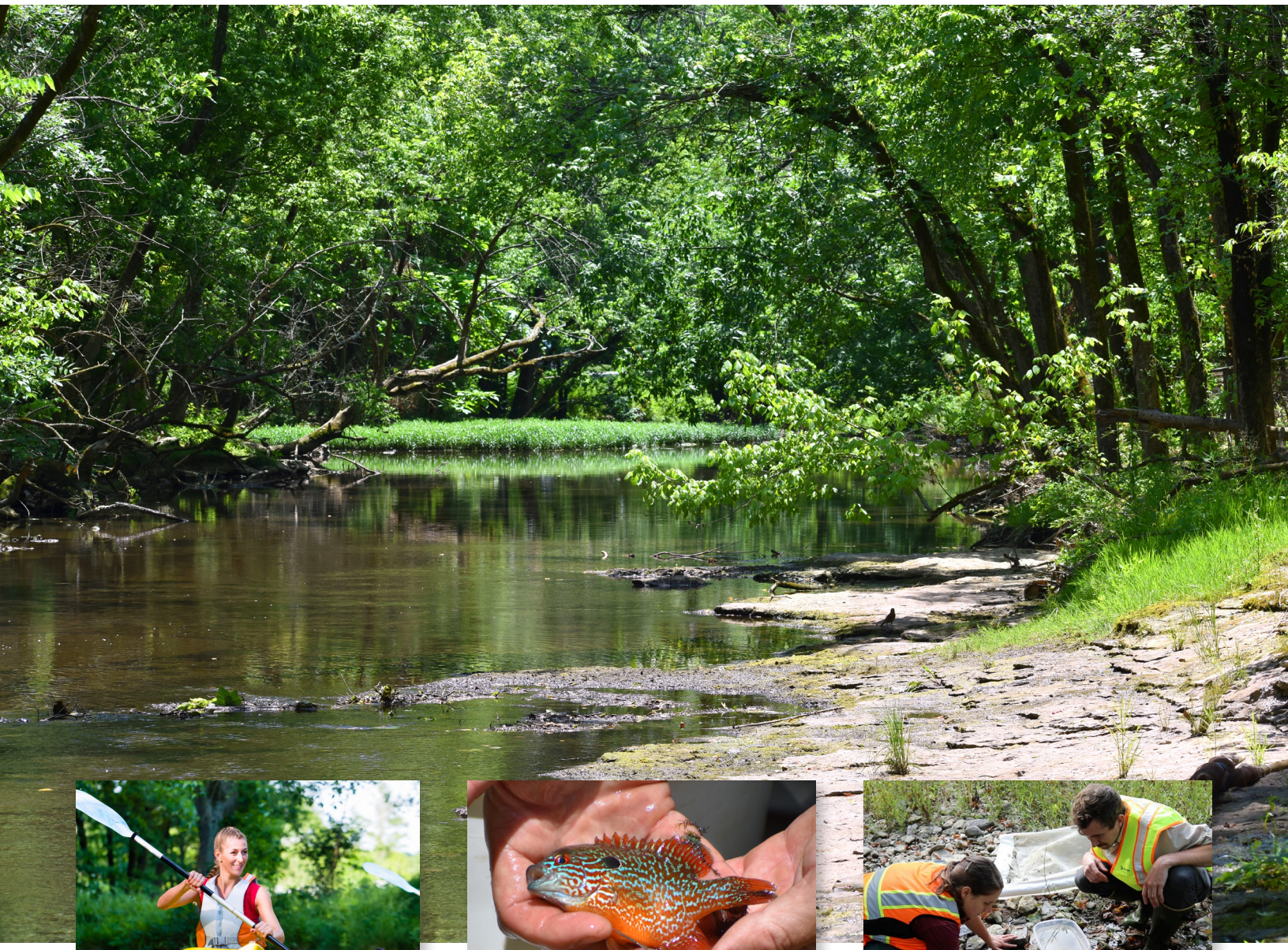
STATE OF THE STREAMS

2021 WATER QUALITY SYNTHESIS REPORT



msd
Safe, clean waterways®

TO OUR COMMUNITY

When it rains or snows, all that stormwater has to go somewhere. Stormwater runoff makes its way into drainage swales, channels, storm drains and pipes that carry it away from our homes and businesses. The water then flows into creeks and streams, and in our area, eventually to the Ohio River. Along its journey, stormwater accumulates soil and pollutants—like lawn chemicals, pet waste and oil—which can harm our waterways.

The 1972 Clean Water Act regulates the pollutants entering the waters of the United States by establishing quality goals for waterways that are fishable, swimmable and safe for use as drinking water supplies. The Act includes strict standards to measure the quality of waterways. Specifically, management of stormwater in our community is regulated through a Municipal Separate Storm Sewer System (MS4) permit, which requires periodic reporting on water quality in local streams through a network of monitoring sites.

The MSD service area has a population of approximately 750,000 people. MSD supports many programs and partnerships to enhance public knowledge of MSD's Mission and responsibilities through open, honest communication with our customers and community stakeholders.

This State of the Streams Report analyzes data from 27 stream monitoring sites and determines trends for several water quality parameters. Some of the reported parameters are directly sampled from the water including Total Suspended Solids (TSS), Escherichia coli (*E. coli*), Total Nitrogen, Oil and Grease, Copper and pH. Other parameters such as fish, aquatic insects, algae, and stream habitat, can also be indicators of the overall health of the aquatic communities. Urban streams can be compromised by one or more factors associated with urban streams:

- Overflows from sewer systems
- Significant and rapid runoff from impervious (hard surfaced) areas
- Stream bank erosion due to increases in runoff
- Sediment that covers habitat needed by fish and aquatic insects
- Channel modifications such as straightening and shoring up with concrete or stones
- Lack of rocks and boulders that create cascades and ponding areas
- Insufficient vegetation along the banks
- Periods of very low flow, high temperatures, or low dissolved oxygen

MSD is continually working toward improving water quality conditions for all community members. This report highlights that together we have made progress toward Clean Water Act goals and standards. While we may not have reached all of the goals yet, MSD has made great progress by eliminating many older, smaller wastewater treatment facilities, improving wastewater collection systems to decrease sewer overflows into our waterways, and increasing the infiltration of stormwater through the Green Infrastructure Incentive Program.

Examples of the Green Infrastructure Incentive Program include infiltration basins at the University of Louisville and Churchill Downs, a rain garden at Scholar House, and permeable pavers and infiltration trenches at Spalding University. MSD has also partnered with businesses, homeowner associations and other groups to plant over 13,000 trees through the Urban Reforestation Program. This program plants on average 1,000 trees each year.

Some of the key results from the monitoring reported include:

- Better quality aquatic communities were found in watersheds with the higher quality stream habitats, generally in watersheds with less urban influence like Floyds Fork and Pennsylvania Run.
- In 2020, eleven of the sites were in excellent condition for fish and nine sites were in excellent condition for algae.
- South Fork of Beargrass Creek, Mill Creek, and Mill Creek Cutoff had poor quality stream habitat and poor aquatic communities.
- Trends in fish, aquatic insects and stream habitat health indicate that conditions at over half of the 27 monitoring sites were improving including Pond Creek and Floyds Fork watersheds.

- Dissolved oxygen was found to be within acceptable ranges at most monitoring sites, as were nutrients and suspended solids (sediment in water) and water temperature was within acceptable ranges at all sites, which is good for aquatic communities and overall water quality.
- Like many urban watersheds, bacteria is the pollutant of concern, especially during and immediately after storms, but the sources are not just from sewers. Pets, birds, and wild animals also contribute bacteria.

Ultimately, what we do on our land affects water quality and the health of our streams. We can all make a positive impact by planting a tree, limiting the use of dishwashers and washing machines during rain events, and picking up pet waste.

MSD is committed to safe, clean waterways. This commitment is what drives us to achieve a system that is more sustainable and accessible to everyone who lives, works, and plays in our waterways. Through continued work with our stakeholders, partners and regulators, we will one day help our waterways meet water quality standards, indicating a healthy waterway. Improving water quality will allow for more uses of our waterways, such as wading, fishing and swimming, while strengthening the connection between the watershed community and the streams themselves. MSD is excited to continue working with businesses, industries, and citizens to create a cleaner, healthier and more sustainable Louisville.

Sincerely,

James A. Parrott, Executive Director

BE PART OF THE SOLUTION

Help us reduce sewer overflows and keep our waterways clean!

Plant a rain garden. They capture water runoff before it can reach storm drains, filter the runoff before it reaches waterways, support biodiversity — and look great!

Avoid using the washing machine or dishwasher during a hard rain — it can overload the sewer system.

Keep storm drains clear of leaves and yard waste. Clogged drains create standing water in neighborhoods and in streets.

Scoop the poop! Pet waste left on the ground is carried to our waterways — contaminating the very same streams that kids and pets play in.

Use rain barrels to collect and store rain water from your roof top. You can use it later on your garden or lawn and help diminish sewer overloads during heavy rain.

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EXECUTIVE SUMMARY

MSD, in cooperation with the United States Geological Survey (USGS), operates a Long-Term Monitoring Network (LTMN) to collect physical, chemical and biological data about streams in the Louisville Metro area. This State of the Streams Report is focused on the conditions of fish, aquatic insects, algae, stream habitat, bacteria, nutrients, total suspended solids (sediment in water), copper, dissolved oxygen, and water temperature of the streams in our community, and whether or not these are improving. Data has been collected at 27 Long Term Monitoring Network sites since 1999. This information helps MSD make decisions about where to focus efforts and understand the status of water quality of streams in the region.

The health of aquatic communities (fish, insects and algae) in streams can be compromised by one or more factors associated with urban streams:

- Overflows from sewer systems
- Significant and rapid runoff from impervious (hard surfaced) areas
- Stream bank erosion due to increases in runoff
- Sediment that covers habitat needed by fish and aquatic insects
- Channel modifications such as straightening and shoring up with concrete or stones can contribute to erosion elsewhere in the stream
- Lack of rocks and boulders in the stream bed that create cascades and ponding areas where fish and aquatic insects can live
- Insufficient vegetation along the banks that provide shade, food, and stability
- Periods of very low flow, high temperatures, or low dissolved oxygen which is harmful to fish

Some of these factors can't be controlled, like low flows due to dry spells or high temperatures, but many things can be done to make improvements in water quality. The MSD Urban Reforestation Program plants on average 1,000 trees annually by working with local businesses, municipal organizations and neighborhood associations. By planting more trees, MSD not only absorbs stormwater but also reduces erosion and flooding, provides shade, reduces noise pollution and carbon dioxide in the air, and provides a habitat for nearby wildlife. MSD has also spent over $42 million on green infrastructure projects to reduce combined sewer overflows and increase infiltration of stormwater. These projects include rain gardens, infiltration basins, bioswales, and pervious pavers. Since 2005, MSD has also been working on a plan to reduce and mitigate the effects of combined sewer overflows and to eliminate sanitary sewer overflows and other unauthorized discharges to meet MSD's Consent Decree. This long-term plan will be carried out through 2035 and includes large projects, such as the Waterway Protection Tunnel and Paddy's Run Flood Pumping Station rehabilitation.

There are also things that individuals can do on private property, like minimizing the use of lawn chemicals, picking up after their dog, leaving a buffer along the banks of streams and planting trees, especially along streams.

The charts on the next page reflect analyses of data as far back as 1999. They tell us that:

- In 2020, algae and fish conditions at more than half the sites were good to excellent. Stream and aquatic insect conditions at most sites were classified poor / very poor to fair.
- Trends in fish and aquatic insects and stream habitat health indicate that about half of the sites were improving or had no trend.
- Condition of the stream habitat and algal communities at most sites either had no trend or were declining over time.

MSD also collects things like bacteria, nutrients and copper that can affect water quality, and physical measures of water quality, like stream temperature and dissolved oxygen.

- Bacterial conditions at most sites are a concern. Escherichia coli (*E. coli*) bacteria which is found in human and warm blooded animal waste can cause illness and disease if it enters the body through the mouth, nose, ears or cuts in the skin. This is more likely to happen during the recreational season (May 1 through October 31) when people spend time in streams, lakes, and rivers. 18 of the 27 Long-Term Monitoring Network sites had levels greater than the instantaneous recreational standard of 240 colonies/100ml. Due to the change of sampling *E. coli* instead of fecal coliform, data is not available to establish a trend.
- Copper samples rarely (about 2% of over 430 analyses) exceed the criteria for aquatic life, and therefore are not a large issue of concern.
- Oxygen is a necessary element for all forms of life, including fish and other aquatic life forms. Eight sites had a poor status for dissolved oxygen, 15 were good and four sites do not have data.
- 18 sites of the 23 gaged sites met water temperature standards of being no more than 31.7 °C (89.1 °F) 100 percent of the time and all sites were within acceptable ranges.

In general, we've found that streams within urban sections of our community have poorer results, especially in the lower sections of the watersheds. A variety of things contribute to the poorer

water quality, but bacteria is the pollutant of concern. As MSD continues to address sewer overflows, this is expected to improve. The challenge will be to implement projects and programs, along with cooperative agreements with others that will show tangible improvements.

The bacteria that are sampled, *E. coli*, is derived from warm blooded animals and are not all from human sources. During and shortly after rainfall events, bacteria concentrations tend to be much higher and from a broader range of sources, including wild animals, pets, and birds as well as collection system issues that have not yet been addressed. MSD continually looks for potential sources of this bacteria to attempt to pinpoint bacteria hotspots during wet and dry weather. It will be a challenge to both identify and rectify sources of bacteria other than sewers. Bacterial conditions at most sites during higher flows are especially a concern.

Since the last State of the Streams Report in 2016, MSD started pursuing Section 319(h) non-point source grant funding from the United States Environmental Protection Agency to develop watershed plans that characterize non-point source pollution and then develop projects to reduce the non-point source pollutants. The first watershed plan was initiated within the Middle Fork of Beargrass Creek and a second watershed plan is being developed in the Mill Creek Watershed. Watershed planning provides communities with an iterative planning mechanism to manage non-point source pollutants like bacteria, sediment, and nutrients (fertilizers) that can runoff to streams, lakes and rivers causing pollution. Stream conditions, land use practices, and other data collected within the watershed help biologists, engineers, planners, government officials, and community members better understand the needs and identify potential projects and best management practices that can be developed to improve water quality conditions within the watershed. Watershed-Based Plans describe some of the larger water quality issues facing each watershed, present the results of water quality monitoring efforts aimed at identifying the sources and levels of non-point pollution, and outline potential efforts to address these issues.

For additional details on individual watersheds, please refer to the appropriate chapters in this report.

LONG-TERM MONITORING NETWORK SUMMARY

2020 Status Category	Fish	Aquatic Insects	Algae	Stream Habitat	Dissolved Oxygen [1]	Water Temp [1]	*E. coli* Median Concentration > Standard	Nitrate	Total Kjeldahl Nitrogen	Total Suspended Solids
Excellent [2]	11 sites	0 sites	9 sites							
Good	5 sites	3 sites	13 sites	6 sites	15 sites	23 sites	9 sites	14 sites	21 sites	16 sites
Fair	9 sites	7 sites	3 sites	7 sites	8 sites	0 sites	11 sites	4 sites	6 sites	7 sites
Poor / Very Poor	2 sites	17 sites	2 sites	14 sites	0 sites	0 sites	7 sites	9 sites	0 sites	4 sites

[1] Four sites have no data for this parameter.
[2] Excellent is a cateogy for fish, algae, and aquatic insects only.

Trend Category	Fish [1]	Aquatic Insects [1]	Algae [1]	Stream Habitat [1]	Dissolved Oxygen [2]
Improving	24 sites	11 sites	7 sites	5 sites	0 sites
No Trend	1 site	5 sites	13 sites	13 sites	23 sites
Declining	2 sites	11 sites	7 sites	9 sites	0 sites

[1] Oldest to 2020
[2] 2016 to 2020; Four sites have no data for this parameter.

INTRODUCTION

ABOUT THE METROPOLITAN SEWER DISTRICT (MSD)

MSD stream sampling at Harrods Creek

MSD's mission is to provide quality wastewater, stormwater and flood protection services to protect public health and safety through sustainable solutions, fiscal stewardship and strategic partnership. Each service is an important part of providing safe, clean waterways for our community.

WASTEWATER TREATMENT

Wastewater treatment occurs at our five Water Quality Treatment Centers (WQTCs). Jefferson County contains 790 miles of streams, 130 miles of improved channels and 38 miles of Ohio River shoreline—all of which are part of the following watersheds discussed in this report. About 153 million gallons of wastewater is treated, and then released back into our local waterways every day.

Most of Louisville Metro is now served by separate sanitary and stormwater systems. Sanitary sewers are intended to carry only wastewater, with no stormwater or groundwater, but these systems deteriorate as they age and may allow clear water to enter the pipes. In some areas, downspouts and sump pumps are connected to the system. During rain events, these lines, similar to the combined system can become overwhelmed, resulting in overflows.

MSD is currently under a federal Consent Decree to improve area waterways, protect public health, and enhance the community's quality of life. To help meet the Consent Decree, MSD prepared a plan to reduce and mitigate the effects of CSOs, and to eliminate SSOs and other unauthorized discharges. This long-term plan will be carried out through 2024, at an estimated cost of $1.15 billion.

STORMWATER DRAINAGE & MANAGEMENT

In 1986, MSD took over responsibility for stormwater management in Jefferson County except in some of the fourth-class cities. Today, the cities of Anchorage, Jeffersontown, Shively and St. Matthews provide most of those services within their borders, and the cities partner with MSD on other aspects including review of new development plans and water quality reporting.

Stormwater contains pollutants that come from areas developed by people, and those pollutants effect our community's water quality. The amount or volume of stormwater that runs off of urban and suburban areas is often greater than the amount of stormwater that runs off forests and farms. Buildings, rooftops, roads and driveways are made of solid, impervious surfaces, so stormwater runs off these areas. In forests and on farms, trees, plants, crops and natural soils allow stormwater to soak into the ground, so less stormwater runs off. As the amount of stormwater runoff increases, so does the amount of pollution it picks up.

The Clean Water Act regulates stormwater discharges and identifies water quality standards for bodies of water that receive stormwater runoff. Management of stormwater in the community is regulated through a Municipal Separate Storm Sewer System (MS4) permit, which requires periodic reporting on water quality in local streams through a network of monitoring sites. MSD's MS4 program is permitted by the Kentucky Division of Water (DOW). The latest MS4 Permit was issued with an effective date of February 1, 2017, for a term of five years.

FLOOD PROTECTION

MSD maintains Louisville Metro's Ohio River Flood Protection System—keeping the river at bay and out of the city. The system protects more than 200,000 people, 137,000 structures, and $34 billion in property throughout 110 square miles of Louisville Metro. It includes 26.1 miles of floodwall and earthen levee, 16 flood pumping stations, nearly 150 floodgates and 79 floodwall closures.

Where creeks and storm drains pass through the floodwall, gates can be closed to keep the river from flowing up the streams, and large pumps at the flood pumping stations lift the water from the creeks and pump it into the river. Additional gates and pumping stations keep the river from backing up through storm drains and pipes, pumping the stormwater into the river.

The U.S. Army Corps of Engineers built the system after the city's two highest floods of record in 1937 and 1945. MSD has been responsible for the Flood Protection System since 1987.

WATERSHED PROJECT SPOTLIGHT

STREAM RESTORATION

MSD works with partners to utilize nature-based solutions to address sedimentation and non-point source pollution, often found from failing stream banks and deteriorating habitats along stream corridors. An example of this kind of effort is the South Peterson environmental restoration project which was originally part of MSD's Stormwater Separation Project at CSO 125.

GREEN INFRASTRUCTURE

Capturing and treating stormwater before it reaches streams and sewers reduces pollution in waterways. In combined sewer areas, it helps to lessen sewer overflows by keeping rainwater from entering the system. MSD builds and promotes green installations that reduce stormwater runoff and administers regulations that require green installations for development disturbing an acre or more.

MSD's Green Infrastructure Program locates, builds or incentivizes opportunities for green installations. This lessens the need and cost of additional infrastructure like storage tanks, large pipes and treatment facilities. It also decreases sewer overflows and treatment facility stress. These cost-effective solutions not only save MSD customers money, they improve local waterway quality.

South Peterson environmental restoration project

Just a few of these green infrastructure solutions are:

- Green roads and alleys
- Permeable pavers
- Rain gardens, constructed wetlands, green basins, bioswales, and other nature based solutions

Additional information on MSD's green infrastructure efforts can be found at louisvillemsd.org/Green.

