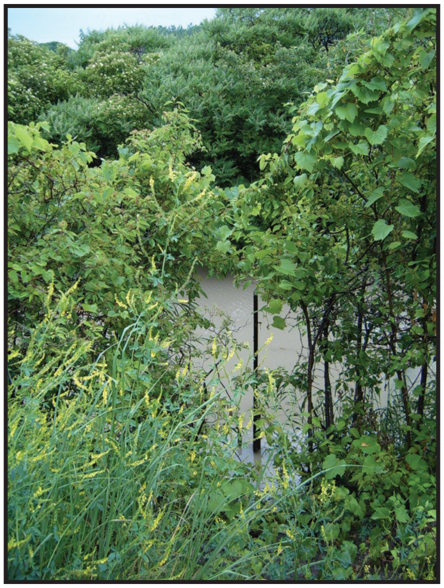
Escherichia coli and Suspended Sediment in Berger Ditch at Maumee Bay State Park, Oregon, Ohio, 2006



Open-File Report 2007–1244

U.S. Department of the Interior
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Cover. Clockwise from upper left—

A. Staff gage in Berger Ditch at Maumee Bay State Park, Oregon, Ohio.
B. U.S. Geological Survey gage house near Berger Ditch.
C. Looking downstream at staff gage in Berger Ditch from Cedar Point Road bridge.
D. Automatic sampler at gage house at Berger Ditch, Oregon, Ohio (station number 04194085).

Escherichia coli and Suspended Sediment in Berger Ditch at Maumee Bay State Park, Oregon, Ohio, 2006

By Amie M.G. Brady

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Conversion Factors and Abbreviations

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	35.31	cubic foot (ft^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
kilogram (kg)	2.205	pound, avoirdupois (lb)

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

°F=(1.8×°C)+32

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L).

Concentrations of bacteria in water are given in colony-forming units per 100 milliliters (cfu/100 mL).

Instantaneous discharges are given in colony-forming units of *Escherichia coli* per second (cfu/s).

Suspended-sediment discharges are given in kilograms per second (kg/s).

Abbreviations

ADVM – acoustic Doppler velocity meter

E. coli – *Escherichia coli*

LEPF – Lake Erie Protection Fund

MBSP – Maumee Bay State Park

mg – milligram

mL – milliliter

NTU – Nephelometric Turbidity Units

µm – micrometer

USGS – U.S. Geological Survey

UT – University of Toledo

Escherichia coli and Suspended Sediment in Berger Ditch at Maumee Bay State Park, Oregon, Ohio, 2006

By Amie M.G. Brady

Abstract

Berger Ditch discharges to the marina at Maumee Bay State Park (MBSP), just east of the MBSP bathing beach. Recent studies by U.S. Geological Survey (USGS) and University of Toledo researchers have identified the ditch as a source of *Escherichia coli* (*E. coli*), an indicator bacterium that is used to assess recreational water quality. An automatic sampler was installed at a USGS streamgage on Berger Ditch. Samples were collected as a function of streamflow, including negative flow conditions. Instantaneous discharges of *E. coli* and suspended sediment from Berger Ditch were calculated. When samples were collected, streamflow ranged from -21 to 227 cubic feet per second (ft^3/s) and over the entire time period, streamflow ranged from -23 to 243 ft^3/s. Discharges of *E. coli* ranged from 2.5×10^8 to greater than 2.6×10^{10} colony-forming units per second (cfu/s), and suspended-sediment discharges ranged from 0.01 to 2.2 kilograms per second (kg/s). One sample was collected during negative flow conditions, and discharges of *E. coli* and suspended sediment in this sample were -4.3×10^8 cfu/s and -0.015 kg/s, respectively.

