Documenting Historical Data and Accessing it on the World Wide Web

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Abstract.—New computer technologies facilitate the storage, retrieval, and summarization of watershed-based data sets on the World Wide Web. These data sets are used by researchers when testing and validating predictive models, managers when planning and implementing watershed management practices, educators when learning about hydrologic processes, and decisionmakers when selecting the best course of action from a set of alternatives. Data sets from the Beaver Creek watershed in north central Arizona have been incorporated into a Web site to illustrate this application (http://www.rms.nau.edu/wsmgt/beavercr/). These particular data sets represent natural resource responses to watershed management practices in ponderosa pine forest and pinyon-juniper woodland types in the Southwest. This paper describes procedures to store, retrieve, and summarize watershed-based data, such as those obtained on Beaver Creek, on the World Wide Web.

Introduction

In the summer of 1955, several ranchers met with a USDA Forest Service representative and an official with the Salt River Project on the Beaver Creek watershed in north central Arizona, near Flagstaff, Arizona. These people were concerned that increasing densities of trees and shrubs on upland watersheds on the Salt and Verde River Basins might be reducing the stream flow and the livestock forage. As a result of this meeting, the University of Arizona was commissioned by the Arizona Land Department to investigate the potential for increasing the water yield from the state's forests and ranges. The findings of this investigation, presented in a report titled Recovering Rainfall: More Water for Irrigation (Barr 1956), better known as the Barr Report, were that surface-water runoff from mountain watersheds increases when high water-using plants, such as trees and shrubs, are replaced with low-water users, such as grasses. This 1956 report spurred demand for an immediate action program. In response to this demand, the USDA Forest Service's Arizona Water Program was initiated in the late 1950s to evaluate the usefulness of selected vegetative management programs in increasing water yields and other multiple resource benefits in the Salt and Verde River Basins (Fox 1958). The Beaver Creek watershed project became a significant component of this program.

The 20-plus years of research conducted during the Beaver Creek watershed project resulted in a large collection of physiographic, climatic, streamflow, floral, and faunal data with inconsistent formats (both spacial and temporal). This information has been difficult to retrieve by even those familiar with the project. Computers have greatly simplified access to large, varied data bases, and the World Wide Web has further advanced our ability to assess and disseminate such data. The data collected during the Beaver Creek project is used to illustrate the use of the Web for storing, retrieving, and summarizing watershed data. These data include precipitation, air temperature and humidity, wind and snowfall, streamflow, sedimentation and erosion, water quality (sediment and nutrient), and herbage and timber production. These data sets were collected at varying time steps ranging from minutes, to daily, to yearly, or more on 40 watersheds ranging in size from 4 to 6,600 ha.

Beaver Creek Watershed

The Beaver Creek watershed is located between 34° 30' and 35° north latitudes and 111° 30' to 112° west longitude in north central Arizona (http://www.rms.nau.edu/beaver_cr/, http://ag.arizona.edu/OALS/watershed/, and http://www.verde.org/). The center of the watershed is about 50 km south of Flagstaff, Arizona (figure 1). The Beaver Creek watershed, encompassing 111,300 ha upstream from the junction of Beaver Creek and the Verde River, is part of the Salt and Verde River Basins, which are major river drainages in central Arizona (Baker 1999). The Salt and Verde Rivers provide much of the surface water for Phoenix and other communities in the heavily populated Salt River Valley. The Beaver Creek watershed was selected for study because it represents of extensive areas of ponderosa pine (*Pinus ponderosa*) forests and pinyon-juniper (*P. edulis-Juniperus* sp.) woodlands in the Southwest.

