Stream Discharge Database, Little River Experimental Watershed, Georgia, United States

Article · September 2007

DOI: 10.1029/2006WR005833 · Source: OAI

David D Bosch
United States Department of Agriculture

Stream discharge database, Little River Experimental Watershed, Georgia, United States

D. D. Bosch[1] and J. M. Sheridan[1]

Received 20 December 2006; revised 23 May 2007; accepted 25 May 2007; published 5 September 2007.

[1] The U.S. Department of Agriculture Agricultural Research Service Southeast Watershed Research Laboratory (SEWRL) initiated a hydrologic research program on the Little River Experimental Watershed (LREW) in 1967. Long-term (up to 37 years) research quality streamflow data are currently available for up to eight flow measurement sites within the Gulf-Atlantic Coastal Plain physiographic region. The LREW stream discharge research program provides fundamental data for research into hydrologic processes, precipitation-runoff relationships, hydrograph characteristics, water yield, and interactive effects of climate, vegetation, soils, and land use for low-gradient Coastal Plain streams. All data are available on the SEWRL anonymous ftp site (ftp://www.tiftonars.org/).

Citation: Bosch, D. D., and J. M. Sheridan (2007), Stream discharge database, Little River Experimental Watershed, Georgia, United States, *Water Resour. Res.*, *43*, W09473, doi:10.1029/2006WR005833.

1. Introduction

[2] The Little River Experimental Watershed (LREW) is located in the headwaters area of the Suwannee River basin, a major U.S. interstate basin that originates in Georgia and empties into the Gulf of Mexico in the Big Bend region of Florida [*Bosch et al.*, 2007, Figure 1]. The LREW stream discharge research program provides fundamental data for research into hydrologic processes, precipitation-runoff relationships, hydrograph characteristics, water yield, and interactive effects of climate, vegetation, soils, and land use for low-gradient Coastal Plain streams. Streamflow data have been collected from the LREW since late 1967. This manuscript provides details on the streamflow component of the LREW database. The streamflow data are maintained on the LREW database anonymous ftp site (ftp://www.tiftonars.org/).

2. Streamflow Data Collection

[3] The LREW is currently instrumented to measure streamflow for the 334 km^2 primary drainage area (Watershed B) and seven subwatersheds that range from approximately 3 km^2 to 115 km^2 [*Bosch et al.*, 2007, Figure 2]. Construction of the original eight streamflow measurement devices began in 1967 and was completed in 1972. Extensive geologic and hydrologic assessments were conducted prior to installation of the weirs [*Yates*, 1976]. A brief description of the flow measurement devices follows. Additional details are available in prior publications [*Yates*, 1970; *Gwinn*, 1974; *Yates*, 1976; *Sheridan et al.*, 1995].

[4] Streams in the LREW have channel slopes ranging from 0.1% to 0.4%. Design and installation of accurate streamflow-measuring structures in these low-gradient streams presented two critical problems: (1) the free-overfall conditions required by most flow-measuring devices are difficult to obtain on these low-gradient streams and (2) raising the measurement control elevation even slightly could cause significant ponding upstream from the control structure. Because of these considerations, a compromise between backwater ponding effects and control submergence (nonfree overfall conditions) was necessary in the structure design and construction. The Virginia V notch weir was selected to fit the design constraints [*Ree and Gwinn*, 1959]. This weir provides accuracy over a wide range of flow rates, including low flow, is less sensitive to submerged flow conditions, and is relatively inexpensive to install and maintain. Because these weirs are normally rated for free-overfall conditions, special laboratory and field studies were conducted to obtain site specific rating curves. The devices were designed so that flows would be contained within the V notch center portion of each weir 90 to 95% of the time.