INTRODUCTION

THE LONG-TERM MONITORING NETWORK

Fish are collected using a common scientific survey method known as electro-fishing. Electricity is used to stun fish before they are caught. This method is used to sample fish populations and normally the fish are returned to the stream unharmed in as little as ten minutes after being stunned. One person operates the equipment that stuns the fish while others catch the stunned fish with a net and place them in a bucket of stream water. The fish are identified and then returned to the stream.

MSD has developed a Stormwater Quality Management Plan (SWQMP)—a roadmap for stormwater management activities to comply with the MS4 permit. The SWQMP is reviewed every year and updated annually if needed. The Stormwater Quality Program permit and plan are based on eight program areas designed to improve stormwater quality.

1. **Public Education, Outreach, Participation and Learning Experiences**
2. **Illicit Discharge Detection and Elimination**
3. **Industrial Program**
4. **Construction Site Stormwater Runoff Control**
5. **Long-Term (Post-Construction) Stormwater Runoff Control**
6. **Good Housekeeping/Pollution Prevention Program**
7. **Monitoring**
8. **Performance Assessment and Reporting**

MSD and the USGS began monitoring water quality and stream flow throughout the Jefferson County area in 1988 through what is referred to as the Long-Term Monitoring Network (LTMN). The LTMN has changed over the years and currently includes 27 monitoring sites. The monitoring sites were selected to represent streams in each of eleven watersheds. MSD collects and analyzes the information in accordance with standards set by the EPA and the DOW. A Quality Assurance Project Plan has been implemented to ensure high quality data for all these collection and analysis methods. MSD collects over 3 million individual water quality records each year. Monitoring results are summarized on an annual basis in the Stormwater MS4 Annual Report as part of the Monitoring program area, and complete data are provided electronically annually to the DOW.

The permit also requires a trend analysis to support long-term assessments of local waterways. This State of the Streams report that summarizes water quality trends is a part of that reporting effort. This report looks at several different criteria to assess how the streams and their watersheds are doing. Some of the criteria that we use are identified in the MS4 permit. They are mostly related to bacteria, chemicals and metals. But we also look at conditions in the streams that either support, or hamper, other living organisms like fish, algae and macroinvertebrates. They are good indicators when it comes to the health of the streams.

Tools to Measure Stream Health		
Biological Communities and Habitat Assessments	**Stream Samples**	**Water Quality and Flow Meters**
Sample every 2 years	Sample at least quarterly	Meter reading every 15 minutes
• Fish • Aquatic • Insects • Algae • Habitat	• Bacteria • Nutrients • Suspended solids • Ammonia • Metals	• Dissolved Oxygen • Water Temperature • Stream Flow • pH • Specific Conductivity

The above dataset was used to assess current stream health (status), and by looking at data collected over time, we can tell whether streams are getting better, staying the same or getting worse (trend). Together, status and trends tells us where streams are doing well and where they are not. This information could be used to focus on better understanding the factors that are affecting the streams and identifying measures that can be undertaken by MSD and all of us to better protect and improve our streams.

BIOLOGICAL SAMPLES AND HABITAT ASSESSMENTS

MSD has been collecting biological samples since 1999, but it is not enough just knowing whether some of these organisms live in the waters. We need to know about their biological communities - what kinds (species) are there, how many of each, and if they are healthy. These biological communities help us to understand overall stream health because they live in the water for weeks (algae) to months (insects) to years (fish). Over that time, they are affected by water quality, stream flow, and habitat quality. Some species require clean water and good habitat to thrive and reproduce, while other species are tolerant of less ideal conditions. By knowing what kinds and how many fish, aquatic insects, and algae are there, we can tell whether a stream is healthy or not.

The DOW developed metrics to evaluate fish, aquatic insect, and algal communities in Kentucky. The US Environmental Protection Agency developed habitat assessment metrics. Individual metrics are combined into a score for each community and habitat assessment. The scores are used to assign narrative ratings of excellent, good, fair, or poor biological condition. Habitat is rated as good, fair, or poor. The ratings are scaled based on the region of Kentucky in which the stream is located and whether the stream is a small headwater or larger wadeable stream. Trends are based on comparisons of the oldest data versus the current data expressed as a percentage of the average results.

Over the past decade, MSD was collecting biological data every two years. For the purposes of this State of the Stream report, it should be noted that due to drought conditions in 2019, fish and algae were collected in 2020 while the aquatic insects were sampled early in the 2019 recreational season.

Fish

Fish are used as biological indicators in streams because of their stable populations. They are the most mobile of the three communities, moving to areas most suitable for their growth and survival as needed. MSD collects fish community samples every two years using methods developed by the DOW. Biologists use electro-fishing equipment to stun the fish, collect them in nets, identify them and return them to the streams. Some of the fish found in Louisville Metro streams are shown on the next pages.

Aquatic Insects

Many insects spend the early parts of their lives in water, including dragonflies, mayflies, damselflies and others. MSD collects aquatic insect community samples every two years using methods developed by the DOW. Biologists use D-frame dip nets to collect the immature (larval) forms of insects that live in the gravel and other habitats in the bottoms of streams. The aquatic insects are sent to a laboratory and identified by biologists looking through a microscope.

Algae

Algae is a natural part of our streams and are a food source for some aquatic insects and fish. Algal communities change in response to changes in stream nutrient concentrations, sunlight, and the amount of sediment. MSD collects algal community samples every two years using methods developed by the DOW. Biologists attach ceramic tiles to the stream bottom and leave them in place for at least 15 days. During this time, algae grow on the tiles. The tiles are frozen and sent to a lab where biologists identify and count the algae from the tiles using microscopes.

Stream Habitat

Stream habitat is a way of describing the "neighborhood" in which the fish, aquatic insect and algal communities live. Fish, aquatic insects, and algae must rely on their local environment for food and shelter. These creatures thrive in streams that have shallow and deep areas, fast and slow water, and places with plenty of rocks and shade. Streams with eroding banks, large deposits of silt and sediment, straightened stream channels and limited shade tend to be populated with biological communities that can tolerate poorer habitats.

STREAM SAMPLES

Water samples are collected from LTMN sites at least quarterly and analyzed in MSD's laboratory for bacteria, oil and grease, nutrients such as nitrogen, ammonia, total suspended solids (sediment in the water) and metals. Trends for oil and grease were not analyzed for this report. Each of these water quality measures is described below.

Bacteria

Bacteria and viruses that live in the water and on the bottom of streams are natural and have an important role in breaking down natural wastes such as leaves, in healthy streams. However, some types of bacteria and viruses from human and animal wastes can lead to unhealthy conditions. *E. coli* bacteria indicate the presence of fecal material from human and animal wastes. Fecal material can get into streams from sewer overflows or leaks in the sewer collection system pipes, failing septic systems and wastes from pets, wildlife, and livestock.

The DOW has established water quality criteria for Escherichia coli bacteria to reduce the risk of infection for people using the water. The criteria require collection of at least five stream samples each month during the May 1 through October 31 recreation season, when people are more likely to be in the water. The Kentucky standard identifies an instantaneous recreational standard of a maximum of 240 colonies/100ml.

Biologist using a D-frame dip net to sample aquatic insects in a stream riffle

Biologist placing ceramic tiles for collecting algae in the Middle Fork of Beargrass Creek

Nutrients and Suspended Solids

Algae depend on nutrients such as nitrogen and phosphorus for growth. The algae, in turn, are a food source for some aquatic insects and fish. Too many nutrients can cause nuisance algal blooms that reduce habitat quality and the amount of dissolved oxygen in the stream. Nutrients can get into streams when rainwater carries fertilizers from lawns, golf courses and farms from the land to the water. MSD's WQTCs are required to limit the amount of phosphorus in treated wastewater discharges, so these facilities are no longer a major source of phosphorus.

Streams that run clear when flows are normal can look muddy during and after storms. The mud can settle out on stream bottoms and cover algae and gravels used by aquatic insects and fish. Measuring the amount of suspended solids gives us information about how much soil and sediment is suspended in the water. Streams can become muddy if the banks are eroding or if bare soil is washed from land to streams during storms. MSD's Stormwater Program requires developers to minimize the amount of bare soil on construction sites and to put controls in place to keep it from washing off site during construction.

MSD monitored concentrations of nutrients (total nitrogen, nitrate) and suspended solids in streams periodically from 2000 to 2005 and quarterly from 2006 to 2020. From 2012 to 2015, samples were also collected five times per month between May and October in addition to the quarterly collections between November and April. For this report, 2016 to 2020 data for each site were compared to the range of concentrations from all sites. This approach was used because Kentucky, like many other

BIOLOGICAL COMMUNITY AND HABITAT ASSESSMENT METRICS*

Assessment	Metrics	
Fish Community	• Number of native species. Non-native species are used as indicators of impairment • Number of darters, madtom and sculpin, and other intolerant species (require good water and habitat quality) • Number of species that require relatively clean gravel for spawning (good habitat quality)	• Percent of individuals that feed on aquatic insects, excluding tolerant species • Percent of pollution tolerant species that increase due to poor water quality and poor habitat • Percent of species that are not typically found in small headwater streams
Aquatic Insect Community	• Measure of pollution tolerant and intolerant aquatic insects (Modified Hilsenhoff Biotic Index) • Number of all classifications found, also known as taxa richness (more is better) • Percent of organisms that require hard, silt-free surfaces on which to "cling" (good habitat quality) • Percent of midges and freshwater worms, which are generally pollution tolerant	• Number of mayfly, stonefly and caddisfly classifications (species that require good water and habitat quality) • Percent of mayfly, stonefly and caddisfly classifications excluding the relatively tolerant caddisfly genus Cheumatopschye (species that require good water and habitat quality) • Percent of mayfly larvae (only in small headwater streams) (species that require good water and habitat quality)
Algal Community	• Number of species that are not tolerant of silt and sediment (good habitat quality) • Number of different species and how evenly distributed they are (Shannon Diversity Index) • Number of diatom taxa (also known as taxa richness) (more is better)	• Percent of pollution tolerant species that increase due to poor water quality (Pollution Tolerance Index) • Percent of individuals that are in the Fragilaria group (species that require good water and habitat quality) • Percent of individuals that are in the Cymbella group (species that require good water and habitat quality)
Habitat Assessment	• Amount and variety of stable habitat, such as gravels, logs, and undercut banks, that provide habitat, food, and spawning sites (more is better) • Extent that gravels, logs and other habitats are covered or sunken into the silt, sand, mud (less covered in sediment is better) • Presence of 1) slow-deep, 2) slow-shallow, 3) fast-deep and 4) fast-shallow habitats (presence of all four is ideal) • Amount of sediment accumulated in pools and changes to the stream bottom due to sediment deposits (less is better) • Degree to which the channel is filled with water (average flow is better)	• Extent of changes to the stream channel such as straightening, artificial bank stabilization, dams, and bridges, dredging, etc. (less is better) • Distance between riffles (rocky places) in a stream. Riffles provide food, shelter, and add dissolved oxygen to water (more riffles are better) • Extent of actual or potential bank erosion on each stream bank (less is better) • Amount of native trees, shrubs and other vegetation that helps protect banks from erosion (more is better) • Width of natural vegetation from the edge of the stream bank. At least 54 feet is an ideal condition.

* *The Kentucky Division of Water developed metrics to evaluate fish, aquatic insect, and algal communities in Kentucky. The US Environmental Protection Agency developed habitat assessment metrics. Individual metrics are combined into a score for each community and habitat assessment. The scores are used to assign narrative ratings of excellent, good, fair, or poor biological condition and good, fair or poor habitat quality. Ratings are scaled based on the region of the Kentucky in which the stream is located and whether the stream is a small headwater or larger wadeable stream.*

Creek chub is a species of minnow that can grow to 10 inches and is tolerant to a wide variety of water conditions.

The diet of the colorful longear sunfish generally includes aquatic insects and small fish.

Top to bottom: greenside, banded, and rainbow darters are very sensitive to pollution and silt.

states, does not have numeric criteria for nutrients or suspended solids. The following thresholds were used:

Total Nitrogen: 0.9 milligrams per liter
Nitrate: 1.32 milligrams per liter (parts per million)
Suspended Solids: 12 milligrams per liter

Sites were classified as good, fair, or poor for nutrients and suspended solids based on the percent of samples above the thresholds:

Good: Less than 29% above the threshold
Fair: Between 29% and 48% above the threshold
Poor: More than 48% of samples above the threshold

Trace Metals

Very small (trace) amounts of metals are necessary for the healthy growth of algae, aquatic insects, and algae. However, if the concentrations are too high, metals can cause "chronic" effects such as shortened lifespans and reproductive problems and "acute" effects by killing these organisms. MSD's LTMN monitoring is focused on copper. Copper may be found in streams affected by historical industrial pollution and can wash off industrial facilities and urban areas. Copper is also used to treat excess algae in ponds.

MSD monitored concentrations of copper in streams periodically from 2000 to 2004 and on a quarterly basis since 2005. Concentrations of total metals at each site were compared to the Kentucky acute and chronic Aquatic Life Criteria which were calculated with equations using total hardness concentrations. Copper samples rarely (about five percent of over 4,000 analyses) exceeded the criteria for aquatic life, and trends were not analyzed for this report.

WATER QUALITY AND FLOW METERS

MSD and the USGS use permanent water quality meters to measure dissolved oxygen, stream temperature, pH, and conductivity every 15 minutes at 24 of the 27 LTMN sites since 2000. Trends for pH and specific conductivity were not analyzed for this report. Flow gages measure the stream flow every 15 minutes at 25 of the LTMN sites. The raw (draft) water quality and flow measurements are relayed to the USGS National Water Information System (NWIS) website in real time and are available to the public. The USGS reviews and finalizes the data, then posts final data to the NWIS website. This level of effort highlights

MSD analyses of water samples

The yellow bullhead is a voracious scavenger that will eat almost anything.

Green sunfish are able to tolerate poorer water quality conditions.

Striped shiner minnows eat zooplankton, insects, plants, and algae, and are themselves food for all types of larger fish.

MSD's commitment to effectively monitor the quality and condition of streams in Jefferson County.

The data are collected using protocols developed by the USGS. It is important to note that collection of continuous dissolved oxygen data requires diligent attention to cleaning and calibrating the meters that are used to collect the readings. In some streams, the meters can become dirty or covered by silt, resulting in missing or incorrect readings. MSD has developed a Quality Assurance Project Plan with USGS to improve the maintenance of these meters. Dissolved oxygen and water temperature data collected by MSD and USGS between 2016 and 2020 were assessed for this report.

Dissolved Oxygen

Both fish and aquatic insects rely on oxygen that is dissolved in water to "breathe." When dissolved oxygen levels are too low, it causes stress on all aquatic organisms. Kentucky's water quality criteria for dissolved oxygen specify:

- Dissolved oxygen shall be maintained at a minimum concentration of five and zero tenths (5.0) mg/L as a twenty-four (24) hour average in water with warm water aquatic habitat use
- The instantaneous minimum shall not be less than four and zero-tenths (4.0) mg/L in water with warm water aquatic habitat use

Factors that can reduce dissolved oxygen include low streamflow, hot water temperature, lack of shade, excessive algae, and organic pollution.

For this report, the average daily dissolved oxygen concentration was calculated from readings collected at 15-minute intervals. Days with more than half of the data available were included in the analysis. Results for the most recent three years of data (2018 to 2020) were grouped into rating categories based on the percent of days when average dissolved oxygen concentrations were above five parts per million.

Good: 90 percent of days above five parts per million
Poor: Less than 90 percent of days above five parts per million

Trends were based on a comparison of the data from 2016 to 2020. The percent change in number of days with dissolved oxygen above five parts per million was used to evaluate trends.

Water Temperature

High water temperatures can stress the aquatic communities by increasing metabolism and respiration, and by lowering the capacity of water to hold dissolved oxygen. The Kentucky water quality criteria for a maximum water temperature in a day is 31.7 °C (89.1 °F).

Days with more than half of the data available were included in the analysis. The maximum daily temperature was identified for each day using the 15-minute water temperature readings. The average number of days for 2016 to 2020 with water temperature above the 31.7 °C criteria was calculated and used to classify LTMN sites as follows:

Good: 100 percent of days below 31.7 °C
Fair: 90 percent of days below 31.7 °C
Poor: Less than 90 percent of days below 31.7 °C

WATERSHED REPORTS

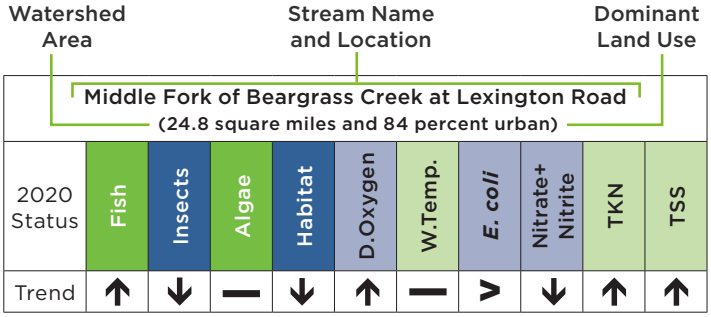
MSD tracks and monitors water quality in eleven defined watersheds in Jefferson County, Kentucky (see map at right). Two of the streams (Harrods Creek and Floyds Fork) have their headwaters in other counties and flow into Jefferson County. About a quarter of the Pond Creek Watershed lies in Bullitt County, and that water enters the main stem of the creek near the southwestern tip of Jefferson County.

MSD has been collecting stream samples from these watersheds for decades, along with a watershed that lies entirely in Bullitt County. Cedar Creek in Bullitt County was included in MSD's sampling program to act as a "control" because there is relatively little development in the watershed and impervious surfaces (roads, parking lots, roofs, etc.) are minimal when compared to the eleven other watersheds.

To assess our past efforts to improve water quality, and to make decisions on future actions, samples are collected from streams and those samples are analyzed for a number of parameters, including bacteria, suspended solids, oxygen demand, nutrients, metals and more. This report utilizes stream samples that were collected through December, 2020.

MSD also evaluated habitats in the streams for a variety of organisms like fish, algae and aquatic insects. This information is compared to previously collected data and compiled into reports for each watershed. The results are presented on the following pages in this section. In addition to the results provided, information about the Ohio River monitoring program is also included.

An example of the results for the Middle Fork of Beargrass Creek at Lexington Road is presented here to explain how to interpret the information presented in each graph. The color coding in each parameter box refers to its **status** for 2020. Bright green for fish indicates the stream is in excellent condition for that parameter, light green is good, light blue is fair, and dark blue indicates the insect community is in poor condition. The **trend** is based on a comparison of the initial baseline conditions to the 2020 conditions. For example, Dissolved Oxygen is in fair condition (light blue) based on the assessment in 2020, but the 2020 numerical score is more than 4% higher than the initial assessment that was obtained in 2015 and so, Dissolved Oxygen conditions are improving over time.



Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

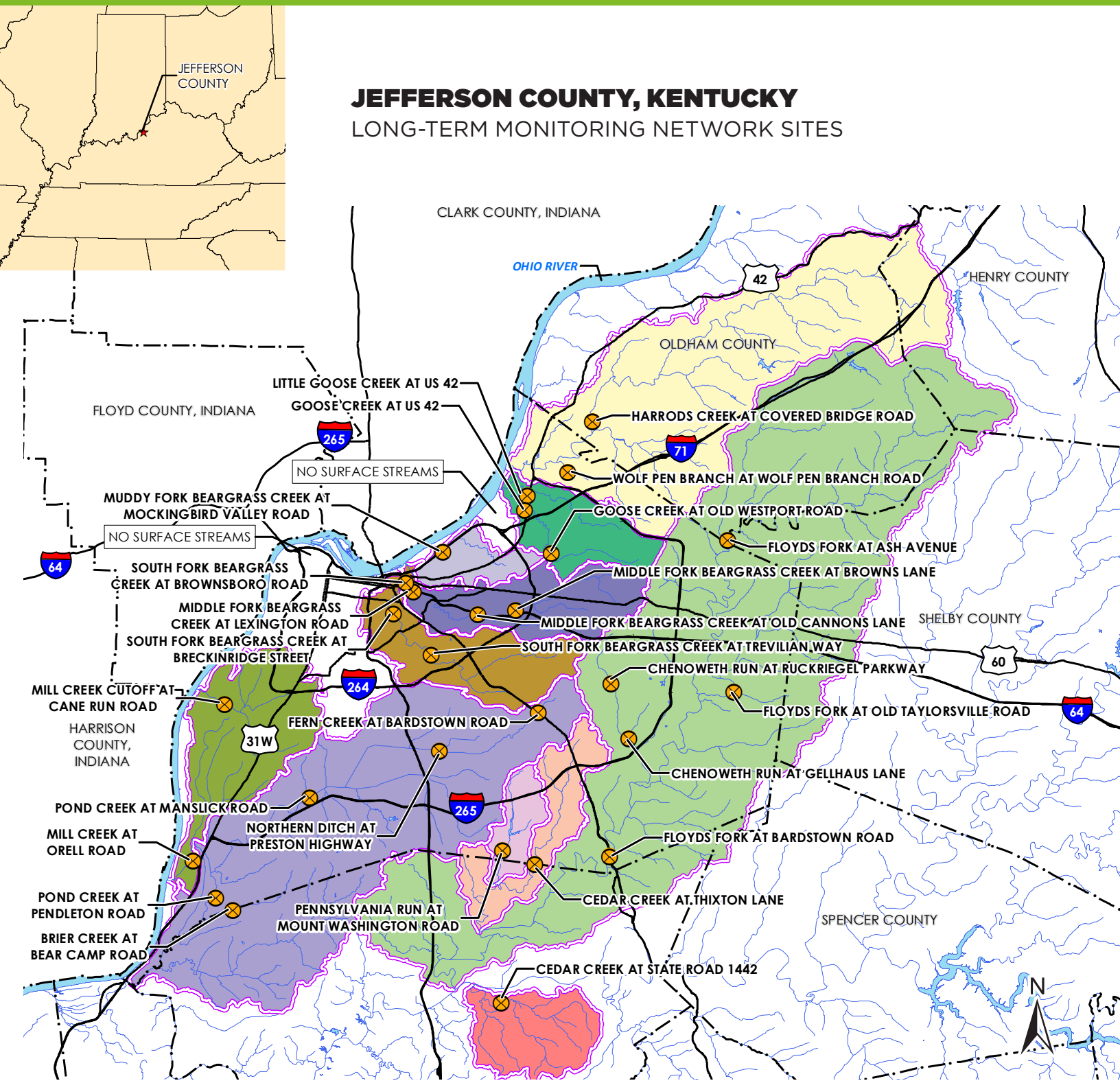
- Improving
- Declining
- Varies
- No Change
- ND No Data

- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

Waterfall on Big Run, along the Glenmary Golf Course in Southeastern Jefferson County

JEFFERSON COUNTY, KENTUCKY

LONG-TERM MONITORING NETWORK SITES



Legend

- Monitoring Site
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Watersheds

- Harrods Creek
- Goose Creek
- Muddy Fork of Beargrass Creek
- Middle Fork of Beargrass Creek
- South Fork of Beargrass Creek
- Floyds Fork
- Cedar Creek
- Pennsylvania Run
- Pond Creek
- Mill Creek
- Cedar Creek (Bullitt County)

HARRODS CREEK WATERSHED

Hite Creek

The small streams that eventually form Harrods Creek originate in Henry County. Harrods Creek flows southwest through Oldham County and drains into the Ohio River in northern Jefferson County near Prospect. The Harrods Creek watershed drains approximately 92 square miles. Commercial and residential development has been expanding in the area.

BACKGROUND AND LAND USE

The 180 square mile Harrods Creek Watershed is located in northeastern Jefferson County, Oldham and Henry Counties. Its headwaters originate in the area east of LaGrange, Kentucky, approximately 17 miles beyond the Jefferson County border. The creek flows generally to the southwest, converging with South Fork Harrods Creek about one-half mile outside the Jefferson County line. From this point, the flow continues southwest through Jefferson County to an outlet on the Ohio River at Guthrie Beach. Major streams in this watershed include Harrods Creek, Wolf Pen Branch, South Fork Harrods Creek, and Hite Creek.

The area is rapidly developing and most of the development is commercial and residential. The area of impervious surfaces is increasing, but a significant portion of this basin is still agricultural. Communities in the study area include Fincastle, Ballardsville, Pewee Valley, Lake Louisvilla, Worthington, and Prospect. Notable landmarks include the Ford Motor Company Kentucky Truck Plant and Hunting Creek Country Club.

A relatively high number of native species and the abundance of insectivores contributed to the "good" rating for the fish community of Harrods Creek.

MSD has monitored water quality and flow in Harrods Creek at Covered Bridge Road since 1999. There are 70.3 square miles of land draining to the Covered Bridge site. Wolf Pen Branch, a tributary of Harrods Creek, originates in Worthington area and flows northwest, merging into Harrods Creek and eventually flowing into the Ohio River. MSD has monitored water quality, but not stream flow, in Wolf Pen Branch at Wolf Pen Branch Road since 2002. There are two square miles of land draining to the Wolf Pen Branch site. This land is a mix of agricultural, forest, urban and suburban uses.

MONITORING FINDINGS

Fish Communities

MSD has monitored the fish communities in Harrods Creek at Covered Bridge Road since 1999. At Harrods Creek, the fish community rated "poor" in 2017 and "good" in 2020. There is no overall change in status over the monitoring period. A relatively high number of native species and the abundance of insectivores contributed to the "good" rating for the fish community of Harrods Creek.

Fish communities have been monitored for Wolf Pen Branch since 2002. The fish community rated "fair" in both 2017 and 2020 and is declining. Wolf Pen Branch had few total numbers of individuals collected during the 2020 survey, most likely due to the lack of cover in this section of stream due to the dominance of bedrock substrates. These low numbers, along with the abundance of pollution tolerant fish, contributed to the lower rating for the fish community of Wolf Pen Branch.

Aquatic Insect Communities

MSD monitored aquatic insect communities since 2000 in Harrods Creek. The aquatic insect communities were "fair" for Harrods Creek and "poor" for Wolf Pen Branch in 2017 and 2019. The communities for both streams are declining over time.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in the watershed since 2001. Using a Diatom Bioassessment Index (DBI), both the Harrods Creek and Wolf Pen Branch sites rated in "excellent" condition in 2017 and "good" condition in 2020. While Wolf Pen Branch showed an improvement over time, there has been relatively little change along Harrods Creek.

Stream Habitat

MSD has assessed stream habitat when fish and aquatic insects were sampled since 2005. Harrods Creek has been consistently rated as "good" with no trend. Along Wolf Pen Branch, the habitat rated as "fair" in 2017 and "poor" in 2020. Wolf Pen Branch had a "poor" habitat rating, partially due to the prevalence of bedrock substrates, and the fact that Wolf Pen Branch is very shallow resulting in sediment deposition and an unstable stream bed.

Dissolved Oxygen and Temperature

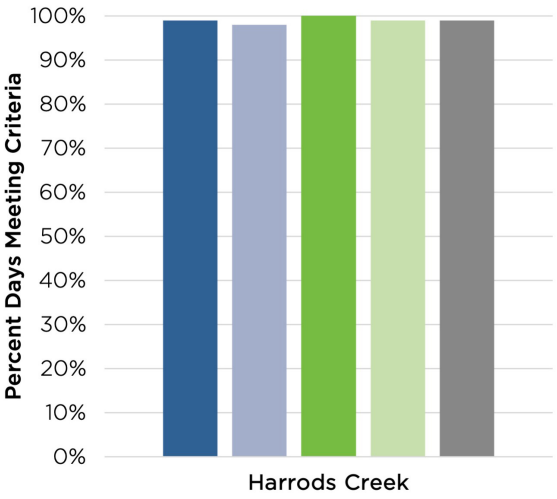
MSD and the USGS continuously monitor streamflow, dissolved oxygen, and water temperature on Harrods Creek at Covered Bridge Road (Highway 329). Streamflow has been monitored at this USGS gage (03292470) since 1999. Dissolved oxygen conditions were "good" at the Harrods Creek site from 2018-2020, which is a slight improvement since 2016. Water temperature criteria were met 100% of the time over the USGS record since 2007. Since there is not a USGS gage at Wolf Pen Branch, no data is available for dissolved oxygen and temperature.

Bacteria

MSD collected fecal coliform data until 2016. Based on the last analysis of fecal coliform, bacteria status was considered "good" or "fair" and trends were declining for both streams. Based on the current analysis of *E. coli* bacteria for the past five years of data collection, the median concentrations for both sites were below the instantaneous recreational standard of 240 colonies/100ml, however, the 2020 median values were above the recreational standard. The geometric means are shown in the chart on the following page.

Dissolved Oxygen in Harrods Creek Watershed

Water Years (October 1 to September 30)

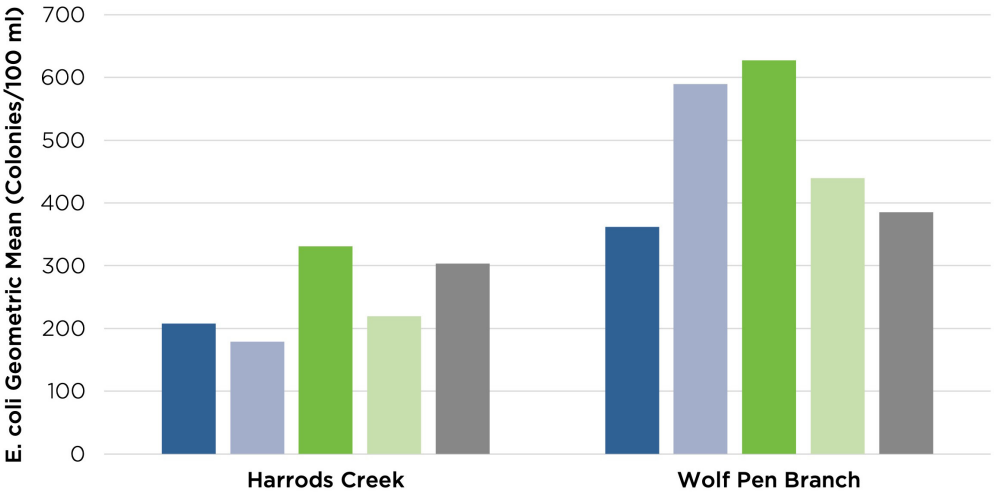


Nutrients

MSD monitored the concentrations of nutrients and total suspended solids in streams periodically from 2000 to 2005 and on a quarterly basis since 2005 at two sites in the Harrods Creek Watershed. All parameters were "good" with the exception of total Kjeldahl nitrogen at Harrods Creek at Covered Bridge Road, which was "fair." Nitrates at Harrods Creek were improving while total suspended solids and total Kjeldahl nitrogen declined. Nitrates and total suspended solids at Wolf Pen Branch were improving while total Kjeldahl nitrogen declined.

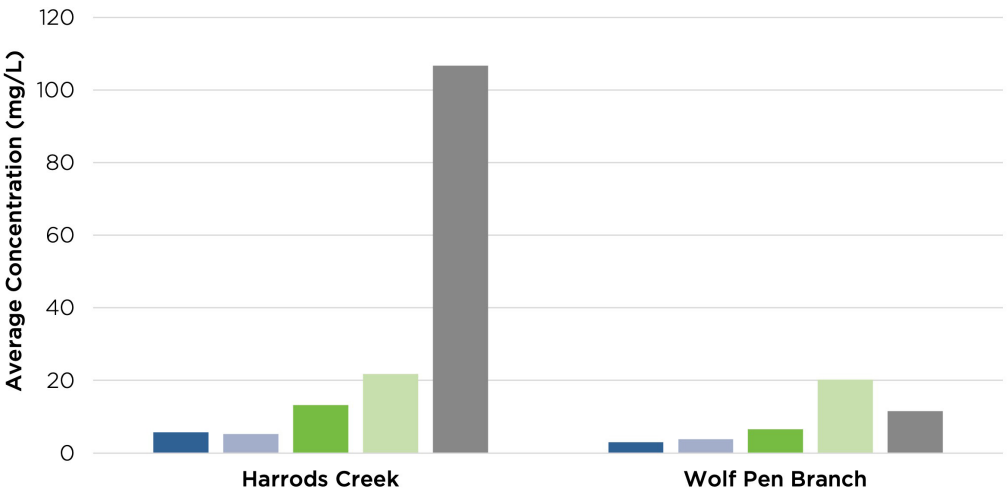
E. coli in Harrods Creek Watershed

Recreational Seasons (May 1 to October 31)

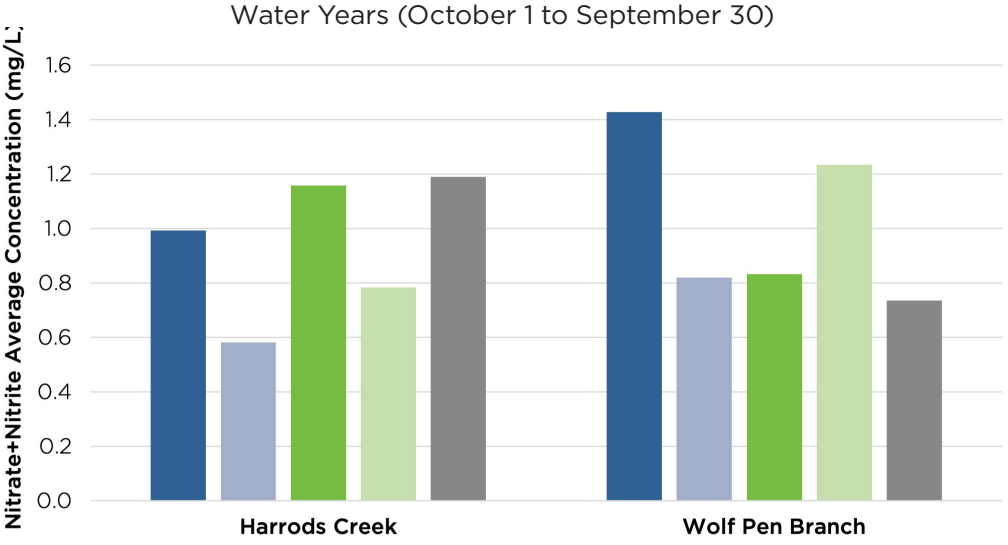


2016 2017 2018 2019 2020

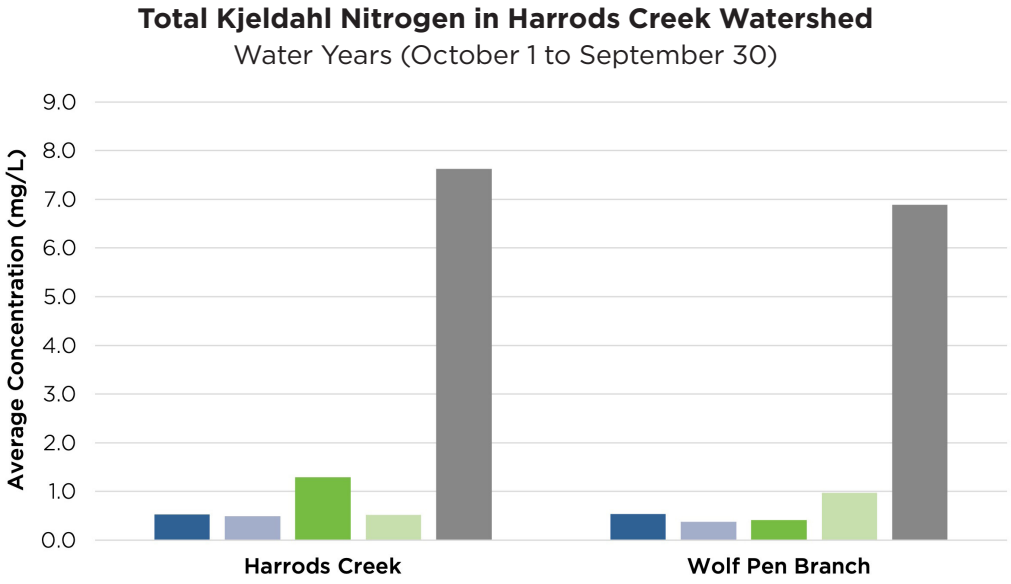
Total Suspended Solids in Harrods Creek Watershed
Water Years (October 1 to September 30)



Nitrate + Nitrite in Harrods Creek Watershed
Water Years (October 1 to September 30)



2016 2017 2018 2019 2020



WATERSHED PROJECT SPOTLIGHT

Harrods Creek Sewer Repairs

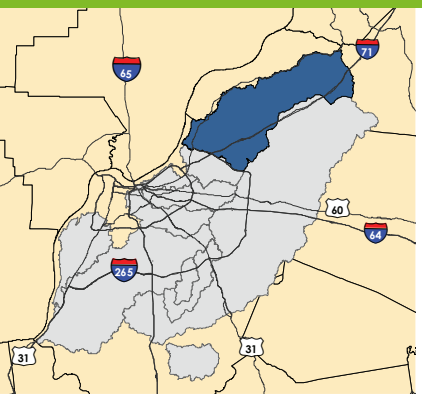
In 2019, MSD discovered a break in two sewer pipes along Harrods Creek. These breaks were causing sewage to run directly into Harrods Creek. MSD crews worked quickly to repair the breaks, but there were challenges due to the depth of the sewer and flooding from the Ohio River. Maintaining the sanitary sewer system is part of MSD's mission to provide safe, clean waterways. If you suspect a broken sanitary sewer, contact MSD's customer service at 502-540-6000.

Harrods Creek sewer repairs

Shaft to access break along Harrods Creek

WATER QUALITY STATUS AND TRENDS

HARRODS CREEK WATERSHED



Watershed area shown in blue

Ohio River

Harrods Creek

42

53

393

71

329

265

HENRY COUNTY

JEFFERSON COUNTY

SHELBY COUNTY

N

Harrods Creek at Covered Bridge Road
(70.3 square miles and 13 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate-Nitrite	TKN	TSS
Trend	—	↓	—	—	↑	—	<	↑	↓	↓

Wolf Pen Branch at 8200 Wolf Pen Branch Road
(2.08 square miles and 60 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate-Nitrite	TKN	TSS
Trend	↓	↓	↑	—	ND	ND	<	↑	↓	↑

Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

GOOSE CREEK WATERSHED

Little Goose Creek

The two streams that form the Goose Creek Watershed, Little Goose Creek and Goose Creek, flow northwest from Anchorage to Glenview Acres. Goose Creek enters into the Ohio River near Lime Kiln Lane and River Road.

BACKGROUND AND LAND USE

The 18 square mile Goose Creek Watershed is located in northeastern Jefferson County. Goose Creek's headwaters originate in Anchorage, flow in a westerly direction to the area of Westport Middle School, then turn generally northwest, and finally outlet into the Ohio River at Six Mile Island. Little Goose Creek's headwaters originate in the Freys Hill area, flow northwesterly, and eventually discharge into Goose Creek about one-half mile from its outlet on the Ohio River. The major streams are Goose Creek and Little Goose Creek.

The watershed is predominantly residential with a mix of urban, forest and some agriculture with nearly 20 percent impervious surfaces. Little Goose Creek watershed is the most developed portion of the overall watershed. Communities situated in this watershed include Anchorage, Rolling Hills, Plantation, Old Brownsboro Place, Hills and Dales, Glenview Heights, Brownsboro Farm, and Green Spring. Notable landmarks include Kentucky Country Day School, E.P. Tom Sawyer State Park, Owl Creek Country Club, Central State Hospital, Standard Country Club, and Ballard High School.

Hounz Lane Park is located along Goose Creek and provides open space and wetland areas that will be preserved. E.P. "Tom" Sawyer State Park is another park located along Goose Creek that provides open space that will be preserved. Woodland Protection Areas have also been created for the Woodstone Subdivision along Goose Creek.

MSD has monitored water quality and flow since 1999 at three stream sites in the watershed. There are two LTMN locations in Goose Creek at Old Westport Road and at US Hwy 42. There is a LTMN location at US Hwy 42 along Little Goose Creek. The Goose Creek Watershed area is currently undergoing intense development. Nutrient levels are high in this area and large nuisance populations of algae are common. The level of nutrients can be attributed to the use of lawn chemicals, agricultural activities, and the high number of septic tank systems. The introduction of sanitary sewers and the removal of small water quality treatment centers have significantly reduced the nutrient levels in the stream, especially phosphorus.

The fish communities of all sites within the Goose Creek Watershed rated "excellent" in 2017 and 2020 with the exception of Little Goose Creek which rated "good" in 2017.

MONITORING FINDINGS

Fish Communities

MSD monitored fish communities in the Goose Creek Watershed since 1999. The fish communities of all sites within the Goose Creek Watershed rated "excellent" in 2017 and 2020 with the exception of Little Goose Creek which rated "good" in 2017. The fish scores at all sites are showing improvement over the collection period. Dominance of the fish community by insectivores and low presence of tolerant species at all three sites contributed to the "excellent" ratings. Two of the sites had drainage areas that were in the 5 to 10 square mile drainage area. The health of the fish communities and stream habitat have continued to improve over time.