Introduction

Maumee Bay, in the southwest corner of Lake Erie near Toledo and Oregon, Ohio, is a popular recreational destination for swimming and boating. Maumee Bay State Park (MBSP), an important tourist attraction in the area, has a Lake Erie shoreline beach and an inland beach. The Lake Erie beach nearshore area often has high *Escherichia coli* (*E. coli*) concentrations, indicating a potential health risk to beachgoers. Berger Ditch, which discharges into the marina just east of the Lake Erie beach, has been identified as a source of *E. coli* (Glatzer and Erichsen, 2003; Francy and others, 2005). As suggested by these studies, the next step is to develop a better understanding of the influence of Berger Ditch on *E. coli* concentrations at the MBSP beach. The U.S. Geological Survey (USGS), in cooperation with the University of Toledo (UT), undertook a project to examine the discharges of *E. coli* and suspended sediment from Berger Ditch in relation to the concentrations of *E. coli* at the MBSP Lake Erie beach. The goal of this report is to summarize the results of actions taken that were funded by the Lake Erie Protection Fund (LEPF) Small Grant, primarily the instantaneous discharges of *E. coli* and suspended sediment from Berger Ditch as determined from samples collected by an automatic sampler installed at the USGS streamgage on the ditch.

Methods

Site Information

Berger Ditch discharges into the marina at MBSP 230 ft east of the Lake Erie bathing beach. The ditch receives flow from Wolf Ditch, which drains approximately 10.7 mi^2 and flows through Oregon and Jerusalem Township. The drainage area of Berger Ditch at its mouth is approximately 16 mi^2. Land use in the Berger Ditch drainage is primarily farmland with some single-family residences. Overland runoff and discharges from septic systems are the expected sources of contamination to the ditch.

Negative flows are frequently observed in Berger Ditch. These negative flows can be caused by localized northern winds that push water upstream into the ditch or by the Lake Erie seiche. A seiche is a standing wave in an enclosed body of water such as a lake, which can be caused by wind, storm events, or earthquakes. Due to the shallowness of Lake Erie, wind-caused seiches are common.

To assist with understanding the hydrology in the ditch, including frequency and duration of negative flows, a USGS streamgage was installed on Berger Ditch in May 2006. An acoustic Doppler velocity meter (ADVM) was installed in the ditch to measure stream-velocity and calculate cross-sectional area (based on instantaneously measured water height and programmed cross-sectional elevations) at 10-minute intervals. The ADVM then calculates and records streamflow using standard USGS techniques (Rantz and others, 1982). Funds provided by the LEPF Small Grant enabled real-time streamflow information for this site to be available online at *http://waterdata.usgs.gov/oh/nwis/nwisman/?site_no=04194085&agency_cd=USGS*.

In June 2006, a refrigerated automatic sampler was installed and programmed to collect samples from the ditch when both of the following conditions exist: (1) there was a change in streamflow of 8 ft^3/s or more over a 10-minute interval and (2) the flow was greater than 15 ft^3/s or less than -15 ft^3/s. Therefore, samples could be collected every 10 minutes if the conditions of the program were met. Because of some technical difficulties, the sampler was not completely ready for use until July 2006. These difficulties included problems with the sampler program and thunderstorms that delayed installation of the equipment required to transmit the data to the Internet which allowed the student to monitor when the sampler collected samples.

Sample Analysis

Samples collected by the automatic sampler were retrieved by a UT student within 24 hours of collection. Also, within 24 hours of sample collection, a UT student determined sample turbidity and filtered the sample to determine *E. coli* concentration. A portable turbidimeter (Hach, Loveland, Colo.) was used to determine turbidity, and results were reported in Nephelometric Turbidity Units (NTU). U.S. Environmental Protection Agency Method 1603 (2002) was used to determine *E. coli* concentrations. Briefly, a volume of sample water was filtered through a 0.45-µm-pore-size filter and then transferred to a modified mTEC agar plate. Plates were incubated at 35°C for 2 hours and then at 44.5°C for 22 to 24 hours. Colonies that appear magenta in color were counted as *E. coli*. Results were reported in colony-forming units per 100 milliliters (cfu/100 mL).

Suspended-sediment analyses were done by Heidelberg College, Tiffin, Ohio. After removing an aliquot to obtain *E. coli* concentrations and turbidity, the sample bottles (with the remaining sample volume) were stored in a cool, dark location until USGS personnel could retrieve and deliver the bottles to Heidelberg College. Concentrations of suspended sediment were determined by means of the filtration method as described in Guy (1969) and reported in milligrams per liter (mg/L).