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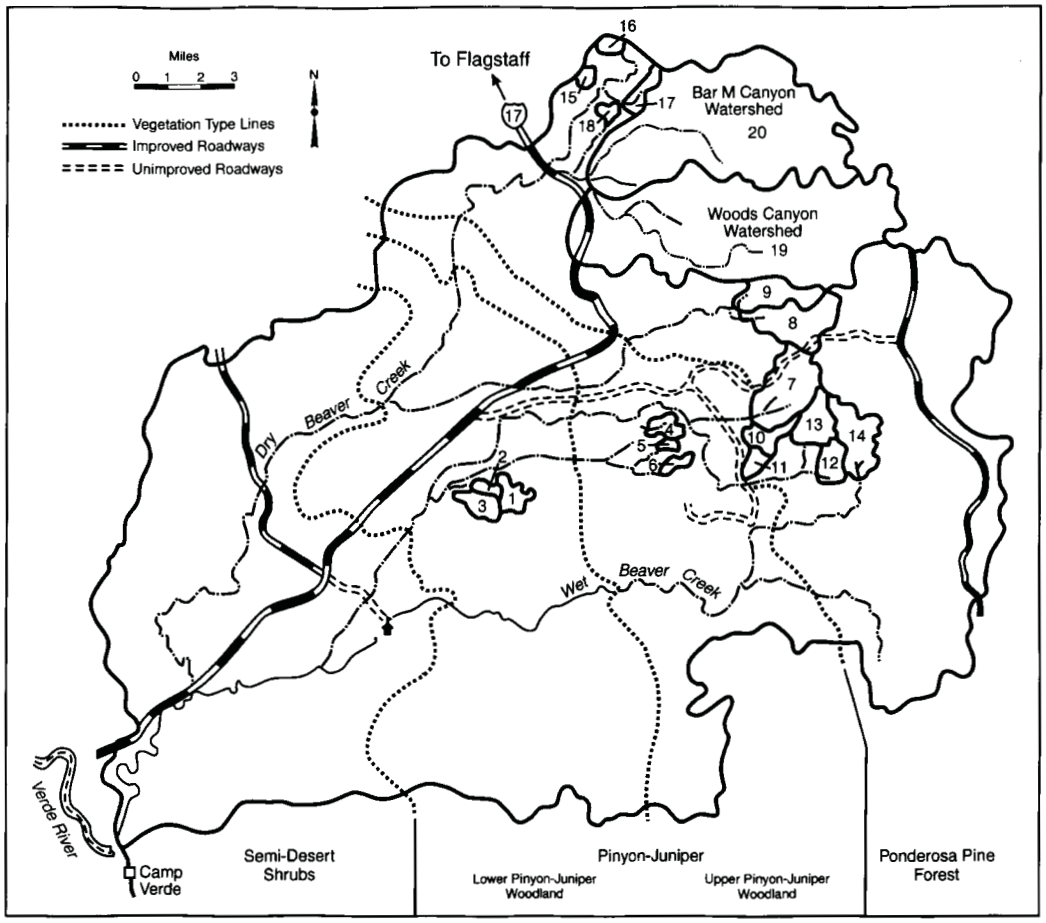

Figure 1. The Beaver Creek Watershed located upstream from the junction of Beaver Creek and the Verde River. Numbers indicate watersheds.

Annual precipitation on the Beaver Creek watershed varies greatly from year-to-year, which is characteristic of the climate in the Southwest (Baker 1999). On average, the ponderosa pine forests receive 500 to 635 mm of water and the pinyon-juniper woodlands receive 460 to 500 mm annually from rain and snow. Most of the annual runoff (95% in the ponderosa pine and 85% in the pinyon-juniper woodlands) is from the melting snowpack, which occurs largely in March and April.

In descending order with respect to elevation, the 3 vegetation types on the watershed are ponderosa pine, pinyon juniper (including alligator juniper [*Juniperus deppeana*] and Utah juniper [*J. osteosperma*] subtypes), and semidesert shrubs (figure 1). Ponderosa pine, characteristic of 4.5 million ha in the Southwest, dominate the hillsides and plateau above 2,000 m (Brown et al. 1974). Scattered throughout these forests are clumps of Gambel oak (*Quercus gambelii*), which is the predominant deciduous tree on Beaver Creek. This oak species is valued for the food and shelter it provides to wildlife. Woodlands of intermingled pinyon (*P. edulis*), Utah juniper, and alligator juniper grow between 1,370 and 2,000 m elevation, as they do on some 20.6 million ha in the Southwest (Clary et al. 1974). Representative plant and animal lists (scientific and common names) by vegetation type are available at http://ag.arizona.edu/OALS/watershed.

