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Annual Peak-Flow Frequency Characteristics and (or) Peak Dam-Pool-Elevation Frequency Characteristics of Dry Dams and Selected Streamflow-Gaging Stations in the Great Miami River Basin, Ohio

Scientific Investigations Report 2009–5177

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

Cover image: Views of dry-dam outlets in the Great Miami River Basin, clockwise from top in approximate location in the basin: Lockington, Taylorsville, Huffman, Germantown, and Englewood Dams. (Photos copyright 1913–2009, Miami Conservancy District, all rights reserved; reproduced with permission.)

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KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

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Contents

Figures

Tables

Conversion Factors and Datums

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to the U.S. Army Corps of Engineers datum of 1912 (COE 1912).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Annual Peak-Flow Frequency Characteristics and (or) Peak Dam-Pool-Elevation Frequency Characteristics of Dry Dams and Selected Streamflow-Gaging Stations in the Great Miami River Basin, Ohio

By G. F. Koltun

Abstract

This report describes the results of a study to determine frequency characteristics of postregulation annual peak flows at streamflow-gaging stations at or near the Lockington, Taylorsville, Englewood, Huffman, and Germantown dry dams in the Miami Conservancy District flood-protection system (southwestern Ohio) and five other streamflow-gaging stations in the Great Miami River Basin further downstream from one or more of the dams. In addition, this report describes frequency characteristics of annual peak elevations of the dry-dam pools. In most cases, log-Pearson Type III distributions were fit to postregulation annual peak-flow values through 2007 (the most recent year of published peak-flow values at the time of this analysis) and annual peak dam-pool storage values for the period 1922–2008 to determine peaks with recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years. For one streamflow-gaging station (03272100) with a short period of record, frequency characteristics were estimated by means of a process involving interpolation of peak-flow yields determined for an upstream and downstream gage. Once storages had been estimated for the various recurrence intervals, corresponding dam-pool elevations were determined from elevation-storage ratings provided by the Miami Conservancy District.

Introduction

The Miami Conservancy District (MCD), whose jurisdiction lies within the Great Miami River Basin in southwestern Ohio (fig. 1), is responsible for the operation and maintenance of a flood-protection system that includes five gateless dry dams: Lockington, Englewood, Taylorsville, Huffman, and Germantown (fig. 2). These dams were designed to safely pass the Official Plan Flood (OPF), which is equal to the 1913 flood magnitude plus 40 percent additional flow (Miami Conservancy District, 2009). Flow through the dams is controlled by means of conduits designed to pass only the amount of water that can be conveyed within the banks of the downstream channel. Excess floodwaters are stored behind the dams in temporary pools, which gradually drain as inflow rates to the dam pools fall below the outflow rates. During times of low to moderate flow, water flows in the conduits through the dams unimpeded, leaving no permanent pools (hence the name “dry dams”).

The dams were constructed simultaneously between 1918 and 1922. Streamflow-gaging stations have been operated near the outlets of each of the dams for all or most of the periods since the dams were constructed. The MCD has collected and maintained records of annual peak dam-pool elevations, as well as peak dam-pool elevations associated with selected smaller floods that resulted in water storage in the dam pools. Other streamflow-gaging stations also have been operated by the MCD (many in cooperation with the U.S. Geological Survey) in the Great Miami River Basin. Frequency characteristics of the peak flows discharged through the dams and of annual peak dam-pool elevations have been assessed in the past, as have frequency characteristics of several streamflow-gaging stations in the basin (Webber and Bartlett, 1977; Song, 1979); however, those assessments were based on appreciably less data than are currently available (2009).

Accurate information on peak flow and annual peak dam-pool-elevation frequency characteristics is important to regulators and emergency managers so that they can make informed decisions about flood-related risks. Consequently, there is a periodic need to reevaluate those characteristics to improve the accuracy of frequency estimates and to evaluate and reflect any changes in frequency characteristics that may result from changes in hydrology. To help meet that need, the U.S. Geological Survey (USGS), in cooperation with the MCD, did a study to characterize annual peak flows and peak dam-pool-elevation frequency characteristics of the dry dams in the Great Miami River Basin, Ohio, and to characterize peak-flow frequency characteristics at selected other gaged locations in the basin.

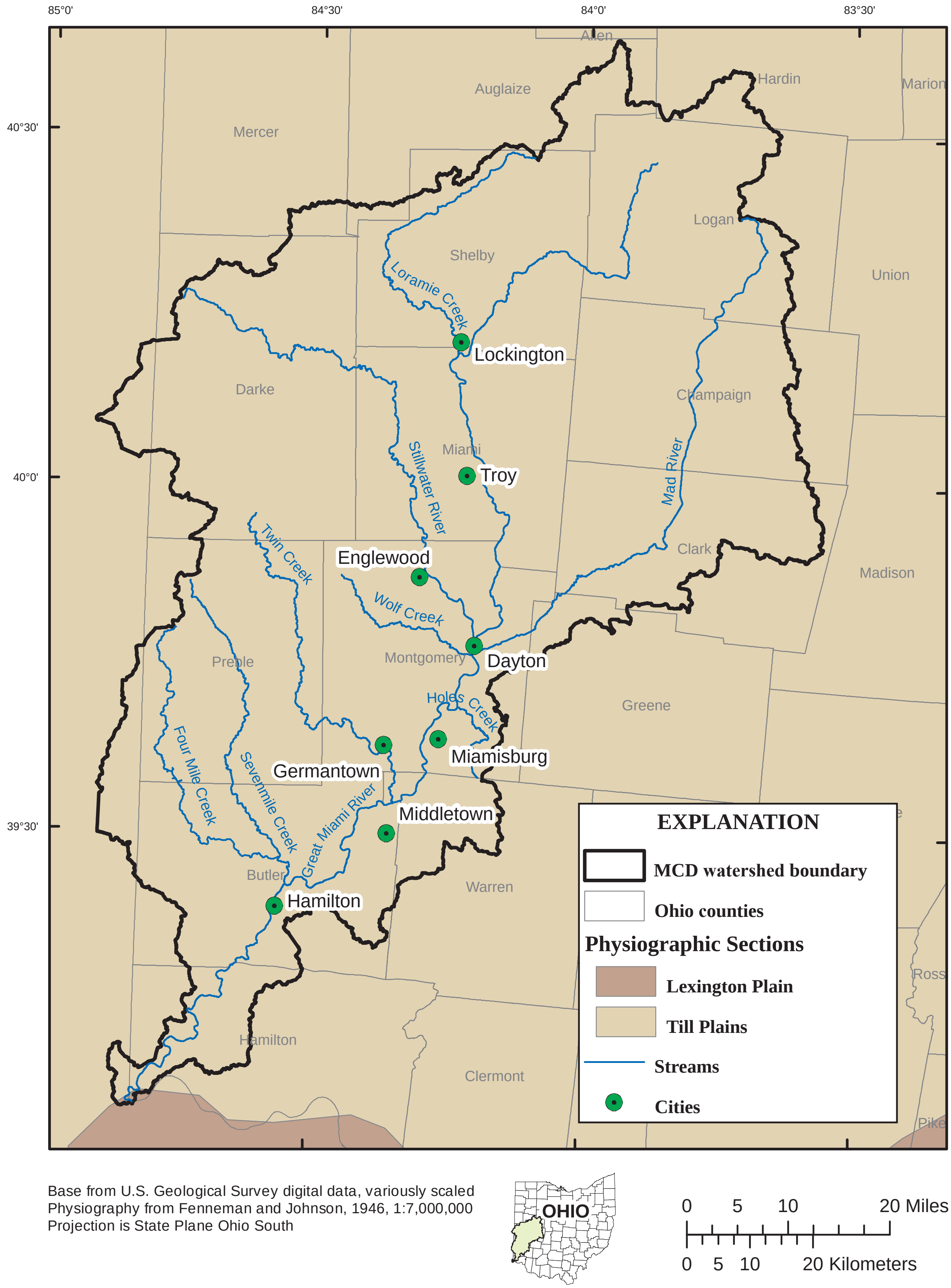

Figure 1. Miami Conservancy District (MCD) watershed boundary with cities, streams, and physiographic sections, southwestern Ohio.