To represent the magnitude of *E. coli* and suspended-sediment transport in the ditch at the time of sampling, instantaneous discharges were computed as follows:

$$\textit{E. coli}\text{ concentration (cfu/100 mL)} \times (10^6\text{ mL / 1 m}^3) \times (1\text{ m}^3\text{ / 35.31 ft}^3) \times \text{streamflow (ft}^3\text{/s)}$$

to obtain instantaneous discharges with the units of colony-forming units of *E. coli* per second (cfu/s), and

$$\text{suspended-sediment concentration (mg/L)} \times (28.32\text{ L / 1 ft}^3) \times (1\text{ kg / }10^6\text{ mg}) \times \text{streamflow (ft}^3\text{/s)}$$

to obtain instantaneous discharges with the units of kilograms per second (kg/s).

Results

A total of 107 samples were collected from the autosampler and analyzed. Forty-one samples were analyzed for both *E. coli* and suspended-sediment concentrations. Forty-two samples were analyzed for *E. coli* concentrations only, and 24 samples were analyzed for suspended-sediment concentrations only. This discrepancy in sample analyses was a result of miscommunication between the USGS and UT scientists. Future studies will be more closely monitored to minimize similar communication problems. Other samples were collected by the sampler but were not analyzed because they were not retrieved within the 24-hour holding time for *E. coli* analysis as required for this project or they were retrieved, but not saved for suspended-sediment analysis.

Streamflow, *Escherichia coli*, and Suspended Sediment

Samples were collected over a range of streamflows (fig. 1). The data will be discussed further in the next few paragraphs. It is worth noting that samples were collected and analyzed for both *E. coli* and suspended-sediment concentrations during two high-flow events as can be seen in figure 1. Also, only one sample was collected during negative flow conditions, and the results are indicated on the figure.

Berger Ditch Streamflow

Instantaneous streamflow during July and August ranged from -23 to 243 ft^3/s. Daily mean streamflow ranged from -0.15 to 155 ft^3/s, with a median of 1.75 ft^3/s. Of the measurements made at the USGS streamgage during this time ($n = 8{,}928$), 25 percent of the measurements were recorded as negative flows. The largest magnitude of negative flow was -23 ft^3/s measured on July 3, 2006. For samples analyzed for *E. coli* concentrations, the instantaneous streamflow at time of collection ranged from -21 to 227 ft^3/s, with a median of 35 ft^3/s. For samples analyzed for suspended-sediment concentrations, instantaneous streamflow ranged from -21 to 118 ft^3/s, with a median of 35 ft^3/s.

Escherichia coli Concentrations and Discharges

Samples that were analyzed for *E. coli* were collected during July 2006 (fig. 2). Of the 83 samples analyzed for *E. coli* concentrations, 30 samples, representing two precipitation events, were too numerous to count (estimated concentrations were greater than 2,700 or greater than 8,000 cfu/100 mL). Unfortunately, these samples were collected during the peak streamflow for the precipitation events. Because results for these samples were estimated values, they were not included in analyses. The bulk of the samples used in data analysis were collected following peak streamflow for the events sampled.

