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Streamflow Gains and Losses for Hellbranch Run, Franklin County, Ohio, August 2007

Scientific Investigations Report 2008–5191

U.S. Department of the Interior
U.S. Geological Survey

Cover image: View of Hellbranch Run downstream from Grove City Road, Franklin County, Ohio (photograph from Franklin Soil and Water Conservation District, reproduced with permission).

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	3.785	liter per minute (L/min)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

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Abstract

On August 7, 2007, the U.S. Geological Survey did a streamflow gain-loss study on Hellbranch Run in western Franklin County, Ohio. From Feder Road to Lambert Road, 26 stream and pipe-discharge measurements were made on the mainstem, tributaries and other sources of inflow. Mainstem streamflows ranged from no measureable flow to 1.75 cubic feet per second; tributary and pipe discharges ranged from 0.001 to 0.23 cubic foot per second. The uncertainty in each discharge measurement was considered when calculating the gain or loss of streamflow. Although streamflow losses occurred over short reaches, including a stretch of dry streambed, Hellbranch Run is gaining water from ground water in much of the study area.

Introduction

Big Darby Creek, a national and state scenic river, is an important resource in west-central Ohio (Fuller, Mossbarger, Scott & May Engineers Inc., 2006). Pollution, runoff, and poor streambank management are degrading some stream segments and reaches in Franklin County. These conditions are of particular concern because of the conversion over the past 10–15 years of farmland to suburban and commercial land uses. Hellbranch Run, in western Franklin County, is a major tributary to Big Darby Creek, whose watershed is being rapidly developed.

Ground-water contributions as base flow are important components of streamflow. It is well understood that ground water and surface water are interdependent and interconnected resources; and sustained depletion of one typically results in depletion of the other, propagating adverse effects throughout the watershed (Winter and others, 2002). A key to understanding ground-water and surface-water relations and the hydrologic balance in any watershed is the quantitative determination of the amount of gain (or loss) of streamflow from ground water. To obtain a better understanding of the ground-water/surface-water interaction of Hellbranch Run, the U.S. Geological Survey (USGS) in cooperation with the Ohio Department of Natural Resources, Division of Water, did a gain-loss study in August 2007.

Purpose and Scope

The purpose of this report is to present data on and describe the gain (or loss) of streamflow along reaches of Hellbranch Run. Findings are based on 26 stream and pipe discharge measurements made on August 7, 2007. Discharge measurements were made on the mainstems of the Hamilton and Clover-Groff Ditches from Feder Road to Hellbranch Run and downstream on Hellbranch Run to Lambert Road (fig. 1). Inflow to the ditches and Hellbranch Run was also measured.

Description of Study Area

The study area (fig. 1) is the Hellbranch Run, in western Franklin County. The land use in the area is changing from mostly agricultural to suburban. The mainstem of Hellbranch Run is a natural stream that has not been channelized. The soils in the area drain poorly; as a result, drainage ditches and underground drainage tiles are common sources of discharge to the run (Fuller, Mossbarger, Scott, & May Engineers Inc., 2006). The topography of the watershed is characterized by nearly level till plains with minor relief due to erosion and glacial features. Buried bedrock valleys, filled with glacial sediments, are present in the county. The bedrock underlying western Franklin County consists of dolomitic limestone. A bedrock valley in the study area is as much as 330 ft deep, but the average depth to bedrock is about 100 ft. The carbonate bedrock is the principal aquifer in the area, with wells yielding as much as 250 gal/min. The surficial glacial sediments consist of fine-grained tills and minor sand and gravel deposits. Thickness of the glacial sediments ranges from 30 to more than 300 ft in the bedrock valley. Wells in the glacial sediments generally yield less than 20 gal/min (Schmidt, 1958, 1993).

The streamflow was investigated along reaches of Hamilton Ditch, Clover-Groff Ditch, and Hellbranch Run from Feder Road to Lambert Road (fig. 1). The ditches and run are generally just a few feet deep, with streambed that ranges from silty to sandy with gravel and cobbles. Inflow to the ditches and Hellbranch Run comes from natural tributaries and numerous pipes of various sizes discharging from multiple sources.