Aquatic Insect Communities

MSD monitored aquatic insect communities at the three sites within Goose Creek watershed since 2000. The aquatic insect communities generally were classified as "fair" at all three sites, with the exception of 2019, when Goose Creek at US 42 was classified as "poor." Overall, the aquatic insect communities along Goose Creek have declined since 2000 while there is no relative change at the site on Little Goose Creek.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in the watershed since 2001. Using a Diatom Bioassessment Index (DBI), there has been relatively little change over time at the sites on Goose Creek. Old Westport Road rated as "good" in 2017 and 2020 while conditions were rated as "excellent" in both years at US 42. Along Little Goose Creek, there has been a decline in the condition of the algal communities over the period of study, and a rating of "good" in both 2017 and 2020.

Stream Habitat

MSD has assessed stream habitat when fish and aquatic insects were sampled since 2005. Based on the latest monitoring, habitat within the Goose Creek Watershed was "good" in 2017, 2019, and 2020 with the exception of Old Westport Road, which rated as "fair" in 2020. No trends were indicated at any of the sites. Sediment deposition and unstable banks were identified in these streams as a limitation of the habitat quality. Old Westport Road is lacking somewhat in rocky riffles that are used as habitat by aquatic organisms.

Dissolved Oxygen and Temperature

MSD and the USGS continuously monitor streamflow, dissolved oxygen, and water temperature at the three sites in the Goose Creek Watershed. Dissolved oxygen criteria were met 100 percent of the time at the Little Goose Creek site (USGS gage 03292480) between 2018 and 2020 and conditions were in the "good" range at the Goose Creek sites at Old Westport Road (USGS gage 03292474) and US 42 (USGS gage 03292475). There was a slight decline in percent of days meeting the criteria at US 42 however, both the Old Westport Road site and the location on Little Goose Creek showed an improvement. Water temperature criteria were met 100 percent of the time.

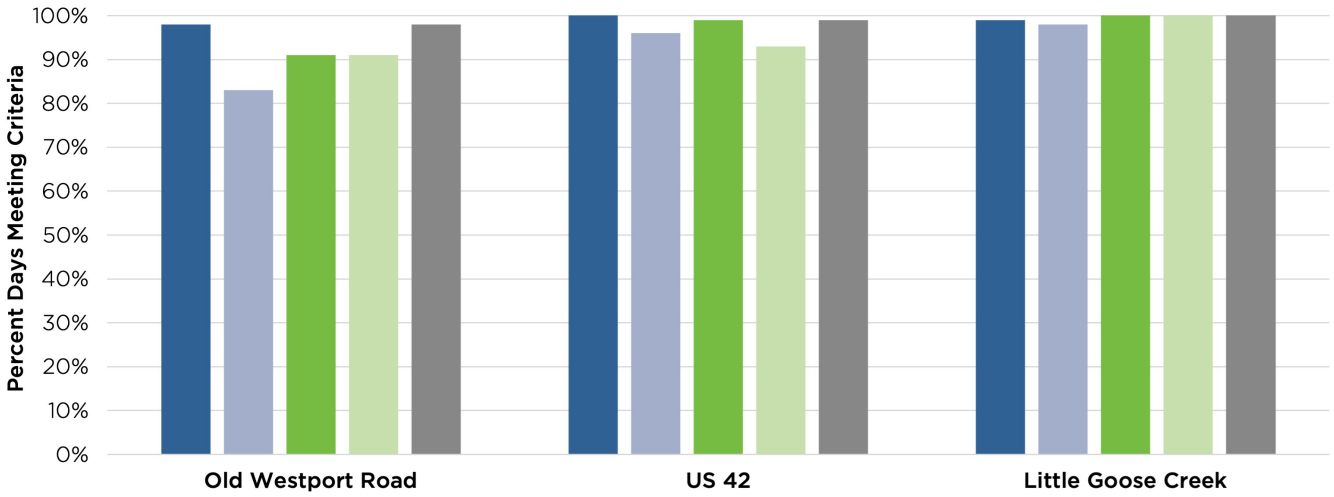
Bacteria

Based on the analysis of *E. coli* bacteria for the past five years of data collection, the median concentrations for both sites on Goose Creek were above the instantaneous recreational standard of 240 colonies/100ml and the 2020 median values were above the recreational standard. For Little Goose Creek, the five-year median concentration was below the recreational standard, however, the 2020 median value was above the standard. The geometric means are shown in the chart on the following page.

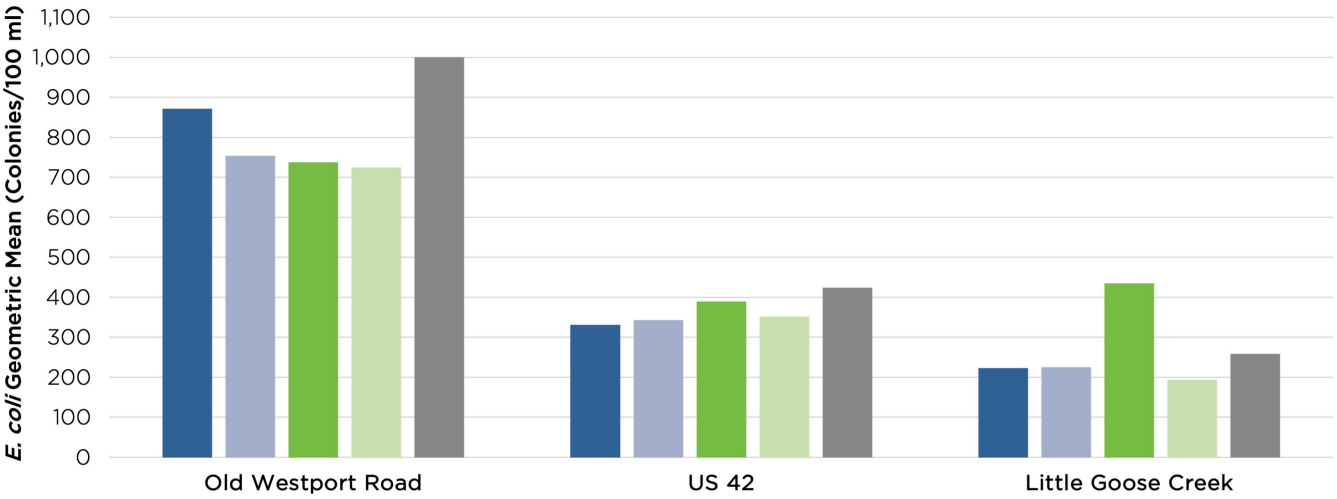
Nutrients

MSD monitored the concentrations of nutrients and total suspended solids periodically from 2000 to 2005 and, on a quarterly basis since 2005 at three sites. Total Kjeldahl nitrogen levels were all "good" while nitrate levels ranged from "fair" to "poor." Total suspended solids varied for the sites with Old Westport Road reporting "good," US 42 reporting "fair," and Little Goose Creek reporting "poor." All sites were either declining or indicated no trend.

Dissolved Oxygen in Goose Creek Watershed
Water Years (October 1 to September 30)



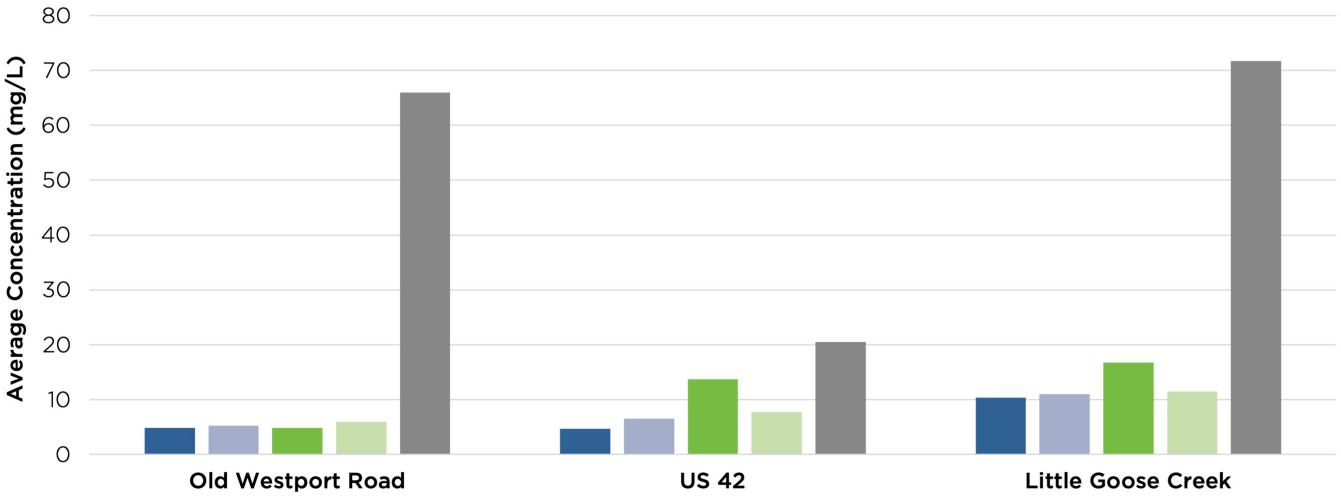
***E. coli* in Goose Creek Watershed**
Recreational Seasons (May 1 to October 31)



2016 2017 2018 2019 2020

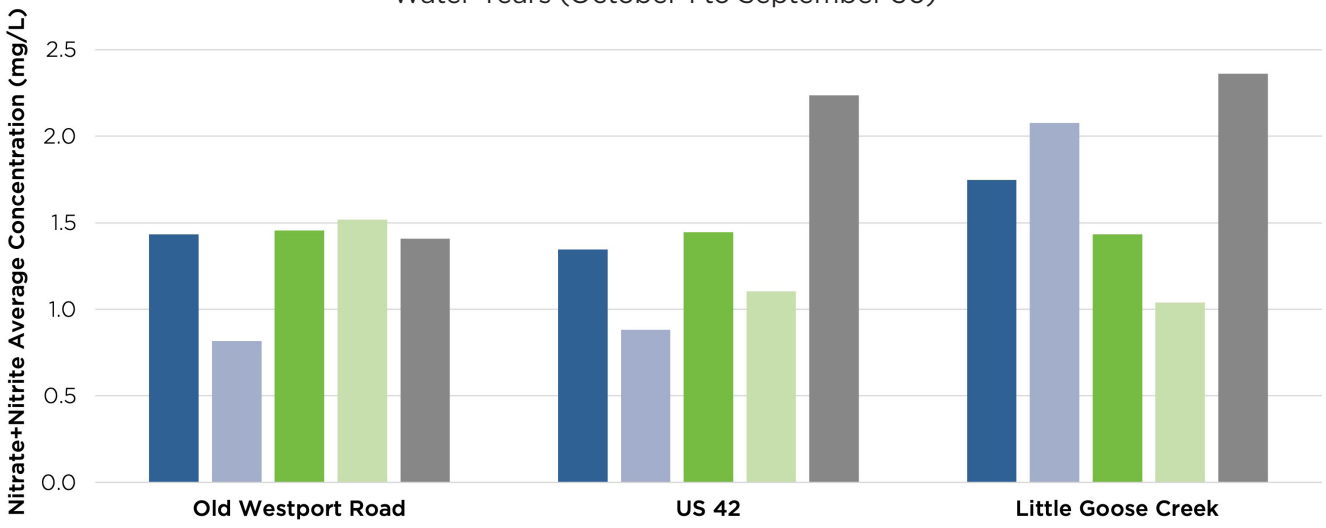
Total Suspended Solids in Goose Creek Watershed

Water Years (October 1 to September 30)



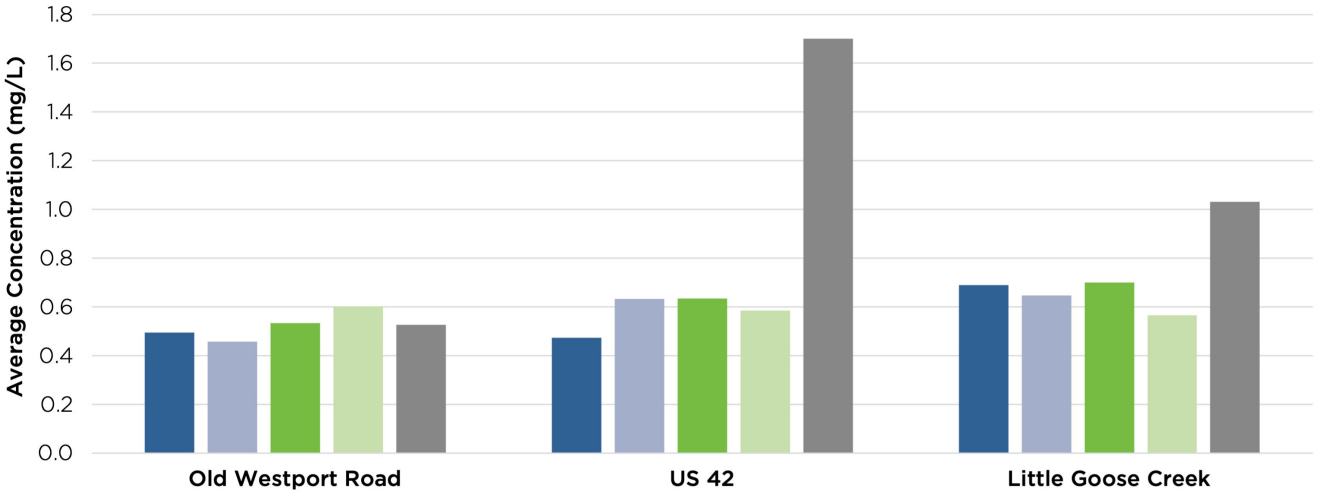
Nitrate + Nitrite in Goose Creek Watershed

Water Years (October 1 to September 30)



2016 2017 2018 2019 2020

Total Kjeldahl Nitrogen in Goose Creek Watershed
Water Years (October 1 to September 30)



WATERSHED PROJECT SPOTLIGHT

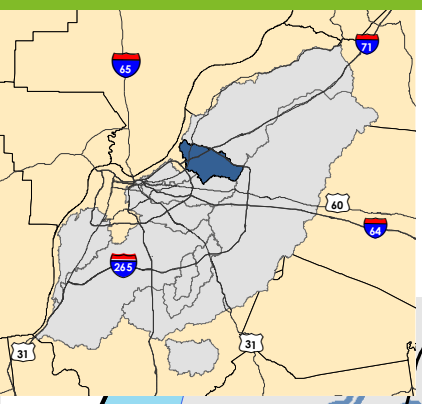
Goose Creek

Open space along streams improves water quality by creating a stream buffer to increase habitat for bugs, fish, birds and animals. Areas like Hounz Lane Park and E.P. "Tom" Sawyer State Park, which are both located along Goose Creek, provide shade for the stream, natural areas for infiltration, and wildlife habitat.

Goose Creek at Hounz Lane Park

WATER QUALITY STATUS AND TRENDS

GOOSE CREEK WATERSHED



Watershed area shown in blue

Ohio River

42

71

JEFFERSON COUNTY

265

42

Goose Creek

Little Goose Creek at US 42
(5.82 square miles and 75 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	—	↓	—	↑	—	<	↓	↓	↓

Goose Creek at Old Westport Road
(6.0 square miles and 62 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↓	—	—	↑	—	>	—	—	↓

Goose Creek at US 42
(10.1 square miles and 61 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↓	—	—	↓	—	>	—	↓	↓

N

Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

MUDDY FORK OF BEARGRASS CREEK WATERSHED

Muddy Fork of Beargrass Creek

The Muddy Fork of Beargrass Creek is one of the three streams that join to form the larger Beargrass Creek Watershed. The Muddy Fork flows west from Windy Hills toward the Ohio River, then southwest along Interstate 71 before joining with the South Fork to become Beargrass Creek near Mellwood and Story Avenues. Historically, major segments of Muddy Fork were straightened along Interstate 71 and along Mockingbird Valley Road.

BACKGROUND AND LAND USE

The eight square mile Muddy Fork Beargrass Creek Watershed is located in the north central portion of Jefferson County. Its headwaters originate in the Graymoor/Devondale area. The stream then flows northwesterly to I-71, turns to the southwest, and parallels I-71 to finally outlet into South Fork Creek Beargrass Creek just downstream of the Beargrass Creek pumping station. The only major creek running through this watershed is Muddy Fork Beargrass Creek.

Due to the intensity of development within this watershed, streams in the Muddy Fork of Beargrass Creek Watershed are true urban streams. A relatively high percentage of this watershed is impervious. Communities lying in this watershed include Graymoor, Devondale, Crescent Hill, Rolling Fields, Mockingbird Valley, Indian Hills, and Windy Hills. Notable landmarks include the Veterans Administration (VA) Hospital and Crescent Hill Park.

Due to the proximity to the Ohio River, the creek receives backwater from the river when water levels are high. There is one LTMN sampling station along Muddy Fork at Mockingbird Valley Road. There are about 6.2 square miles of land draining to the sampling site at Mockingbird Valley Road, which MSD has monitored since 2002.

There are still a number of poorly performing septic tanks in this area and a considerable level of lawn chemicals used. This combination results in moderate to high nutrient levels. High nutrients, high water fluctuations during storm events, and backwater from the Ohio River result in severe impacts on the biological communities within the streams. Fast moving stormwater scours the stream banks, causing erosion, sedimentation, and siltation, and results in the decline of water quality and habitat quality.

Overall impacts to the Muddy Fork of Beargrass Creek Watershed area are considered moderate to severe. Sewering, resulting in the elimination of septic tanks, will have a positive impact on this watershed. Revegetation of stream banks and modification of stream channels to produce reaeration zones will help to improve both habitat and water quality.

MONITORING FINDINGS

Fish Communities

MSD has monitored fish communities in the Muddy Fork of Beargrass Creek since 2002. The fish communities at the Muddy Fork at Mockingbird Valley Road site were highly variable from year to year. Conditions were "fair" in 2017 and "excellent" in 2020 and improving. The abundance of native species and insectivores, contributed to the "excellent" rating.

Aquatic Insect Communities

MSD has monitored aquatic insect communities at the Muddy Fork site since 2004. The aquatic insect communities were poor in 2017 and 2019 with relatively little change over time.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in the Muddy Fork Watershed since 2002. Using a Diatom Bioassessment Index (DBI), the Muddy Fork site was rated "excellent" in 2017 and "good" in 2020. The site showed significant decline in the condition of the algal communities over the period of study.

Stream Habitat

MSD has assessed stream habitat conditions since 2005 at the Mockingbird Valley Road site. In 2017, 2019, and 2020, the habitat of Muddy Fork of Beargrass Creek was classified as "poor" with relatively little change over time based on epifaunal substrate cover, sedimentation deposition, embeddedness, and frequency of riffles. The poor quality habitat is associated with straightening of the channel, lack of trees and other protective vegetation along the stream banks and eroding banks. These issues have contributed to silt and sediment accumulating in the stream, which covers habitats used by aquatic insects and fish.

Dissolved Oxygen and Temperature

MSD and the USGS have continuously monitored streamflow, dissolved oxygen, and water temperature on the Muddy Fork of Beargrass Creek at Mockingbird Valley Road (USGS gage 03293530) since 2002. Dissolved oxygen conditions were "good" at the Muddy Fork site from 2018-2020, which is a slight improvement since 2016. Water temperature criteria were met 100 percent of the time over the USGS record since 2007.

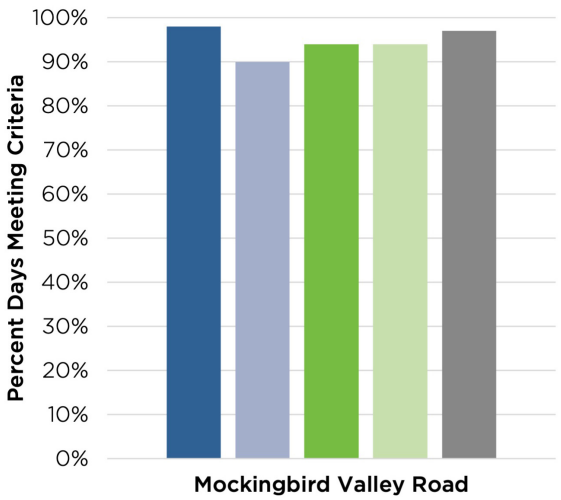
MSD has monitored fish communities in the Muddy Fork of Beargrass Creek since 2002. The fish communities at the Muddy Fork at Mockingbird Valley Road site were highly variable from year to year. Conditions were "fair" in 2017 and "excellent" in 2020 and improving. The abundance of native species and insectivores, contributed to the "excellent" rating.

