History of Small Watershed Research in Non-Forested Watersheds in Arizona and New Mexico

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Abstract

Small watershed research to support land use and conservation technology on non-forested areas in Arizona and New Mexico has a long history with many reasons for failure. The programs originated from need for solutions to land degradation in arid and semiarid areas of the southwestern United States. Speculation was that degrad-ation resulting from intense grazing of delicate vegetation and that other land uses led to excessive erosion and loss of soil resources. Efforts began in the early 1930s to establish experimental programs on watersheds to understand hydrologic and erosion phenomenon. Technical and administrative factors leading to research termination are discussed with emphasis on the importance of long-term programs to ensure conservation of semi-arid lands.

Keywords: hydrology, watersheds, rainfall, runoff, semiarid

Introduction

Watershed research to quantify rates and amounts of the factors in the hydrologic cycle and the consequences of varying land uses on environmental conditions became a research priority throughout the U.S. in the mid-1930s, including Arizona and New Mexico. The early research programs in the western United States were often complicated by attempts to apply measurement technology that worked in more humid areas to the unique conditions of semiarid regions. In sparsely vegetated areas such as those in the southwestern United States, runoff measurement was often difficult/inaccurate because of heavy sediment loads which confounded measurements. The efforts are summarized in this paper including information on land uses, and some information on why the work was terminated. While Walnut Gulch is currently one of the premier semiarid experimental watershed in the world, the research program has benefited greatly from earlier watershed studies in Arizona and New Mexico. A summary table lists the characteristics of research sites described below (Table 1).

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Mexican Springs, New Mexico

Research on the Navajo Experiment Station began in 1934 in an effort to provide information on water spreading and the role of land use on water rates and amounts. Work at the station included soil conservation demonstration areas and instrumented watersheds (see Table 1). The watersheds located in the Navajo Section of northwestern New Mexico were the first on larger instrumented watersheds in the Southwest and were among the earliest research watersheds in the United States. A comparatively dense rain gage network with runoff measurements from integrated subwatersheds provided data critical to quantifying rainfall-runoff-erosion information in a comprehensive way. The Soil Conservation Service Division of Operations and Research operated the watersheds. Progress of research at the location is given in Lowdermilk (1936).

Soil Conservation Service Experimental Watersheds

The Soil Conservation Service (SCS) in the U.S. Department of Agriculture initiated early watershed studies across the U.S. in collaboration with the Soil Erosion Service (a USDA agency that preceeded the formation of ARS in 1954). This early precipitation and runoff work often also included soil erosion

measurements. Most of the instrumentation at these sites was selected to represent the climate-topography-cropping (land use) combinations on the lands of the U.S.. The instrumentation was constructed in the late 1930s by workers in the Civilian Conservation Corp (CCC camps) and used broadcrested V-notch weirs (Brakensiek et al. 1979, Johnson et al. 1982). The use of such weirs and design considerations is described in Ruff et al. (1977). The weirs were subsequently found to be inadequate for accurate measurement in highly erodible areas where sediment accumulation negated weir principles of neglible velocity head at the depth measuring point.

Table 1. Experimental watersheds - Arizona and New Mexico.

Location / City	Altitude (ft.)	Predominant Land Use	Cover	Record Years	Number of Watersheds	Responsible Group
1. Navajo Experiment Station						
(20 mi N of Gallup, NM) Mexican Springs	5000-6000	Grazing	Mixed Grass-Brush	1934-50	12	USDA-Plant Industry and Navajo Indian Nation
2. Albuquerque Watersheds						
(40 mi NW of Albuquerque – middle Rio Grande)	5000	Grazing	Grassland	1939-75	3	USDA-SCS and Laguna Indian Reservation
3. Alamogordo Creek						
(40 mi East of Santa Rosa, NM)	4500-5500	Grazing	Mixed Grass-Brush	1954-79	3	USDA-SCS USDA-ARS
4. Fort Stanton Watershed						
(70 mi SE of Capitan, M)	6000	Grazing	Mixed Grass	1966-83	3	USDA-ARS NMSU
5. Jornada Experimental Range						
(25 mi N of Las Cruces, NM)	4000-5000	Grazing	Mixed Brush	1906-Present	2	USDA-ARS
6. Safford Experimental Watersheds						
(circle of 40 mi from Safford, AZ - San Carlos Basin)	4000-5000	Grazing	Mixed Grass-Brush-Cacti	1939-75	4	USDA-SCS USDA-ARS USDI-BLM
7. Walnut Gulch Experimental Watershed						
(Tombstone, AZ)	4200-5000	Grazing-Urban	Mixed Brush-Grass	1954-Present	>20	USDA-SCS USDA-ARS
8. Santa Rita Experimental Range						
(30 mi E of Green Valley, AZ)	3800-4500	Grazing	Mixed Brush-Grass-Cacti	1975-Present	8	USDA-ARS Univ. of AZ
9. Santa Fe, NM						
(Upper Rio Grande basin)	3200-3500	Grazing	Sparse grass	1940-47	3	USDA-SCS
10. Atterbury, AZ						
(East Tucson)	2560	Grazing-Urban	Sparse grass -Brush	1955-70	5	U of A Water Res.
11. Tucson, AZ						
(Tucson Metro)	2400	Urban	Mixed Landscape	1971-80	3	U of A Water Res.