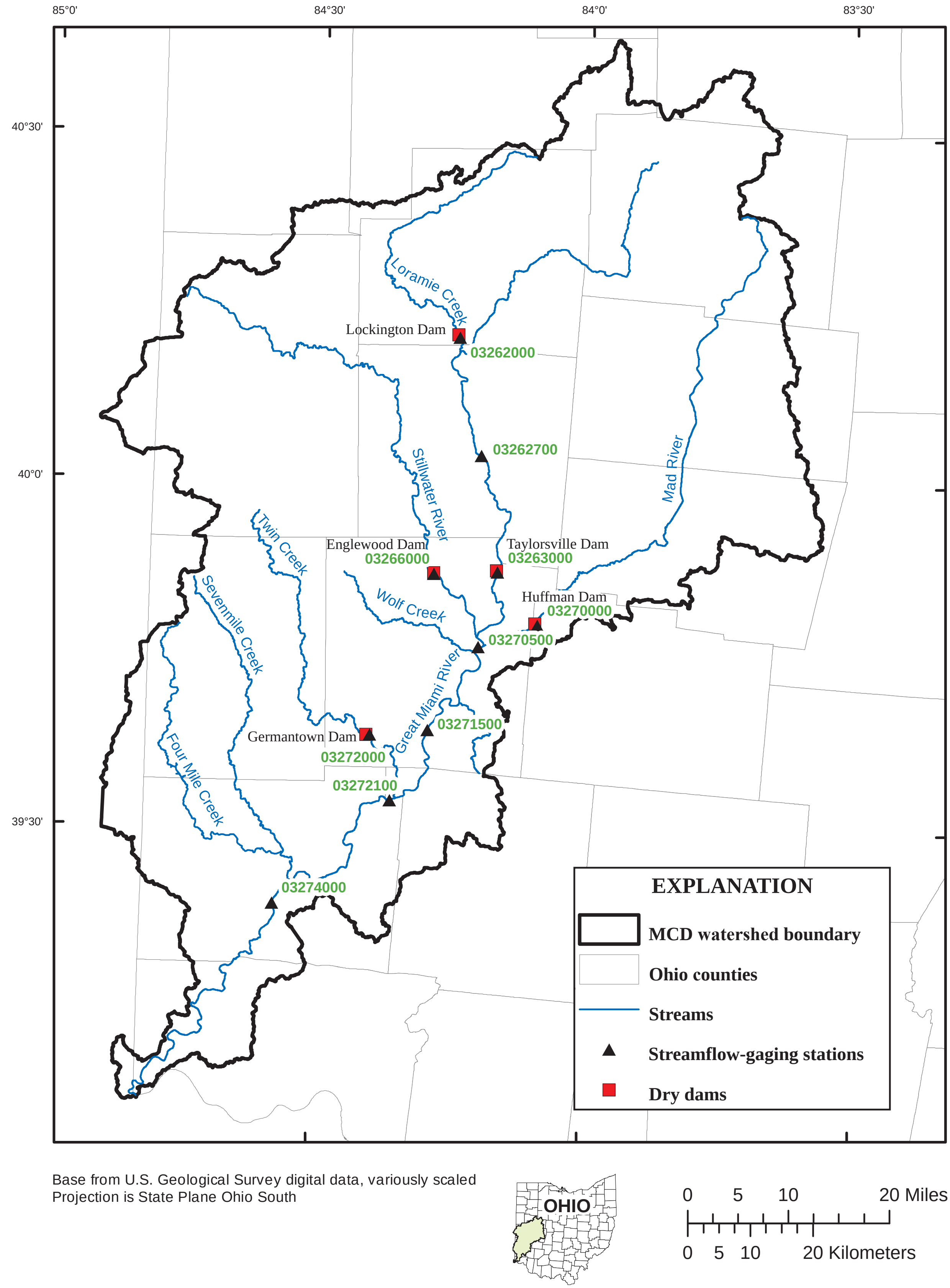

Figure 2. Locations of dry dams and selected streamflow-gaging stations in the Miami Conservancy District (MCD), Ohio.

Description of the Study Area

The part of the Great Miami River Basin within the watershed boundaries of the MCD drains approximately 3,800 mi^2 in southwestern Ohio and 100 mi^2 of Indiana. The MCD's watershed boundary encompasses all of the Great Miami River drainage except that from the Whitewater River, which itself drains approximately 1,470 mi^2 (mostly from Indiana) and discharges to the Great Miami River about 6.3 mi upstream from its mouth. The Great Miami River Basin within the watershed boundaries of the MCD will be referred to as "the basin" for the remainder of this report.

The basin lies almost entirely within the Till Plains section of the Central Lowland physiographic province (fig. 1) (Fenneman and Johnson, 1946). Most of the basin was glaciated, resulting in flat to gently rolling land surfaces that are cut by steep-walled river valleys of low to moderate relief. Glacial till overlies most of the basin; however, coarse-grained stratified sediments consisting of well-sorted sand and gravel also are common, particularly in river valleys.

The basin has a temperate continental climate characterized by well-defined winter and summer seasons that are accompanied by large annual temperature variations. On average, about 38.3 in. of precipitation falls annually within the basin, on the basis of data collected from 1915 through 2000 (Miami Conservancy District, 2007), with an average runoff of about 12.6 in. March through August tend to be the wettest months; January and February tend to be the driest.

The Lockington, Taylorsville, Englewood, Huffman, and Germantown Dams discussed in this report are on Loramie Creek, Great Miami River, Stillwater River, Mad River, and Twin Creek, respectively. The drainage area upstream from the Taylorsville Dam is the largest for the five dams at 1,149 mi^2. The drainage area upstream from Lockington Dam is the smallest (257 mi^2). A description of these and the other three dry dams in the MCD flood-protection system can be found at *http://www.miamiconservancy.org/flood/dams.asp*.

The dry dams provide substantial regulation of peak flows in the Great Miami River and affected tributaries. Appendix table 1–1 shows the percentages of the drainage areas regulated by the dry dams at selected locations in the basin, as well as information about the dams providing regulation at those locations.

Purpose and Scope

The purpose of this report is to describe the results of a study to determine selected frequency characteristics of postregulation annual peak flows measured at 10 streamflow-gaging stations (5 of which are at or near the outlets of the dry dams in the MCD flood-protection system and the other 5 of which are further downstream from one or more of the dry dams) and to determine frequency characteristics of annual peak elevations in the dry-dam pools. Because of the close proximity of five of the streamflow-gaging stations to the five dams, peak flows at those stations are considered to be approximately equal to peak flows discharging through the dams. Frequency characteristics presented in this report for streamflow-gaging stations are based on annual peak streamflows from water years[1] listed in table 1 and annual peak dam-pool elevations from water years 1922 through 2008.

[1] A water year is the period from October 1 to September 30 and is designated by the calendar year in which it ends.

Table 1. Streamflow-gaging stations and time periods analyzed for peak-flow frequency characteristics.

[na, not applicable; bolded station numbers indicate streamflow-gaging stations located at or near the outlets of dry dams]

Station number	Station name	Decimal latitude	Decimal longitude	Drainage area (mi^2)	Period analyzed
03262000	Loramie Creek at Lockington, Ohio	40.2145	-84.2438	257	1922–2007
03262700	Great Miami River at Troy, Ohio	40.0403	-84.1977	926	1958, 1963–2007
03263000	Great Miami River at Taylorsville, Ohio	39.8728	-84.1641	1,149	1922–2007
03266000	Stillwater River at Englewood, Ohio	39.8703	-84.2861	650	1926–2007
03270000	Mad River near Dayton, Ohio	39.7973	-84.0885	635	1922–2007
03270500	Great Miami River at Dayton, Ohio	39.7653	-84.1974	2,511	1922–2007
03271500	Great Miami River at Miamisburg, Ohio	39.6445	-84.2897	2,711	1925–35, 1953–2008
03272000	Twin Creek near Germantown, Ohio	39.6378	-84.4038	275	1921–23, 1927–2007
03272100	Great Miami River at Middletown, Ohio	39.5199	-84.4127	3,134	na
03274000	Great Miami River at Hamilton, Ohio	39.3912	-84.5722	3,630	1922–2007

Data Aggregation and Quality-Assurance Checks

Annual peak-flow values and the dates of their occurrence retrieved from the USGS National Water Information System (NWIS) for USGS streamflow-gaging stations at or near the outlets of the dry dams are listed in Appendix 1, table 1–2. Annual peak-flow data for the other streamflow gages discussed in this report are not listed but can be obtained from the USGS NWIS Web server at *http://waterdata.usgs.gov.* A suite of tests (Ryberg, 2008) were run on the annual peak-flow data as quality-assurance checks. All potential data-quality issues identified in the tests were examined further to ensure that the peak-flow data were accurate.