Bacteria

MSD collected fecal coliform data until 2016. Based on the last analysis of fecal coliform, bacteria status was considered "fair" and demonstrating no trend. Based on the analysis of *E. coli* bacteria for the past five years of data collection, the median concentrations for Muddy Fork were above the instantaneous recreational standard of 240 colonies/100ml and the 2020 median values were above the recreational standard. The geometric means are shown in the chart on the next page.

Dissolved Oxygen in Muddy Fork Watershed

Water Years (October 1 to September 30)

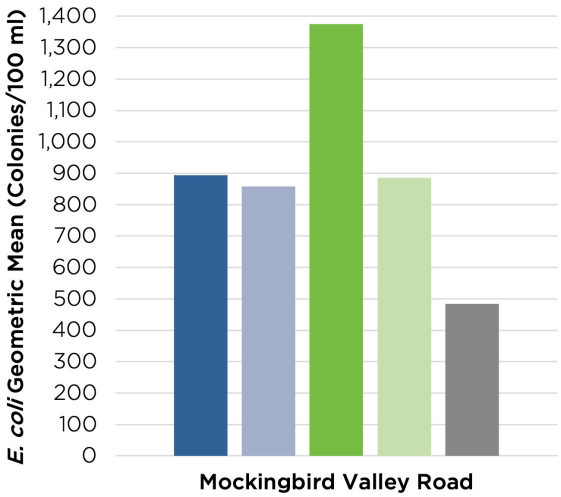


Nutrients

MSD monitored the concentrations of nutrients and total suspended solids in streams periodically from 2000 to 2005 and on a quarterly basis since 2005 at the Muddy Fork site. Total Kjeldahl nitrogen and total suspended solids levels in this largely forested urban residential watershed are generally "good" while nitrate was "poor." In comparison with historic conditions, nitrate and total Kjeldahl nitrogen are declining, however, total suspended solids are improving.

E. coli in Muddy Fork Watershed

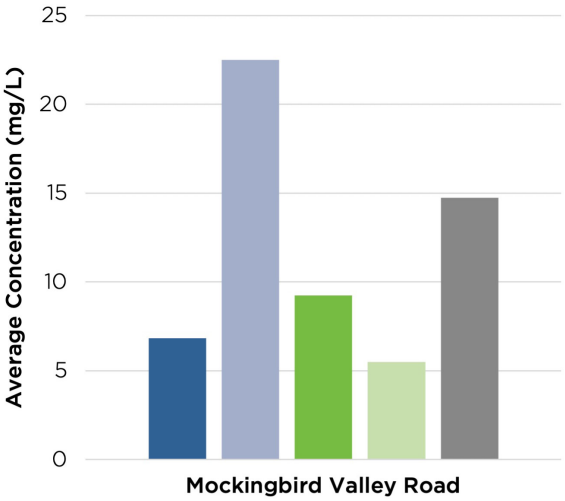
Recreational Seasons (May 1 to October 31)



2016 2017 2018 2019 2020

Total Suspended Solids in Muddy Fork Watershed

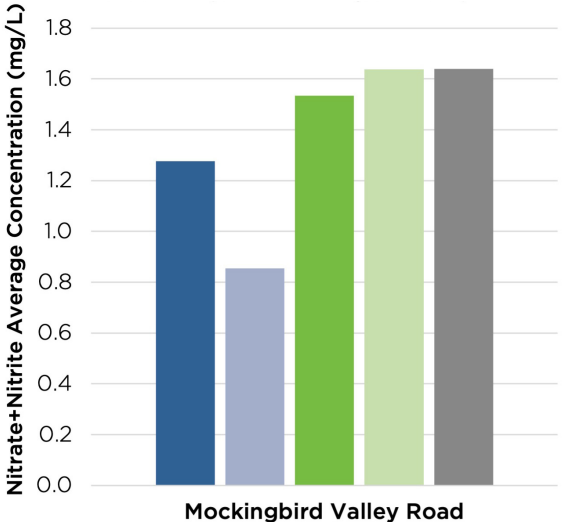
Recreational Seasons (October 1 to September 30)



Muddy Fork at Mockingbird Valley Road

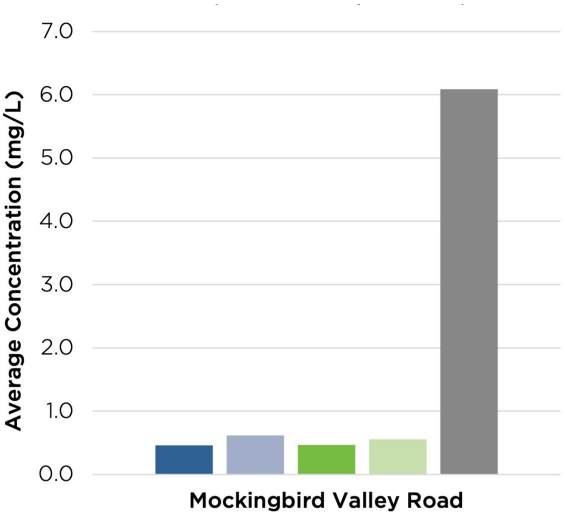
Nitrate + Nitrite in Muddy Fork Watershed

Water Years (October 1 to September 30)



Total Kjeldahl Nitrogen in Muddy Fork Watershed

Water Years (October 1 to September 30)



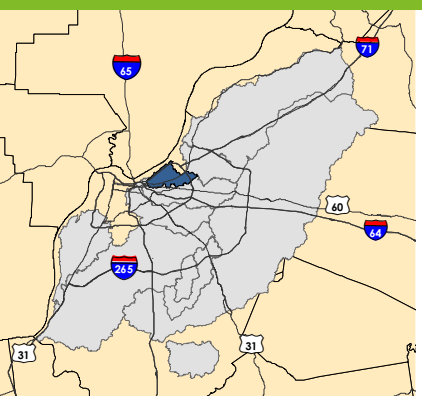
2016 2017 2018 2019 2020

WATERSHED PROJECT SPOTLIGHT

CLIFTON HEIGHTS CSO BASIN

The Clifton Heights CSO basin, in the Muddy Fork watershed, was built into a grassy hillside next to the Mellwood Arts and Entertainment Center. The 7 million gallon basin captures and stores wastewater and stormwater during rain events and gradually releases it back into the sewer system when treatment capacity is available. This type of underground storage helps prevent wastewater from overflowing into Louisville's waterways.

Clifton Heights CSO Basin



Watershed area shown in blue

WATER QUALITY STATUS AND TRENDS

MUDDY FORK OF BEARGRASS CREEK WATERSHED

Goose Creek

JEFFERSON COUNTY

Muddy Fork of Beargrass Creek

Beargrass Creek

Middle Fork of Beargrass Creek

LEXINGTON RD

Muddy Fork of Beargrass Creek at Mockingbird Valley Road
(6.2 square miles and 62 percent urban)

	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
2020 Status										
Trend	↑	—	↓	—	↑	—	>	↓	↓	↑

N

Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

MIDDLE FORK OF BEARGRASS CREEK WATERSHED

Beargrass Creek

The Middle Fork of Beargrass Creek is one of three streams that join to form the larger Beargrass Creek Watershed. The small streams that eventually form the Middle Fork of Beargrass Creek originate in Middletown and Douglass Hills, and flow west across St. Matthews. The stream then joins the South Fork of Beargrass Creek near Irish Hill. The South Fork then joins with the Muddy Fork to become Beargrass Creek near the intersection of Interstates 71 and 64. Prominent features of this watershed include Cherokee Park, Seneca Park and Cave Hill Cemetery. The downstream part of this watershed is currently served by combined sewers.

BACKGROUND AND LAND USE

Middle Fork of Beargrass Creek includes approximately 61 linear miles of stream in Jefferson County originating in Anchorage and Middletown areas and flowing west through the major urban areas of Louisville Metro. The Middle Fork of Beargrass Creek Watershed drains 25.2 square miles. Its watershed also includes Cherokee and Seneca Parks. There are three LTMN locations within the watershed located at Browns Lane, Old Cannons Lane, and Lexington Road. Cherokee and Seneca Parks are located in between Old Cannons Lane and Lexington Road. Middle Fork of Beargrass Creek flows into South Fork Beargrass Creek just upstream of the LTMN location at Brownsboro Road.

Due to the nature of development within this watershed, these streams are true urban streams due to channelization and increased runoff from impervious surfaces. A very high percentage of this watershed is covered by impervious surfaces (asphalt, cement, rooftop, etc.). In addition, there are combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) in the watershed that are actively being addressed through MSD Consent Decree programs and projects. Large stream flow fluctuations during storm events result in impacts to the biological communities and their habitat in the streams. Fast-moving stormwater scours the stream banks, causing erosion, sedimentation and siltation, resulting in the decline of water quality and habitat quality.

While much of the land use in the Middle Fork of Beargrass Creek watershed is residential and commercial, there are also several golf courses, walking trails, and parks located throughout. Oxmoor Farm, an historic landmark which is predominantly agricultural is also located in this watershed.

Better water quality requires the reduction of CSOs and elimination of SSOs, as well as addressing non-point source pollution issues. The Middle Fork of Beargrass Creek is the focus of MSD's first watershed plan. Watershed planning involves working with stakeholder groups to manage non-point source pollutants that can runoff to streams and rivers. The planning group identified opportunities to address non-point source pollution control best management practices and projects. MSD and stakeholders will implement this watershed plan and track results.

MONITORING FINDINGS

Fish Communities

MSD has monitored the fish communities in the Middle Fork Watershed since 1999. Overall, fish communities within the watershed are improving. In 2017 and 2020, the fish communities were "fair" at Browns Lane; however, they changed from "fair" to "good" at Old Cannons Lane, and from "poor" to "excellent" at Lexington Road. The main differences between the "fair" fish community and the "good" and "excellent" fish communities are an increase in species that eat insects and a decrease in pollution tolerant fish.

Aquatic Insect Communities

MSD has monitored aquatic insect communities at the Old Cannons Lane site since 2000 and at the other sites since 2004. The aquatic insect communities were poor for all sites in 2017 and 2019 with the exception of Lexington Road which ranked as fair in 2017. The overall trend throughout is declining.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in the watershed since 2002. Using a Diatom Bioassessment Index (DBI), the Middle Fork Watershed has varied results. Browns Lane was in "fair" condition in 2017 and "excellent" condition in 2019, Old Cannons Lane was in "good" condition in both 2017 and 2019, and Lexington Road was in "excellent" condition in both 2017 and 2020. Old Cannons Lane showed a decline in the condition of the algal communities over the period of study, however, no change was indicated at the other two sites.

MSD has monitored the fish communities in the Middle Fork Watershed since 1999. Overall, fish communities within the watershed are improving.

Stream Habitat

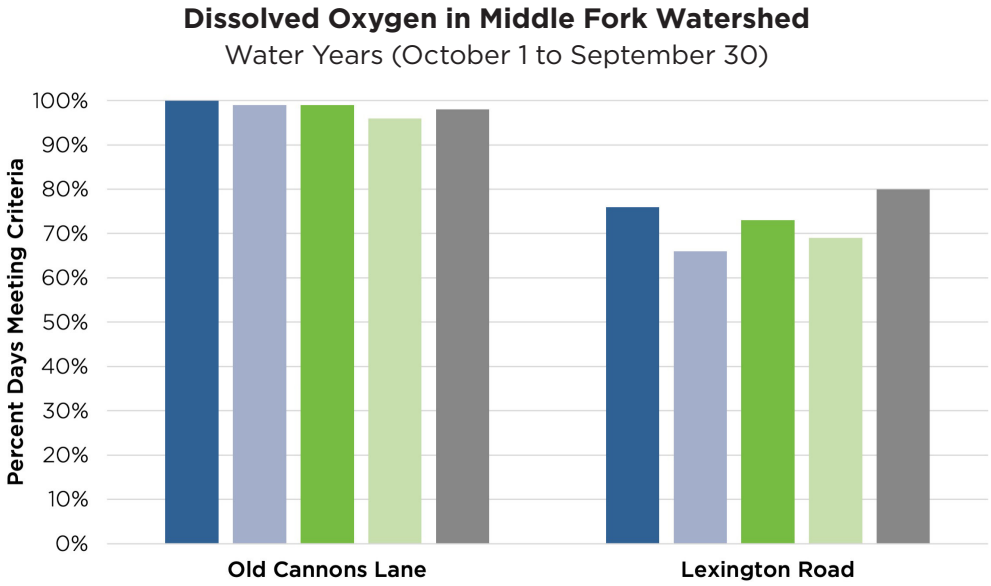
MSD has assessed stream habitat when fish and aquatic insects were sampled since 2005. Based on the latest monitoring, habitat within the Middle Fork of Beargrass Creek Watershed was "fair" to "good" in 2017 and 2019 and "poor" to "fair" in 2020. As seen in many urban streams, a lack of trees and other protective vegetation along stream banks, and unstable stream beds or stream banks impacted habitat scores for the Middle Fork of Beargrass Creek Watershed. Turbidity levels may have been impacted by the presence of large numbers of geese in the stream. The trend varies throughout the watershed with improvements upstream, no change at Lexington Road, and declining results downstream.

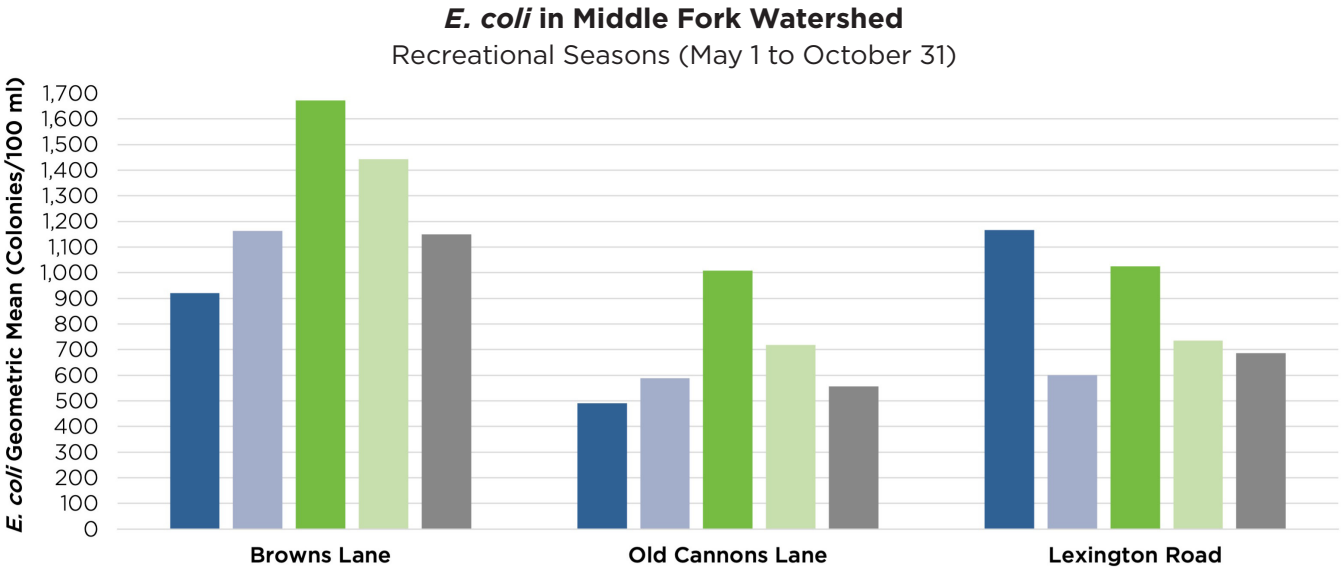
Dissolved Oxygen and Temperature

MSD and the USGS continuously monitor streamflow, dissolved oxygen, and water temperature on the Middle Fork of Beargrass Creek at Old Cannons Lane (USGS gage 03293000) and at Lexington Road (USGS gage 03293500). Since there is not a USGS gage at Browns Lane, no data is available for dissolved oxygen and temperature at that location. Stream flow has been monitored at Old Cannons Lane since 1944 and at Lexington Road since 2003. Dissolved oxygen conditions were "good" at the Old Cannons Lane site from 2018-2020 and "fair" at Lexington Road. Water temperature criteria at the Middle Fork sites were met 100 percent of the time.

Bacteria

MSD collected fecal coliform data until 2016. Based on the last analysis of fecal coliform, bacteria status was considered "fair" or "poor" and trends were improving at Lexington Road, declining at Browns Lane, and demonstrating no trend at Old Cannons Lane. Based on the current analysis of *E. coli*, the period of record median *E. coli* concentrations for all three sites were above the instantaneous recreational standard of 240 colonies/100ml in both 2020 and for the five-year period (2016-2020). The geometric means are shown in the chart below.

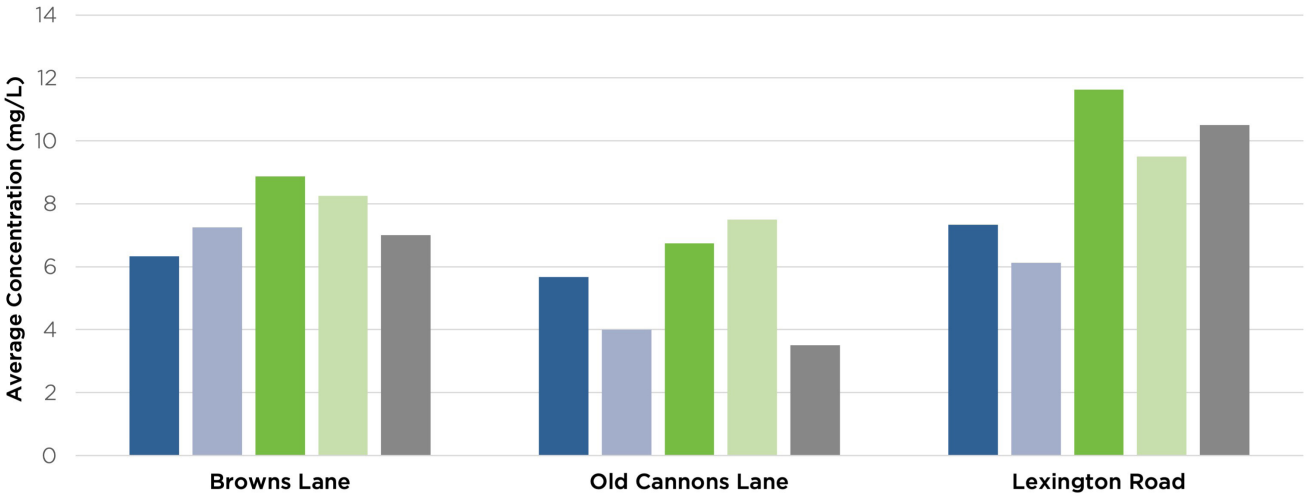




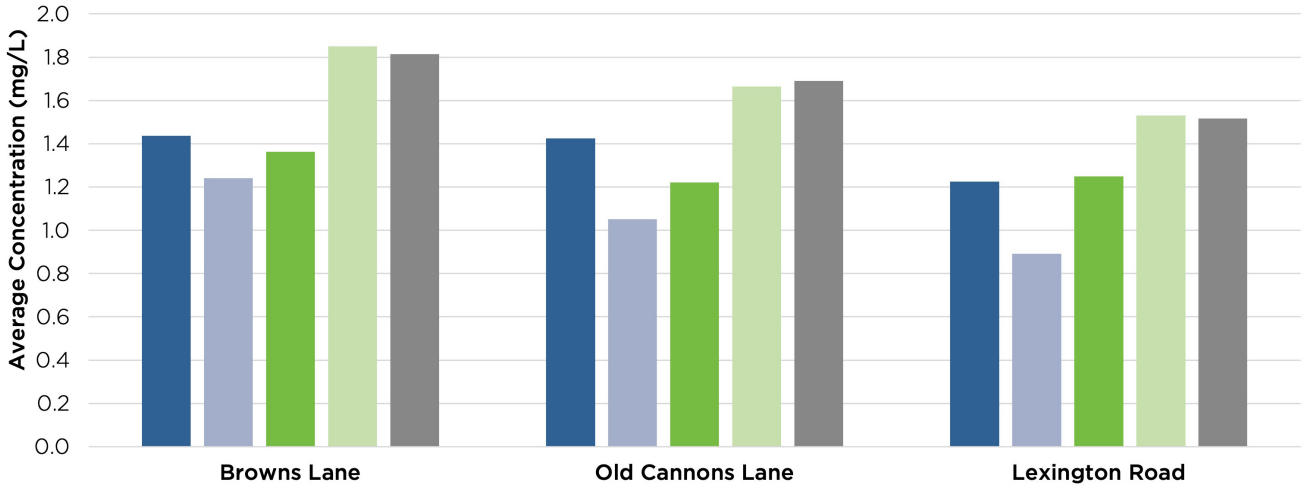
Nutrients

MSD monitored the concentrations of nutrients and total suspended solids in streams periodically from 2000 to 2005 and on a quarterly basis since 2005 at the three sites in the Middle Fork of Beargrass Creek Watershed. All sites were "good" for total Kjeldahl nitrogen and total suspended solids and improving; however, they were "fair" or "poor" for nitrate levels and declining.