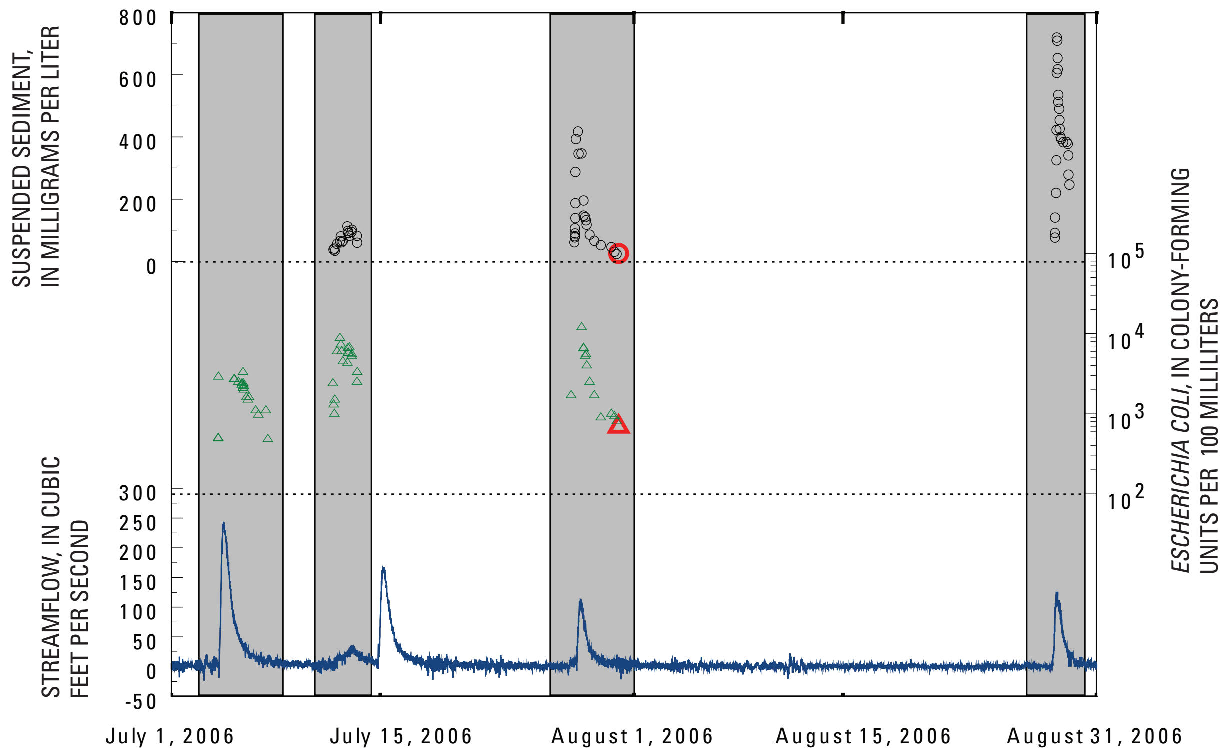

Figure 1. Instantaneous streamflow, *Escherichia coli* concentrations, and suspended-sediment concentrations near the mouth of Berger Ditch, Oregon, Ohio, July and August 2006. The sample collected during negative flow is indicated by the enlarged red symbols.