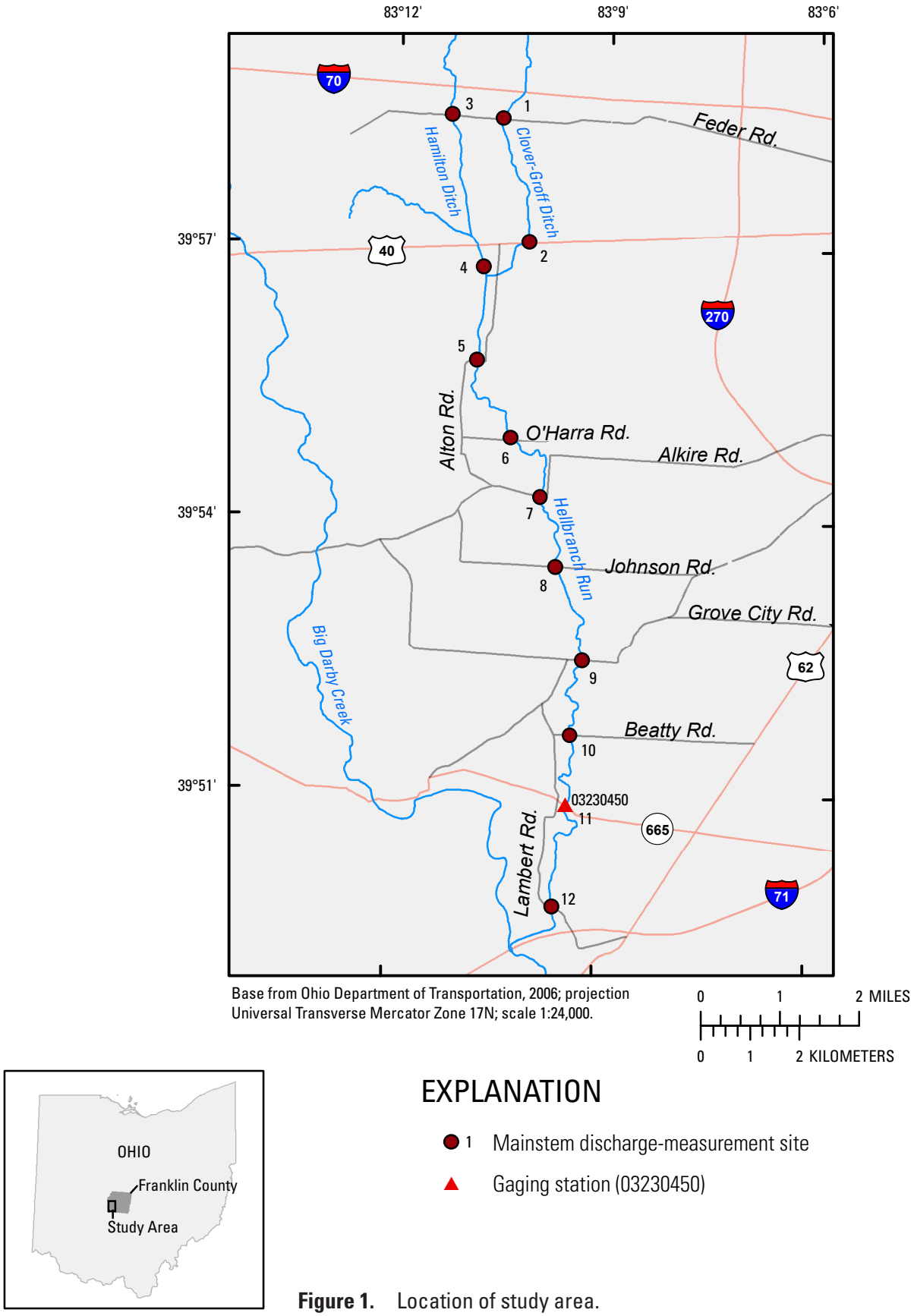


Figure 1. Location of study area.

Methods

A gain-loss study consists of making a series of discharge measurements along the mainstem of a stream reach and discharge measurements of all inflows within the reach. The discharge measurements were made according to the methods outlined by Rantz and others (1982), either by the conventional current-meter (wading) method or the volumetric method. Discharge measurements are rated from excellent to poor on the basis of flow conditions at the site. These ratings are an assessment of the potential error in the discharge measurement: "excellent" is defined as the discharge volume that is estimated to be within 2 percent of the true discharge; "good" is within 5 percent, "fair" is within 8 percent, and "poor" is greater than 8 percent. These ratings can be used to calculate an uncertainty interval (UI) for the discharge measurement; for this report, the UI for "poor" ratings was set at ±10 percent.