Total Suspended Solids in Middle Fork Watershed
Water Years (October 1 to September 30)

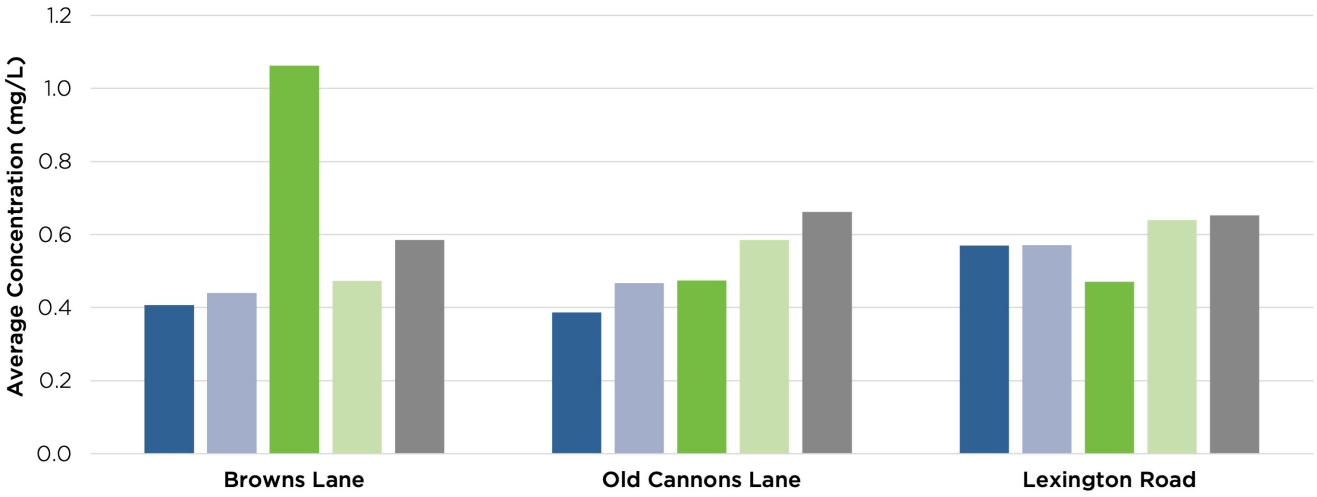


Nitrate + Nitrite in Middle Fork Watershed
Water Years (October 1 to September 30)



2016 2017 2018 2019 2020

Total Kjeldahl Nitrogen in Middle Fork Watershed
Water Years (October 1 to September 30)

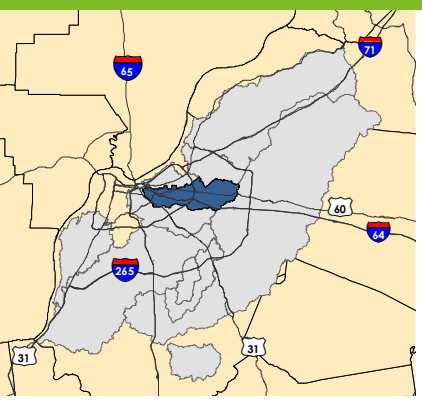


WATERSHED PROJECT SPOTLIGHT

On September 22, 2020, after 21 months of carving its way through four miles and 625,000 tons of rock 18 stories underground, the boring machine, "Bumblebee," completed the path of the Waterway Protection Tunnel. The machine broke through the retrieval shaft wall at the intersection of Lexington Road and Grinstead Drive. Bumblebee was then disassembled and removed from the tunnel over the course of nearly two months.

Now the tunnel is being lined with 12-inch-thick concrete. The tunnel will capture and store up to 55 million gallons of combined stormwater and wastewater during rains, preventing the water from flowing untreated into the Ohio River and Beargrass Creek. The $214 million project is part of MSD's Consent Decree with the federal government to significantly reduce combined sewer overflows.

Waterway Protection Tunnel



Watershed area shown in blue

WATER QUALITY STATUS AND TRENDS

MIDDLE FORK OF BEARGRASS CREEK WATERSHED

Middle Fork of Beargrass Creek at Lexington Road
(24.8 square miles and 84 percent urban)

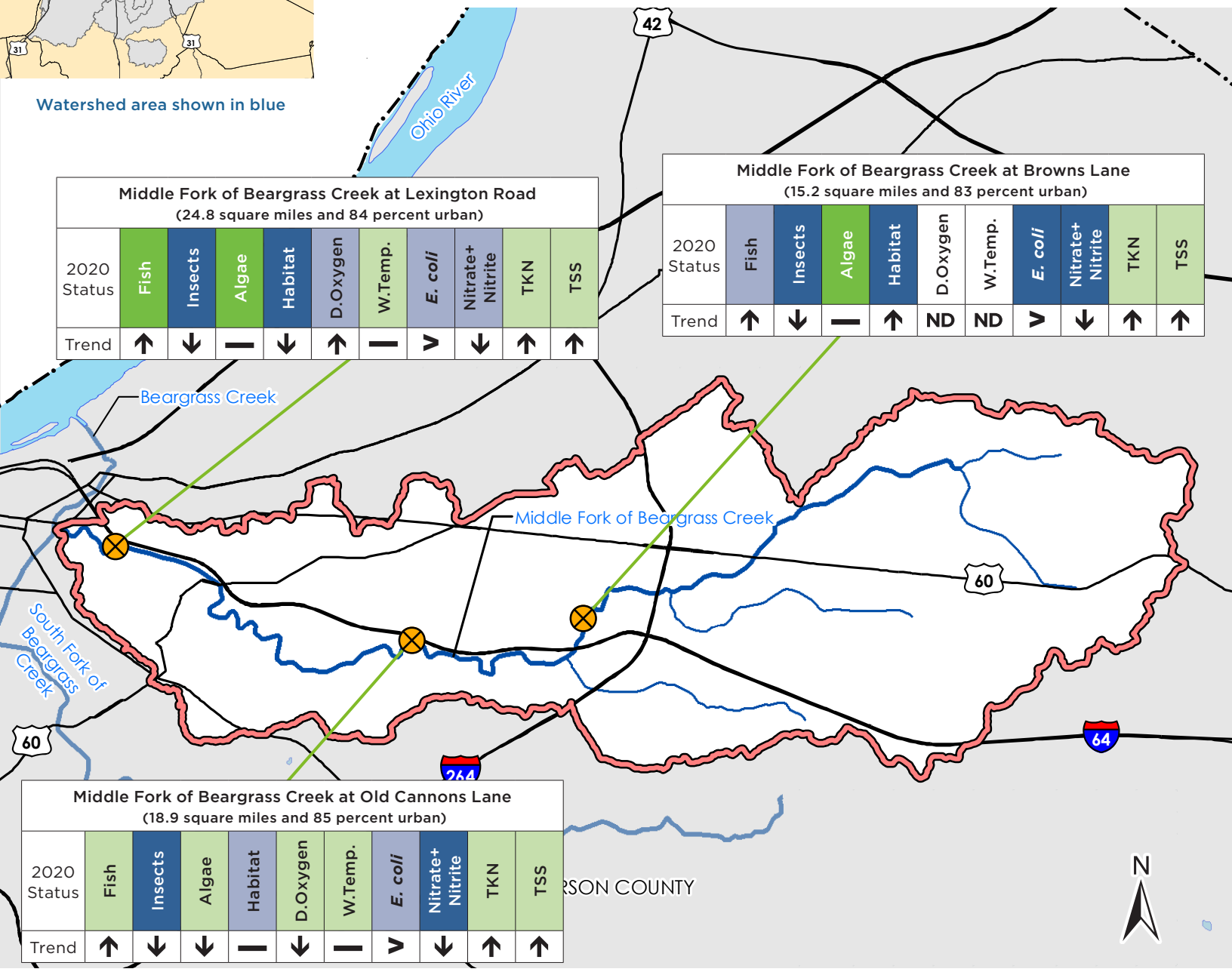
2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↓	—	↓	↑	—	>	↓	↑	↑

Middle Fork of Beargrass Creek at Browns Lane
(15.2 square miles and 83 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↓	—	↑	ND	ND	>	↓	↑	↑

Middle Fork of Beargrass Creek at Old Cannons Lane
(18.9 square miles and 85 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↓	↓	—	↓	—	>	↓	↑	↑



Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

SOUTH FORK OF BEARGRASS CREEK WATERSHED

South Fork of Beargrass Creek at Jim King Trail

The South Fork of Beargrass Creek is one of the three streams that join to form the larger Beargrass Creek Watershed. The small streams that eventually form the South Fork of Beargrass Creek originate in Jeffersontown and Hurstbourne Acres and flow west across Buechel and Audubon Park before joining the Middle Fork of Beargrass Creek near Irish Hill. The South Fork then joins with the Muddy Fork to become Beargrass Creek near the intersection of Interstates 71 and 64. In the past, streams in this watershed were straightened and several miles have been enclosed in concrete channels to reduce flooding. The downstream part of this watershed is currently served by combined sewers.

BACKGROUND AND LAND USE

The 27 square mile South Fork Beargrass Creek Watershed is located in the north central portion of Jefferson County. Its headwaters originate in Jeffersontown, flow in a westerly direction to Buechel, turn northwest into the Highlands, and finally, turn slightly northeast at the Louisville and Nashville Railroad and eventually outlet into the Ohio River near Towhead Island. Major streams in this watershed include South Fork Beargrass Creek and Buechel Branch.

The majority of the land use in the South Fork Watershed is residential, however many commercial properties are located in the downtown area and along major roads such as Bardstown Road, Poplar Level, and Hurstbourne Parkway. Some industrial properties also exist in the South Fork Watershed and are mostly located near the downtown area and the Newburg Road area south of the Watterson Expressway. Communities lying in the watershed include Jeffersontown, Phoenix Hill, Germantown, Audubon Park,

Strathmoor, Wellington, Buechel, Highgate Springs, Houston Acres, Forest Hills, Schnitzelburg, Smoketown, Shelby Park, Tyler Park and the Highlands. Notable landmarks include the Beargrass Creek Pumping Station, Calvary Cemetery, the Louisville Zoo, Tyler Park, and Rest Haven Memorial Cemetery. Several parks are located within the floodplain of South Fork Beargrass Creek, including Joe Creason Park and the Beargrass Creek State Nature Preserve. Buechel Park is located along Buechel Branch, a tributary of South Fork Beargrass Creek. Conservation easements have also been granted along South Fork Beargrass Creek near Poplar Level Road and Illinois Avenue by Audubon Hospital, Calvary Cemetery, Day Spring, and the St. Joseph Home for the Aged.

There are three LTMN sites along South Fork of Beargrass Creek. MSD has been monitoring water quality at the Trevilian Way site since 1999, at Schiller Avenue since 2000, and at Brownsboro Road since 2004. MSD moved the Schiller Avenue site downstream to Breckinridge Street in 2015 because the Schiller Avenue site was not accessible during construction of a nearby wet weather basin. Data from the two sites was integrated for this assessment.

Several miles of this stream have been enclosed in concrete U-shaped channels. Due to the intensity of development within this watershed, streams in the South Fork of Beargrass Creek Watershed are true urban streams. A very high percentage of this watershed is impervious. In addition, there are CSOs and SSOs in the area. This combination results in moderate to high nutrient levels. Fast moving stormwater scours the stream banks, causing erosion, sedimentation, and siltation, resulting in the decline of water quality and habitat quality. Physical pressures, high water fluctuations during storm events, and microbiological effects result in severe impacts on both habitat and the biological communities in the streams.

Several miles of this stream have been enclosed in concrete U-shaped channels. Due to the intensity of development within this watershed, streams in the South Fork of Beargrass Creek Watershed are true urban streams.

MONITORING FINDINGS

Fish Communities

MSD has monitored fish communities in the South Fork of Beargrass Creek Watershed since 1999. In 2017, ratings varied for the sites with a "fair" rating upstream, "poor" rating at Breckinridge Street, and "very poor" downstream. In 2020, all three sites rated "fair." Lack of diversity in species and the low population of darter, madtom, and sculpin contributed to the "fair" ratings at all three sites. The communities are showing improvement at all three sites.

Aquatic Insect Communities

MSD monitored aquatic insect communities in the South Fork of Beargrass Creek Watershed since 2000. The aquatic insect communities were found to be "poor" at all sites in 2017 and 2019 with the exception of Trevilian Way which rated "very poor" in 2017. The numerical indices at the three sites, however, actually show a slight improvement over time at Breckinridge Street and Brownsboro Road with no relative change at Trevilian Way.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in the watershed at the Brownsboro Road site since 2002 and the other sites since 2007. Using a Diatom Bioassessment Index (DBI), the South Fork Watershed has varied results. At Trevilian Way and Breckinridge Street, the ratings were "excellent" in 2017 and "good" in 2020. Over time, conditions have declined at Trevilian Way, but there has been little overall change at Breckinridge Street. At Brownsboro Road, conditions were "fair" in 2017 and "good" in 2020, however, the overall trend showed a decline perhaps a result of heavy tree cover.

Stream Habitat

MSD has assessed stream habitat when fish and aquatic insects were sampled since 2005. At Trevilian Way and Breckinridge Street, the habitats rated as "poor" in 2017, 2019, and 2020. There has been an overall improvement in conditions at Trevilian Way, however the data at Breckinridge Street does not indicate a trend. At Trevilian Way, the stream has been channelized and has accumulations of silt and sediment, which cover the habitat used by fish and aquatic insects. At Breckinridge Street, the South Fork is a concrete lined channel lacking any likeness to a natural stream. At both of these sites, the stream lacks the variety of habitats typically found in good quality streams, including shallow rocky riffles and slow deep pools.

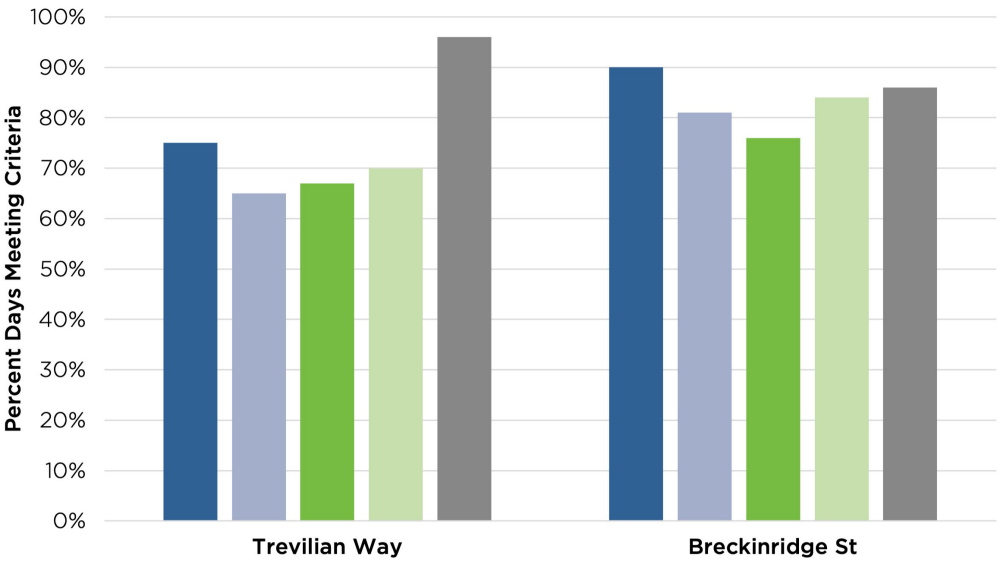
At the Brownsboro Road site, conditions were "good" in 2017, "fair" in 2019, and "poor" in 2020 with no evident trend. This site has habitat issues similar to the other two sites, however conditions are less severe at Brownsboro Road since the stream bed has a substantial rocky substrate. Additionally, there is more tree cover along this section of the creek.

Dissolved Oxygen and Temperature

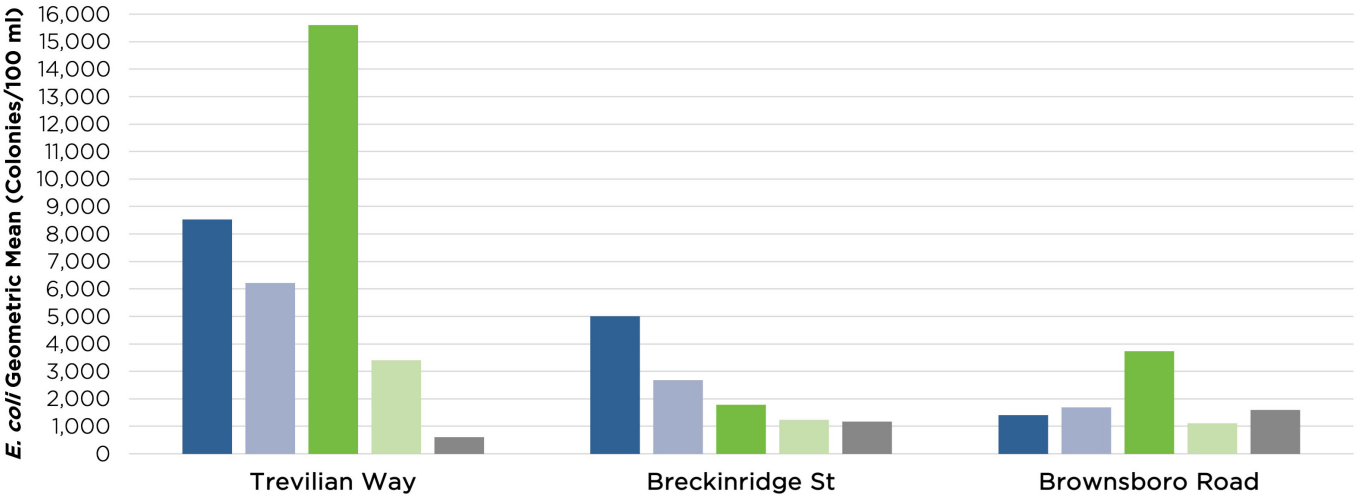
MSD and the USGS continuously monitor streamflow, dissolved oxygen, and water temperature in the South Fork of Beargrass Creek Watershed at Trevilian Way (USGS gage 03292500) and Breckinridge Street (USGS gage 03292555).

SOUTH FORK OF BEARGRASS CREEK WATERSHED (CONTINUED)

Dissolved Oxygen in South Fork Watershed
Water Years (October 1 to September 30)



***E. coli* in South Fork Watershed**
Recreational Seasons (May 1 to October 31)



2016 2017 2018 2019 2020

Since there is not a USGS gage at Brownsboro Road, no data is available for dissolved oxygen and temperature at that location. Dissolved oxygen conditions were "fair" at the South Fork sites from 2018-2020 and improving. Water temperature criteria were met 100 percent of the time.

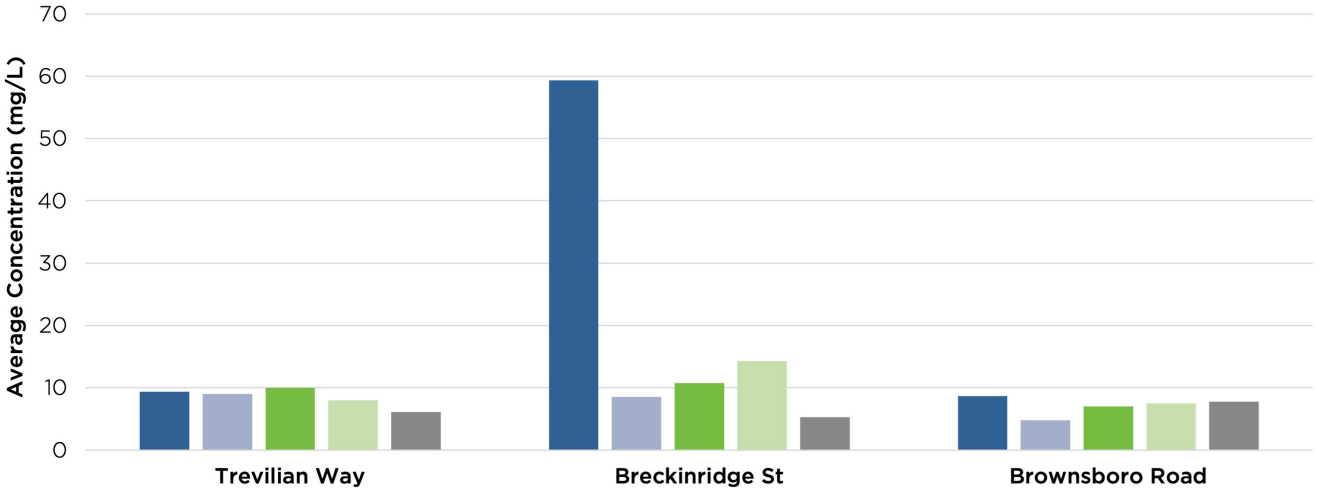
Bacteria

MSD collected fecal coliform data until 2016. Based on the previous analysis of fecal coliform bacteria, concentrations were some of the highest in the Louisville Metro and were getting worse. Based on the analysis of *E. coli* bacteria for the past five years of data collection, the median concentrations for both sites were above the instantaneous recreational standard of 240 colonies/100ml and the 2020 median values were above the recreational standard. The geometric means are shown in the chart below (on the page to the left).

