2021 WATER QUANTITY REPORT
FOR THE GREAT MIAMI RIVER WATERSHED

MCD staff member, Alex Hackney, measuring streamflow using an acoustic Doppler current profiler (ADCP) on the Mad River at St Paris Pike in Clark County, Ohio

Contents

Abstract

A cooperative partnership between USGS and MCD has facilitated long-term tracking of changes in water availability including precipitation, runoff and groundwater levels. The data collected is used to estimate water inflows and outflows for the Great Miami River Watershed upstream of the Hamilton stream gaging station, an area of more than 3,630 square miles.

Nearly all of the water coming into the Great Miami River Watershed arrives as precipitation. The average annual precipitation recorded in the Great Miami River Watershed during 2021 was 44.15 inches. This amount was 2.23 inches above the 30-year average precipitation (1991 – 2020) for the watershed. The long-term precipitation data shows average annual precipitation is trending upward in the Great Miami River Watershed.

Most of the water leaving the Great Miami River Watershed exits through the processes of evapotranspiration and runoff. Estimated runoff for the Great Miami River in 2021 was 15.45 inches. This amount was 0.77 inches less than the 30 year average (1991 – 2020) precipitation for the watershed. As in the case of precipitation, average annual runoff in the Great Miami River Watershed is increasing.

The MCD flood protection system recorded a total of 37 storage events during 2021. The average number of annual storage events for the five restricting (retarding) basins, over the entire life of the system, is 20. None of the storage events that occurred in 2021 were large enough to exceed MCD's top-10 storage event ranking.

Groundwater levels measured in 2021 at eight index wells ended the year at or close to the levels measured during the beginning of the year. Average annual groundwater levels measured in all index wells have been relatively stable over the long term.

In 2020, surface water withdrawals in the Great Miami River Watershed averaged 23 million gallons of water per day. Groundwater withdrawals averaged 259 million gallons of water per day. Water use data for the Great Miami River Watershed shows that total water withdrawals peaked during the decade of the 2000s at around 600 million gallons of water per day. Since that time, total water withdrawals have declined to around 300 million gallons of water per day.

Long-term trends in precipitation, runoff, and streamflow are increasing while groundwater levels in the buried valley aquifer system are stable. These trends likely reflect climatic variability coupled with declining water use.

For more information on the current programs of MCD, visit www.MCDWater.org.

Background

The Miami Conservancy District (MCD) is a conservancy district, which is a political subdivision of the State of Ohio. MCD works as a regional government agency throughout the 15-county Great Miami River Watershed. Formed in 1915, MCD provides flood protection, water resource monitoring and information, and recreational opportunities. MCD operates automated and observer precipitation stations and an extensive stream gaging network to record stream stage and calculate streamflow. MCD has operated the stream gaging network with the U.S. Geological Survey (USGS) under a cooperative agreement since 1931. Partnering with a variety of federal, state, and local governments, MCD conducts surface water and groundwater quality and quantity studies.

A cooperative partnership between USGS and MCD has facilitated long-term tracking of changes in water availability including precipitation, runoff and groundwater levels. The data collected is used to estimate water inflows and outflows for the Great Miami River Watershed upstream of the Hamilton stream gaging station, an area of more than 3,630 square miles. These records can be used to compare current hydrologic measurements with historical measurements, and analyze trends of water entering and leaving the watershed, as well as trends in aquifer levels. The information can be useful for planning related to water supply, flood protection, construction, agriculture, commerce, and industry.

The Water Cycle

Precipitation falls on the land surface of the Great Miami River Watershed as rain, snow, or ice. Some of the precipitation flows by gravity toward streams and rivers and becomes surface runoff which eventually reaches the Great Miami River. Some of the precipitation infiltrates the ground and percolates through the soil until it reaches the water table. This water provides groundwater recharge to the aquifers and helps sustain the abundant water resources in the Great Miami River Watershed. Water in the aquifer either remains underground and in storage for a long period of time or stays close to the ground surface and seeps into nearby streams or rivers as base flow. As a result, some streams and rivers in the Great Miami River Watershed are able to sustain flow, even during periods of prolonged drought, because the underlying buried valley aquifer provides base flow to the streams and rivers.

Precipitation

Nearly all of the water coming into the Great Miami River Watershed arrives as precipitation. The Miami Conservancy District (MCD) maintains a network of 42 precipitation stations within the Great Miami River Watershed staffed by observers who record daily precipitation from standard National Weather Service rain and snow gages (see Figure 1). MCD calculates annual precipitation for the watershed by averaging annual precipitation totals measured at each of the stations.

The average annual precipitation recorded in the Great Miami River Watershed during 2021 was 44.15 inches. This amount was 2.23 inches above the 30-year average precipitation (1991 – 2020) for the watershed. MCD's observer station at Ingomar recorded the most precipitation at 49.69 inches, while the Ft. Loramie station recorded the lowest amount at 38.22 inches.

While monthly precipitation in the Great Miami River Watershed was recorded at below average amounts for four of the first five months of the year, July had the highest monthly precipitation total at 5.72 inches.

Overall, the monthly precipitation amounts recorded were greater than normal during the second half of the year. Precipitation totals recorded in the months of July, September, October, and December were significantly above-average.

The annual precipitation total recorded during 2021 was consistent with the trend of increasing annual precipitation in the Great Miami River Watershed. The 30-year average annual precipitation is trending upward (see Figure 3). Average annual precipitation for the 30-year timespan of 1951 – 1980 was 37.29 inches. For the 30-year timespan of 1991 – 2020 average annual precipitation climbed to 41.92 inches showing an increase of 4.63 inches over 40 years.

