WATER RESOURCES IMPACT

NO/ND

LONG-TERM WATERSHED RESEARCH IN USDA-AGRICULTURAL RESEARCH SERVICE

Charles W. Slaughter and Clarence W. Richardson

INTRODUCTION AND RATIONALE

Sustained hydrologic research founded on high-quality data is integral to the national research program of the USDA Agricultural Research Service (ARS). A fundamental component of ARS hydrologic research is its national network of instrumented experimental watersheds and field research facilities.

While ARS was formally established as a separate Agency within USDA in 1954, several of its hydrologic research facilities predate the agency, having been established in the 1930s. In 1959 Congress recognized the need for sustained scientific research and for data base development to support hydrologic process research in agricultural and rangeland watersheds. The rationale outlined in Senate Document 59 (86th Congress, 1959) stressed the urgent need to determine soil and water problems of regional and national importance and to carry out research leading to the solution of these problems, and called for "prompt and orderly application of conservation practices necessary for the protection of the Nations's most vital natural resources – soil and water" (Senate Document 59:1). The report recommended that "Special attention should be given to hydrologic research of agricultural watersheds..." and that four to six major experimental watersheds be established and located in the Northeast, the Southeast, the Southern Great Plains, the North Central States, the Pacific Northwest, and the Southwest of the U.S. (86th Congress, 1959). ARS consequently invested in an unprecedented national field instrumentation infrastructure involving spatially extensive precipitation and snowfall, climate, soil moisture, ground water recharge, sediment yield, and streamflow measurement and analysis. Guidelines for many aspects of field hydrology research were summarized by Brakensiek *et al.* (1979). Much of the ARS investment was in six regional Hydrology Research Centers, which evolved into a network of Research Watersheds. Those regional Research Watersheds are complemented by hydrologic research facilities which may not be "research watersheds" but that conduct fundamental hydrologic, hydraulic, and climate research. In this paper we summarize the current national ARS research watershed network.

> *Experimental watersheds are outdoor laboratories in which observation and experimentation can proceed hand-in-hand with model development and analysis.*

THE ARS RESEARCH WATERSHED NETWORK

Nine long-term research watershed facilities (Figure 1) form the backbone of the ARS hydrology program. These watershed locations are complemented by watershed-related hydrologic process research conducted at additional ARS locations throughout the nation. These facilities and experimental watersheds provide long-term, instrumented research sites representing major biogeographic areas of the conterminous U.S., and typically are available to university, private and other federal investigators for collaborative research.

◆ *North Appalachian Experimental Watershed, Ohio.* The North Appalachian Experimental Watershed was established in 1935 on 419 ha in Coshocton County, Ohio, to study and develop methods for conserving soil and water resources. Research accomplishments include over 35 years of research on effectiveness of no-till agriculture to reduce soil loss from cultivated slopes, extensive research on effects of surface mining and mined land reclamation on hydrology, water quality and sediment yield, and over 30 years of research on movement and transformation of nutrients and pesticides in agricultural soil water and runoff. A 60-year data base of measurements from rain gauges, flumes and weirs, lysimeters, and climate stations provides a frame of reference for research to develop knowledge of basic water, sediment, and chemical movement and to support transport model development and validation.