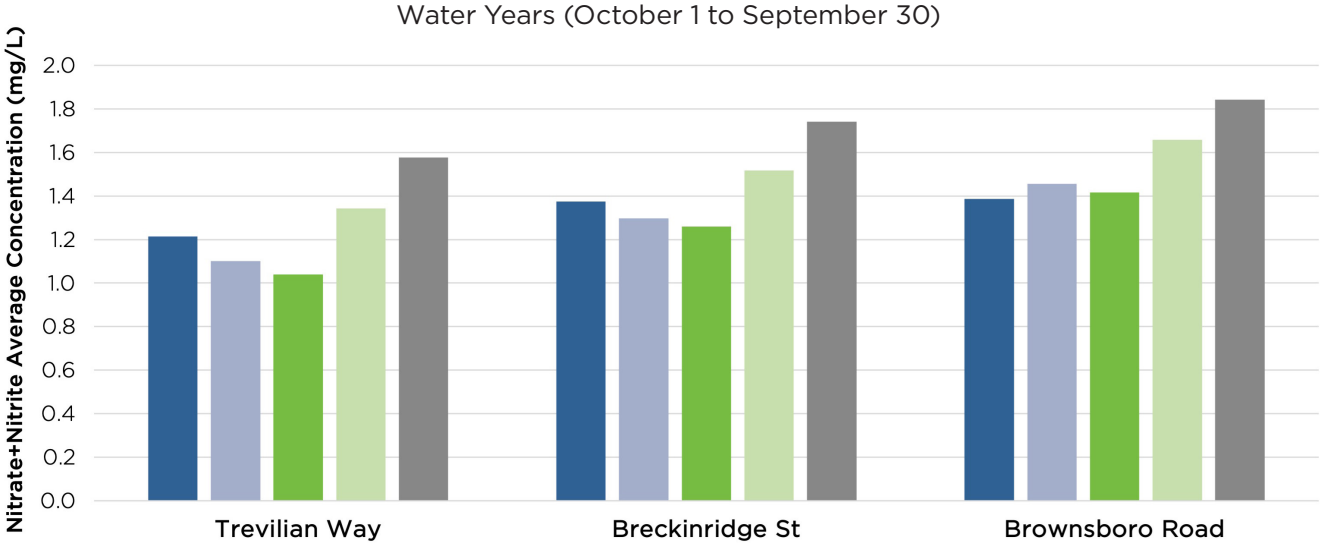
Nutrients

MSD monitored the concentrations of nutrients and total suspended solids in streams periodically from 2000 to 2005 and on a quarterly basis since 2005 at three sites in the South Fork of Beargrass Creek Watershed. Overall, the results were varied for nutrients. At Trevilian Way and Brownsboro, total Kjeldahl nitrogen and total suspended solids were "good" and improving. At Breckinridge, total Kjeldahl nitrogen and total suspended solids were "fair" and improving. For nitrate, Trevilian Way results were "fair" with no notable trend, while nitrate concentrations at Breckinridge and Brownsboro Road were "poor" and declining.

Total Suspended Solids in South Fork Watershed
Water Years (October 1 to September 30)



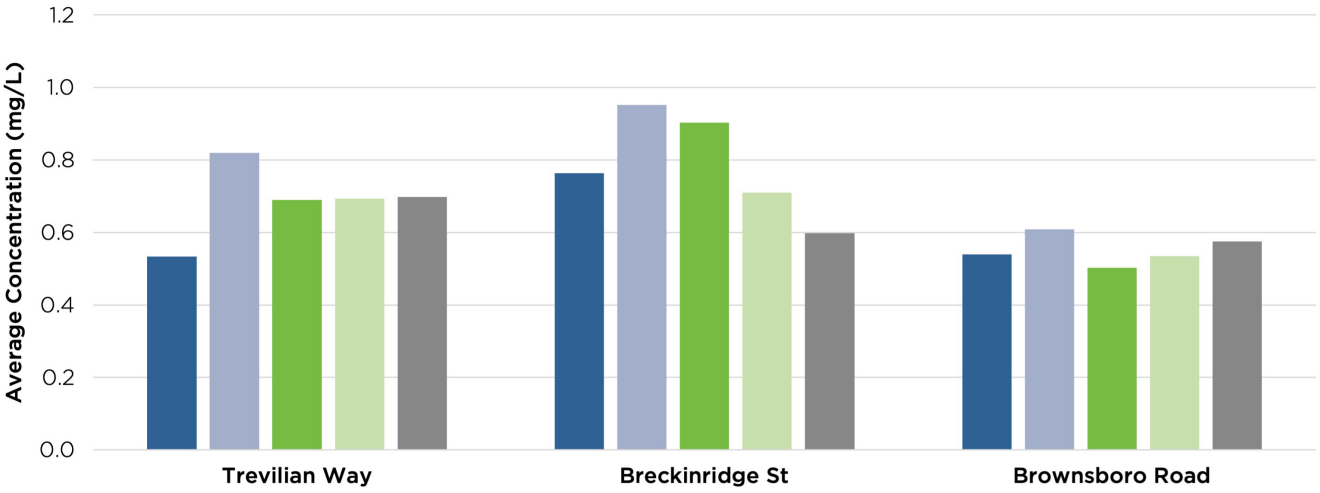
Nitrate + Nitrite in South Fork Watershed
Water Years (October 1 to September 30)



2016 2017 2018 2019 2020

SOUTH FORK OF BEARGRASS CREEK WATERSHED (CONTINUED)

Total Kjeldahl Nitrogen in South Fork Watershed
Water Years (October 1 to September 30)



WATERSHED PROJECT SPOTLIGHT

LOGAN STREET BASIN

Operational since December 20, 2017, the Logan Street Combined Sewer Overflow (CSO) Basin at 935 Logan Street now captures 11 combined sewer overflow points that used to discharge 15,400,000 gallons of a mixture of sewage and rainwater in a typical rainfall year into the South Fork of Beargrass Creek.

The basin is a concrete underground structure with a storage capacity of 16.7 million gallons. It has an above ground operations building and an access ramp to allow service vehicles to enter for periodic maintenance. There are 10,000 feet of 24- to 96-inch sewer pipes that collect flow from 11 overflow points and convey it to the basin. The sewer water is stored in the basin until capacity is available in the sewer system. At that time, the water is conveyed to Morris Forman Water Quality Treatment Center, treated and released into the Ohio River.

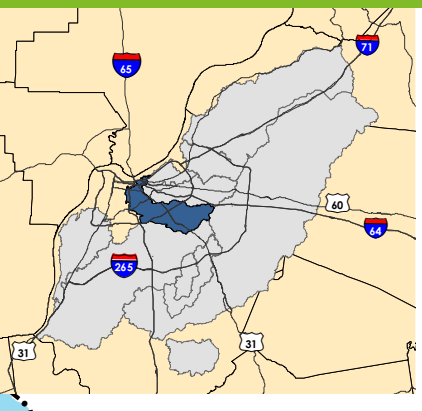
WATERWAY PROTECTION TUNNEL

MSD's Waterway Protection Tunnel is an innovative way to store overflow of rainwater and wastewater underground until it can be pumped to a wastewater treatment facility, where it is cleaned and released to the Ohio River. The tunnel is a $201 million project now underway and planned to be operational in 2022. It is one part of MSD's $1.15 billion Consent Decree to reduce sewer overflows. The tunnel is 4 miles long and 20 in diameter. It holds 55 million gallons, which is equivalent to 83 Olympic-size swimming pools.

South Fork of Beargrass Creek at Eastern Parkway

WATER QUALITY STATUS AND TRENDS

SOUTH FORK OF BEARGRASS CREEK WATERSHED



Watershed area shown in blue

Beargrass Creek

South Fork Beargrass Creek at Brownsboro Road
(51.5 square miles and 88 percent urban)

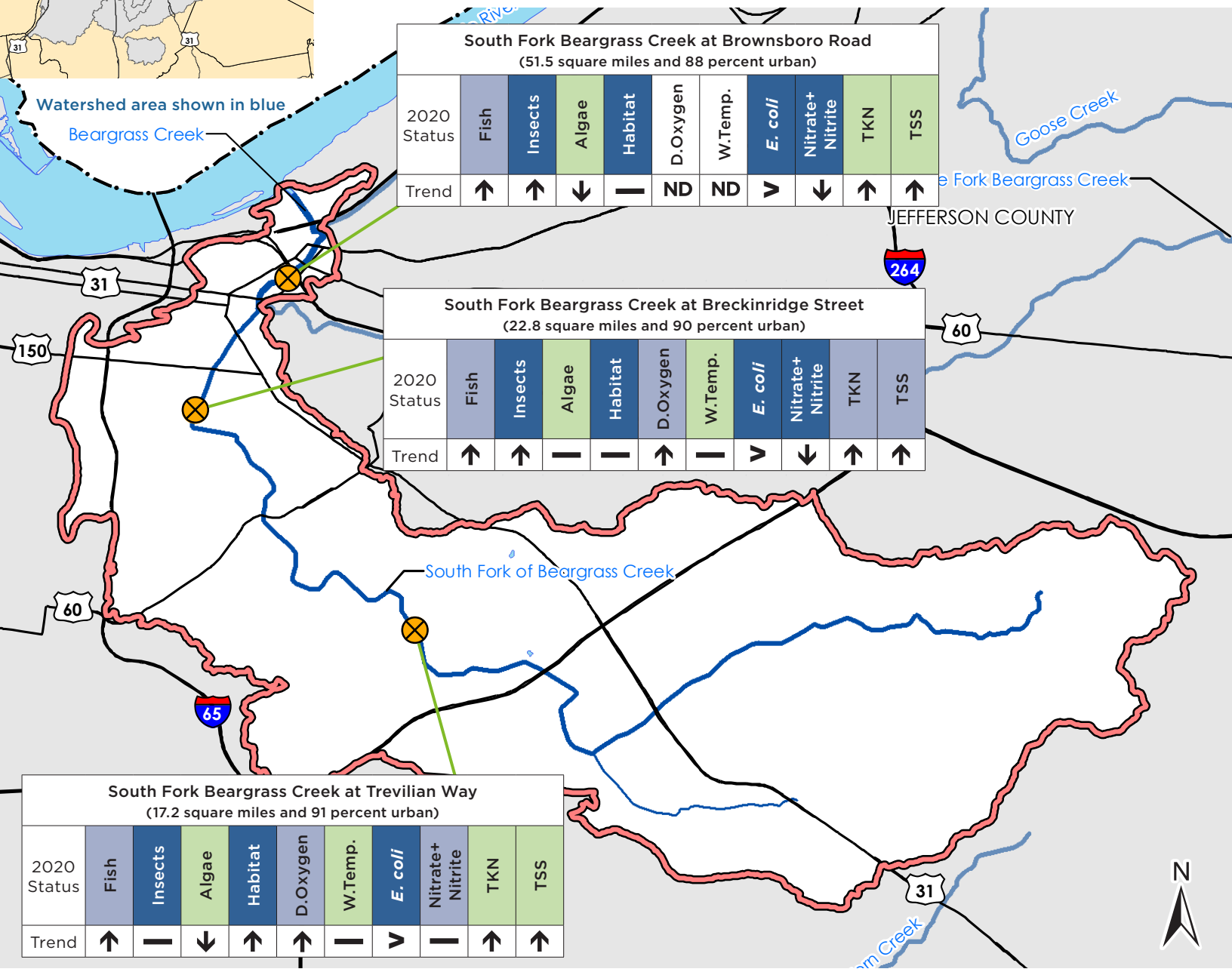
2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↑	↓	—	ND	ND	>	↓	↑	↑

South Fork Beargrass Creek at Breckinridge Street
(22.8 square miles and 90 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↑	—	—	↑	—	>	↓	↑	↑

South Fork Beargrass Creek at Trevilian Way
(17.2 square miles and 91 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	—	↓	↑	↑	—	>	—	↑	↑



Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

FLOYDS FORK WATERSHED

Floyds Fork

The small streams that form Floyds Fork originate in Henry, Oldham, Shelby, and Spencer Counties. Floyds Fork flows south through Oldham, eastern Jefferson, and northern Bullitt Counties where it drains into the Salt River near Shepherdsville.

BACKGROUND AND LAND USE

The 460 square mile Floyds Fork Watershed is located in eastern Jefferson County. The major streams in this watershed are Floyds Fork, Pope Lick, and Chenoweth Run. There are three LTMN locations on the main stem of Floyds Fork at Ash Avenue, Old Taylorsville, and at Bardstown Road.

Chenoweth Run is a tributary of Floyds Fork, which originates in the Middletown area and flows south, merging into Floyds Fork between the upstream and downstream locations. There are two LTMN locations in Chenoweth Run, an upstream location at Ruckriegel Parkway and a downstream location at Gelhaus Lane.

Communities in the study area include parts of Jeffersontown, Middletown, Anchorage, Berrytown, Woodland Hills, Tucker Station, and Hopewell. Notable landmarks include the Parklands, Fishermens Park, Chenoweth Park, parts of Bluegrass Industrial Park, Eastern High School, and Jeffersontown High School. Existing parks along Floyds Fork include Floyds Fork Park and William F. Miles Park. The majority

of the land use in the Floyds Fork Watershed is residential and agricultural. The watershed is the most heavily developing area in Jefferson County, seeing an increase with new residential, commercial and industrial areas.

Nutrient enrichment is also a problem in the watershed. Much of the nutrient load to the streams comes from chemically treated lawns and golf courses, agriculture, and septic tanks. The stream is also being impacted by silt loads from construction sites and agriculture. These impacts threaten the habitat quality within the stream and the diversity of life it now supports.

The Floyds Fork Water Quality Treatment Center was constructed by MSD to eliminate less efficient small package plants and septic systems from the most populated areas of the watershed. A premier park system, The Parklands of Floyds Fork, has been developed along Floyds Fork. Extensive tracts of land have been preserved and the system of five parks is providing a variety of opportunities for recreation and enjoyment of the stream and natural areas.

MONITORING FINDINGS

Fish Communities

MSD has monitored the fish communities in the Floyds Fork Watershed since 1999. The fish communities of the Floyds Fork mainstem sites all rated "fair" in 2017. In 2020, while Bardstown Road remained "fair," all other sites rated "excellent." Overall, the ratings for fish communities are improving along the mainstem. These sites had high numbers of the generally pollution intolerant darter, madtom, and sculpin group of fishes.

The fish communities of the Chenoweth Run sites rated "fair" in 2017, "good" at Ruckriegel in 2020, and "excellent" at Gelhaus Lane in 2020. Native richness increased from the upstream Chenoweth Run site to the downstream site. The overall trend at all sites showed an improvement on the fish communities.

Aquatic Insect Communities

MSD has monitored aquatic insect communities at five sites in the Floyds Fork Watershed since 2000. The aquatic insect communities at all sites along Floyds Fork were "fair" in 2017 and 2019 with the exception of Bardstown Road which rated "good" in 2019. Overall, the communities are improving over time.

The aquatic insect communities at all sites along Chenoweth Run were "poor" in 2017 and 2019 with the exception of Ruckriegel Parkway which rated "very poor" in 2019. Overall, the communities are declining over time.

A premier park system, The Parklands of Floyds Fork, has been developed along Floyds Fork. Extensive tracts of land have been preserved and the system of five parks is providing a variety of opportunities for recreation and enjoyment of the stream and natural areas.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in the watershed since 2001. Using a Diatom Bioassessment Index (DBI), the Floyds Fork Watershed has varied results. In 2017, conditions ranged from "good" to "excellent" along the Floyds Fork main stem and from "fair" to "excellent" in 2019, however, over time, there was relatively little change at the sites. Along Chenoweth Run, conditions rated as "fair" at Ruckriegel Parkway and "good" at Gelhaus Lane in 2017. Both sites have shown an overall improvement and rated "excellent" in 2020.

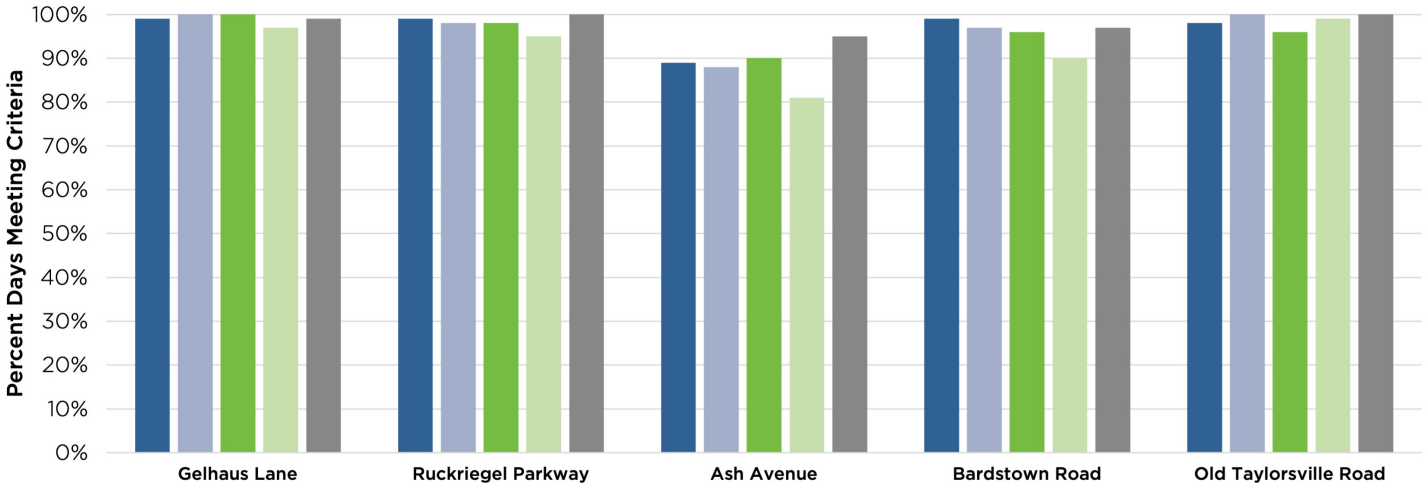
Stream Habitat

MSD has assessed stream habitat when fish and aquatic insects were sampled since 2000. In 2017 and 2019, all sites along Floyds Fork and Chenoweth Run rated as "good." In 2020, all sites rated as "fair" with the exception of Old Taylorsville Road, which was rated as "good." Over time, there has been relatively little change in habitat along Chenoweth Run, however, there has been an overall decline in habitat along Floyds Fork. Sediment deposition, unstable banks and a general lack of trees and other protective bank vegetation were identified at Ruckriegel Parkway as limitations of habitat quality.