[5] Because of the broad, flat floodplains characteristic of the region, flow measurement installations on the LREW were located at road crossings. Three sites were installed at highway bridges and five at highway box culverts. Station coordinates along with physical characteristics and record periods are listed by watershed (Table 1). Each flow measurement site consists of a fixed control (or weir) for constricting and measuring streamflow, steel-sheet piling cutoff walls across the stream channel, guide walls or wing walls to direct streamflow across the control device, a concrete apron for energy dissipation immediately downstream from the control, and stilling wells hydraulically connected to stream sections immediately above and below the control. Weirs at highway bridges were positioned approximately 8 m downstream from the bridges. At all culvert sites except M, weirs were located between the outer ends of the upstream culvert wing walls, approximately 3 m upstream from the culvert. At site M, weirs were placed inside the downslope end of two small box culverts.

[1]Southeast Watershed Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Tifton, Georgia, USA.

Table 1. Geographic Locations, Basic Descriptions, and Record Lengths for the LREW Stream Gauging Stations

Station Name	Road Crossing	UTM[a] Easting, m	UTM[a] Northing, m	Drainage Area, km^2	Stream Order	Data Record
B	Dual Bridges	254518	3485875	334.3	5	14 Oct 1971 to present
F	Single Bridge	250365	3499631	114.9	4	29 Nov 1968 to present
I	Single Bridge	244933	3507512	49.9	4	8 Dec 1967 to present
J	4 Barrel Box Culvert	243864	3509522	22.1	3	1 Dec 1967 to present
K	4 Barrel Box Culvert	244320	3509946	16.7	3	6 Dec 1967 to present
M	2 Barrel Box Culvert	241910	3514711	2.6	2	6 Dec 1967 to 31 Dec 1988, 1 Nov 2002 to present
N	3 Barrel Box Culvert	254403	3489904	15.7	4	3 Oct 1970 to 31 Jan 1982, 1 Aug 2002 to present
O	3 Barrel Box Culvert	256119	3487152	15.9	4	29 Nov 1968 to 31 Jan 1982, 1 Jan 1993 to present

[a]Universal transverse Mercator coordinate system, zone 17, NAD 83 datum, resolution ±2 m.

[6] The original design flow measurement control section at all sites other than M consisted of a horizontal 0.41 m width weir with a V notch center section. A concrete weir cap was constructed atop an interlocking steel-sheet piling cutoff wall placed perpendicular to the direction of streamflow within the stream channel. Pilings at highway bridge sites were driven into the undisturbed channel bed and the adjacent stream banks for a width equal to the highway drainage opening. Cutoff walls were driven though the loose, unconsolidated, alluvial material into the undisturbed parent material below. The parent material, a relatively impermeable cemented clayey sand, constrains the surface aquifer [*Asmussen and Thomas*, 1974]. Depth of the alluvium, as determined by subsurface borings, ranges from 2 m at the headwater streams to 6 m at the lower end of watershed B [*Shirmohammadi et al.*, 1986]. At the bridge crossings, guide walls to prevent bypass flow extend approximately 15 m downstream from the bridge abutments and are high enough to contain the anticipated 25-year flow, with an extra 1 m freeboard added to provide additional capacity for more extreme events [*Yates*, 1976]. At the highway bridges, the guide walls are turned out parallel to the roadways for a distance of approximately 3 m. The wing walls are driven into the road shoulder to prevent streamflow from passing outside the guide walls and eroding the road banks. A 0.3 m thick concrete apron, built immediately downstream and extending 7.6 m, provides energy dissipation and erosion control. Rock rip-rap was placed on highway embankment sideslopes downstream from the highway bridge structures [*Yates*, 1976].

[7] At locations with box culverts, pilings were installed under the weir caps and on the apron extensions. Existing sloped wing walls were raised approximately 0.3 m above the culvert ceiling to eliminate the possibility of flow bypassing the control sections. The weirs at the box culverts extend the full length between the outer ends of the upstream culvert wing walls.