Annual peak dam-pool elevations and the dates of their occurrences were provided by the MCD. In most cases, these annual peak dam-pool elevations were determined from staff-gage readings made at the dams by MCD personnel. In some cases, the elevations were determined by means of automated equipment that measures and records the height of water above a reference datum.

As a quality-assurance check, annual peak dam-pool-elevation data were paired by date of occurrence with corresponding peak-flow values (when available) retrieved from NWIS[2]. Outflow ratings, developed by digitizing outlet-capacity rating curves contained in a MCD report (Miami Conservancy District, 1964), were used to estimate peak flows as a function of peak dam-pool elevations. The estimated peak flows were compared with peak-flow values retrieved from the NWIS database to ensure that there were no substantial discrepancies.

Determination of Peak Dam-Pool Storages

As discussed in more detail later, annual peak storages in the dam pools were used to determine frequency characteristics of peak dam-pool elevations. Elevation-storage ratings for the dam pools were furnished by the MCD. The MCD used a geographic information system (GIS) to determine elevation-storage ratings for the dam pools on the basis of a 2.5-ft-grid digital elevation model (DEM) that was developed by the Ohio Statewide Imagery Program (OSIP, a partnership between State agencies and the Federal government; Ohio Geographically Referenced Information Program, 2009). For Englewood Dam, a 10-m DEM was used to determine storages for elevations at or below 810 ft; then, cumulative incremental changes in storages relative to the 2.5-ft DEM-based storage at 810 ft were summed to the GIS-based storage at 810 ft to determine total storages above 810 ft. This was necessary because the OSIP data were collected in the Englewood area during a flood period, so the resulting elevations in the 2.5-ft-grid DEM reflected the elevation of water in the dam pool instead of the elevation at land surface (Barry Puskas, Miami Conservancy District, oral commun., 2009). Storages determined for elevations ranging from the conduit inverts to at or near the top of the dams (in 0.1-ft increments) were used in lookup form to determine the storages associated with the annual peak dam-pool elevations (Appendix 1, table 1–3).

[2] The dates of peak streamflow and peak dam-pool storage for a given water year are not the same in all cases. A variety of reasons (for example, obstructions lodging in outflow conduits) can cause these differences to occur.

Tests for Trends

The annual peak flow and peak dam-pool storage time series were tested for stationarity by means of the Kendall test for trends, as implemented in the USGS program SWSTAT (U.S. Geological Survey, 2009a). The Kendall test for trends involves calculating a nonparametric measure of correlation (tau) between time and corresponding measures of some characteristic (in this case, annual peak flows or peak dam-pool storages). None of the time series exhibited statistically significant trends at $\alpha = 0.05$, thereby supporting the assumption of stationarity that is required for frequency analysis.

Frequency Analyses

Frequency analyses were done to estimate peak-flow and peak dam-pool-elevation magnitudes with recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years (annual exceedance probabilities of 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.005, and 0.002, respectively). Methods used to compute these frequency characteristics are described below.

Analysis of Peak Flows

In all except one case (station 03272100), peak-flow frequency estimates were determined by fitting a log-Pearson Type III (LPIII) distribution to the base-10 logarithms of the annual peak-flow series. The peak flows corresponding to selected recurrence intervals were computed by the following equation:

$$\log_{10}(Q_t) = \overline{X} + K(S)$$

where

Q_t is the t-year-recurrence-interval peak flow, in cubic feet per second,

$\overline{X}$ is the mean of the logarithms of the annual peak flows,

K is a factor dependent on the recurrence interval and the skew coefficient of the log-transformed annual peak flow series, and

S is the standard deviation of the log-transformed annual peak-flow series.

Peak-flow frequency estimates were calculated with version 5.2 of the USGS program PKFQWin (U.S. Geological Survey, 2009b), which is a Windows Operating System version of the USGS program PEAKFQ (Flynn and others, 2006). PKFQWin performs frequency analyses on the basis of guidelines established by the Interagency Advisory Committee on Water Data (1982). Station skew was used instead of the weighted skew in all cases because skews may be affected by regulation from the dry dams and therefore may be inconsistent with regional skew estimates.

Peak-flow frequency characteristics for station 03272100 initially were computed by means of a LPIII analysis. Examination of the computed frequency characteristics indicated that the magnitudes of the peaks computed for a given recurrence interval were consistently smaller than those at both the upstream and downstream streamflow-gaging stations on the same stream (stations 03271500 and 03274000, respectively). That result was considered unreasonable and was attributed to the fact that only 13 years of peak-flow data were available for analysis for station 03272100 as compared to 67 years of record at station 03271500 and 86 years of record at 03274000. The poor LPIII estimate of frequency characteristics at station 03272100 likely is due to time-sampling error, which results from analysis of data for a particular short time period that are not representative of the longer time period. Examination of same-event annual peak flows for the three stations that occurred during the common period of record extending from 1995 to 2007 indicated that, on average, peak flows at station 03272100 tended to have magnitudes between those of the upstream and downstream stations. Consequently, the frequency characteristics for station 03272100 were estimated by interpolating, as a function of drainage area, between peak-flow yields (that is, flow divided by drainage area) determined for stations 03271500 and 03274000, and then multiplying the interpolated yield by the drainage area at station 03272100. Peak-flow frequency estimates for station 03272100 and the other streamflow-gaging stations listed in table 1 are shown in table 2.

Analysis of Annual Peak Dam-Pool Elevations

Frequency characteristics of peak dam-pool elevations were not determined from direct analysis of the annual peak dam-pool-elevation time series but instead were determined from corresponding annual peak dam-pool storages. Annual peak storage in the dam pool generally is closely related to annual peak streamflow at the dry dams (fig. 3). The same cannot necessarily be said about the relation between peak flows and peak dam-pool elevations because elevation-storage relations vary as a function of water level at a given dam due to variable topography of the dam pools (fig. 4). An added benefit of analyzing storages instead of elevations is that the strong linear correlation between logarithms of annual peak flows and annual peak storages at dry dams gives theoretical support for using an LPIII distribution to describe the storage-frequency characteristics.

Annual peak dam-pool-elevation frequency characteristics were estimated with version 5.2 of the USGS program PKFQWin (U.S. Geological Survey, 2009b) by determining the parameters of the LPIII distribution that fit the base-10 logarithms of the observed annual peak dam-pool storages. The LPIII distribution was then used to estimate the peak dam-pool storages (and corresponding confidence limits) with recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years. As described in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982), conditional probability adjustments were made to the frequency estimates to account for zero-storage years (years in which peak flows were insufficient to cause water to go into dam-pool storage). Once storages had been estimated for the various recurrence intervals, corresponding dam-pool elevations were determined from the elevation-storage ratings discussed in the section titled "Determination of Peak Dam-Pool Storages." The resulting dam-pool-elevation frequency characteristics for the five dry dams are listed in table 3.

Summary

This report describes the results of a study, done by the U.S. Geological Survey (USGS) in cooperation with the Miami Conservancy District (MCD), to determine frequency characteristics of postregulation annual peak flows at streamflow-gaging stations near five dry dams (Lockington, Englewood, Taylorsville, Huffman, and Germantown) in the MCD flood-protection system and annual peak elevations of the corresponding dam pools. In addition, peak-flow frequency characteristics were determined for five other streamflow-gaging stations in the basin. These frequency characteristics are used by regulators and emergency managers to make informed decisions about flood-related risks.

Annual peak-flow time series obtained from the USGS NWIS database and annual peak dam-pool elevation time series provided by the MCD were checked to ensure accuracy, consistency, and stationarity. In most cases, log-Pearson Type III distributions were fit to annual peak-flow values and annual peak dam-pool storage values to determine peaks with recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years. In one case (for station 03272100), frequency characteristics were estimated by means of a process involving interpolation of peak-flow yields determined for an upstream and downstream streamflow-gaging station. Conditional probability adjustments were made to the dam-pool storage frequency estimates to account for zero-storage years. Once storages had been estimated for the various recurrence intervals, corresponding dam-pool elevations were determined from elevation-storage ratings provided by the MCD.

Table 2. Peak-flow frequency estimates at selected streamflow-gaging stations in the Great Miami River Basin, Ohio.