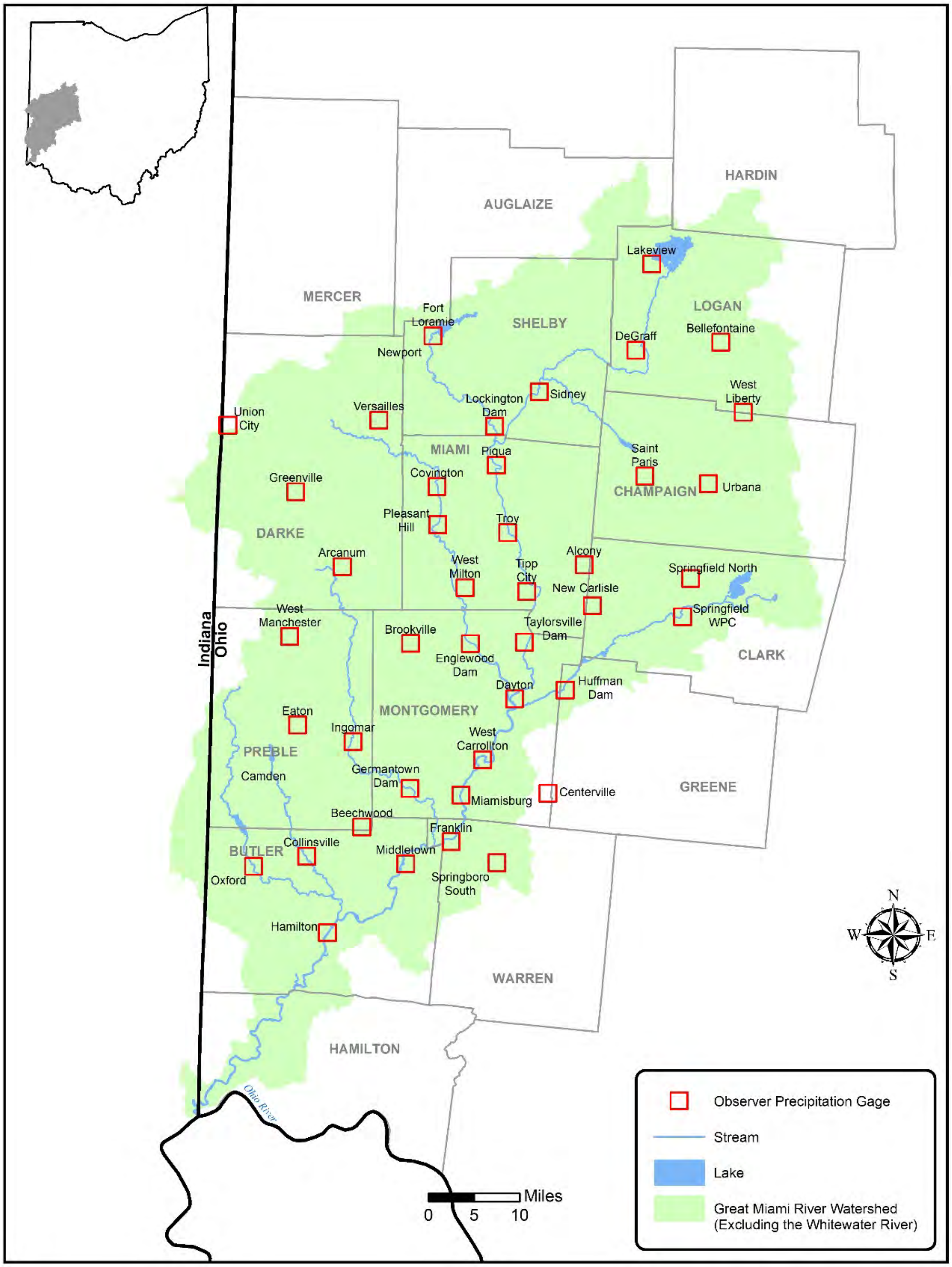

Figure 1. Map of the locations of MCD observer precipitation stations.

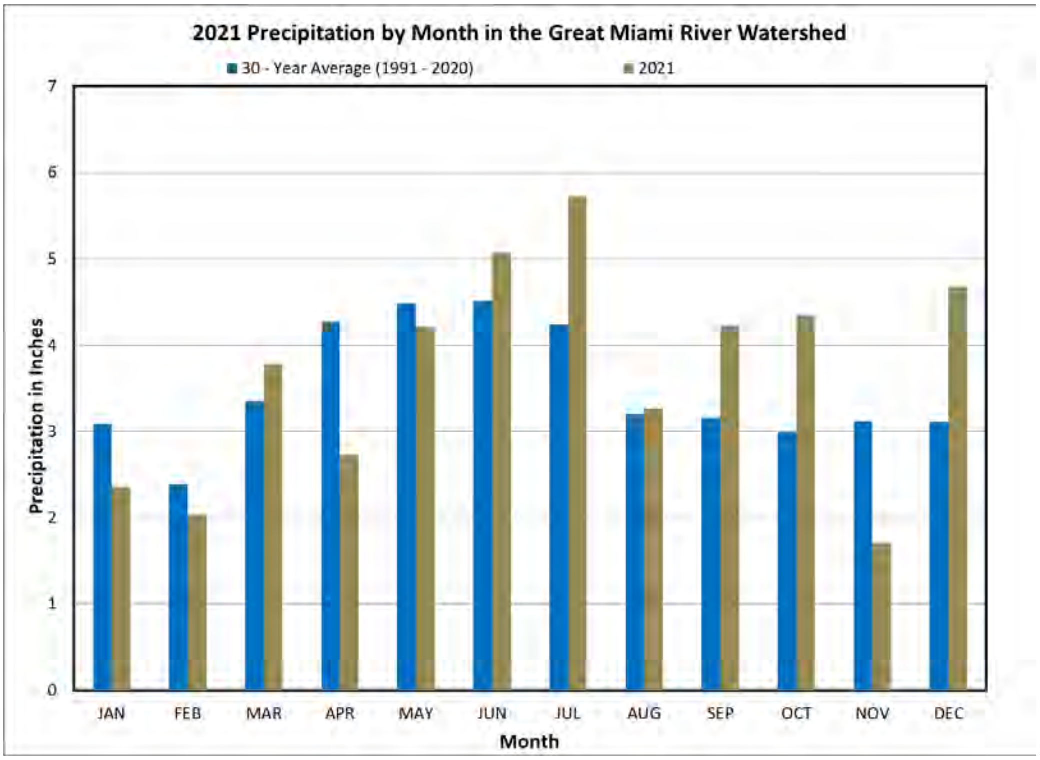

Figure 2. Monthly precipitation compared to 30-year averages for the Great Miami River Watershed in 2021

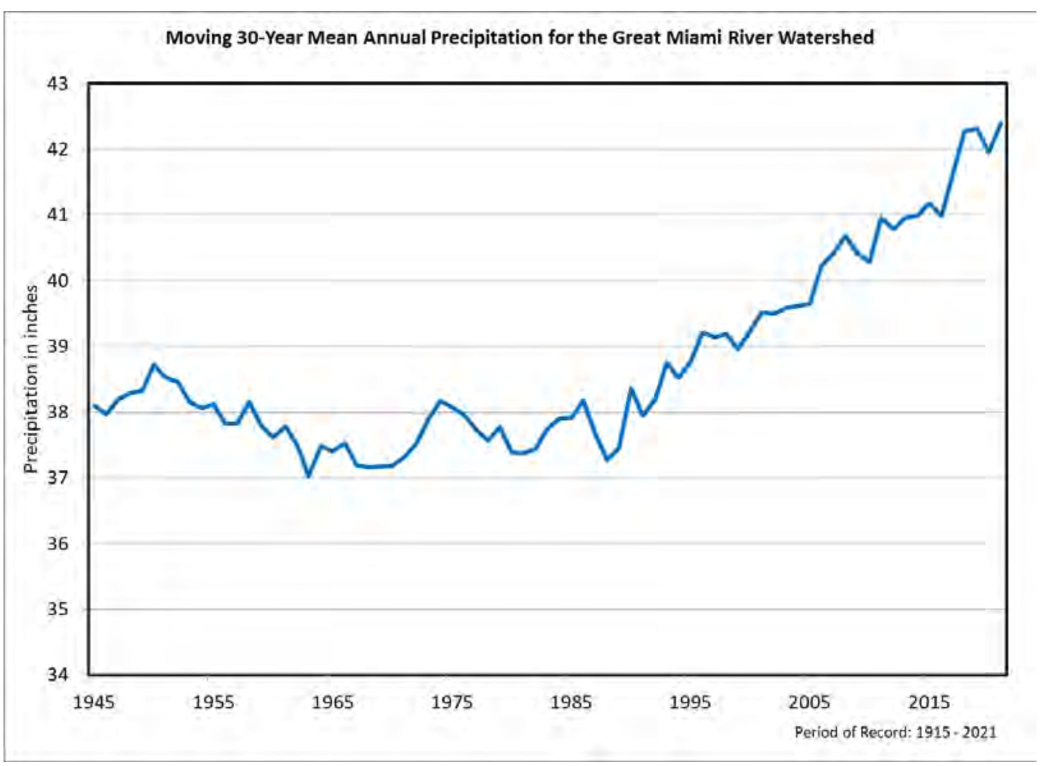

Figure 3. Plot showing the moving 30-year mean precipitation for the Great Miami River Watershed

Streamflow and Runoff

Most of the water leaving the Great Miami River Watershed exits through the processes of evapotranspiration and runoff. MCD does not measure evapotranspiration directly, but staff does measure runoff. Runoff includes all the water that flows across the land and enters streams, as well as water discharged from aquifers into streams. Runoff is measured directly by streamgages.