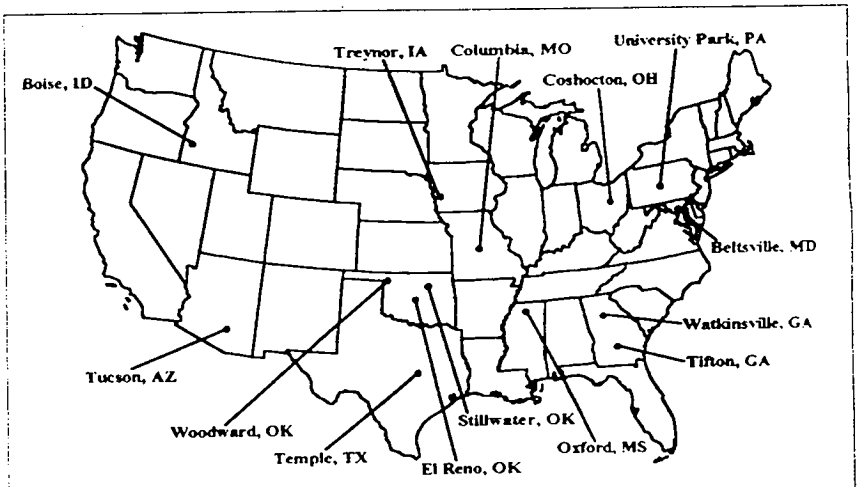

Figure 1. Primary Hydrology and Hydraulics Research Locations of USDA Agricultural Research Service.

◆ *Blackland Experimental Watershed, Texas.* The Blackland Experimental Watershed was established in 1937 in a setting selected to be representative of heavy clay soils in a subhumid climate, with the initial purpose to determine effects of conservation practices on surface runoff, erosion, and sediment yield. An array of 20 individual basins, 55 ha to 18 km^2 drainage area, is instrumented and monitored to supply data surface runoff, ground water recharge, clay soil cracking, and water quality for hydrologic and hydraulic modeling. Over 60 years of hydrologic data are available for analysis. Current data are telemetered in near-real-time to a central data bank. The Blackland Experimental Watershed is operated by the Grassland Soil and Water Research Laboratory in Temple, Texas.

◆ *Walnut Gulch Experimental Watershed, Arizona.* The 150 km^2 Walnut Gulch Experimental Watershed was established at Tombstone, Arizona, in 1953 in a setting representative of semiarid southwestern U.S. grass and shrub rangelands. The Watershed is intensively instrumented for precipitation and runoff monitoring, and a data telemetry system is being installed. Research addresses erosion and sedimentation processes, water quality and remote sensing, and supports development of simulation models for resource management, and regional remote sensing research initiatives. Nearly 50 years of basic climate and hydrology data are available. Walnut Gulch Experimental Watershed is operated by the Southwest Watershed Research Laboratory, Tucson, Arizona.

◆ *Reynolds Creek Experimental Watershed, Idaho.* The Reynolds Creek Experimental Watershed was established in 1960 in the Owyhee Mountains of the interior Pacific Northwest, in a site selected to be representative of high-relief semi-arid rangelands with highly diverse geology, topography, soils, climate, vegetation, ownership, and land use in which seasonal snow and frozen soil processes dominates the annual hydrologic cycle. Research addresses watershed hydrologic processes and management issues in a hierarchy of intensively-instrumented catchments from 1.2 ha to 238.7 km^2 drainage area, with automated data telemetry to a central archive. A comprehensive 35-year hydrologic and climate data base is currently (2000) being prepared for publication and posting on an anonymous FTP site. These data support detailed hydrologic process research; longitudinal (time trend) studies of climate, precipitation, snow ablation and water yield; streamflow regime and vegetation development; and evaluation of change of landscape attributes including water yield and vegetation community composition and biological productivity in response to forcing factors such as specific management practices, weather events, and climate change. Reynolds Creek Experimental Watershed is operated by the Northwest Watershed Research Center, Boise, Idaho.

◆ *Little Washita Experimental Watershed, Oklahoma.* The 610 km^2 Little Washita River Watershed, the largest in the ARS network, was established in 1961 to be representative of the extensive Southern Great Plains. A major original objective was to determine downstream consequences of PL83-566 floodwater retarding structures. In the 1990s instrumentation was augmented to support research on climate variation and watershed hydrology, and research now includes support of large-scale multi-agency remote sensing-based hydrologic experiments. Instrumentation on the Little Washita includes 42 meteorological stations providing telemetered 15-minute data in support of ARS research and the Oklahoma Mesonet. The Little Washita Experimental Watershed is operated by the Grazingland Research Laboratory, El Reno, Oklahoma.