Albuquerque and Santa Fe, New Mexico

Small watersheds were instrumented in New Mexico in 1939-40 to collect precipitation and runoff records from grazing lands (see Table 1). The three watersheds near Santa Fe were on sparse grassland and because of high sediment loads, the weirs rapidly became inundated with sediment and the record collection was discon-tinued in 1947. The records from the Albuquerque location continued through 1975. However, for the weirs to operate hydraulically correct, the sediment deposits were removed in the ponded area upstream from the concrete overfall. Thus the weir pond area was maintained below the concrete weir invert so that the velocity head was negligible, an important feature for weir flow measurements (Burford et al. 1962).

Safford, Arizona

Four small watersheds in the vicinity of Safford, AZ were instrumented in 1939, again with raingages and broadcrested V-notch weirs (Table 1). The watersheds were instrumented such that the runoff data was felt to be adequate with periodic removal of the sediment accumulations upstream from the weir. The watersheds were discontinued in 1975 because Agricultural Research Service personnel felt that the records being collected were probably adequate for most peak flow records but not for an entire hydrograph (Brakensiek et al. 1979).

Santa Rita and Jornada Experimental Ranges

The Santa Rita and Jornada Experimental Ranges were established by the U.S. Forest Service in the early part of the Twentieth Century as locations for range research. In later years (mid 1970s) hydrologic and erosion programs were added to the grazing and ecologic programs. Four paired watersheds with different grazing patterns were instrumented in the Santa Rita Range (Renard et al. 1986) to evaluate hydrologic and erosion/sediment yield changes resulting from mesquite growth control on one of each paired watershed. Different grazing practices were used in each of the four pairs. The mesquite control was accomplished with diesel fuel applications at the base of each tree. In each watershed pair, the vegetation and channel changes resulting altered the runoff and soil erosion (Lane et al. 1977). Studies continue even today with the increasing record lengths adding certainty to work where climatic variability is appreciable. Vegetation control in the two cited states is important for forage production and management (Morton et al. 1990).

The range research facility near Las Cruces, N.M. was established in 1906. Range research programs have continued at the location with considerable long-term precipitation data collection. In the mid 1980s some runoff and erosion data was collected using a Santa Rita type flume and sediment sampler (Renard et al. 1986). Considerable information on precipitation patterns have resulted from the long term precipitation records at the location (Nichols et al. 1996).

Fort Stanton, New Mexico watersheds

Two small watersheds were instrumented on the flat escarpment near Capitan, N.M. in 1966. In addition, one stock pond (>100 ac watershed) was instrumented with a water level recorder and recording raingages. The data collection activities were transferred to the Range Science Department of New Mexico State University in the 1970s. The work was terminated in 1983 when a regional airport was constructed over the two small watersheds. Data from the location are of limited value because of the short period of record.

Urban Watersheds

Atterbury watersheds

The small watersheds on the eastern edge of the city of Tucson were instrumented with recording raingages and critical depth flumes in 1955. The instrumentation was maintained from 1955 until 1970 when funds were no longer available (Table 1) (Resnick et al. 1983).

Tucson metropolitan watersheds

Establishment of Water Resource Centers in connection with Land Grant universities led to the establishment of three urban watersheds within the metropolitan area of the city of Tucson. In addition to raingages, the runoff was measured with critical depth flumes. A comprehensive analysis/final report on the project was prepared by Resnick et al. (1983).