MCD, in cooperation with the U.S. Geological Survey (USGS), maintains a network of 24 streamgages equipped with telemetry (see Figure 4). Data collected by each of the streamgages is transmitted to, and archived in, the USGS National Water Information System (NWIS). The streamgage closest to the mouth of the Great Miami River is the gage located near Hamilton, Ohio.

Average daily flow for the Great Miami River at Hamilton in 2021 was 4,155 cubic feet per second. Average daily flow for the time period of 1991 – 2010 at the Hamilton gage is 4,341 cubic feet per second. Average 2021 daily flows for the winter, spring, summer, and fall seasons were 5,088, 5,719, 3,442, and 2,370 cubic feet per second respectively.

MCD estimates annual runoff for the Great Miami River Watershed by the following process:

- sum the volume of water that flows past the Great Miami River at Hamilton gage in a given year
- apply the volume of water over the entire watershed area (3,630 mi^2) upstream of the gage
- determine the water depth in inches.

Estimated runoff for the Great Miami River in 2021 was 15.45 inches. This amount was 0.77 inches less than the 30 year average (1991 – 2020) precipitation for the watershed.

Similar to precipitation, monthly runoff amounts recorded in 2021 were significantly below average in January, February, and April and significantly above average in March, October, and December of 2021 (see Figure 5). Evapotranspiration rates are highest in southwest Ohio during the late spring, summer, and early fall months. Increased evapotranspiration rates likely reduced runoff during the months of June, July, and September despite significantly higher than average precipitation for those months.

As in the case of precipitation, average annual runoff in the Great Miami River Watershed is increasing. The 30-year average annual runoff is trending upward (see Figure 6). Average annual runoff for the 30 year timespan of 1951 - 1980 was 12.23 inches. For the 30 year timespan of 1991 – 2020 average annual runoff climbed to 16.22 inches showing an increase of 3.99 inches over 40 years.

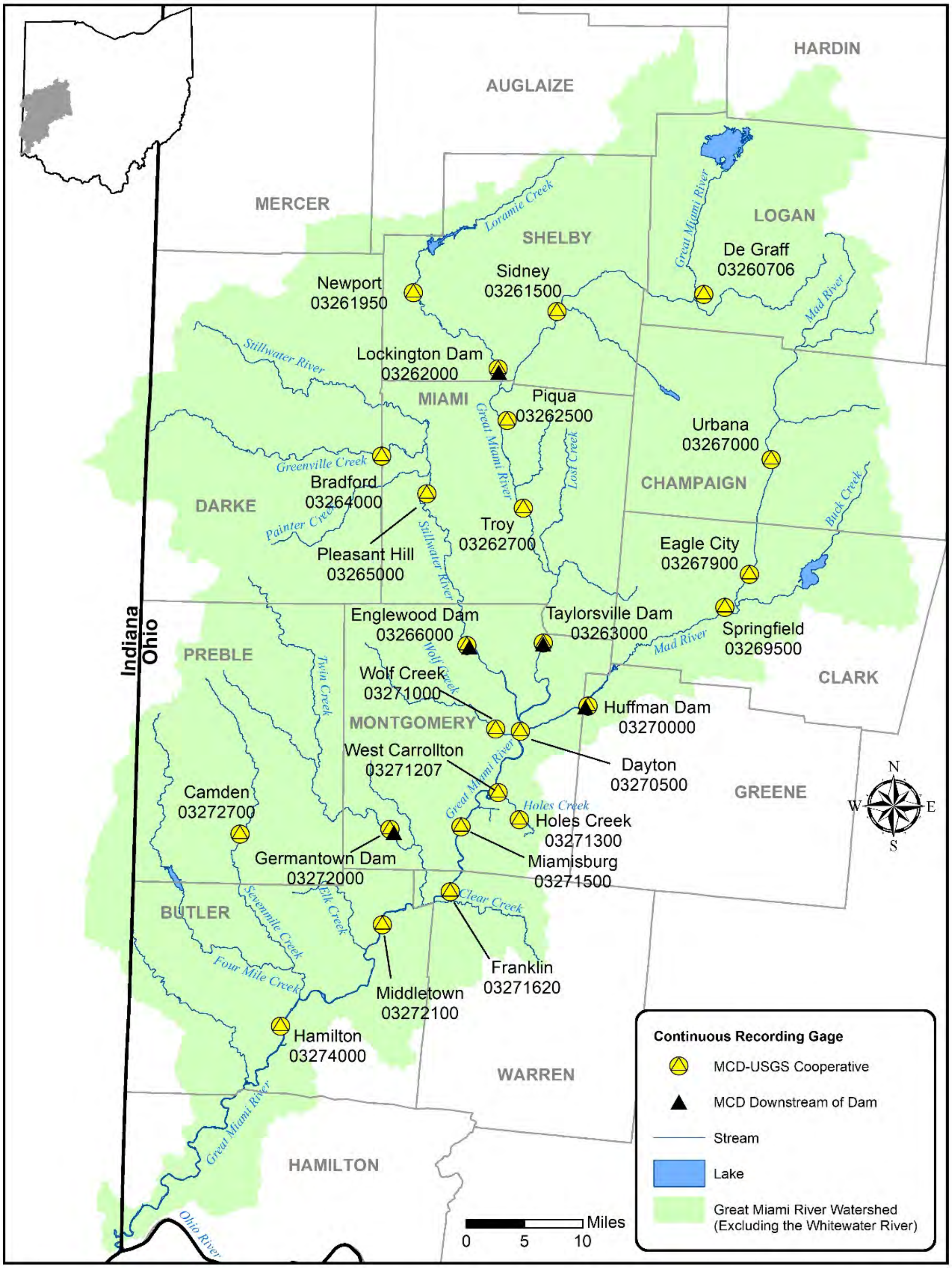

Figure 4. Map showing locations of MCD-USGS streamgages.

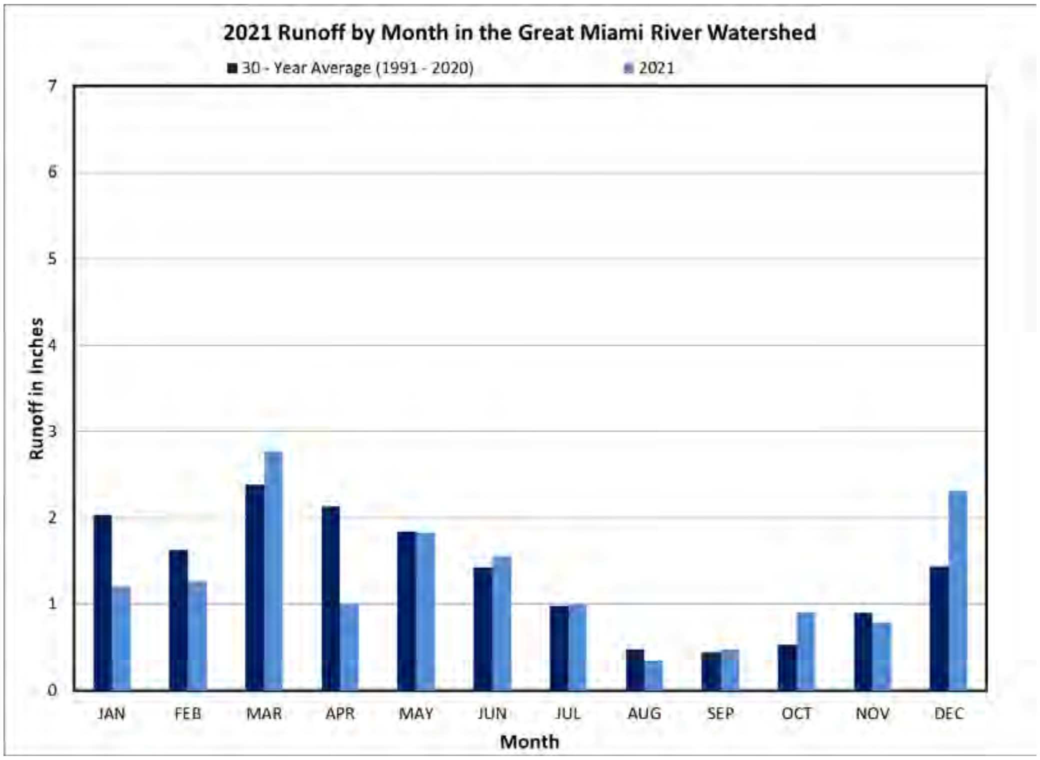

Figure 5. Monthly runoff compared with 30-year averages for the Great Miami River Watershed in 2021