[ft^3/s, cubic feet per second; values in italics are estimated; nd, not determined; bolded station numbers indicate streamflow-gaging stations located at or near the outlets of dry dams]

Annual exceedance probability	Recurrence interval (years)	Peak streamflow (ft^3/s)	95-percent confidence limits	
			Lower (ft^3/s)	Upper (ft^3/s)
Loramie Creek at Lockington, Ohio (**03262000**)				
0.500	2	4,340	4,120	4,580
0.200	5	5,350	5,050	5,700
0.100	10	5,830	5,480	6,270
0.040	25	6,300	5,890	6,830
0.020	50	6,580	6,130	7,170
0.010	100	6,810	6,320	7,440
0.005	200	7,000	6,480	7,670
0.002	500	7,200	6,660	7,920
Great Miami River at Troy, Ohio (03262700)				
0.500	2	12,600	11,800	13,500
0.200	5	15,800	14,800	17,200
0.100	10	17,800	16,500	19,700
0.040	25	20,200	18,400	22,800
0.020	50	21,900	19,800	25,100
0.010	100	23,600	21,100	27,400
0.005	200	25,300	22,400	29,700
0.002	500	27,400	24,100	32,700
Great Miami River at Taylorsville, Ohio (**03263000**)				
0.500	2	15,000	14,000	16,100
0.200	5	20,100	18,600	21,900
0.100	10	22,800	20,900	25,200
0.040	25	25,700	23,400	28,800
0.020	50	27,500	24,900	31,000
0.010	100	29,000	26,200	33,000
0.005	200	30,400	27,300	34,700
0.002	500	32,000	28,600	36,700
Stillwater River at Englewood, Ohio (**03266000**)				
0.500	2	6,960	6,670	7,260
0.200	5	8,300	7,930	8,750
0.100	10	9,010	8,560	9,570
0.040	25	9,750	9,210	10,500
0.020	50	10,200	9,600	11,000
0.010	100	10,600	10,000	11,500
0.005	200	11,000	10,300	12,000
0.002	500	11,400	10,700	12,500
Mad River near Dayton, Ohio (**03270000**)				
0.500	2	7,200	6,670	7,770
0.200	5	10,300	9,510	11,360
0.100	10	12,500	11,400	14,000
0.040	25	15,400	13,800	17,600
0.020	50	17,600	15,600	20,500
0.010	100	19,900	17,400	23,500
0.005	200	22,300	19,300	26,700
0.002	500	25,500	21,800	31,100

Annual exceedance probability	Recurrence interval (years)	Peak streamflow (ft^3/s)	95-percent confidence limits	
			Lower (ft^3/s)	Upper (ft^3/s)
Great Miami River at Dayton, Ohio (03270500)				
0.500	2	26,400	24,700	28,300
0.200	5	35,900	33,300	39,100
0.100	10	41,700	38,400	46,000
0.040	25	48,700	44,300	54,600
0.020	50	53,600	48,300	60,800
0.010	100	58,200	52,100	66,800
0.005	200	62,700	55,800	72,600
0.002	500	68,500	60,400	80,100
Great Miami River at Miamisburg, Ohio (03271500)				
0.500	2	26,800	24,800	29,000
0.200	5	36,900	33,900	40,800
0.100	10	43,400	39,400	48,700
0.040	25	51,200	45,800	58,800
0.020	50	56,900	50,400	66,200
0.010	100	62,400	54,800	73,600
0.005	200	67,800	59,000	81,000
0.002	500	74,800	64,500	90,700
Twin Creek near Germantown, Ohio (**03272000**)				
0.500	2	6,120	5,840	6,420
0.200	5	7,240	6,880	7,670
0.100	10	7,700	7,290	8,210
0.040	25	8,100	7,640	8,680
0.020	50	8,300	7,820	8,920
0.010	100	8,450	7,950	9,100
0.005	200	8,570	8,050	9,240
0.002	500	8,670	8,140	9,360
Great Miami River at Middletown, Ohio (03272100)				
0.500	2	*33,000*	nd	nd
0.200	5	*45,700*	nd	nd
0.100	10	*53,700*	nd	nd
0.040	25	*63,100*	nd	nd
0.020	50	69,800	nd	nd
0.010	100	*76,300*	nd	nd
0.005	200	*82,500*	nd	nd
0.002	500	*90,400*	nd	nd
Great Miami River at Hamilton, Ohio (03274000)				
0.500	2	40,900	38,000	44,100
0.200	5	57,100	52,600	62,700
0.100	10	67,000	61,100	74,700
0.040	25	78,500	70,700	89,000
0.020	50	86,500	77,300	99,200
0.010	100	94,000	83,400	109,000
0.005	200	101,000	89,100	118,000
0.002	500	110,000	96,300	130,000

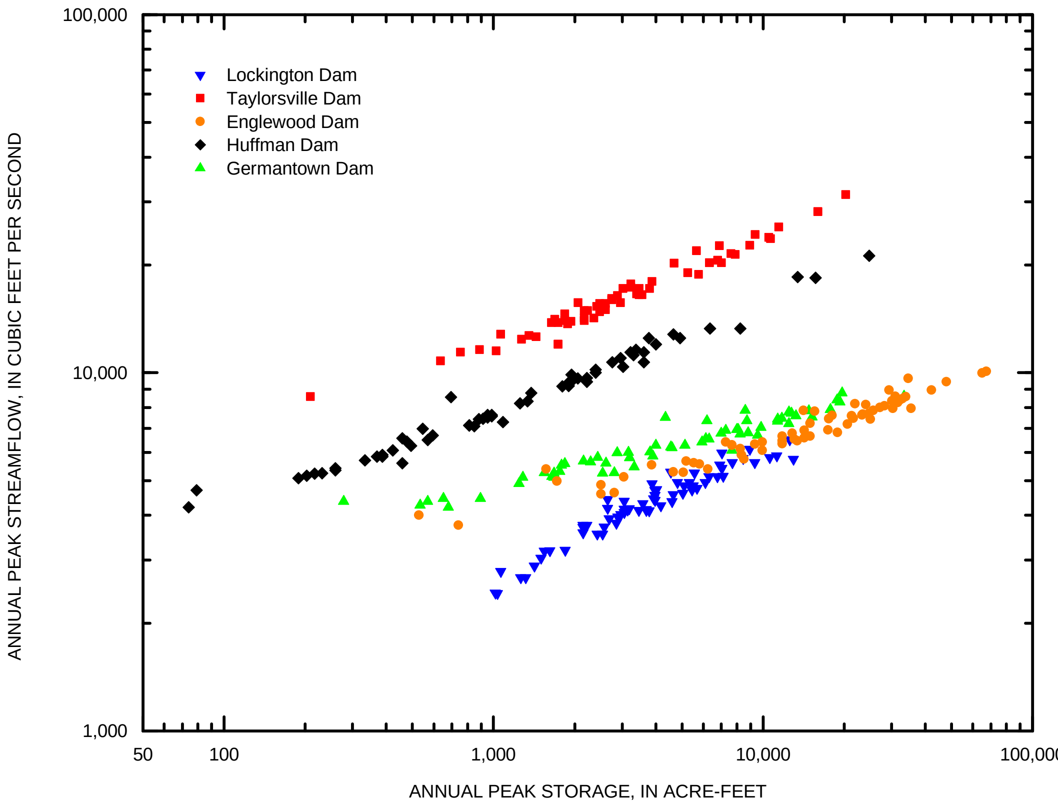

Figure 3. Scatterplot of annual peak flows against non-zero annual peak storages for the Lockington, Englewood, Taylorsville, Huffman, and Germantown Dams, Ohio, water years 1922–2007.