◆ *Deep Loess Research Station Watersheds, Iowa.* Four field-size watersheds, 30.3 ha to 60.7 ha drainage area, were instrumented beginning in 1964 to determine factors causing gully and channel erosion and evaluate effects of land treatment and cropping practices on that erosion and on surface and ground water quality in cropped loess lands of the North Central Corn Belt. Treatments (management systems) have been maintained for up to 30 years to permit long-term evaluation of effectiveness for soil conservation. The watersheds are operated by the Deep Loess Research Station, National Soil Tilth Laboratory, Treynor, Iowa.

◆ *Little River Watershed, Georgia.* The 335 km^2 Little River Watershed was established in 1966, at a site selected to represent the Coastal Plain Region of the southeastern U.S., to determine relationships among precipitation, runoff, and water quality in Coastal Plain agricultural watersheds. Research has supported major model development including CREAMS and GLEAMS and REMM for simulation of physical, chemical, and biological processes of agricultural systems. Long-term hydrologic data bases have been developed for eight watersheds, ranging from 2.6 km^2 to 335 km^2 drainage area. Little River Watershed is operated by the Southeast Watershed Research Laboratory, Tifton, Georgia.

◆ *Mahantango Creek WE-38 Watershed, Pennsylvania.* The 7.4 km^2 Watershed WE-38 of Mahantango Creek Watershed was established in 1968 in the Appalachian Valley and Ridge physiographic province, to support research on water quality and hydrology of mixed agricultural, urban and municipal landscapes in New England. A 30-year data base of climate, stream flow, ground water, and water quality information is available. Mahantango Creek WE-38 Watershed is operated by the Pasture Systems and Watershed Management Research Unit, University Park, Pennsylvania.

◆ *Goodwin Creek Experimental Watershed, Mississippi.* The 21.3 km^2 Goodwin Creek Experimental Watershed was established in 1980 as a part of the "Streambank Erosion Control Evaluation and Demonstration Project" authorized by Public Law 93-251. The U.S. Army Corps of Engineers provided major construction funding. Goodwin Creek is representative of mixed land use watersheds throughout the loess region of the Mississippi Alluvial Plain, with excessive upland erosion, steep

degrading channels, loss of land due to channel incision and bank caving, and downstream deposition problems. The watershed is partitioned into 14 nested gaged sub-basins, 0.053 to 21.3 km^2 drainage area; precipitation is monitored with 30 recording raingages in and adjacent to the watershed. In the last decade multi-agency remote-sensing stations have been added to support climate and hydrometeorological research. Goodwin Creek Experimental Watershed is operated by the National Sedimentation Laboratory, Oxford, Mississippi.

Additional ARS hydrologic research is conducted at sites across the U.S. Major research facilities include:

◆ *The Southern Plains Range Research Station,* initially established in 1913 at Woodward, Oklahoma, utilizes a 2094 ha Southern Plains Experimental Range and Field Station in research to develop resource-efficient grazing systems for southern mixed-grass and shortgrass prairie range and pasture systems. Research includes four small watersheds used to analyze runoff, erosion, and water use efficiency.

◆ *The Southern Piedmont Conservation Research Unit* was established at Watkinsville, Georgia, in 1937 to determine hydrologic impacts of cropping systems in the southeastern U.S., and to improve understanding of chemical, physical, and biological interactions in agricultural systems of the Southern Piedmont region. Research addresses sustainability of agricultural systems at a farm level, and includes instrumented catchments over a scale range from 300 m^2 to 2 km^2 within the Upper Oconee River Basin of Georgia. The Research Unit is operated by the Phil Campbell, Sr., Natural Resource Conservation Center, Watkinsville, Georgia.

◆ *The Stillwater Outdoor Hydrologic Laboratory* was established in Stillwater, Oklahoma, in 1940 to conduct large-scale hydraulic model studies. The research has included developing design criteria for grassed waterways, and for structures utilized in the USDA NRCS small watershed programs under the Flood Control Act of 1994, Pilot Watershed Program of 1953-54, Watershed Protection and Flood Prevention Act of 1953, and Resource Conservation and Development Program. The Laboratory is widely recognized for contributions to soil and water conservation structure and channel design criteria, and development and validation of hydraulic models. The Laboratory is operated by the ARS Hydraulic Engineering Research Unit, Stillwater, Oklahoma.