Agricultural Research Service Experimental Watersheds

The work of the Southwest Watershed Studies Group began in 1951 led by the joint efforts of the SCS Division of Operation and Research. In 1953, this project was combined with earlier small watershed projects, and reorganization brought the studies into the newly formed Agricultural Research Service. The broad research objectives were to determine if conservation practices would affect water yields and sediment movement, and to evaluate flood runoff from rangeland watersheds. Reasons for the objectives included fears of water users that range conservation work would deplete irrigation supplies and Arizona law, which prior to 1954, permitted range conservation work on cultivated areas further than one mile from the site. Most rangeland data were derived from plots with minimal understanding of watershed scale processes.

From August 1951 to June 1952, a team of scientists and engineers led by J. Gardner, Joel Fletcher, and Willis Barrett in cooperation with local SCS personnel traveled throught Arizona, New Mexico, and southern Colorado to examine, screen, and select watersheds suitable for long-term hydrologic research. Several criteria were developed for watershed selection with primary focus on the physical attributes of the watershed while incorporating the social impacts of the proposed research. In general, watersheds on semiarid rangelands of the Southwestern U.S. are characterized by ephemeral channels, relatively sparse vegtetation, and seasonal thunderstorm rainfall that contributes to surface water yield (Figure 1).

Suitable research watersheds were to range in size from 25 to 75 square miles, with coincident subterranean and topographic divide, and could include a secondary tributary to a main channel that furnished irrigation water. The watersheds should receive 10-16 inches of precipitation annually. Vegetative cover was desired to include range grasses (Blue grama, Black grama, and their associates), with little or no cultivated land. Vegitative cover could not be deteriorated beyond recovery. The watershed should contain no closed basin, appreciable water should not be lost to deep percolation, and the watershed should be in a sediment producing area.

Research efforts required that the sites be accessible during stormy weather and contain sufficient bedrock in the channel upon which to build gaging stations. The cooperation of ranchers within the area was a very important consideration in the selection for a research watershed. In addition, chosen watersheds were desired to be within a major drainage area in which a water supply controversy might develop.

The establishement of Alamagordo Creek and Walnut Gulch experimental watersheds

The Walnut Gulch and Alamagordo Creek watersheds were selected as research sites. Work to instrument the two selected sites began in 1954 again with less than optimum success. Initial funding was insufficient to complete the raingage network and construct hydraulic measurement facilities. The original flumes installed in 1954 overtopped in the first couple of years and the structures failed. The structures failed because they were a) hydrologically undersized, b) hydraulically inadequate, and c) structurally incapable to withstand the sediment loads involved. Thus a joint project was begun with personnel of the ARS Hydraulic Structures Laboratory in Stillwater, OK (Gwinn 1964, Gwinn 1970, Smith et al. 1981) and new a runoff measuring structure was developed. Following the early experiences and the model work, supercritical flume designs evolved to measure the flow in “flashy” ephemeral streams (Brakensiek et al. 1979, Figure 2.1).

Base on citizen input, the U.S. Senate appropriations Committee in 1959 produced a report on needed water research in the United States. The resulting hearings led to a recommendation for greatly expanded hydrologic research on six regional watershed centers, one of which became the Southwest Watershed Research Center established in FY 1961 in Tucson, AZ. Research on the Walnut Gulch and Alamogordo Creek experimental watersheds was funded at an accelerated level from this appropriation. An interdisciplinary team of engineers and scientists accelerated water resource problem solving and environmental resource management at the headquarters in Tucson, AZ. Major early efforts at both locations involved precipitation measurements (Osborn 1983, Renard et al. 1993) and provided information on depth-area-frequency relationships widely used today.