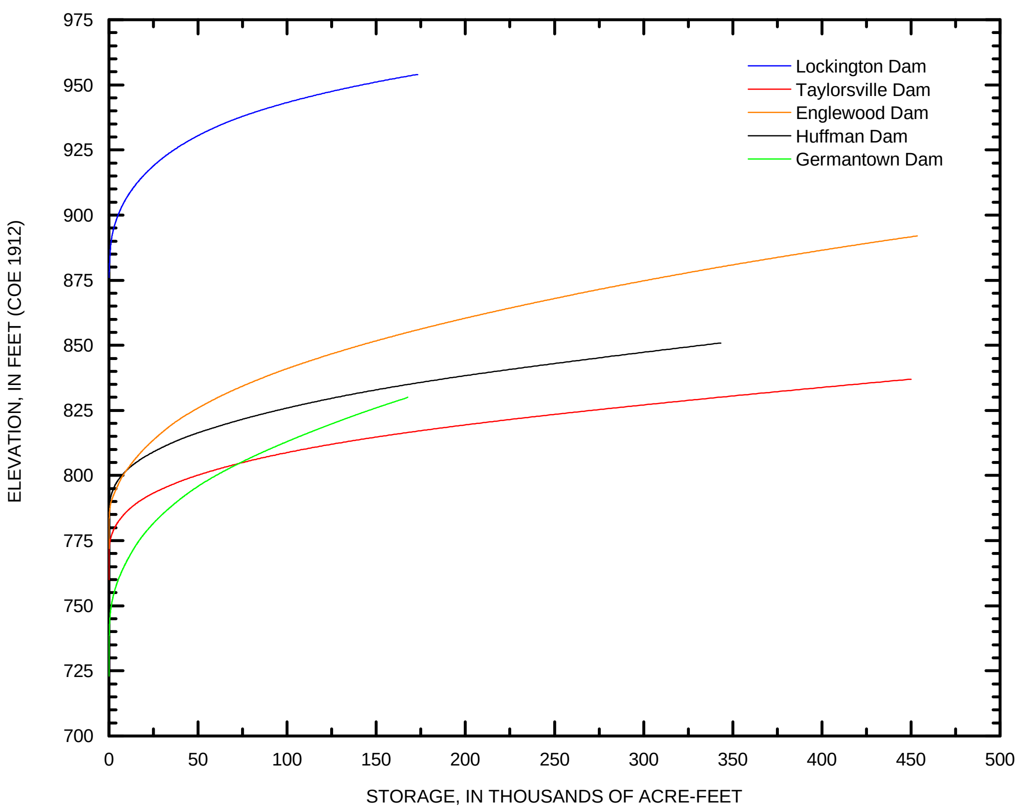

Figure 4. Plot of elevation against dam-pool storage for the Lockington, Englewood, Taylorsville, Huffman, and Germantown Dams, Ohio (source data for curves furnished by the Miami Conservancy District).

Table 3. Peak dam-pool-elevation frequency characteristics for dry dams in the Great Miami River Basin, Ohio.

[Elevations are referenced to the U.S. Army Corps of Engineers 1912 datum]

Annual exceedance probability	Recurrence interval (years)	Peak dam-pool elevation (feet)	95-percent confidence limits	
			Lower (feet)	Upper (feet)
Lockington Dam (spillway, 938 feet; top of dam, 954 feet)				
0.500	2	897.6	896.6	898.5
0.200	5	902.6	901.3	904.2
0.100	10	905.6	903.9	907.6
0.040	25	908.9	906.9	911.5
0.020	50	911.1	908.8	914.2
0.010	100	913.3	910.6	916.8
0.005	200	915.3	912.3	919.3
0.002	500	917.8	914.4	922.4
Taylorsville Dam (spillway, 818 feet; top of dam, 837 feet)				
0.500	2	778.8	778.1	779.4
0.200	5	782.3	781.4	783.5
0.100	10	784.7	783.5	786.3
0.040	25	787.7	786.0	790.0
0.020	50	789.9	787.8	792.6
0.010	100	792.0	789.6	795.1
0.005	200	794.0	791.3	797.7
0.002	500	796.7	793.5	801.2
Englewood Dam (spillway, 876 feet; top of dam, 892.5 feet)				
0.500	2	806.2	804.1	808.6
0.200	5	816.8	813.5	820.8
0.100	10	822.3	818.4	827.1
0.040	25	827.6	823.0	833.5
0.020	50	830.7	825.7	837.3
0.010	100	833.3	827.9	840.6
0.005	200	835.6	829.8	843.3
0.002	500	838.0	831.9	846.4
Huffman Dam (spillway, 835 feet; top of dam, 850 feet)				
0.500	2	791.0	790.3	791.7
0.200	5	794.9	793.8	796.3
0.100	10	797.8	796.2	799.7
0.040	25	801.4	799.2	804.5
0.020	50	804.2	801.4	808.1
0.010	100	807.0	803.7	812.1
0.005	200	810.0	805.9	816.3
0.002	500	814.2	809.0	822.2
Germantown Dam (spillway, 815 feet; top of dam, 830 feet)				
0.500	2	757.3	755.6	759.0
0.200	5	766.2	763.6	769.7
0.100	10	772.1	768.4	776.9
0.040	25	778.9	774.2	785.0
0.020	50	783.3	778.0	790.5
0.010	100	787.3	781.3	795.6
0.005	200	791.0	784.3	800.2
0.002	500	795.5	788.0	805.7

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View of Englewood Dam in flood storage, April 15, 1922. Note whirlpool at inlet at lower left. This flood event was used in the frequency analyses discussed in this report. (Photo copyright 1913–2009, Miami Conservancy District, all rights reserved; reproduced with permission.)

Appendix 1. Technical Data

Table 1–1. Percentages of drainage areas regulated and sources of regulation at selected locations in the Great Miami River basin, Ohio.

[mi^2, square miles; E, Englewood Dam; G, Germantown Dam; H, Huffman Dam; L, Lockington Dam; T, Taylorsville Dam]

Stream	Location	MCD dam influence	Drainage area (mi^2)	Drainage area regulated (mi^2)	Drainage area regulated (percent)
Great Miami River	Above confluence with Loramie Creek		568	0	0.0
Great Miami River	Below confluence with Loramie Creek	L	832	257	30.9
Great Miami River	At station 03262700 (at Troy, Ohio)	L	926	257	27.8
Great Miami River	Above confluence with Stillwater River	LT	1,175	1,149	97.8
Great Miami River	Below confluence with Stillwater River	ELT	1,851	1,799	97.2
Great Miami River	Above confluence with Mad River	ELT	1,853	1,799	97.1
Great Miami River	Below confluence with Mad River	ELTH	2,510	2,434	97.0
Great Miami River	At station 03270500 (at Dayton, Ohio)	ELTH	2,511	2,434	96.9
Great Miami River	Above confluence with Wolf Creek	ELTH	2,512	2,434	96.9
Great Miami River	Below confluence with Wolf Creek	ELTH	2,583	2,434	94.2
Great Miami River	Above confluence with Holes Creek	ELTH	2,605	2,434	93.4
Great Miami River	Below confluence with Holes Creek	ELTH	2,635	2,434	92.4
Great Miami River	At station 03271500 (at Miamisburg, Ohio)	ELTH	2,711	2,434	89.8
Great Miami River	Above confluence with Twin Creek	ELTH	2,794	2,434	87.1
Great Miami River	Below confluence with Twin Creek	GELTH	3,109	2,709	87.1
Great Miami River	At station 03272100 (at Middletown, Ohio)	GELTH	3,134	2,709	86.4
Great Miami River	Above confluence with Four Mile Creek	GELTH	3,298	2,709	82.1
Great Miami River	Below confluence with Four Mile Creek	GELTH	3,613	2,709	75.0
Great Miami River	At station 03274000 (at Hamilton, Ohio)	GELTH	3,630	2,709	74.6
Loramie Creek	At mouth	L	265	257	97.0
Stillwater River	At mouth	E	676	650	96.2
Mad River	At mouth	H	657	635	96.7
Twin Creek	At mouth	G	316	275	87.0

Table 1–2. Annual peak streamflows for streamflow-gaging stations 03262000, 03263000, 03266000, 03270000, and 03272000, water years 1921–2007.