◆ *The ARS National Sedimentation Laboratory (NSL),* established in 1959 at Oxford, Mississippi, conducts multidisciplinary hydrologic studies of climate, runoff, erosion, sedimentation, water quality, and ecology in support of the Congressionally-mandated Demonstration Erosion Control (DEC) and Total Maximum Daily Loads (TMDL) Projects in the Yazoo River basin, Mississippi. Most streams and lakes in this basin are ecologically impaired due to channel incision and the movement of sediment and agricultural chemicals from both adjoining and upstream agricultural lands. NSL is conducting a multi-agency program of monitoring and evaluation to reduce flooding, erosion, sedimentation, and contamination problems by applying environmentally sound management practices. Research is focused on the 783 km^2 Yalobusha River basin, a main tributary of the Yazoo.

◆ *The Cropping Systems and Water Quality Research Unit, Columbia, Missouri,* established the 73 km^2 Goodwater Creek Experimental Watershed in 1969, in rolling claypan and loess croplands to explore precipitation, runoff, and ground water relationships in north-central Missouri farmlands. The research program has been incorporated into the Missouri Management System Evaluation Area with emphasis on water quality and on scaling research from field to area and state scales.

◆ *The ARS Hydrology Laboratory* was established in 1961 at Beltsville, Maryland, to provide a national center for agricultural hydrologic research and analysis. Research addresses developing improved methodologies for predicting water yield from agricultural lands and for monitoring and evaluating the impact of management practices and environmental change on water resources. The Hydrology Laboratory operates four 4-ha agricultural watersheds for research on climate, ground water flux, surface runoff, energy flux, and remote sensing for evaluation of soil moisture. The Hydrology Laboratory maintains the ARS Water Database, a national archive of precipitation and streamflow data from ARS research watershed, containing over 16,000 station-years of data for watersheds ranging from 0.2 ha to 12,400 km^2. Those data are available at http://hydrolab.arsusda.gov/wdc/arswater.html. The Hydrology Laboratory is operated by the National Resources Institute, Beltsville Agricultural Research Center, Beltsville, Maryland.

Additional hydrologic and soil and water conservation research is conducted at ARS research units in Morris, Minnesota; Beaver, West Virginia; Lafayette, Indiana; Florence, South Carolina; Las Cruces, New Mexico; Fort Collins, Colorado; Lincoln, Nebraska; Cheyenne, Wyoming; Phoenix, Arizona; Kimberly, Idaho; Burns, Oregon; Corvallis, Oregon; Pendleton, Oregon; Fresno, California; Riverside, California; Prosser; Washington; and Pullman, Washington.

REDUNDANCY?

Given the extreme diversity in landscape characteristics and ecological conditions which exists across the continental United States, it is appropriate that individual research programs be paralleled (*not duplicated*) in some respects in markedly different environmental settings. For example, research at Reynolds Creek Experimental Watershed is paralleled and augmented by research in Walnut Gulch Experimental Watershed. Both locations address issues of hydrology of rangeland watersheds, but Walnut Gulch focuses on arid rangelands of the extreme southwestern U.S., while Reynolds Creek addresses snow-fed hydrologic systems and seasonally

frozen soils of the interior Pacific Northwest and northern Great Basin with highly heterogenous climate, land ownership, land use, and management.