[8] The width of the horizontal weir and the depth of the V notch vary from site to site (Table 2). Structural dimensions were based on respective estimated design flows, which were computed using the Cypress Creek Formula [*Stephens and Mills*, 1966] and limited USGS stream data for the Coastal Plain [*Yates*, 1976]. All weirs, except M, were designed with 10:1 side slopes in the V notch section which is centered in the horizontal weir cap. Station M has two box culverts with a V notch weir with a 5:1 side slope installed in one of the box culverts and a horizontal weir installed in the other, each made of a 0.10 m wide by 0.15 m high-angle iron. The V notch weir was installed at a lower elevation so that most flow will pass through the more accurate portion of the device. Each weir crest is horizontal outside of the limits of the V notch section.

[9] Because of observed submergence conditions occurring at I, K, and O, weir-crests at those sites were raised 0.15 m after about 1 year of operation. At Station O the control section was raised by attaching a 0.10 m wide by 0.15 m high-angle iron to the existing weir cap. At Stations I and K, a 0.15 m concrete weir cap was added to the existing structure.

[10] The flow control installed at Station B is unique among the large LREW flow measurement installations in that there are two bridges at the road crossing. The larger (west) bridge has a horizontal weir with a V notch center section, while the smaller (east) bridge has a horizontal weir

Table 2. Description of LREW Flow Measurement Devices

Station Name	Flow Measurement Device	Weir Length, m	V Notch Depth, cm	Anticipated 25 – Year Maximum Flow Rate,[a] $m^3 s^{-1}$
B (primary structure)	horizontal weir with V notch center section	69.4	93.0	191.4
B (auxiliary overflow structure)	horizontal weir	22.9	NA[b]	–
F	horizontal weir with V notch center section	43.1	61.0	81.9
I	horizontal weir with V notch center section	26.6	49.7	41.7
J	horizontal weir with V notch center section	16.8	47.2	20.8
K	horizontal weir with V notch center section	17.8	44.2	16.5
M (primary structure)	horizontal weir with V notch center section	1.8	19.2	4.0
M (auxiliary overflow structure)	horizontal weir	1.8	NA	–
N	horizontal weir with V notch center section	14.8	62.2	15.4
O	horizontal weir with V notch center section	14.8	62.5	14.5

[a]*Yates* [1976].
[b]NA means not applicable.

Table 3. Instrumentation History at the LREW Flow Stations

Period of Record	Data Recording Device	Water Surface Elevation Measurement Device	Accuracy, mm	Data Collection Interval, min
1967–1993	Fischer-Porter	Float/pulley	3	5
1993–2000	Campbell Scientific BDR320	Pressure transducers	2	5
2001 to present	Campbell Scientific CR10	Pressure transducers	2	5

only that is installed 0.15 m higher than the horizontal portion of the primary structure. At high flows, streamflow occurs through both structures and data are collected from the secondary structure as well as the primary one.

[11] Free-overfall over the weir crest, without interference from the tailwater or the downstream water pool is typically required for highly accurate flow measurements. To provide information on periods when tailwater levels could potentially impact flow control structure ratings; that is, when submerged flow conditions exist, both upstream and downstream water surface elevations are recorded. Stilling wells are connected hydraulically to the upstream and the downstream sides of the structures. The original instrumentation used to record water surface elevations consisted of two Fischer-Porter digital stage recorders that punched 5-min data in binary decimal code on a 16-channel punched paper tape. Timing on the digital recorders was synchronized across the entire LREW hydrologic network, permitting near simultaneous recording of both upstream and downstream water surface elevations. The original Fischer-Porter recorders measured elevations in increments of 3 mm. Beginning in 1993, the Fischer-Porter gauges were replaced with a strain gauge pressure-transducer digital data logger system to measure and record water surface elevations. The pressure transducers measure the water depth to the nearest 2 mm. The data are stored on data loggers and transferred to computer storage for processing and review prior to entry into the hydrologic database. A chronological description of the different measurement systems is presented in Table 3.