[ft^3/s, cubic feet per second; nop, station not in operation; pre, preregulation]

Water year	Loramie Creek at Lockington (03262000)		Great Miami River at Taylorsville (03263000)		Stillwater River at Englewood (03266000)		Mad River near Dayton (03270000)		Twin Creek near Germantown (03272000)	
	Date	Peak flow (ft^3/s)	Date	Peak flow (ft^3/s)	Date	Peak flow (ft^3/s)	Date	Peak flow (ft^3/s)	Date	Peak flow (ft^3/s)
1921	03/27/1921	6,590	nop	nop	nop	nop	pre	pre	03/29/1921	5,630
1922	04/15/1922	4,900	04/15/1922	17,300	nop	nop	04/15/1922	10,000	04/15/1922	6,070
1923	05/15/1923	3,750	05/16/1923	10,600	nop	nop	03/16/1923	5,590	03/16/1923	4,270
1924	03/29/1924	5,970	06/09/1924	21,600	nop	nop	03/29/1924	12,500	nop	nop
1925	03/14/1925	2,190	04/22/1925	5,610	nop	nop	04/22/1925	6,060	nop	nop
1926	09/05/1926	5,280	04/09/1926	13,800	11/14/1925	6,290	04/09/1926	4,120	nop	nop
1927	03/21/1927	5,870	03/22/1927	21,600	03/22/1927	8,580	01/20/1927	9,880	04/05/1927	5,400
1928	12/14/1927	4,170	12/14/1927	14,000	12/15/1927	5,610	12/01/1927	6,420	12/01/1927	6,410
1929	02/26/1929	5,420	02/26/1929	23,700	02/27/1929	8,400	02/26/1929	18,400	02/27/1929	7,640
1930	01/14/1930	4,710	01/10/1930	20,600	01/15/1930	8,940	01/09/1930	10,600	01/10/1930	6,800
1931	04/03/1931	1,660	04/04/1931	4,750	04/04/1931	2,720	04/03/1931	2,450	04/03/1931	2,470
1932	01/15/1932	3,190	01/18/1932	9,430	01/18/1932	4,620	01/18/1932	8,560	01/17/1932	5,520
1933	05/13/1933	5,810	05/14/1933	25,500	05/14/1933	9,910	05/14/1933	12,500	12/31/1932	7,350
1934	03/27/1934	2,430	03/03/1934	5,500	03/28/1934	3,750	03/03/1934	4,530	03/27/1934	3,370
1935	05/03/1935	4,130	05/04/1935	11,400	05/04/1935	5,670	05/03/1935	3,850	05/03/1935	4,370
1936	02/27/1936	4,130	02/27/1936	15,600	02/27/1936	7,440	02/27/1936	6,570	02/26/1936	4,790
1937	01/15/1937	5,290	01/15/1937	25,500	01/22/1937	9,550	01/22/1937	15,400	01/15/1937	7,890
1938	04/07/1938	4,120	04/09/1938	16,600	04/09/1938	8,960	04/07/1938	7,500	03/16/1938	6,150
1939	06/19/1939	3,550	06/19/1939	13,600	06/20/1939	7,820	04/16/1939	6,620	04/16/1939	5,850
1940	04/20/1940	3,340	04/21/1940	14,600	04/21/1940	7,220	04/21/1940	5,590	04/20/1940	5,250
1941	06/15/1941	1,800	06/16/1941	4,980	07/04/1941	1,700	06/04/1941	1,380	06/11/1941	1,720
1942	04/10/1942	3,550	04/11/1942	12,800	04/10/1942	6,050	02/07/1942	3,600	02/07/1942	4,460
1943	03/20/1943	4,960	03/20/1943	21,900	03/21/1943	8,930	03/20/1943	11,200	03/20/1943	7,200
1944	04/11/1944	4,840	04/12/1944	17,700	04/13/1944	8,140	04/12/1944	7,620	04/12/1944	5,370
1945	06/18/1945	4,840	06/19/1945	17,200	06/19/1945	7,610	03/07/1945	11,400	03/06/1945	6,360
1946	02/27/1946	2,680	02/14/1946	8,410	12/31/1945	4,870	06/20/1946	4,520	02/14/1946	5,250
1947	06/02/1947	4,160	06/03/1947	20,200	06/03/1947	7,090	06/03/1947	12,000	06/02/1947	7,040
1948	03/24/1948	4,260	02/14/1948	16,200	04/14/1948	6,460	02/14/1948	13,300	02/14/1948	5,870
1949	01/05/1949	4,580	01/06/1949	17,200	01/06/1949	8,350	01/06/1949	9,440	01/05/1949	7,520
1950	02/15/1950	5,300	01/16/1950	20,300	02/16/1950	8,710	01/17/1950	9,200	01/16/1950	6,740
1951	02/21/1951	4,820	12/04/1950	18,300	02/22/1951	8,000	12/04/1950	9,680	02/21/1951	6,690
1952	01/27/1952	4,940	01/27/1952	21,500	01/28/1952	8,600	01/27/1952	13,300	01/27/1952	8,790
1953	05/17/1953	3,200	05/22/1953	9,210	05/24/1953	6,280	05/23/1953	5,340	03/04/1953	2,610
1954	03/30/1954	2,420	06/17/1954	7,520	03/30/1954	4,000	06/09/1954	2,750	04/17/1954	1,420
1955	02/21/1955	3,180	02/22/1955	9,000	03/22/1955	5,530	03/22/1955	4,680	03/22/1955	3,970
1956	11/16/1955	4,700	02/26/1956	14,000	02/27/1956	6,910	11/16/1955	6,430	11/17/1955	7,340
1957	06/29/1957	4,940	06/29/1957	17,200	06/30/1957	8,200	04/05/1957	10,400	04/04/1957	7,860
1958	06/10/1958	6,540	06/14/1958	21,400	06/15/1958	9,980	06/14/1958	10,700	06/11/1958	7,010
1959	01/22/1959	5,750	01/22/1959	31,400	01/23/1959	9,450	01/22/1959	21,200	01/22/1959	8,590
1960	01/15/1960	2,360	02/11/1960	6,310	02/11/1960	5,390	05/28/1960	3,490	02/10/1960	2,970
1961	04/26/1961	3,750	04/26/1961	16,100	04/27/1961	6,780	04/26/1961	6,980	04/26/1961	6,300
1962	01/26/1962	4,020	02/27/1962	12,400	02/27/1962	6,330	02/27/1962	7,140	02/26/1962	5,790
1963	03/05/1963	4,930	03/05/1963	24,300	03/06/1963	9,370	03/05/1963	18,500	03/05/1963	8,400

Table 1–2. Annual peak streamflows for streamflow-gaging stations 03262000, 03263000, 03266000, 03270000, and 03272000, water years 1921–2007.—Continued

[ft³/s, cubic feet per second; nop, station not in operation; pre, preregulation]