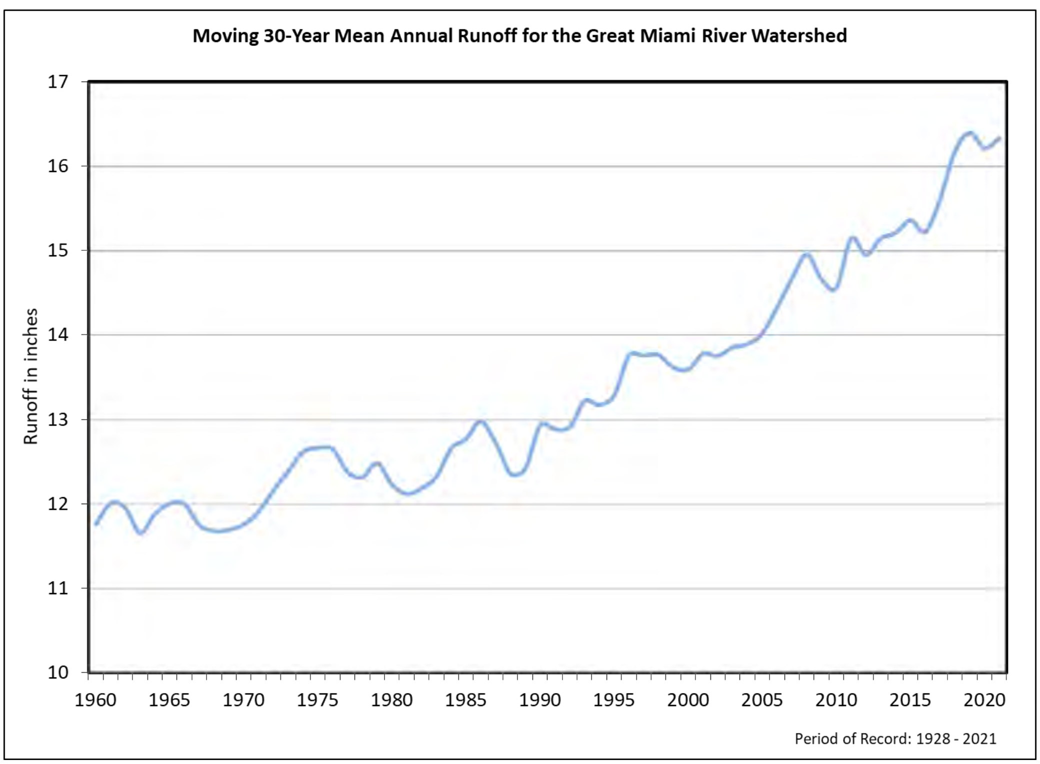

Figure 6. Plot showing the moving 30-year mean runoff for the Great Miami River Watershed

Storage Events at MCD Dams

MCD built and maintains five flood protection dams in the Great Miami River Watershed named Germantown, Englewood, Lockington, Huffman, and Taylorsville dams (see Figure 7). The five dams have a combined peak storage capacity of 841,000 acre-feet, or about 274 billion gallons of water. The dams are designed to act as flow regulators.

During times of high precipitation and runoff, the dams reduce downstream flows on the Stillwater, Great Miami, and Mad rivers and on Loramie and Twin creeks. The flow reductions allow MCD flood protection channels and levees downstream of the dams to accommodate the river flow without being overtopped. The dams accomplish this by temporarily storing floodwaters in the land behind the dams. Under normal conditions there is no water stored or pooled behind any of the MCD flood protection dams. When flows in the rivers upstream of the dams reach a certain threshold, the dams begin to store water and the restricting (retarding) basins behind the dams begin to fill with water.

A floodwater storage event is recorded when the pool elevation reaches a minimum stage at which the conduits begin to slow the flow of water. That storage event continues until the pool elevation drops below that minimum stage. Storage events at each of the dams are recorded separately. So if all five dams are in storage at the same time, it is counted as five storage events.

Table 1 lists the stage at each of the dams when storage begins. Table 2 provides pertinent information regarding each storage event in the restricting (retarding) basins upstream of MCD dams during the year.

A total of 37 storage events were recorded during 2021. The average number of annual storage events for the five restricting (retarding) basins, over the entire life of the dams, is 20. None of the storage events that occurred in 2021 were large enough to exceed MCD's top-10 storage event ranking.

Out of the 37 storage events that occurred in 2021, eight of the events occurred during the March, and nine events occurred in December (see Figure 8).

Table 1—Restricting (Retarding) Basin Stages Where Storage Begins

Dam	Stage Where Storage Begins (ft.)
Germantown	12
Englewood	11.6
Lockington	12
Taylorsville	15
Huffman	11

The construction of the five flood protection dams in the MCD flood protection system were completed by 1922. Since that time, MCD has recorded each of the storage