[12] The raw data are examined on a monthly basis for possible errors. Missing or erroneous data are flagged in the data files. All streamflow data from each LREW site dating back to inception of the network are available. Varying lengths of record are available from the eight LREW flow measurement stations (Table 1). Record lengths and in some cases, continuity, have varied depending on data needs of the specific research projects, research objectives, and varying funding constraints. Efforts were made to maintain the core hydrologic data collection capability over time; particularly within the upper (49.9 km^2) LREW Subwatershed I study area. A detailed description of the spatial soils, geology, topography, and vegetation data for LREW study areas are provided by *Sullivan et al.* [2007].

3. Rating of the Structures

[13] Rating curves for each flow measurement structure were developed on the basis of theoretical considerations, results of laboratory model testing, and an intensive field streamflow measurement program. Prior to weir construction, model studies of control cross-sections and selected installation sites were conducted to determine the appropriate flow control design specifications as well as to provide relevant information for developing stage-discharge rating curves. A large bridge-weir installation, similar to the control installation at LREW B, was modeled at the ARS Hydraulics Laboratory in Stillwater, Oklahoma [*Gwinn*, 1974]. Model studies were also conducted at the University of Georgia for smaller controls similar to those installed at intermediate to smaller LREW sites [*Sheridan*, 1968].

[14] The stage or rate of flow at which the transition from free-overflow to submerged-flow conditions occurs varies from structure to structure because of differences in floodplain resistance downstream from the control and differences in vertical placement of the V notch as well as physical dimensions of the respective control structures. Because of these factors, an intensive field streamflow measurement program was conducted to develop site-specific stage-discharge ratings for each structure. Discharge measurements were made at each site using timed volumetric catch at very low flow and current meter discharge measurements at intermediate and high flows.

[15] Stream stage-discharge ratings developed from the field measurements were used in conjunction with the model-based ratings to develop stage-discharge rating curves for converting recorded stream stage data to instantaneous flow rates. Correlations were developed by plotting the log of measured discharge versus the log of upstream depth above the V notch center section, or head. Further details on model studies of the LREW structures and the development of stage-discharge ratings for these structures may be found in work by *Sheridan* [1968], *Gwinn* [1974], and *Sheridan et al.* [1995].

4. Data Availability

[16] Discharge data from the eight LREW flow measurement sites are available from an anonymous ftp site (ftp://www.tiftonars.org/) maintained by the U.S. Department of Agriculture Agricultural Research Service (USDA-ARS) Southeast Watershed Research Laboratory, Tifton, Georgia, United States. Updates and revisions to the data collection system and the data are contained in metadata files located on the site. Two sets of data are available, the 5-min stage data and average daily flow data. LREW streamflow data have been reviewed to remove obvious errors which may result from instrument or operational malfunctions.

5. Examples of Data Use

[17] The LREW data have been used in development of water yield and water balance information, hydrologic and water quality budgets, and rainfall-streamflow relationships, as well as in development of hydrologic and hydraulic parameters and improved methodologies required for natural resource and environmental quality model testing and

simulations in the Coastal Plain. *Shirmohammadi et al.* [1986] demonstrated that the primary runoff-producing areas within regional watersheds are the low-lying, poorly drained, near-stream areas where the water table is typically near the ground surface throughout the winter and early spring months. Equations commonly used for estimating storm peak flows in current water resource and quality models were tested on storm event data from the LREW and were found to overestimate peak flows by an average of ~250% for all events. Improved regional peak flow equations were developed for estimating storm event peak flows occurring on regional watersheds based on watershed physical characteristics [*Sheridan*, 2002]. Improved methods for estimating storm hydrograph characteristics, including the hydrograph time-to-peak parameters [*Sheridan*, 1994] and hydrograph shape parameters [*Sheridan et al.*, 2002], were developed for hydrologic design and natural resource and environmental modeling applications on ungauged Coastal Plain watersheds. Equations were also developed for estimating mean maximum daily streamflow for a range of recurrence intervals on regional watersheds as a function of watershed drainage area [*Sheridan and Mills*, 1985].