Water year	Loramie Creek at Lockington (03262000)		Great Miami River at Taylorsville (03263000)		Stillwater River at Englewood (03266000)		Mad River near Dayton (03270000)		Twin Creek near Germantown (03272000)	
	Date	Peak flow (ft³/s)	Date	Peak flow (ft³/s)	Date	Peak flow (ft³/s)	Date	Peak flow (ft³/s)	Date	Peak flow (ft³/s)
1964	04/21/1964	5,290	04/21/1964	18,800	04/23/1964	9,640	03/10/1964	12,800	03/10/1964	7,420
1965	04/25/1965	3,700	04/26/1965	11,500	04/26/1965	6,400	04/26/1965	5,160	04/25/1965	4,900
1966	02/11/1966	2,510	02/11/1966	8,570	02/11/1966	4,990	02/11/1966	4,210	02/11/1966	4,430
1967	05/07/1967	4,550	12/11/1966	12,200	12/11/1966	7,860	05/07/1967	4,620	05/07/1967	5,980
1968	12/03/1967	4,430	01/31/1968	10,800	05/29/1968	6,460	05/28/1968	8,790	05/24/1968	7,760
1969	05/19/1969	4,140	01/30/1969	12,700	01/31/1969	6,530	08/10/1969	6,680	01/30/1969	6,010
1970	01/29/1970	4,190	04/03/1970	13,900	01/29/1970	6,140	04/03/1970	9,170	04/02/1970	6,280
1971	02/22/1971	3,040	06/27/1971	13,100	02/23/1971	5,380	06/26/1971	7,430	02/22/1971	5,260
1972	04/07/1972	4,080	04/08/1972	11,600	04/08/1972	5,280	12/30/1971	4,720	04/13/1972	4,210
1973	08/15/1973	4,390	11/15/1972	14,100	11/15/1972	6,660	06/20/1973	5,840	11/14/1972	5,300
1974	01/19/1974	4,310	01/20/1974	15,700	01/20/1974	6,080	04/02/1974	5,080	06/23/1974	5,800
1975	02/24/1975	5,130	02/24/1975	22,600	02/25/1975	8,250	02/24/1975	11,400	02/24/1975	7,460
1976	01/26/1976	4,720	01/27/1976	11,400	01/26/1976	6,000	01/26/1976	4,700	01/26/1976	5,140
1977	04/02/1977	2,680	04/03/1977	9,420	04/03/1977	5,120	04/03/1977	5,420	04/03/1977	5,460
1978	03/17/1978	3,900	03/15/1978	14,900	03/17/1978	7,630	03/15/1978	6,260	03/15/1978	6,530
1979	03/05/1979	4,300	02/24/1979	14,200	03/06/1979	7,710	09/15/1979	7,620	02/24/1979	7,500
1980	06/29/1980	5,530	06/03/1980	15,300	06/30/1980	8,460	06/29/1980	9,640	11/26/1979	5,660
1981	06/14/1981	4,410	06/15/1981	14,900	06/07/1981	6,340	06/06/1981	9,470	06/06/1981	4,370
1982	02/17/1982	4,180	02/18/1982	15,600	02/18/1982	6,820	02/01/1982	10,200	02/01/1982	6,950
1983	05/02/1983	2,440	05/04/1983	10,900	05/03/1983	5,300	05/02/1983	5,350	05/04/1983	5,590
1984	03/16/1984	3,710	03/17/1984	10,100	03/17/1984	5,900	03/16/1984	4,300	04/05/1984	4,450
1985	02/24/1985	4,760	02/24/1985	16,400	02/25/1985	7,460	02/23/1985	5,750	02/24/1985	5,310
1986	12/12/1985	4,460	12/12/1985	13,800	12/13/1985	6,590	03/13/1986	6,340	03/13/1986	5,640
1987	07/02/1987	5,260	10/05/1986	18,000	10/05/1986	7,590	10/05/1986	6,490	10/02/1986	6,270
1988	02/02/1988	1,920	02/02/1988	6,320	02/02/1988	3,920	02/02/1988	4,480	02/02/1988	5,260
1989	05/26/1989	3,960	05/27/1989	17,200	05/27/1989	7,190	05/27/1989	7,290	05/26/1989	7,330
1990	02/16/1990	4,940	02/16/1990	16,000	02/17/1990	6,920	07/13/1990	7,560	02/16/1990	6,180
1991	12/31/1990	6,520	12/30/1990	25,200	01/01/1991	8,720	12/31/1990	10,700	12/31/1990	7,590
1992	07/13/1992	5,620	07/14/1992	13,700	04/19/1992	5,560	07/18/1992	5,700	07/24/1992	4,880
1993	07/03/1993	5,770	07/03/1993	15,000	07/04/1993	6,400	07/02/1993	5,900	04/16/1993	5,110
1994	11/15/1993	5,130	11/18/1993	14,200	11/18/1993	7,880	01/28/1994	7,090	01/28/1994	5,990
1995	08/08/1995	6,130	08/09/1995	23,900	05/21/1995	7,050	08/09/1995	5,830	05/19/1995	6,000
1996	01/19/1996	5,150	01/19/1996	16,500	01/20/1996	7,960	04/30/1996	9,380	04/30/1996	7,710
1997	06/02/1997	4,610	06/02/1997	16,500	06/03/1997	7,950	06/02/1997	7,450	06/02/1997	6,780
1998	06/12/1998	3,920	01/08/1998	12,300	06/13/1998	5,270	05/08/1998	8,330	04/16/1998	5,590
1999	01/23/1999	3,640	01/23/1999	15,700	01/24/1999	7,430	01/22/1999	5,250	01/23/1999	6,550
2000	04/08/2000	2,890	04/08/2000	12,600	04/09/2000	5,740	04/08/2000	8,210	04/08/2000	6,210
2001	05/27/2001	2,790	05/19/2001	9,170	04/12/2001	4,590	07/29/2001	5,230	04/11/2001	5,110
2002	04/14/2002	3,810	12/18/2001	14,800	04/15/2002	6,650	12/18/2001	7,140	12/18/2001	6,910
2003	07/10/2003	6,710	07/10/2003	22,700	07/11/2003	7,850	09/02/2003	6,070	07/07/2003	5,570
2004	01/05/2004	4,370	01/05/2004	19,000	01/06/2004	7,670	01/05/2004	11,000	01/05/2004	7,830
2005	01/06/2005	5,620	01/06/2005	28,200	01/08/2005	10,100	01/06/2005	11,600	01/06/2005	8,280
2006	06/02/2006	3,580	03/13/2006	12,000	06/04/2006	5,770	03/12/2006	5,890	03/13/2006	6,380
2007	12/01/2006	5,180	03/24/2007	20,300	03/25/2007	8,080	03/02/2007	8,990	03/02/2007	6,950

Table 1–3. Annual peak dam-pool storages for the Lockington, Englewood, Taylorsville, Huffman, and Germantown Dams, water years 1922–2008.

[acre-ft, acre-feet; ns, no storage]

Water year	Lockington Dam		Taylorsville Dam		Englewood Dam		Huffman Dam		Germantown Dam	
	Date	Storage (acre-ft)	Date	Storage (acre-ft)	Date	Storage (acre-ft)	Date	Storage (acre-ft)	Date	Storage (acre-ft)
1922	04/15/1922	3,880	04/15/1922	3,240	04/15/1922	17,900	04/15/1922	2,390	04/15/1922	7,670
1923	05/15/1923	2,220		ns	05/16/1923	2,050		ns	03/16/1923	534
1924	03/29/1924	7,040	06/08/1924	8,380	06/10/1924	42,600	03/29/1924	4,920	03/29/1924	8,160
1925		ns		ns	04/23/1925	4,720		ns	09/19/1925	558
1926	09/05/1926	4,550	04/09/1926	1,640	04/09/1926	9,530	04/07/1926	79	09/02/1926	8,370
1927	03/21/1927	11,300	03/21/1927	9,200	03/22/1927	33,900	01/20/1927	1,950	04/06/1927	2,260
1928	12/14/1927	3,060	12/14/1927	2,180	12/15/1927	5,540	12/01/1927	477	12/01/1927	5,950
1929	02/26/1929	7,040	02/26/1929	10,700	02/27/1929	32,200	02/26/1929	15,600	02/26/1929	20,900
1930	01/14/1930	5,450	01/10/1930	6,790	01/15/1930	42,100	01/10/1930	1,290	01/10/1930	8,800
1931		ns		ns		ns		ns		ns
1932	01/15/1932	1,620		ns	01/18/1932	2,810	01/18/1932	695	01/17/1932	1,790
1933	05/13/1933	10,600	05/14/1933	11,400	05/15/1933	56,100	05/14/1933	3,770	12/31/1932	8,730
1934	03/27/1934	1,020		ns	03/28/1934	741		ns	12/17/1933	265
1935	05/03/1935	3,690	05/03/1935	687	05/04/1935	5,190		ns	05/03/1935	278
1936	02/27/1936	3,460	02/27/1936	2,480	02/27/1936	17,600	02/27/1936	459	02/27/1936	863
1937	01/14/1937	9,090	01/14/1937	11,100	01/23/1937	52,100	01/21/1937	8,480	01/15/1937	17,800
1938	04/07/1938	3,780	04/09/1938	3,400	04/09/1938	29,400	04/07/1938	949	03/14/1938	1,220
1939	06/19/1939	2,540	04/16/1939	1,310	04/17/1939	16,900	04/15/1939	670	04/16/1939	3,910
1940	04/21/1940	2,810	04/21/1940	1,840	04/21/1940	14,900	04/21/1940	459	04/20/1940	2,540
1941		ns		ns		ns		ns		ns
1942	04/10/1942	2,430	04/11/1942	1,070	04/11/1942	6,560		ns	02/07/1942	894
1943	03/19/1943	5,930	03/20/1943	5,680	03/22/1943	27,900	03/20/1943	3,300	03/20/1943	12,500
1944	04/11/1944	5,510	04/12/1944	3,240	04/13/1944	24,100	04/12/1944	949	04/11/1944	3,720
1945	06/18/1945	5,100	06/18/1945	2,610	06/19/1945	18,100	03/07/1945	3,610	03/07/1945	6,430
1946	02/27/1946	1,320		ns	12/31/1945	2,510		ns	02/14/1946	1,680
1947	06/02/1947	3,690	06/03/1947	4,690	06/04/1947	17,300	06/03/1947	4,000	06/02/1947	9,850
1948	03/24/1948	4,180	04/14/1948	2,960	04/14/1948	13,400	02/14/1948	6,340	02/13/1948	5,540
1949	01/05/1949	4,650	01/06/1949	3,800	01/06/1949	30,100	01/06/1949	2,220	01/05/1949	15,200
1950	02/14/1950	7,470	01/16/1950	7,010	02/15/1950	37,400	01/17/1950	1,900	01/16/1950	8,230
1951	02/22/1951	5,330	02/21/1951	4,870	02/22/1951	27,200	12/04/1950	2,220	02/21/1951	9,540
1952	01/27/1952	6,120	01/27/1952	7,630	01/28/1952	31,000	01/27/1952	8,220	01/27/1952	19,700
1953	05/17/1953	1,850		ns	05/24/1953	7,680		ns		ns
1954	03/30/1954	1,030		ns	03/30/1954	529		ns		ns
1955	02/21/1955	1,550		ns	03/22/1955	3,860		ns	03/21/1955	534
1956	02/25/1956	4,180	02/26/1956	1,840	02/27/1956	14,200	11/17/1955	520	11/17/1955	6,190
1957	04/04/1957	5,040	06/29/1957	3,030	06/30/1957	21,900	04/05/1957	3,020	04/04/1957	8,580
1958	06/11/1958	15,600	06/14/1958	7,880	06/15/1958	65,200	06/14/1958	3,610	08/02/1958	5,950
1959	01/22/1959	13,000	01/22/1959	20,300	01/23/1959	47,900	01/22/1959	24,800	01/22/1959	33,400
1960		ns		ns	02/11/1960	1,570		ns		ns
1961	04/26/1961	2,150	04/26/1961	2,750	04/27/1961	12,800	04/26/1961	545	04/25/1961	5,140
1962	01/26/1962	2,980	02/27/1962	1,270	02/27/1962	9,320	02/27/1962	813	02/26/1962	3,200
1963	03/06/1963	7,760	03/05/1963	9,340	03/07/1963	39,400	03/05/1963	13,400	03/05/1963	18,900
1964	04/22/1964	10,400	04/21/1964	5,780	04/23/1964	34,600	03/10/1964	4,650	03/10/1964	11,300
1965	04/25/1965	2,150	04/26/1965	1,020	04/26/1965	7,270	04/26/1965	203	04/25/1965	1,250
1966		ns	02/11/1966	209	02/11/1966	1,720	02/11/1966	203	02/10/1966	787
1967	05/07/1967	3,980	05/08/1967	1,110	12/11/1966	14,100		ns	05/07/1967	2,880