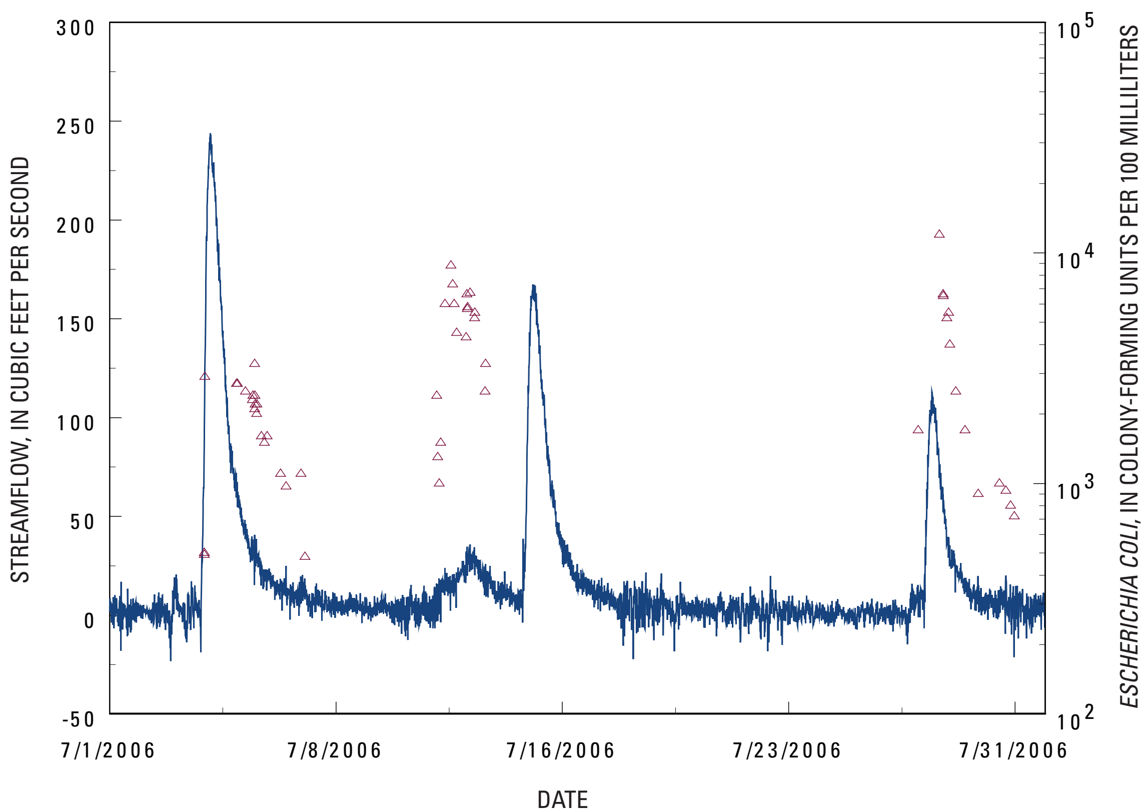

Figure 2. Instantaneous streamflow and *Escherichia coli* concentrations near the mouth of Berger Ditch, Oregon, Ohio, July and August 2006.

Concentrations (within countable limits) of *E. coli* in samples ranged from 480 to 12,000 cfu/100 mL, with a median of 2,400 cfu/100 mL. Discharges of *E. coli* when flow was positive ranged from 2.5×10^8 to 2.4×10^{10} cfu/s, with a median of 2.0×10^9 cfu/s. For the single sample collected when flow was negative (-21 ft^3/s), the discharge of *E. coli* was -4.3×10^8 cfu/s. In the boxplot of the data (fig. 3), the negative-flow sample is shown as a single point.

Suspended-Sediment Concentrations and Discharges

Samples analyzed for suspended-sediment concentrations were collected during July and August (fig. 4). Suspended-sediment concentrations ranged from 24 to 720 mg/L, with a median value of 130 mg/L. Discharges of suspended sediment when flow was positive ranged from 0.01 to 2.2 kg/s, with a median of 0.15 kg/s. For the sample collected during negative flow, the associated discharge was -0.015 kg/s.

Correlation Analyses

Correlation analysis and scatterplots were used to examine the relations between *E. coli* and suspended-sediment concentrations and discharges. Pearson's *r* is a correlation coefficient that measures the linear association between two variables. The more the correlation coefficient differs from 1 or -1 and approaches zero, the weaker the relation. The level of significance was set at $\alpha = 0.05$ for this report.

E. coli concentrations were significantly related to both turbidity and suspended-sediment concentrations ($r = 0.42$ and $r = 0.73$, respectively). However, *E. coli* concentrations were not related to streamflow in the ditch at time of sampling. *E. coli* concentrations tended to increase after streamflow increased. Based on analyses, the highest correlations were observed between *E. coli* concentrations and streamflow 40 minutes prior to sampling ($\log_{10}$-transformed values) (fig. 5). As expected, concentrations of suspended sediment were significantly related to turbidity ($r = 0.98$). Suspended-sediment concentrations were also significantly related to streamflow (fig. 6).