[18] **Acknowledgments.** The accuracy and reliability of the LREW stream data attest to the efforts and dedication of the many technical support staff of the SEWRL over the period of record. In particular, we would like to express our gratitude to Homer D. Allison, Herman E. Henry, and M. Lynne Hester, who played key roles in the installation and implementation of the original data network, as well as in the development of data collection and editing protocols for the LREW hydrologic databases. This is a contribution from the USDA-ARS, Southeast Watershed Research Laboratory, in cooperation with University of Georgia Coastal Plain Experimental Station. All programs and services of the U.S. Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, age, marital status, or disability.

References

Asmussen, L. E., and A. W. Thomas (1974), Computing phreatic groundwater storage, *Agric. Res. Serv. Res. Bull. 153*, 23 pp., U.S. Dep. of Agric., Washington, D. C.

Bosch, D. D., J. M. Sheridan, R. R. Lowrance, R. K. Hubbard, T. C. Strickland, G. W. Feyereisen, and D. G. Sullivan (2007), Little River Experimental Watershed database, *Water Resour. Res.*, *43*, W09470, doi:10.1029/2006WR005844.

Gwinn, W. R. (1974), Hydraulic model studies of Little River Gaging Station B, *Agric. Res. Serv. Publ. ARS-S-38*, 32 pp., U.S. Dep. of Agric., Washington, D. C.

Ree, W. O., and W. R. Gwinn (1959), The Virginia V-notch weir, *Agric. Res. Serv. ARS-S-41-10*, 7 pp., U.S. Dep. of Agric., Washington, D.C.

Sheridan, J. M. (1968), Discharge characteristics of submerged broad-crested V-notch weirs, M.S. thesis, 68 pp., Univ. of Ga., Athens.

Sheridan, J. M. (1994), Hydrograph time parameters for flatland watersheds, *Trans. ASAE*, *37*, 103–113.

Sheridan, J. M. (2002), Peak flow estimates for Coastal Plain watersheds, *Trans. ASAE*, *45*, 1319–1326.

Sheridan, J. M., and W. C. Mills (1985), Hydrologic research on Coastal Plain watersheds of the southeastern United States, *Transp. Res. Rec. 1017*, pp. 16–25, Natl. Res. Counc., Washington, D.C.

Sheridan, J. M., W. C. Mills, and M. L. Hester (1995), Data management for experimental watersheds, *Trans. ASAE*, *11*, 249–259.

Sheridan, J. M., W. H. Merkel, and D. D. Bosch (2002), Peak rate factors for flatland watersheds, *Appl. Eng. Agric.*, *18*, 65–69.

Shirmohammadi, A., J. M. Sheridan, and L. E. Asmusssen (1986), Hydrology of alluvial stream channels in southern Coastal Plain watersheds, *Trans. ASAE*, *29*, 135–142.

Stephens, J. C., and W. C. Mills (1966), Evaluating and applying the Cypress Creek Formula, *Trans. ASAE*, *9*, 550–555.

Sullivan, D. G., H. L. Batten, and D. D. Bosch (2007), Little River Experimental Watershed, Tifton, Georgia, United States: A geographic database, *Water Resour. Res.*, *43*, W09471, doi:10.1029/2006WR005836.

Yates, P. (1970), V-notch weir for submerged flow measurement, *Agric. Eng.*, *51*, 132–133.

Yates, P. (1976), Design, construction, and operation of streamflow-measuring facilities in the Little River Watershed, Georgia, *Agric. Res. Serv. Publ. ARS-S-148*, 15 pp., U.S. Dep. of Agric., Washington, D.C.

D. D. Bosch and J. M. Sheridan, Southeast Watershed Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, P.O. Box 748, Tifton, GA 31793, USA. (david.bosch@ars.usda.gov)