The gain or loss of water in a reach is determined by calculating the difference between the two mainstem measurements and then subtracting any tributary inputs. A positive result indicates the reach is gaining water; negative indicates the reach is losing. To accurately assess the gain or loss of a reach, the potential errors (UI) in the measurements must be taken into account. Figure 2 is an example of the calculations to determine streamflow gain or loss. A reach was defined as gaining only if the final four values in step 3 were positive; four negative values defined a losing reach. A combination of positive and negative numbers indicates that the procedure cannot determine with reasonable confidence whether the stream is gaining or losing.

The Franklin County Soil and Water Conservation District (FSWCD) has created a database of the locations of streams, ditches, pipe outfalls, bridges, and tributaries to the streams in the county (J. Pierce, FSWCD, written commun., 2007). Data from the FSWCD indicated that numerous pipes discharge to Hellbranch Run. Discharges from these pipes could be anything from road runoff and gutter connections to household gray-water discharges. During reconnaissance of the stream, a 2- to 3-in.-diameter pipe was observed to discharge what appeared to be soapy water for a minute or so, then stop for a few minutes, then briefly discharge again. Because of the many potential and unpredictable discharge sites, it was necessary to walk the entire length of the gain-loss reach, from Feder Road to Lambert Road; all inflows were noted and measured when possible.

Gain or Loss of Streamflow

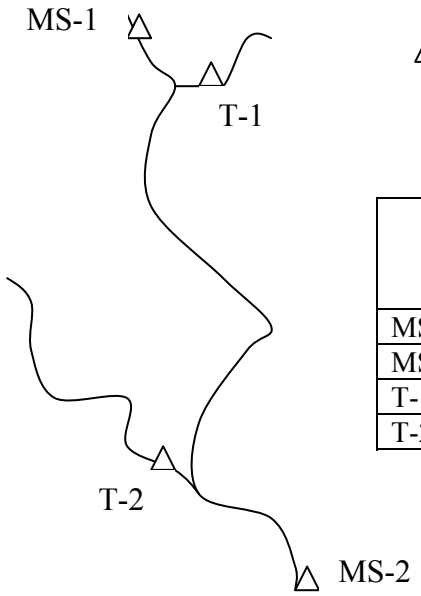
After factoring in the mainstem flow and the inflow of tributaries, the gain or loss of streamflow can be assumed to be from ground water entering the stream (gain) or stream water discharging to the ground water (loss). Therefore, the ideal time for a gain-loss study is during minimum surface runoff, so that the interaction between the stream water and ground water will be the dominant process.

The locations of and data on the discharge measurements are presented in table 1. Discharge measurements were made at 12 mainstem sites and 14 tributary or pipe-discharge sites. At two measurement locations, the first and the last mainstem measurement on Hellbranch Run, water present but no flow was measured. Mainstem measurements ranged from no measureable flow to 1.75 ft^3/s; tributary and pipe discharges ranged from 0.001 to 0.23 ft^3/s. Between the gaging station (Hellbranch Run near Harrisburg, 03230450) and Lambert Road, a section of dry streambed was found. Additional observations related to streamflow conditions are noted on table 1.

On August 7, 2007, precipitation occurred before daybreak—but a review of radar and precipitation data that morning indicated that the precipitation had occurred largely outside of the study area, so runoff was not expected to have a significant impact on Hellbranch Run. Although the streamflow hydrograph (fig. 3) from the gaging station on Hellbranch Run (03230450) indicates some runoff on August 7, the gage height measured at 0910 hours was 4.40 ft and at 1315 hours, 4.39 ft, indicating that streamflow in Hellbranch Run was fairly constant during the time of data collection. (Measurements were made between 0800 and 1215 hours.) Based on 13 years of data, the discharge measured at the gage (1.69 ft^3/s) corresponds to about 60 percent on the July-October flow-duration curve, which indicates the study was indeed done during a time of low flow.

Hellbranch Run is crossed by roads at frequent intervals, and most of the mainstem discharge measurements were made near a road (fig. 1). Therefore, the reaches were essentially defined by the interval between two roads. Table 2 lists the various reaches for which gains or losses were calculated. The gain or loss for six of reaches could not be determined because the UIs for the discharge measurements were greater than the differences in discharge between measurements. The mainstem measurement at Alton Road was not used in the gain/loss calculations because there was no measurable flow at this site, possibly an effect of the beaver dams found above and below Alton Road (table 1).