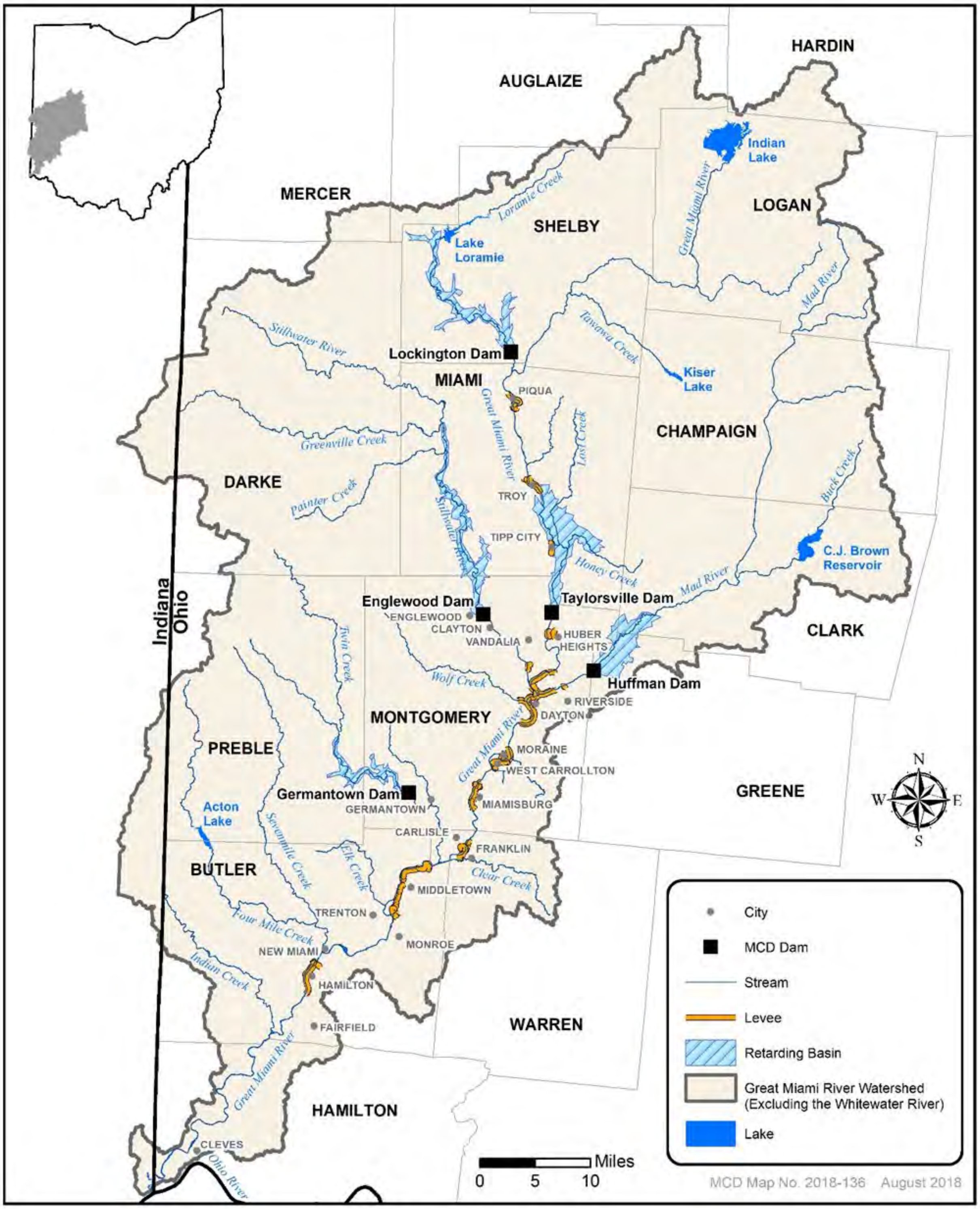

Figure 7. Map showing locations of MCD flood protection dams, restricting (retarding) basins, and levees.

Table 2—Restricting (Retarding) Basin Operation (Storage Events) during 2021

Restricting (Retarding) Basin	Date	Maximum Elevation (ft.)	Maximum Stage (ft.)	Maximum Storage (ac. ft.)	Storage Used (percent)	Pool Area (acres)	Maximum Outflow (c.f.s.)
Germantown Twin Creek (Zero 723.2)*	1/2/2021	735.5	12.3	140	0.1%	50	2,780
	2/25/2021	735.2	12.0	135	0.1%	46	2,700
	2/28/2021	743.1	19.9	785	0.7%	144	4,190
	3/19/2021	750.8	27.6	2,420	2.3%	325	5,330
	5/10/2021	741.0	17.8	530	0.5%	112	3,820
	6/3/2021	740.3	17.1	470	0.4%	102	3,700
	6/19/2021	753.2	30.0	3,150	3.0%	400	5,630
	6/30/2021	735.4	12.2	140	0.1%	48	2,750
	7/17/2021	742.5	19.3	690	0.7%	135	4,080
	7/17/2021	737.5	14.3	270	0.3%	69	3,190
	12/11/2021	739.5	16.3	410	0.4%	92	3,560
	12/29/2021	737.1	13.9	240	0.2%	65	3,110
Englewood Stillwater River (Zero 771.2)*	1/3/2021	788.6	17.4	2,050	0.7%	290	3,850
	3/1/2021	796.8	25.6	6,200	2.0%	720	5,470
	3/20/2021	807.8	36.6	16,800	5.4%	1,260	6,810
	5/11/2021	799.0	27.8	7,800	2.5%	820	5,750
	6/20/2021	785.8	14.6	720	0.2%	185	3,220
	7/2/2021	791.2	20.0	3,100	1.0%	440	4,390
	9/24/2021	788.8	17.6	2,160	0.7%	290	3,890
	10/26/2021	796.4	25.2	5,900	1.9%	700	5,410
	10/31/2021	790.4	19.2	2,725	0.9%	360	4,220
	12/12/2021	792.0	20.8	3,600	1.2%	480	4,570
	12/26/2021	784.8	13.6	490	0.2%	156	3,010
	12/28/2021	782.8	11.6	400	0.1%	120	2,550
	12/30/2021	794.6	23.4	4,700	1.5%	620	5,100
Lockington Loramie Creek (Zero 875.2)*	1/2/2021	887.8	12.6	225	0.3%	99	2,350
	3/1/2021	891.9	16.7	725	1.0%	190	3,340
	3/19/2021	895.6	20.4	1,525	2.2%	305	4,180
	5/10/2021	894.4	19.2	1,250	1.8%	270	3,910
	12/11/2021	888.4	13.2	270	0.4%	108	2,510
	12/29/2021	890.8	15.6	520	0.7%	165	3,070
Taylorsville Great Miami River (Zero 759.2)*	3/1/2021	776.2	17.0	2,815	1.5%	515	12,700
	3/19/2021	778.0	18.8	3,950	2.1%	665	14,600
	5/10/2021	778.3	19.1	4,200	2.3%	700	15,000
	12/29/2021	775.5	16.3	2,500	1.3%	470	11,800
Huffman Mad River (Zero 776.3)*	3/19/2021	788.6	12.3	600	0.4%	220	5,850
	5/10/2021	789.6	13.3	850	0.5%	265	6,480

* Denotes floor elevations of conduits referenced to NAVD88 vertical datum.

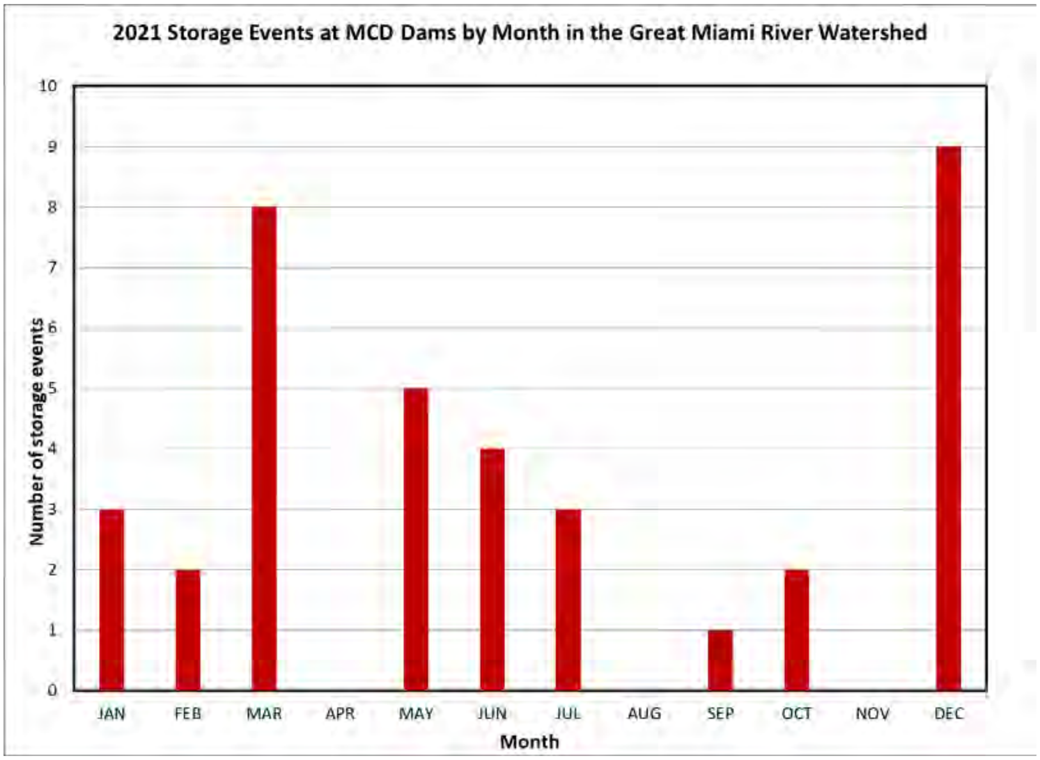

Figure 8. Number of storage events by month in 2021.