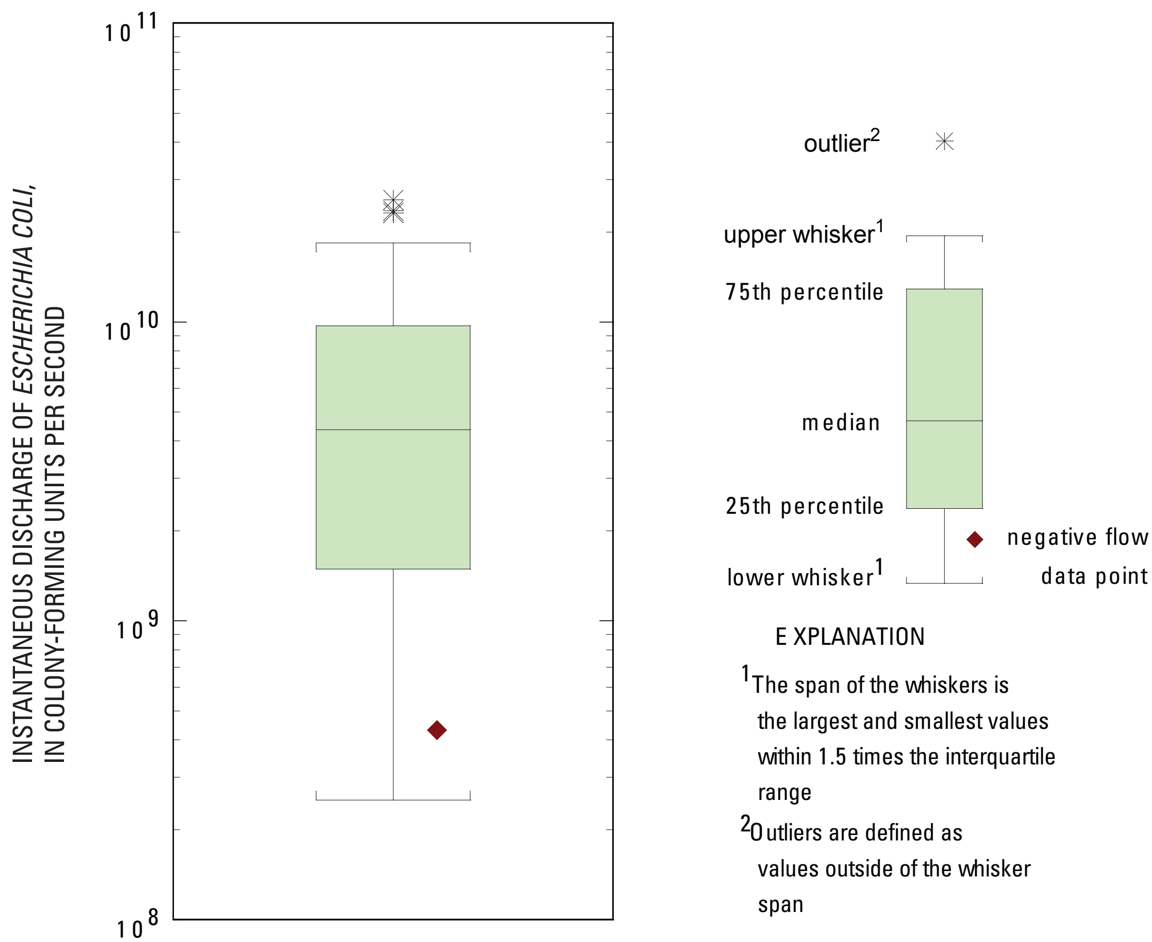

Figure 3. Instantaneous discharges of *Escherichia coli* near the mouth of Berger Ditch, Oregon, Ohio, July 2006. One sample was collected during negative flow, and the magnitude of discharge associated with that sample is indicated by the diamond.