People have modified the Beaver Creek watershed since the late 19th century. The earliest modification was the introduction of domestic livestock. Most of the ponderosa pine area has also been logged, which has changed the size and age-class distribution of trees but has not caused major ecosystem changes. Suppression of naturally occurring fire since the early 1900s has had a slow, cumulative effect. Approximately 16,500 ha of pinyon-juniper woodlands were converted in the early 1960s to improve range conditions and water yields. Conversion was accomplished by uprooting trees with a cable or heavy chain (chaining) or by pushing trees out of the ground with a tractor (pushing). In addition, the watersheds have been altered by road and fence construction and watering site development. At the lower end of the watershed, near the Verde River, several small residential

communities have developed, while summer home developments have evolved on isolated parcels at higher elevations (e.g., Double Cabin Park, K-T Ranch, and Stoneman Lake). Other important impacts on the Beaver Creek watershed include sand and gravel operations on the Verde River and its tributaries, agriculture use, increase groundwater demand for irrigation and domestic use, and invasion of riparian areas by introduced plant species such as tamarix *(Tamarix pentandra*) or salt cedar

Methods of Data Collection

A system of paired pilot watersheds, established within a given vegetation type, received a single treatment at a given time for evaluation. Initial comparisons of the water yield and other products from these small, natural watersheds were completed before any treatments were applied. After the pretreatment evaluation, one of the paired watersheds was altered by vegetative manipulations and the other was used as a control. Twenty pilot watersheds within the Beaver Creek area (Brown et al. 1974, Clary et al. 1974) were established between 1957 and 1962 to test treatment effects (figure 1). Of these, 18 watershed were from 27 to 824 ha in size. The other 2 basins, encompassing 4,900 and 6,680 ha, were created to demonstrate the effects of management practices on areas similar to those common to land managers. In the early 1970s, 24 smaller subwatersheds, each having more uniform soil, plant life, and topography, were delineated in areas of diverse ecological characteristics. Seventeen of these subwatersheds were on the Beaver Creek watershed. Information from these watersheds helped refine and verify findings from studies on the pilot watersheds and promoted application to a wider range of conditions.

Studies in ponderosa pine forests and pinyon-juniper woodlands evolved from evaluation of changes in water yield to evaluation of changes in livestock forage, timber production, wildlife habitats, recreational values, and soil movement. A wide range of management treatments were tested on Beaver Creek (Baker 1999, Brown et al. 1974, Clary et al. 1974). Treatments included conversion of vegetation type in the pinyon-juniper woodlands, and practices, such as clearcutting, severe thinning, and strip cutting, to increase water yields, patch cutting to favor wildlife, and shelterwood cutting to promote maximum sustained timber production in the ponderosa pine forest. Hydrologic response, timber and forage yields, soil erosion, sediment production, water quality, scenic beauty, and the dynamics of insect, bird, small animals, and big game populations were measured posttreatment. Early research was summarized in state-of-the-art publications (Brown et al. 1974, Clary et al. 1974).

Data Sets and Coverage

Data sets from Beaver Creek are organized to reflect the components of a water budget; that is, precipitation inputs (quantity and quality) minus streamflow outputs (quantity and quality) equals evapotransiration (as modified by geology, soil, elevation, and vegetation). Data are expressed in English units of measure as was used in data collection. Computers allow rapid conversion to other units of measure, if desired.

The Beaver Creek watershed Web site (http://www.rms.nau.edu/wsmgt/beavercr/) has links to the categories described below. Searchable lists of the various types of information available about the Beaver Creek watershed project are available to users. Drop down lists are also available for easy access to various data for specific years and particular watersheds.

- *Overview* provides a brief narrative on why, when, and where the project was initiated. There is a site description and history, a description of research, and highlights of research findings.
- *Publications Data Base* links to the project's searchable publication data base (www.rms.nau.edu/beaver_cr/) that contains nearly 700 annotated citations for publications and reports that were developed during the Beaver Creek project (Baker and Ffolliott 1998, Baker et al. 2000a).
- *Personnel* lists names, status (deceased, working, or retired), and address (where appropriate).
- *Data* categories include weather, precipitation, streamflow, vegetation, soil, and fauna. All data categories have drop down lists for specific years and particular watersheds allowing users to make their own selection. Most data collecting was terminated by October 1983.
- *Weather* contains air temperature and humidity, wind speed and direction, snow, and solar radiation.
- *Precipitation* includes precipitation depth by gage and watershed and precipitation chemistry.
- *Stream* consists of instantaneous and daily streamflow information by watershed and stream flow chemistry.
- *Vegetation* includes timber and range data by inventory dates for the various watersheds. Plant species lists (scientific and common names) are included for the major vegetation types; ponderosa pine, pinyon juniper, and desert shrub.