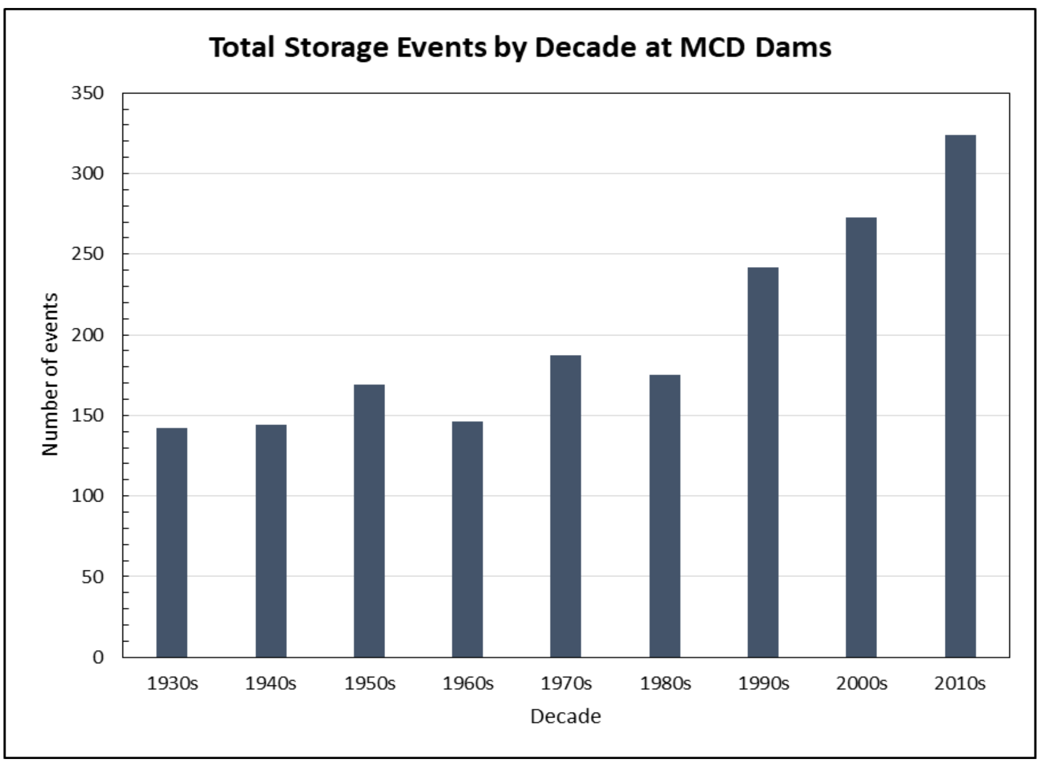

Figure 9. Number of storage events recorded by MCD for each decade.

events that have occurred. The total number of storage events per decade has increased in recent decades (see Figure 9).

MCD recorded 175 storage events during the decade of the 1980s. Since that time MCD recorded 242, 273, and 324 storage events respectively during the decades of the 1990s, 2000s, and 2010s.

Groundwater Levels in the Buried Valley Aquifer System

MCD maintains a network of 93 observation wells in the Great Miami River Watershed. Of these wells, 58 are installed in the buried valley aquifer system. The Ohio Department of Natural Resources (ODNR) Division of Water Resources also maintains a network of observation wells in Great Miami River Watershed system which includes 26 wells.

MCD selected eight observation wells (6 MCD and 2 ODNR wells) as index wells for the buried valley aquifer system between the mouth of the Great Miami River and the Dayton region (see Figure 10). An index well is a well installed in a representative portion of the surrounding buried valley aquifer system that can allow for measuring and interpreting hydrologic responses at local scales. Data trends in index wells provide a strong indication of buried valley aquifer responses to changes in human water use as well as shifts in local climate.

Table 3 displays the depths of each of the index wells. All of the index wells are equipped with loggers and telemetry. The loggers measure the depth to water below ground surface every hour and transmit the data to NWIS allowing the data to be accessed in near real-time.

Table 3—Index Well Depths

Index Well	Well Depth (ft.)
BU-32	234
BU-70	54
BU-179	43
BU-282	74
H-1	124
MT-49	220
MT-73	95
W-10	51