A number of unmeasurable inflows or outflows, such as intermittently discharging pipes, pumps, and seeps (table 1), could affect the determination of a gain or loss of streamflow in a reach. Although the gain-loss calculation shows that Hamilton Ditch was losing water (table 2), the field observation of colder water (table 1) in a section of the ditch indicates that there may be some short sections where cooler ground water discharged to the ditch (streamflow gain). The gain or loss of water in the reach from Johnson Road to Grove City Road could not be determined—an intermittently discharging pipe and an idle pump was observed in this reach. Likewise, the gain or loss of water in the reach from Beatty Road to the gaging station could not be determined. However, the seep and the probable intermittent discharge (table 1) would both add water to the reach; therefore, the similar discharges at Beatty Road and the gaging station (table 1) could indicate possible loss in the reach. But, in contrast, the seep observed in the same reach indicates at least some gain of water in that reach.



△ Discharge-measurement location
MS, mainstem
T, tributary inflow

Site	Discharge (cubic feet per second)	Measurement error (percent)	Uncertainty interval (UI) for discharge measurements
MS-1	100	5	95–105
MS-2	250	10	225–275
T-1	75	10	68–83
T-2	100	10	90–110

Step 1: Calculate the uncertainty interval (UI) for gain or loss between mainstem measurements only:

A. Calculate upper limit by subtracting maximum of MS-2 from minimum of MS-1:

275 – 95 = 180

B. calculate lower limit by subtracting minimum of MS-2 from maximium of MS-1:

225 – 105 = 120

Thus, the UI only for the mainstem measurements is 120 – 180.

Step 2: Calculate the UI for tributary inflows by adding the minimum and maximum of the tributary measurements

68 + 90 = 158

83 + 110 = 193

Thus, the UI only for inflow to the reach is 158 – 193.

Step 3: Determination of the gain or loss status of the reach — subtract the maximum and minimum of the inflow UI from the maximum and minimum of the mainstem UI:

120 – 158 = –38 120 – 193 = –73

180 – 158 = 22 180 – 193 = –13

If the results of these four calculations are positive, then the reach is gaining water; if all four are negative, then the reach is losing water. If, as in this example, there is mixture of positive and negative results, then the gain or loss of the reach cannot be determined with reasonable confidence due to the range of potential errors in the measurements.

Figure 2. Example of steps in the calculation of streamflow gain or loss.

Table 1. Site identification, measurement, and stream-description data for discharge measurements along Hellbranch Run, August 7, 2007.

[trib., tributary; P, pygmy meter; V, volumetric; P-F, pygmy meter and a flume of bed materials; V-E, visual estimate; ft, feet; s, second; F, Fahrenheit; —, less than 0.001]