- *Soil* contains soil descriptions, type, texture, and depth by watershed.
- *Fauna* includes data for the various animal inventories by date and watershed. Animal species lists (scientific and common names) for the major vegetation types are included.
- Watershed Description includes watershed number, area, slope, aspect, elevation, universal transverse mercator coordinates of gages, vegetation type, stream gage type, year initiated and terminated, treatment information, and comments.
- *Image Data Base* provides a link to the project's searchable image data base (www.rms.nau.edu/imagedb/wm/) that contain over 2,000 images collected during the Beaver Creek project (Baker et al. 2000b).
- *Related Links* include those with a direct connection to the Beaver Creek watershed project.
- *Contacts* is a list of people to reach for information about the Beaver Creek project that was not found on the Web site.

Additional Information

To help understand the Web site data sets for better interrogation and interpretation of the information, the following is presented.

Precipitation Data

Precipitation (inches) falling on the Beaver Creek watershed was measured with a network of about 60 gages from 1957 through 1982. All hydrologic data were collected on a water-year basis from October 1, Julian Day (JD) 274 through September 30, JD 273.

We used 4 types of rain gages on Beaver Creek. Recording rain gages (0100 series), standard 20.3 cm (8 inch) rain gages located next to recording gages (0200 series), remote (not adjacent to a recording gage) standard rain gages (0300 series), and Sacramento storage gages (0400 series). Generally at least one recording rain gage (0100 series) and its companion standard gage (0200 series) was located on each watershed. A number of additional standard rain gages (0300 series) were located on each watershed (the number of additional gages depended on the size of the watershed). These gages were visited weekly. The Sacramento storage gages, large gages capable of storing up to 40 inches of precipitation, were used in very remote locations that were difficult to reach and were serviced twice a year. Gage locations were selected on the bases of access and adequate coverage of each watershed. Precipitation measured in the standard 20.3-cm (8 inch) rain gage was used to designate the true amount at each site. The nearest recording gages was used to prorate the amounts measured in all non-recording gages.

All watersheds on Beaver Creek contained 2 to 6 precipitation gages. Average watershed precipitation inputs were subsequently determined using the Theissen Method of averaging for the allotted number of precipitation gages. Point rainfall amounts for 8 frequencies (15 min to 24 hr) and durations of 2, 5, 10, 25, 50, and 100 years were derived from Arizona State maps of precipitation (U.S. Department of Commerce 1968).

Air Temperature and Relative Humidity

A weather station was located in the Utah juniper vegetation type on watershed 3 (WS3) (0001), in the alligator juniper type on WS4 (0009), and 3 stations in the ponderosa pine type, WS8 (0020), WS17 (0035), and WS20 (0038). Analog hygrothermographs were used with a weekly chart. Period of record is usually from water year 1957 through 1982.

Streamflow Data

Streamflow was measured using the Beaver Creek, supercritical, trapezoidal flume on the 18 pilot watersheds (Baker 1986). Larger flumes, developed to measure flow in excess of 28.3 m^3/sec but with sufficient precision for long-term hydrologic investigations, were located on Woods Canyon (WS19) and Bar M Canyon (WS 20), the two largest watersheds (Brown 1969). Streamflow from the 24 subwatersheds, established in the early 1970s, was measured in 0.6 m H flumes with a maximum capacity of 0.3 m^3/sec. Daily streamflow data includes total flow in m^3 and area mm, peak discharge in m^3/sec and time of occurrence. Monthly flow is included for all water years of record.

Annual peak discharge for each watershed and water year are included. The discharges are expressed in m^3/sec per ha so flow from areas of different sizes are comparable.

Applications

Availability of data sets, such as illustrated in this paper, has unlimited use by researchers, land managers, educators, policy makers, and interested public. These

and similar data sets provide a basis to help watershed managers resolve future land stewardship issues. Although these data bases are in the public domain, they are minimally useful if access is limited by knowledge of their existence and by physical accessibility. Accessing these data bases via the Web allows individuals to down load them into software packages and models that did not exist when the data were being collected. Research results from the Beaver Creek watershed project find application in many arid and semi-arid regions of the world and provide long-term resource data for new analysis techniques and model application. There have been over 70 technical publications produced since the project was terminated in 1982 (Baker and Ffolliott 1998).

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