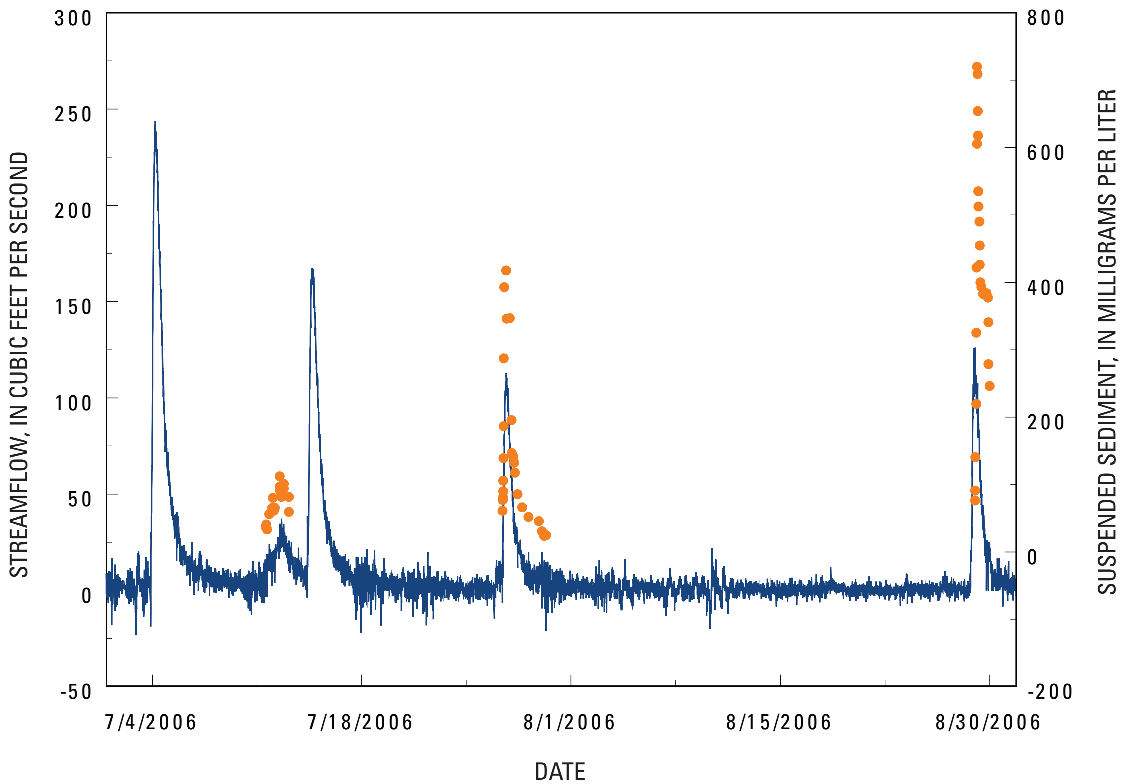

Figure 4. Instantaneous streamflow and suspended-sediment concentrations near the mouth of Berger Ditch, Oregon, Ohio, July and August 2006.

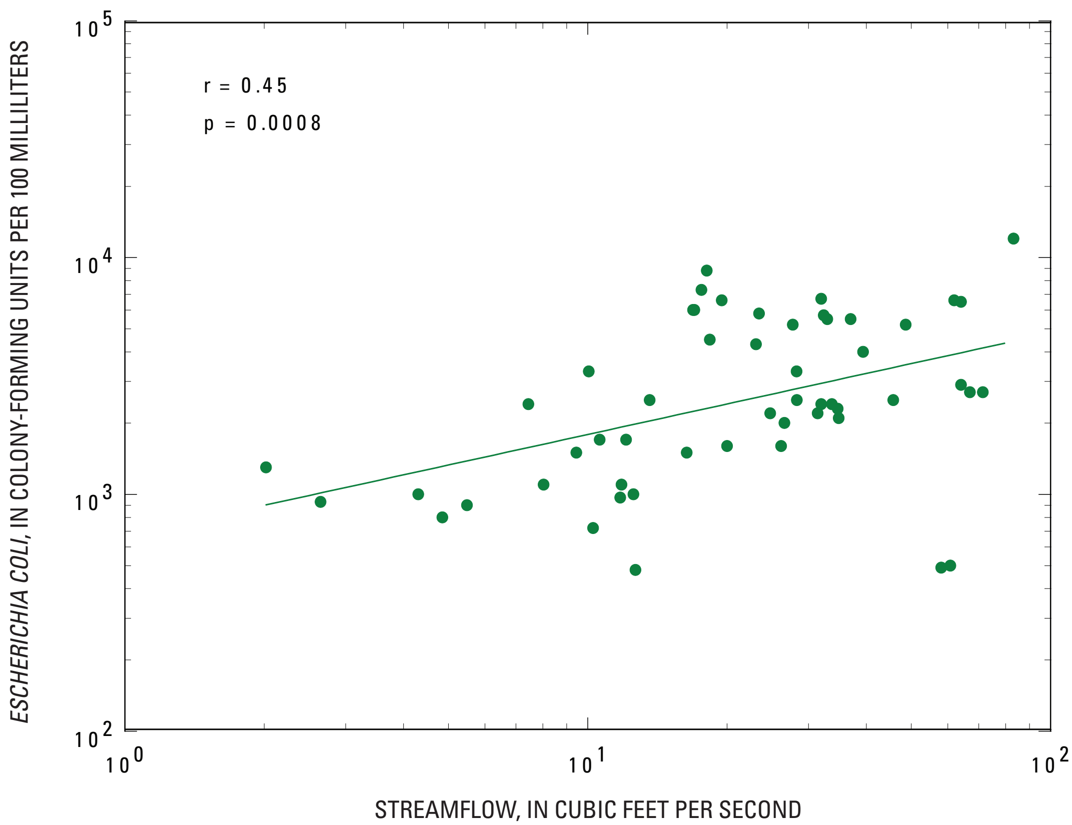

Figure 5. Relation between *Escherichia coli* and streamflow 40 minutes prior to sampling in Berger Ditch, Oregon, Ohio, July 2006. The line is the linear-fit line. [r, Pearson's correlation coefficient; p, significance of the relation.]