Mainstem location number (fig. 1) and site name (Indented sites are inflows to reach)	Method	Rating[1]	Discharge (ft^3/s)	Uncertainty interval[2] (ft^3/s)	Comments
1 Clover-Groff Ditch at Feder Road	P	Fair	0.99	0.91 - 1.1	
Pipe discharge to Clover-Groff Ditch	V	Excellent	.001	—	
Unnamed trib. to Clover-Groff Ditch	P	Fair	.23	.21 - .25	
Pipe discharge to Clover-Groff Ditch	V	Excellent	.003	—	
Pipe discharge to Clover-Groff Ditch	V	Excellent	.001	—	
Unnamed trib. to Clover-Groff Ditch	P	Fair	.010	—	
2 Clover-Groff Ditch at Alton Road	P	Fair	1.17	1.08 - 1.26	
3 Hamilton Ditch at Feder Road	P	Poor	.08	.07 - .09	
Pipe discharge to Hamilton Ditch	V	Excellent	.015	—	
Pipe discharge to Hamilton Ditch	V	Excellent	.002	—	
Pipe discharge to Hamilton Ditch	V	Excellent	.001	—	
Colder water, "maybe 20 degrees F colder" was noted in Hamilton Ditch below State Route 40.					
4 Hamilton Ditch above Hellbranch Run	P-F		.03	—	South of U.S. Route 40
Multiple beaver dams observed from confluence of ditches to O'Harra Road.					
5 Hellbranch Run at Alton Road	P	Excellent	0.0		Water present but no flow
Unnambed trib. to Hellbranch Run	V	Excellent	.001	—	
6 Hellbranch Run at O'Harra Road	P	Good	1.47	1.40 – 1.54	
Pipe discharge to Hellbranch Run	V-E	Poor	.03	—	Culvert half buried
7 Hellbranch Run at Alkire Road	P	Fair	1.29	1.19 – 1.39	
8 Hellbranch Run at Johnson Road	P	Poor	1.55	1.40 – 1.71	
Unnamed trib. to Hellbranch Run	V	Excellent	.006	—	
Pipe discharge to Hellbranch Run	V	Excellent	.022	—	
Pipe discharge to Hellbranch Run	V	Excellent	.027	.026 - .028	
Near Grove City Road, 3-inch pipe observed intermittently discharging soapy water—unable to measure due to variable flow.					
Temporary pump observed in a pool—possibly for lawn irrigation—not pumping at time of observation.					
9 Hellbranch Run at Grove City Road	P	Good	1.75	1.66 – 1.84	
Inflow to Hellbranch Run	P	Fair	.03	—	2 in. pipe, natural channel
10 Hellbranch Run at Beatty Road	P	Fair	1.70	1.56 – 1.84	
A section of streambank, about 70 feet long, was observed to be seeping water—impossible to estimate flow.					
A damp drain pipe was observed; not flowing at the time of observation—possible intermittent discharge.					
11 Hellbranch Run at gaging station	P	Fair	1.69	1.55 – 1.83	
Dry streambed observed between gaging station and Lambert Road.					
12 Hellbranch Run at Lambert Road	P	Excellent	0.0		Water present but no flow

[1]Rating category is based on conditions at the time of measurement.

[2]Based on the rating category; excellent, within 2 percent; good, within 5 percent; fair, within 8 percent; poor, 10 percent.

