permissible velocities of intermittent flow and presented a "graphic method of determining a cross section that will permit a channel to carry the expected flow at a velocity not exceeding the permissible" (Ree & Palmer 1949, p. 3). The outdoor laboratory hydraulic work was eventually moved to Stillwater, Oklahoma.

The Soil Conservation Service and then the Agricultural Research Service had a cooperative working relationship with the St. Anthony Falls Hydraulic Laboratory from 1939 to 1984. Lorenz G. Straub of the University of Minnesota had founded the station on Hennepin Island at the head of St. Anthony Falls on the Mississippi River. Eventually the laboratory grew to a five-story building. The two top floors protruded above the Mississippi's headwater pool and the lower floors housed the experiment areas which utilized the natural power of the falls. Originally, SCS foresaw concentrating on structures for the central United States, and especially their region 5, the Upper Mississippi Region. The agreement with the laboratory stipulated cooperation on hydraulic structures that would "reduce the cost of safely handling and disposing of the flood water originating on farm lands." These included terrace outlet systems and gully controls, open channels, check dams, spillways, energy dissipators, culverts, drop boxes, and drop inlets (Marsh 1987). SCS field engineers typically utilized these types of structures. David Ralston, civil engineer (retired) of SCS, has explained the rationale for the hydraulic studies at St. Anthony Falls.

Prior to the activities of the SCS in the field of water control structures, the design of spillway hydraulics was based on idealized configurations which permitted use of proven standard relationships. These designs were then model tested when investments were significant. The utilization of numerous small spillway structures for erosion control in diverse field layouts did not lend itself to site specific model studies in that the study's costs would be out of proportion to that of the installation. Generalized studies were conceived which allowed spillway configurations to be used based on parametric relationships with confidence of the prototype performance. The design of a wide range of physical sizes could be prepared and constructed with a high level of confidence in the resulting performance (D Ralston 2007, pers. comm., 10 April).

SCS's principal investigator at the St. Anthony Falls laboratory, Fred Blaisdell, has provided a detailed account of the work in "Engineering Structures for Erosion Control" (Blaisdell 1981, pp. 325-355). Of particular interest would be Blaisdell's development of the SAF stilling basin, a structure which has been used internationally. Other developments at St. Anthony Falls may be generalized as the following: (1) pioneering use of generalized hydraulic research methods for spillways in contrast to model tests of specific structure spillways, (2) contributions to the hydraulics of closed conduit spillways for development of a uniquely defined discharge relationship with inflow depth, (3) development of economical spillway outlet basins to control erosion, (4) development of spillway inlet configurations to closed conduit spillways that assure dependable performance regardless of trash/debris aggregation, (5) and development of the erosion prediction for flows through vegetated earth auxiliary spillways (D Ralston 2007, pers. comm., 10 April).

Geomorphology Studies--Climatic and Physiographic Division

In addition of the hydrology division, the Office of Research included a Climatic and Physiographic Division. The division's creation dates to a suggestion by the historical geographer Carl Sauer to the Science Advisory Board that research in these areas could benefit the soil conservation program. C. Warren Thornthwaite, a Sauer student who achieved fame for his climatic studies, directed the unit. Sauer projected studies of gully formation and erosion in diverse physiographic and climatic regions. Sauer also proposed "erosion history" studies to illuminate the land-use practices that either caused erosion or conserved land. For instance Arthur Hall, historical geographer, contributed information for *Principles of Gully Erosion in the Piedmont of South Carolina* (1939) by H. A. Ireland, D. F. S. Sharpe, and D. H. Eargle, which was one of the early studies of mass movement. A year earlier Columbia University Press published Sharpe's dissertation, *Landslides and Related Phenomena*, which became a classic in mass movement studies. After the original investigator, Francis A. Johnson, resigned, Thornthwaite, Sharpe, and Earl F. Dosch used Johnson's notes to complete *Climatic and Accelerated Erosion in the Arid and Semi-Arid Southwest, With Special Reference to the Polacca Wash Drainage Basin, Arizona*. The study emphasized overgrazing as the causal factor in the erosion rather than climatic variation, the explanation favored by Harvard geologist Kirk Bryan. The Thornthwaite-Bryan debate resounds to the present (Effland & Effland 1993, pp. 197).

Conclusions

Several interpretive points arise from the Soil Conservation Service's experience in hydrologic and hydraulic research. When the agency was created, little was known about hydrology and hydraulics on a scale that would benefit the design of on-farm soil and water conservation measures. The trial-anderror process at the demonstration projects illustrated the lack of basic design data at the time. SCS started a research program simultaneously with the opening of the demonstration projects, and a strong link was forged between field needs and research. The research eventually provided the information for better designs. The applied research also made basic contributions to science and technology. Government sponsorship of the research made continuity possible. There are records for more than seventy years in some data sets. Institutional support, rather than periodic grants, was necessary to sustain such a program. Finally, the credibility of the national program of soil conservation rested on being able to offer practical, cost-effective solutions. That the research effort was able to supply some of these solutions validated the wisdom of the public investments and public policy on soil conservation.

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