Table 1–3. Annual peak dam-pool storages for the Lockington, Englewood, Taylorsville, Huffman, and Germantown Dams, water years 1922–2008.—Continued

[acre-ft, acre-feet; ns, no storage]

Water year	Lockington Dam		Taylorsville Dam		Englewood Dam		Huffman Dam		Germantown Dam	
	Date	Storage (acre-ft)	Date	Storage (acre-ft)	Date	Storage (acre-ft)	Date	Storage (acre-ft)	Date	Storage (acre-ft)
1968	12/03/1967	2,650	01/31/1968	636	05/29/1968	11,800	05/28/1968	74	05/24/1968	12,500
1969	05/19/1969	3,140	01/30/1969	1,360	01/31/1969	13,000	08/10/1969	595	01/30/1969	3,810
1970	04/02/1970	3,230	04/03/1970	1,940	01/29/1970	8,230	04/03/1970	1,800	04/02/1970	5,140
1971	02/22/1971	1,500	06/26/1971	1,310	02/23/1971	6,250	06/26/1971	881	02/22/1971	2,800
1972	04/07/1972	3,060	04/08/1972	889	04/08/1972	4,650		ns	04/13/1972	680
1973	08/15/1973	3,060	11/15/1972	1,690	11/15/1972	11,800	06/20/1973	387	11/14/1972	1,760
1974	01/19/1974	3,590	01/20/1974	2,060	01/20/1974	9,940	04/02/1974	189	06/23/1974	2,430
1975	02/24/1975	6,770	02/24/1975	6,900	02/25/1975	31,700	02/24/1975	3,220	02/24/1975	11,700
1976	01/26/1976	4,030	01/27/1976	754	01/27/1976	5,680	01/26/1976	79	01/26/1976	1,650
1977	04/02/1977	1,260		ns	04/03/1977	3,050	04/03/1977	259	04/03/1977	3,330
1978	03/16/1978	3,320	03/15/1978	2,240	03/17/1978	23,300	03/15/1978	495	03/15/1978	6,310
1979	03/04/1979	3,830	02/24/1979	2,360	03/06/1979	24,700	09/15/1979	983	02/24/1979	4,340
1980	06/29/1980	6,910	06/03/1980	2,420	06/30/1980	32,900	06/29/1980	2,050	11/26/1979	2,160
1981	06/14/1981	3,980	06/15/1981	2,180	06/07/1981	11,800	06/06/1981	1,950	06/06/1981	570
1982	05/28/1982	3,280	02/18/1982	2,610	02/18/1982	18,900	02/01/1982	2,390	02/01/1982	8,090
1983	05/03/1983	1,140	05/03/1983	721	05/04/1983	6,330	05/02/1983	259	05/03/1983	4,100
1984	03/16/1984	2,580		ns	03/17/1984	8,330		ns	04/05/1984	653
1985	02/24/1985	5,680	02/24/1985	2,890	02/25/1985	21,600	02/24/1985	351	02/23/1985	1,900
1986	12/12/1985	3,930	12/12/1985	1,740	12/13/1985	14,200	03/13/1986	495	03/13/1986	2,290
1987	07/02/1987	5,570	10/05/1986	3,880	10/05/1986	21,300	10/05/1986	570	10/02/1986	4,000
1988		ns		ns	02/03/1988	894		ns	02/02/1988	1,540
1989	05/26/1989	2,890	05/27/1989	3,480	05/27/1989	20,600	05/27/1989	1,080	05/26/1989	11,300
1990	02/16/1990	5,330	02/16/1990	2,750	02/17/1990	17,400	07/13/1990	983	02/16/1990	4,600
1991	12/31/1990	12,600	12/31/1990	12,100	12/31/1990	42,100	12/31/1990	2,760	12/31/1990	13,300
1992	07/13/1992	7,690	07/14/1992	1,890	04/19/1992	5,820	07/18/1992	333	04/19/1992	976
1993	07/03/1993	8,440	07/03/1993	2,610	07/04/1993	9,940	07/02/1993	387	04/16/1993	1,680
1994	11/15/1993	6,310	11/18/1993	2,180	11/19/1993	14,500	01/28/1994	847	01/28/1994	3,160
1995	08/08/1995	8,930	08/09/1995	10,500	05/20/1995	16,400	08/09/1995	369	05/18/1995	3,120
1996	01/19/1996	7,110	01/19/1996	3,480	01/20/1996	30,300	04/30/1996	1,900	04/30/1996	12,800
1997	06/02/1997	5,040	06/02/1997	3,560	06/03/1997	35,400	06/02/1997	915	06/02/1997	7,010
1998	06/12/1998	2,690	01/09/1998	1,590	04/11/1998	5,190	05/08/1998	1,340	04/16/1998	2,620
1999	01/22/1999	2,930	01/23/1999	2,960	01/24/1999	25,100	01/22/1999	231	01/23/1999	6,130
2000	04/08/2000	1,420	04/08/2000	1,440	04/09/2000	8,520	04/08/2000	1,250	04/08/2000	4,550
2001	05/27/2001	1,060		ns	04/12/2001	2,510	07/29/2001	217	04/11/2001	1,290
2002	04/14/2002	2,850	12/18/2001	2,480	04/15/2002	14,900	12/18/2001	813	12/18/2001	7,270
2003	07/09/2003	15,900	07/10/2003	8,930	07/11/2003	25,700	09/02/2003	423	07/07/2003	1,840
2004	01/05/2004	4,600	01/05/2004	5,270	01/06/2004	23,500	01/05/2004	2,960	01/05/2004	14,800
2005	01/12/2005	9,690	01/06/2005	16,000	01/08/2005	67,300	01/06/2005	3,380	01/06/2005	19,300
2006	06/02/2006	2,150	03/13/2006	1,740	03/14/2006	9,840	03/13/2006	387	03/12/2006	4,450
2007	03/24/2007	6,370	03/24/2007	6,330	03/25/2007	28,200	03/03/2007	1,650	03/02/2007	8,020
2008	02/07/2008	7,190	03/20/2008	5,680	03/21/2008	23,200	03/20/2008	2,220	03/20/2008	12,400

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