CONCLUSIONS

These highly instrumented ARS experimental watersheds are fundamental tools in developing better understanding of hydrologic process for important biogeographic regions. Experimental watersheds are outdoor laboratories in which observation and experimentation can proceed hand in hand with model development and analysis. The value of experimental watersheds was emphasized by the National Research Council (1991) which concluded that "hydrologic science is currently data limited." The National Research Council (1997) has specifically cited ARS watershed research as offering promising areas for collaboration with other agencies, while the Subcommittee on Global Change Research (1999), has repeatedly recognized the importance of long-term terrestrial monitoring and research to understand change over time. With the increasing importance of national issues such as water availability, environmental quality, food production, and climate change, the composite network offers unparalleled capabilities to examine potential impacts and changes both regionally and nationally.

The ARS experimental watersheds complement similar long-standing programs of other agencies including the USDA Forest Service, with its legacy of Experimental Forests and Research Watersheds; the U.S. Geological Survey, with its Vigil Network, Benchmark Basins and WEBB basin research programs; the USDI National Park Service's research program; and the National Science Foundation's Long-Term Ecological Research (LTER) program.

It might be argued that such a research network can only be sustained over the long term at the federal level. While state and local governments, universities, and private organizations will continue to need watershed-based research. Few, if any, have the responsibility or resources to conduct an integrated national watershed research program addressing critical national problems of natural resource conservation, environmental protection, sustainable agriculture, and rural development. The ARS watershed network provides unique data, a reserve of knowledge, and a body of scientific information which would otherwise not be available on a national basis.

LITERATURE CITED

Brakensiek, D.L., H.B. Osborn, and W.J. Rawls, 1979. Field Manual for Research in Agricultural Hydrology. Agriculture Handbook 224, U.S. Department of Agriculture, Washington, D.C., 550 pp.

86th Congress, 1959. Senate Document 59. Facility Needs – Soil and Water Conservation Research, 1959

National Research Council, 1991. Opportunities in the Hydrologic Sciences. Water Science and Technology Board, Commission on Geosciences, Environment, and Resources. National Academy Press, Washington, D.C., 348 pp.

National Research Council, 1997. Watershed Research in the U.S. Geological Survey. Water Science and Technology Board, Commission on Geosciences, Environment, and Resources. National Academy Press, Washington, D.C., 86 pp.

Subcommittee on Global Change Research, 1999. Our Changing Planet. The FY2000 U.S. Global Change Research Program Implementation Plan and Budget Overview. Committee on Environment and Natural Resources, National Science and Technology Council, Washington D.C., 100 pp.

AUTHOR LINK

Charles W. Slaughter
1112 East Hays Street
Boise, ID 83712
(208) 383-1084 / Fax: (208) 334-1502

Clarence W. Richardson
USDA-REE-ARS-SPA-S&WR Lab
Lab Director
808 Blackland Road
Temple, TX 76502-9601
(254) 770-6500 / Fax: (254) 770-6561

E-MAIL

macwslaugh@icehouse.net
richards@brc.tamus.edu

Chuck Slaughter is Adjunct Professor, University of Idaho (Boise). Past assignments include Research Leader, Northwest Watershed Research Center, USDA Agricultural Research Service, Boise, Idaho, and Principal Watershed Scientist, Institute of Northern Forestry, Fairbanks, Alaska. His research has included snow and ice hydrology, landscape/stream interactions, fluvial geomorphology, and interactions of renewable resources management with rangeland, boreal, and high-latitude watershed systems. He holds a B.S. in Forest Management from Washington State University, and a Ph.D. in Watershed Management from Colorado State University.

Clarence Richardson is an Agricultural Engineer and Laboratory Director with the USDA Agricultural Research Service, Grassland Soil and Water Research Laboratory in Temple, Texas. His research deals with agricultural hydrology and weather simulation. He holds B.S. and M.S. degrees in Agricultural Engineering from Texas A&M University and a Ph.D. in Civil Engineering from Colorado State University. He is a Registered Professional Engineer in Texas.

SUBSCRIPTION RATES / WATER RESOURCES IMPACT

DOMESTIC.....$45.00
FOREIGN.....$55.00
FOREIGN AIRMAIL OPTION.....$25.00

CONTACT THE AWRA HQ OFFICE FOR ADDITIONAL INFORMATION OR TO SUBSCRIBE