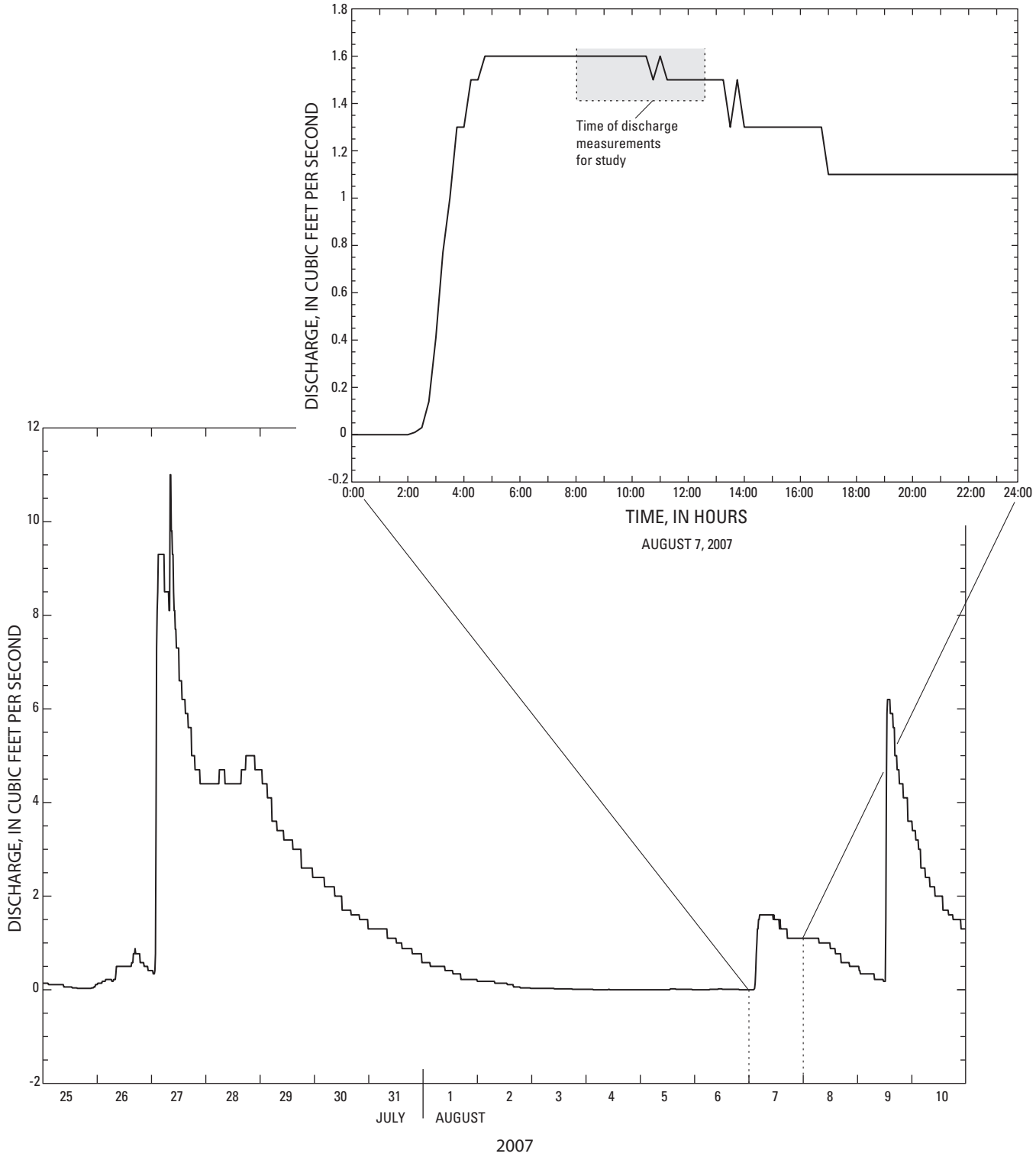


Figure 3. Hydrograph of stream discharge at Hellbranch Run near Harrisburg (03230450).

Table 2. Determination of streamflow gains or losses for selected reaches on Hellbranch Run, August 7, 2007, based on the confidence intervals of measurement errors.

[Shaded reaches are an amalgamation of shorter reaches; UI, uncertainty interval; ft, feet; s, second; negative values indicate streamflow loss; positive numbers indicate streamflow gains; —, no tributary inflow in reach; bold reaches have gains or losses greater than the measurement errors]

Reach (mainstem measurement sites, fig. 1)	Minimum mainstem UI[1] (ft^3/s)	Maximum mainstem UI[1] (ft^3/s)	Minimum inflow UI[1] (ft^3/s)	Maximum inflow UI[1] (ft^3/s)	Mainstem streamflow gain or loss (ft^3/s) [1]
Clover-Groff Ditch (1-2)	-0.02	0.35	0.23	0.27	Cannot be determined
Hamilton Ditch (3-4)	-.06	-.04	.018	.018	Loss 0.06 – 0.08
Ditches to O'Harra Road (2&4-6)	.11	.43	.001	.001	Gain 0.11 – 0.43
O'Harra Road to Alkire Road (6-7)	-.35	-.01	.03	.03	Loss 0.04 – 0.38
Alkire Road to Johnson Road (7-8)	.01	.52	—	—	Gain 0.01 – 0.52
O'Harra Road to Johnson Road (6-8)	-.14	.31	.03	.03	Cannot be determined
Johnson Road to Grove City Road (8-9)	-.05	.44	.054	.056	Cannot be determined
Alkire Road to Grove City Road (7-9)	.27	.65	.054	.056	Gain 0.214 – 0.596
Grove City Road to Beatty Road (9-10)	-.28	.18	.03	.03	Cannot be determined
Johnson Road to Beatty Road (8-10)	-.15	.44	.084	.086	Cannot be determined
Beatty Road to gaging station (10-11)	-.29	.27	—	—	Cannot be determined
Alkire Road to gaging station (7-11)	.16	.64	.08	.09	Gain 0.07 – 0.56
Ditches to gaging station (2&4– 11)	.26	.72	.12	.12	Gain 0.2 – 0.6

[1]See figure 2 for an example calculation of uncertainty intervals and streamflow gain or loss.

In general, Hellbranch Run is gaining water from confluence of the ditches to the gaging station, although losses in some areas may occur over short reaches. A dry stretch of streambed (table 1) noted between the gaging station and Lambert Road; indicates a total loss of streamflow. Water (though no measureable flow) was present at Lambert Road, this water could be a residual pool left over from earlier flows or the water could indicate that the stream was beginning to gain from ground-water discharge again.

The results of this study are comparable to those of a similar study in west-central Ohio, on a shorter reach of Chapman Creek (Dumouchelle, 2001). Both studies found that the streams may change from gaining to losing over fairly short reaches. Both studies also found that, over longer reaches, the streams were generally gaining.

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