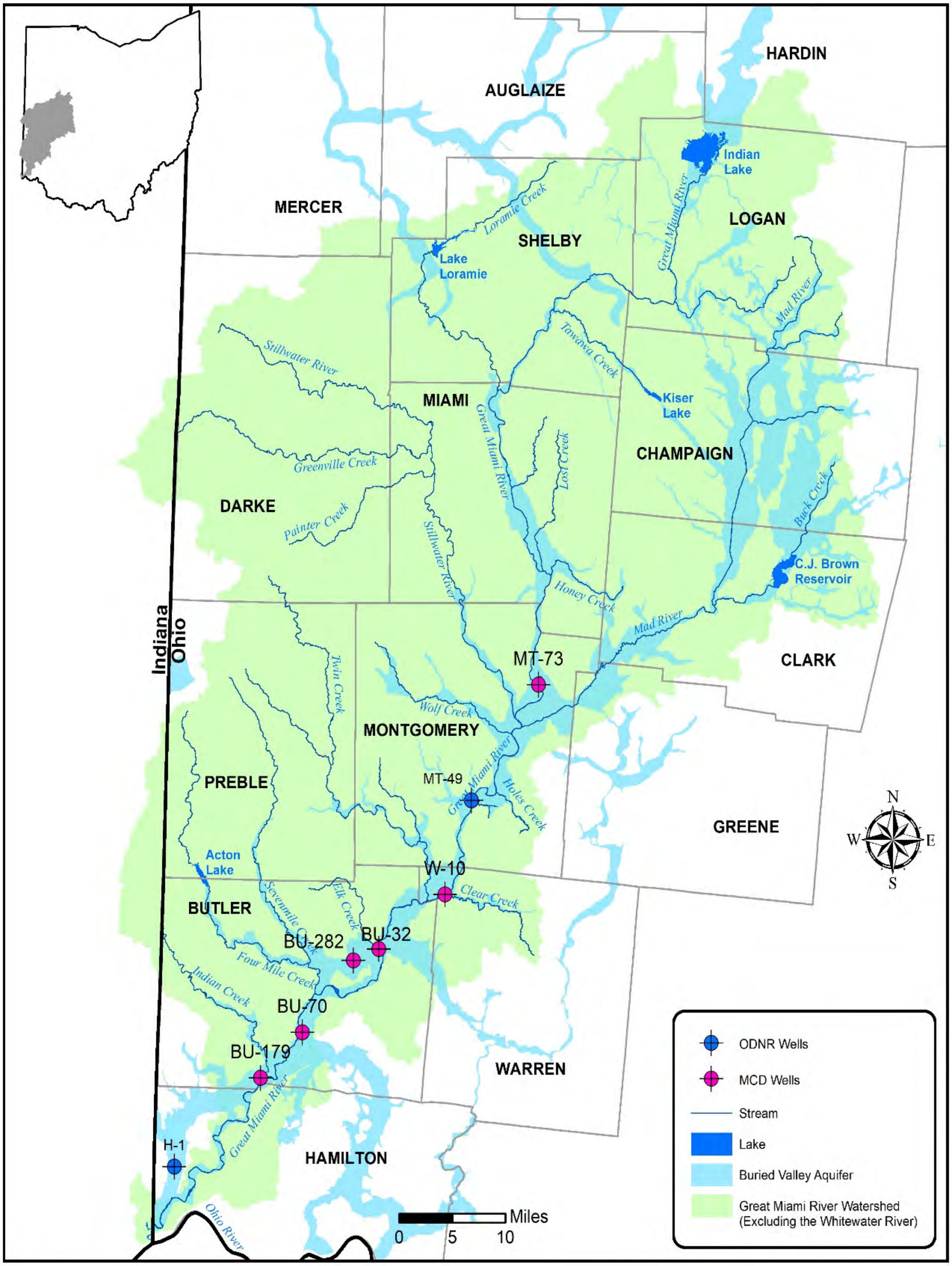

Figure 10. Map showing Locations of index observation wells.

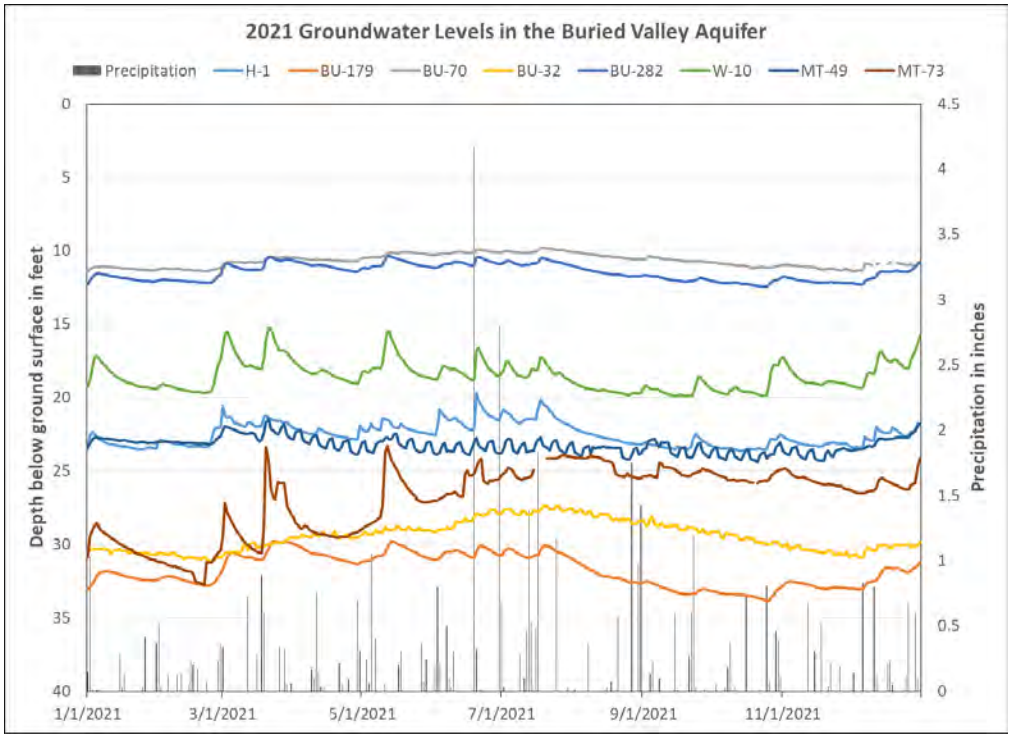

Figure 11. Depth below ground surface measured at eight buried valley aquifer observation wells in 2021.

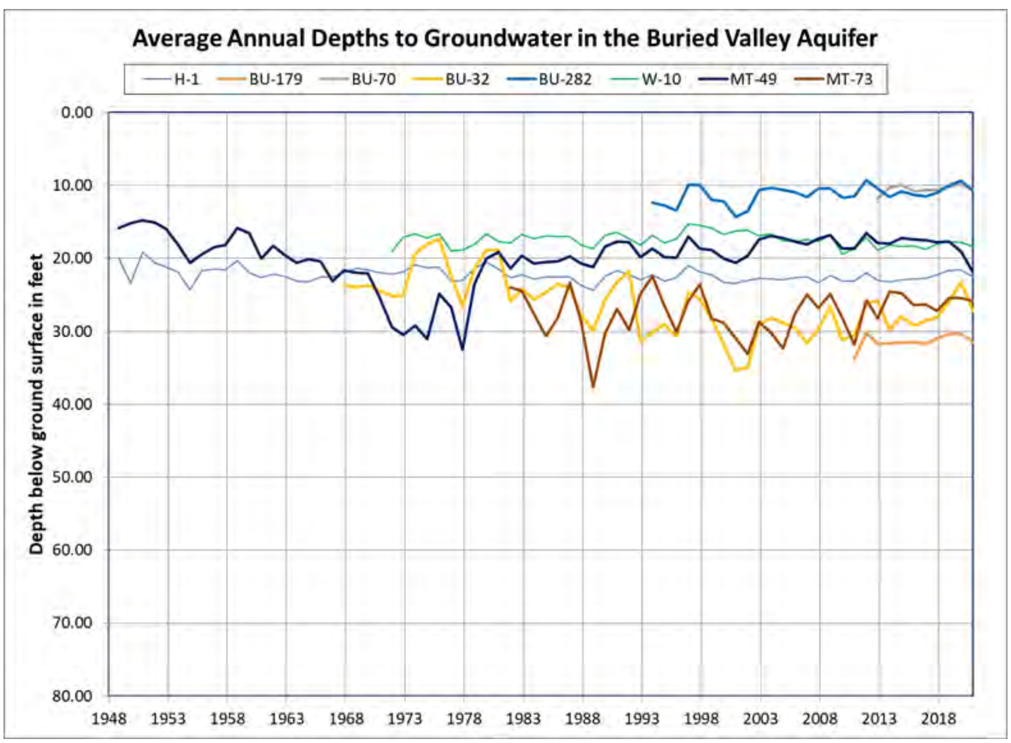

Figure 12. Average annual depths to groundwater at eight buried valley aquifer observation wells.

Groundwater levels measured at the eight index wells in 2021 ended the year at or close to the levels measured during the beginning of the year (see Figure 11). The lowest groundwater levels (greatest depths to groundwater) at most index wells tended to occur between the months of September and October. Highest groundwater levels tended to occur between the months of March and May. The levels observed at wells BU-32 and BU-70 were notable exceptions. The highest groundwater levels measured at both wells occurred in July.

Average annual groundwater levels measured in all index wells have been relatively stable over the long term (see Figure 12). Historically, the average annual groundwater levels observed at well MT-49 declined during the 1960s and early 1970s. However, in the late 1970s, groundwater levels recovered and they have been stable ever since. Likewise, average annual groundwater levels observed at well BU-32 were declining during the 1980s and 1990s. Groundwater levels stabilized around the year 2000 and have been trending upward since that time.

Overall, groundwater level measurements at the index wells show a long term balance between groundwater recharge and groundwater discharge.

Water Use in the Great Miami River Watershed

Through its water withdrawal facilities registration program, the ODNR records water usage that occurs in the Great Miami River Watershed. The program requires all water users who have the capacity to withdraw more than 100,000 gallons of water daily to register their facility. Water use information for 2021 was not available at the time of this report and so 2020 water use information is reported instead. Given recent water use trends it’s likely the differences between 2020 and 2021 water use data are negligible.