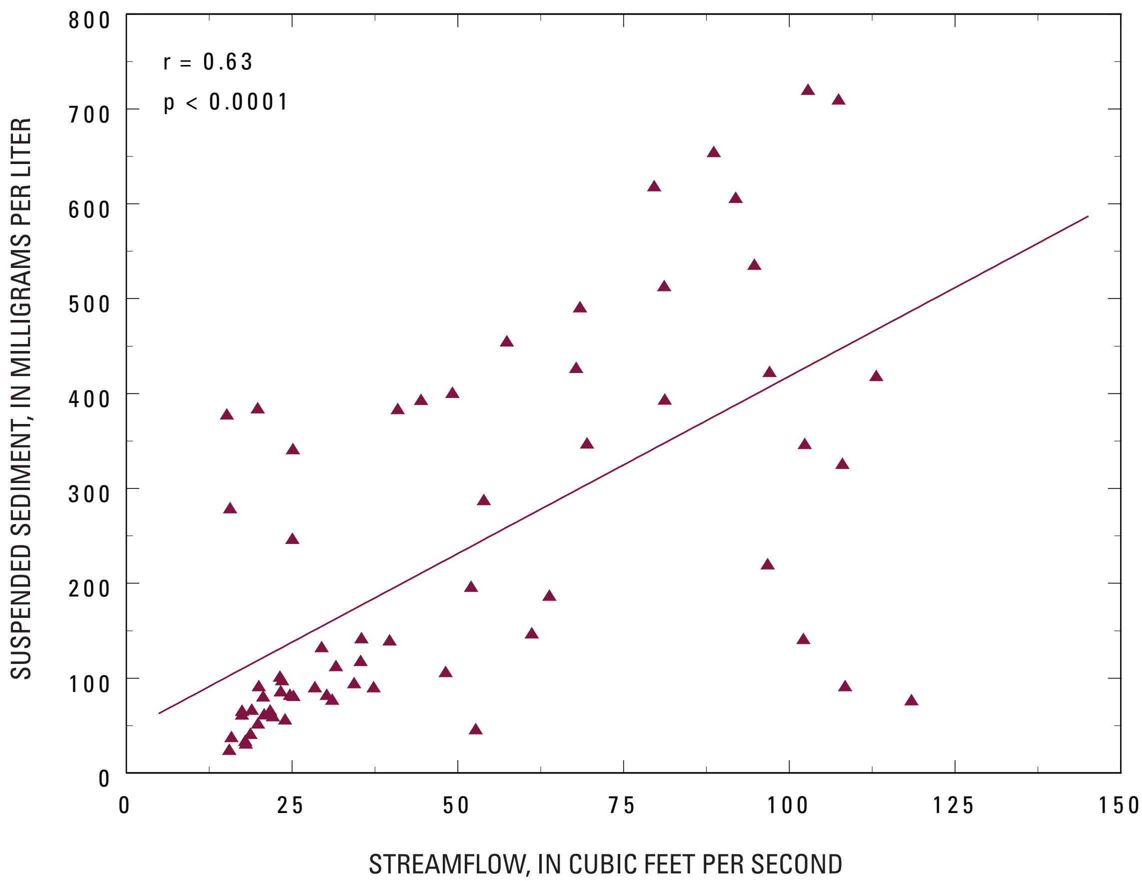

Figure 6. Relation between suspended sediment and streamflow in Berger Ditch, Oregon, Ohio, July–August 2006. The line is the linear-fit line. [r, Pearson's correlation coefficient; p, significance of the relation; <, less than]

Acknowledgments

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