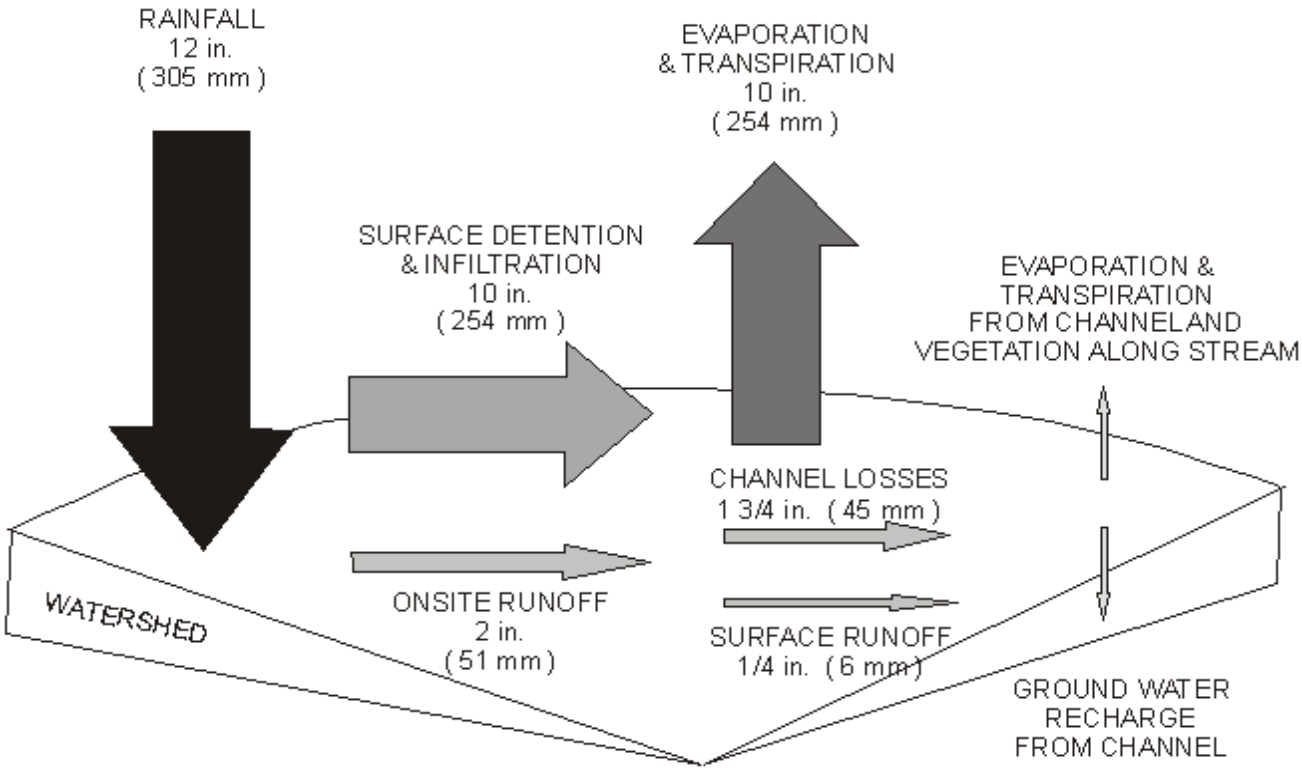

Figure 1. Annual water balance for the USDA-ARS Walnut Gulch Experimental Watershed (Renard et al. 1993).

In 1979, the research program on Alamogordo Creek was terminated because of resource and staff limitations. This unfortunate scenario restricted valuable information on thunderstorm dynamics in eastern New Mexico that are often quite different from those in southeastern Arizona (Osborn et al. 1980).

Many major conclusions have been reported from the Walnut Gulch Experimental Watershed Program. These include:

1) Precipitation amounts and models developed to describe such (Osborn 1983; Osborn et al. 1980).
2) Instrument developments to monitor the hydrologic and erosion cycle in semiarid areas (Renard et al., 1993).
3) The role and magnitude of transmission losses in ephemeral streams (Lane 1990).

The precipitation and runoff monitoring network and the innovations and research results have allowed researchers to prepare a water balance for Walnut Gulch that is typical of semiarid rangeland watersheds (Figure 1). Research and data collection continues at the WGEW and the core hydrologic and erosion monitoring networks have expanded to include meteorologic and remotely sensed data.

Conclusions

Considerable precipitation-infiltration-runoff data are available in the southwestern arid watersheds in AZ-NM as described herein. Published material describing such work is extensive, especially as it pertains to precipitation and the research of Walnut Gulch Experimental Watershed.

Experimental watersheds with comprehensive monitoring and measurement infrastructure are a critical resource for research to understand semi-arid hydrologic, geomorphic, and ecosystem processes. The long-term data sets collected at the Walnut Gulch Experimental Watershed and at other experimental watersheds in Arizona and New Mexico have been used throughout the world to quantify rainfall and runoff relationships, to develop runoff and sediment yield prediction technologies, and to support soil and water conservation projects. The continued support of the currently operating experimental watersheds is critical to future soil and water conservation efforts.

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