In 2020, surface water withdrawals in the Great Miami River Watershed averaged 23 million gallons of water per day. Groundwater withdrawals averaged 259 million gallons of water per day. Groundwater withdrawals comprise 92 percent of total water use in the Great Miami River Watershed. Total groundwater withdrawn during 2020 was 94.5 billion gallons of water. Most of this water was returned to the Great Miami River Watershed by discharges from water reclamation facilities.

Water withdrawn for use by public water suppliers comprised about 75 percent of total groundwater use (see Figure 13). The remaining groundwater withdrawals were by industry, miscellaneous (mainly for open loop geothermal systems), mineral extraction, and agricultural irrigation.

Water use trends in the Great Miami River Watershed illustrate that total water withdrawals peaked during the decade of the 2000s at around 600 million gallons of water per day (see Figure 14). Since that time, total water withdrawals have declined to a little over 300 million gallons of water per day. Surface water withdrawals declined more than groundwater.

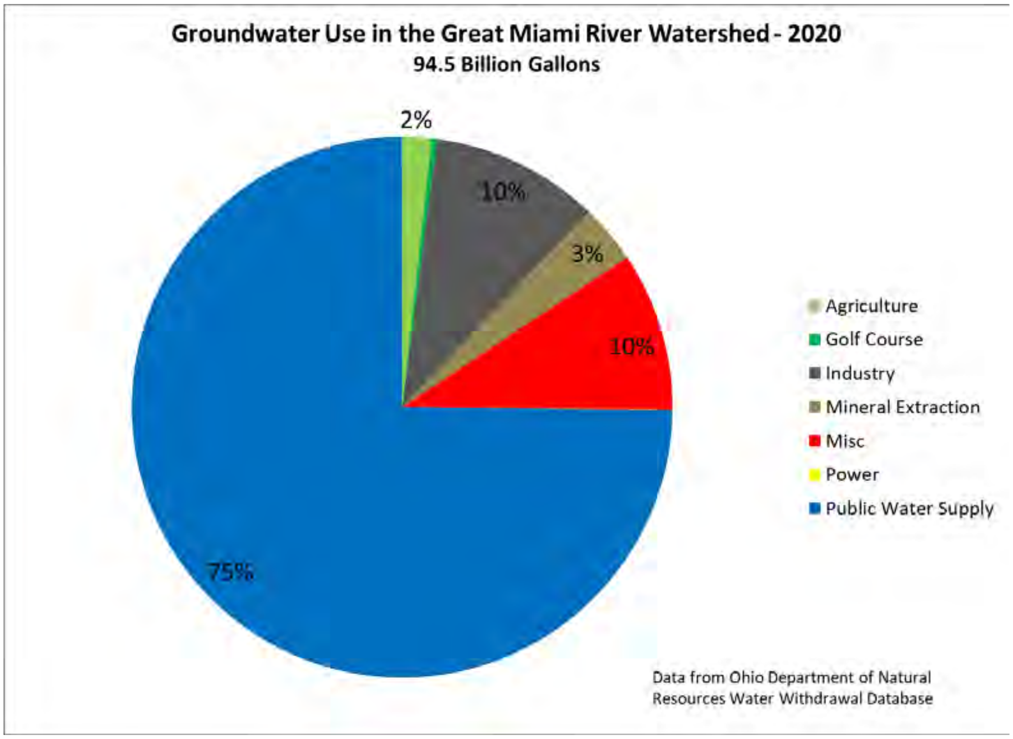

Figure 13. Groundwater use in the Great Miami River Watershed during the year 2020.

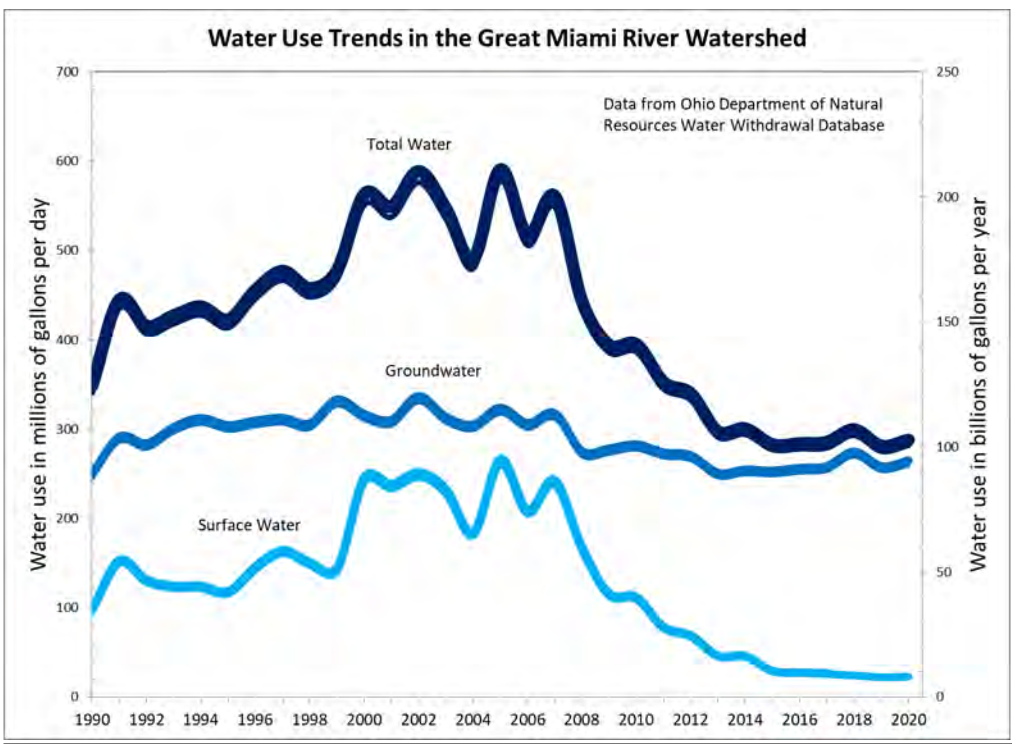

Figure 14. Total water, surface water, and groundwater withdrawals in the Great Miami River Watershed between 1990 and 2020.

Surface water withdrawals peaked at 261 million gallons of water per day in 2005, and declined to 23 million gallons of water per day in 2020. Most of this decrease occurred as a result of the closure of two power-generating stations which used surface water for cooling. Groundwater withdrawals peaked in 2002 at 330 million gallons of water per day. In 2020, groundwater use was down to 259 million gallons of water per day.

Summary

Precipitation amounts in the Great Miami River Watershed in 2021 were recorded above the 30-year average, while runoff amounts were slightly below the 30-year average. The MCD flood protection system recorded 37 separate storage events during the year. Groundwater levels in the buried valley aquifer system tended to reach their highest levels between March and May, and dropped to their lowest levels during the months of September and October.

Average annual precipitation and average annual runoff amounts recorded in the Great Miami River Watershed are trending upward. These upward trends are resulting in an increased number of storage events per decade at the MCD flood protection dams.

Groundwater levels in the buried valley aquifer system are generally stable over the long term. Water use in the Great Miami River Watershed has declined since the 2000s. Most of the decline was in surface water withdrawals.

Long-term hydrologic trends likely reflect regional climatic shifts coupled with declining water use.

Acknowledgements

MCD compiled this report using MCD data and from information supplied by:

Streamflow and runoff data:
U.S. Geological Survey, Water Resources Division

Groundwater Level and Water Use Data:
Ohio Department of Natural Resources, Division of Water Resources

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