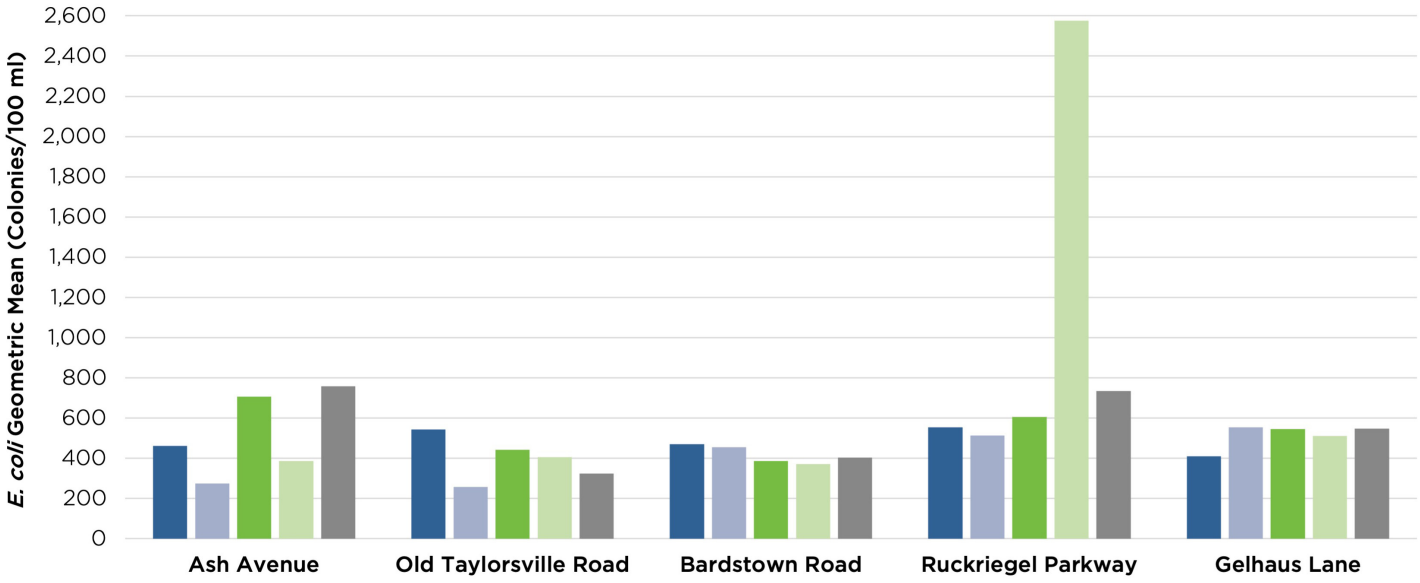
Dissolved Oxygen and Temperature

MSD and USGS continuously monitor dissolved oxygen, water temperature, and streamflow at all five stream sites in the watershed; Gelhaus Lane (USGS Gage 03298150), Ruckriegel Parkway (USGS Gage 03298135), Ash Avenue (USGS Gage 03297900), Bardstown Road (USGS Gage 03298200), and Old Taylorsville Road (USGS Gage 03298000). Dissolved oxygen conditions were "good" along Floyds Fork at Old Taylorsville Road and Bardstown Road from 2018-2020 but declining and the water temperature criteria were met 99 percent of the time. At Ash Avenue, dissolved oxygen conditions had improved slightly but were still considered "fair" and the water temperature criteria were met 100 percent of the time. Dissolved oxygen conditions were "good" at both gages on Chenoweth Run meeting criteria 98% of the time from 2018-2020. At the Gelhaus Lane site, there was a slight decline from 2016 in dissolved oxygen conditions and the water temperature criteria were met 98 percent of the time. At the Ruckriegel Parkway site, there was no change in dissolved oxygen and the water temperature criteria were met 100 percent of the time.

Dissolved Oxygen in Floyds Fork Watershed
Water Years (October 1 to September 30)



***E. coli* in Floyds Fork Watershed**
Recreational Seasons (May 1 to October 31)



2016 2017 2018 2019 2020

Bacteria

MSD collected fecal coliform data until 2016. Based on the last analysis of fecal coliform bacteria, results varied at each site. Fecal coliform bacteria concentrations were elevated and decreasing on Chenoweth Run at Ruckriegel Parkway, however, they were moderate and improving at Gelhaus Lane. Concentrations along Floyds Fork were moderate at all sites with improvements at Old Taylorsville Road.

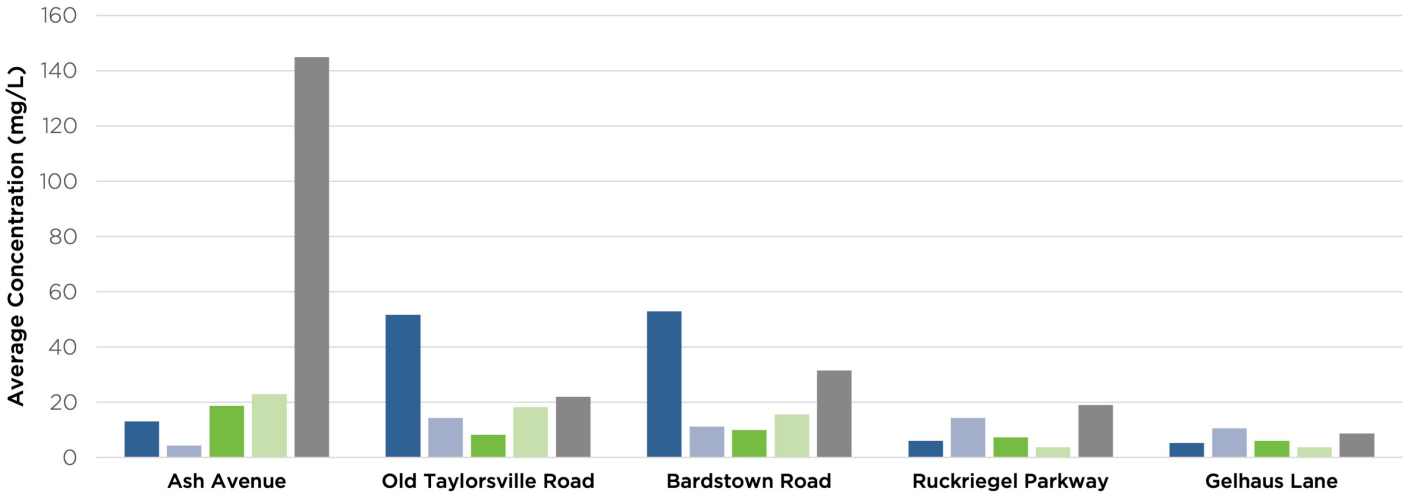
Based on the analysis of *E. coli* bacteria for the past five years of data collection, the median concentrations for both sites on Chenoweth Run were above the instantaneous recreational standard of 240 colonies/100ml however the 2020 median values were below the recreational standard. For Floyds Fork, the five-year median concentration was above the recreational standard at Ash Avenue and below the standard at Old Taylorsville Road and Bardstown Road. The 2020 median value was above the standard at Ash Avenue and Bardstown Road and below the standard at Old Taylorsville Road. The geometric means are shown in the adjacent chart.

Nutrients

MSD monitored the concentrations of nutrients and total suspended solids in streams periodically from 2000 to 2005 and, on a quarterly basis since 2005 at all five sites in the Floyds Fork Watershed. Gelhaus Lane and Ruckriegel Parkway overall showed "good" levels and consistent or improving results for all nutrients. Nutrient levels at the other sites on Floyds Fork varied from "good" to "fair" with the exception of Bardstown Road, which reported "poor" levels of total suspended solids. Nitrate levels were improving at all sites. Total Kjeldahl nitrogen and total suspended solids were declining or showing no trend.

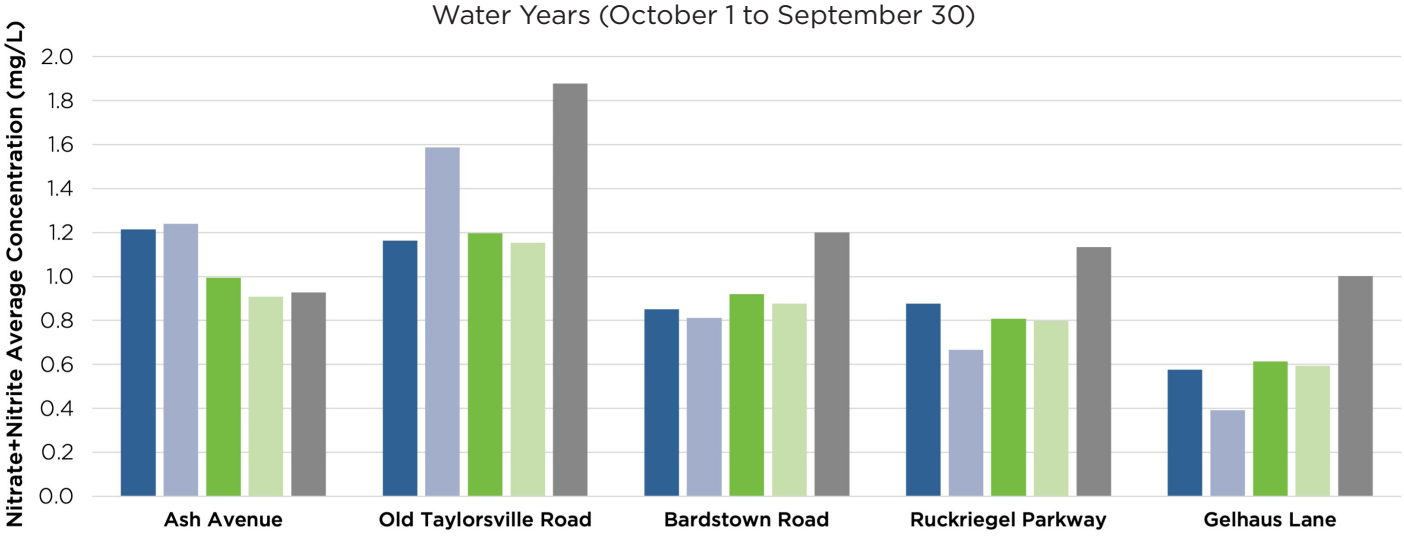
Total Suspended Solids in Floyds Fork Watershed

Water Years (October 1 to September 30)



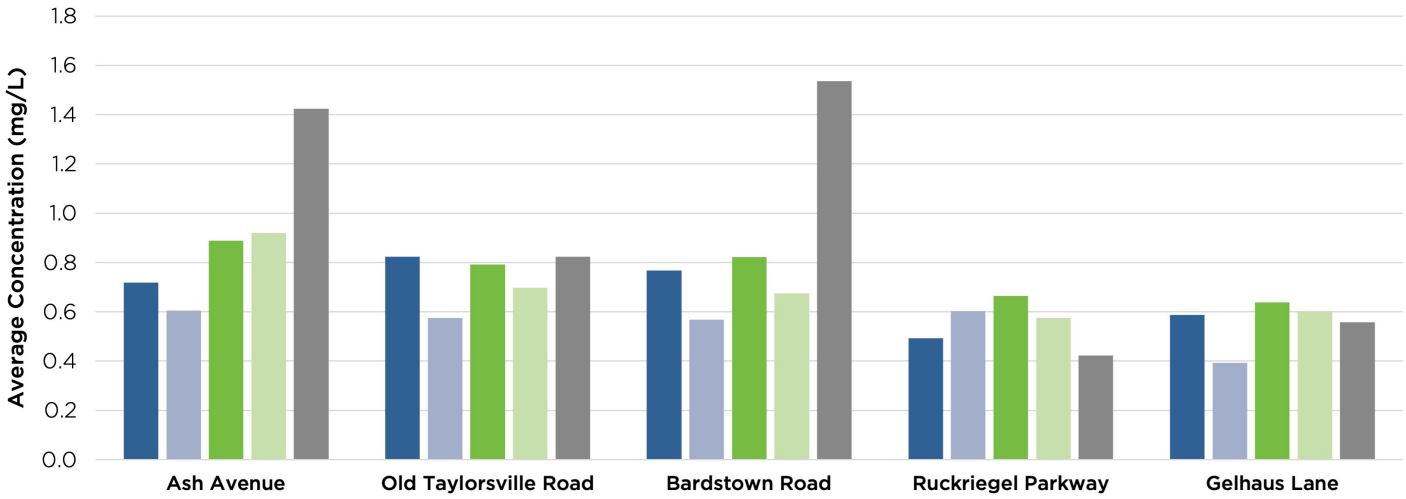
Nitrate + Nitrite in Floyds Fork Watershed

Water Years (October 1 to September 30)



2016 2017 2018 2019 2020

Total Kjeldahl Nitrogen in Floyds Fork Watershed
Water Years (October 1 to September 30)



WATERSHED PROJECT SPOTLIGHT

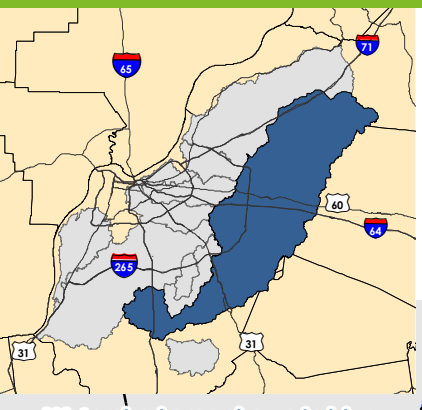
ENVIRONMENTAL EDUCATION

MSD partners with schools to provide environmental education and tours at MSD's Floyds Fork Water Quality Treatment Center. The program includes learning about water quality monitoring, flood safety, and wastewater treatment.

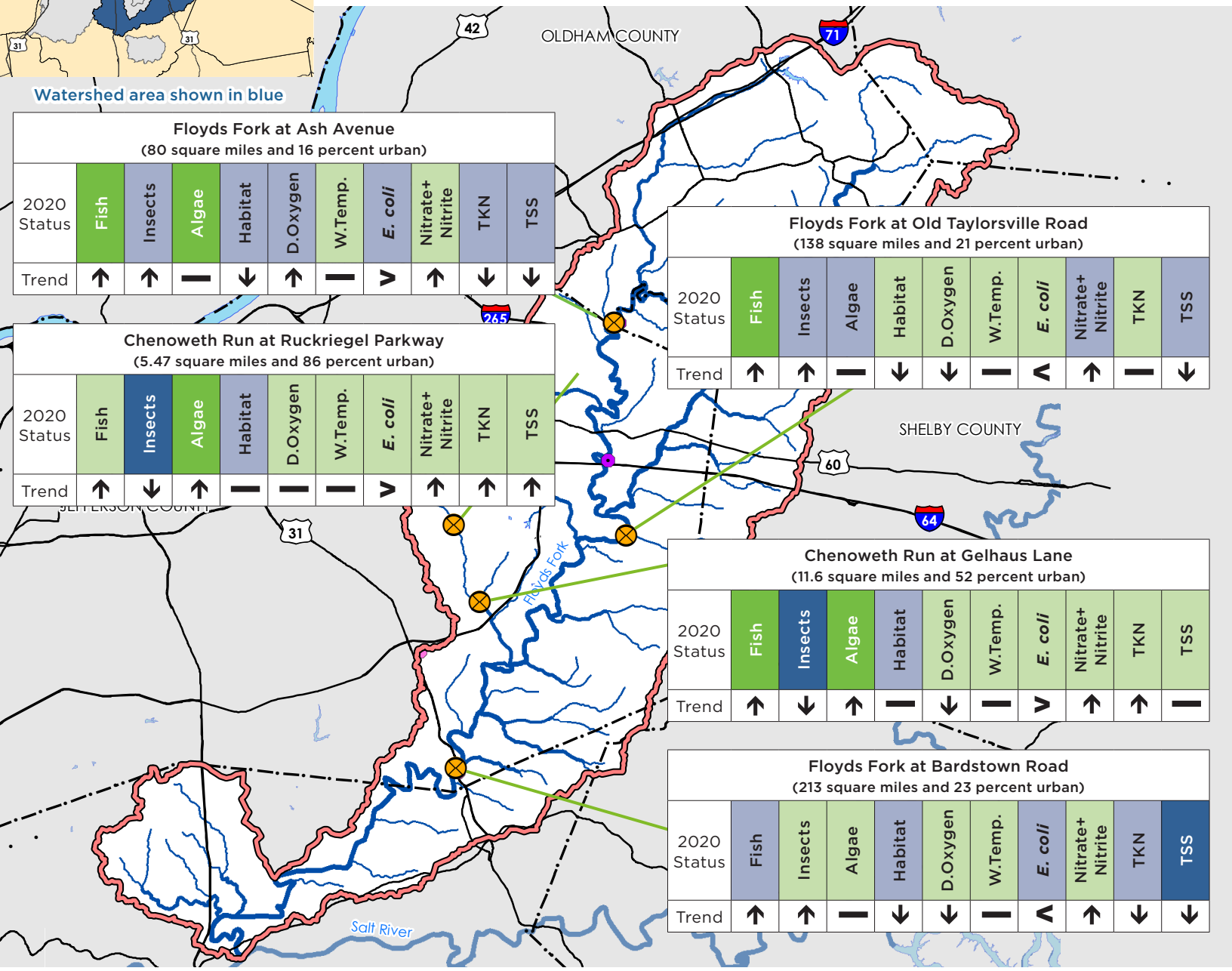
MSD's Floyds Fork Water Quality Treatment Center

WATER QUALITY STATUS AND TRENDS

FLOYDS FORK WATERSHED



Watershed area shown in blue



Floyds Fork at Ash Avenue
(80 square miles and 16 percent urban)

	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
2020 Status										
Trend	↑	↑	—	↓	↑	—	>	↑	↓	↓

Chenoweth Run at Ruckriegel Parkway
(5.47 square miles and 86 percent urban)

	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
2020 Status										
Trend	↑	↓	↑	—	—	—	>	↑	↑	↑

Floyds Fork at Old Taylorsville Road
(138 square miles and 21 percent urban)

	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
2020 Status										
Trend	↑	↑	—	↓	↓	—	<	↑	—	↓

Chenoweth Run at Gelhaus Lane
(11.6 square miles and 52 percent urban)

	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
2020 Status										
Trend	↑	↓	↑	—	↓	—	>	↑	↑	—

Floyds Fork at Bardstown Road
(213 square miles and 23 percent urban)

	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
2020 Status										
Trend	↑	↑	—	↓	↓	—	<	↑	↓	↓

Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

CEDAR CREEK / PENNSYLVANIA RUN WATERSHED

Cedar Creek at Thixton Lane

The small streams that eventually form Cedar Creek in Jefferson County originate in the Fern Creek area, flow south and empty into Floyds Fork east of Shepherdsville. Pennsylvania Run originates in the Highview area, flows south through McNeely Lake and empties into Cedar Creek east of Zoneton.

BACKGROUND AND LAND USE

The 11 square mile Cedar Creek Watershed is located in south central Jefferson County and is bisected by the Gene Snyder Freeway. The stream flows in a southerly direction, passing into Bullitt County, and eventually discharges into Floyds Fork. Cedar Creek is the only major stream in this watershed. Communities lying in this watershed include Fern Creek and Highview. Notable landmarks include Beulah Church and Fern Creek High School. The Cedar Creek Watershed is mainly residential, with large tracts of agricultural land use, especially in the eastern portion of the watershed. The Cedar Creek Water Quality Treatment Center was constructed and eliminated the need for the small water quality treatment centers that existed within the watershed. MSD maintains one LTMN location at Thixton Road in the 11 square mile watershed.

The 7 square mile Pennsylvania Run Watershed is located in south central Jefferson County. Pennsylvania Run is the only major stream in this watershed. Highview is the only community in the Pennsylvania Run Watershed. Notable landmarks include McNeely Lake and McNeely Lake Park. McNeely Lake Park is located along Pennsylvania Run and provides preserved open space in the floodplain. The majority of the land use in the Pennsylvania Run Watershed is residential. There is one sampling station located within the watershed at Mount Washington Road. MSD has monitored this site since 1999.

MSD monitored fish communities at the Thixton Lane and Mount Washington Road sites since 1999. The fish communities in Cedar Creek rated "excellent" in 2017 and 2020.

Water quality and biological diversity within Pennsylvania Run are impaired and show moderate levels of impact. Nutrient enrichment is also a problem in the watershed. Much of the nutrient load to the stream comes from chemically treated lawns and golf courses, small agriculture, and septic tanks. These impacts threaten the habitat quality within the stream and the diversity of life it now supports. MSD has monitored these sites since 1999.

MONITORING FINDINGS

Fish Communities

MSD monitored fish communities at the Thixton Lane and Mount Washington Road sites since 1999. The fish communities in Cedar Creek rated "excellent" in 2017 and 2020. The communities in Pennsylvania Run rated "fair" in 2017 and "excellent" in 2020. The majority of the fish populations consisted of insectivores or insect feeding fish that rely on clear water. Fish communities at both of the sites are improving.

Aquatic Insect Communities

MSD has monitored aquatic insect communities at the Thixton Lane and Mount Washington Road sites since 2000. In Cedar Creek, the aquatic insect communities rated "poor" in 2017 and 2019 and are declining. Along Pennsylvania Run, the aquatic insect communities rated "fair" in 2017 and 2019 and are improving.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in both watersheds since 2001. Using a Diatom Bioassessment Index (DBI), both sites rated as "excellent" in 2017. In 2020, the Cedar Creek site rated as "fair," however, there was relatively little change over time. The Pennsylvania Run site showed an overall improvement and rated as "good" in 2020.

Stream Habitat

MSD has assessed stream habitat when fish and aquatic insects were sampled since 2005. Based on the latest monitoring, habitat along Cedar Creek is rated as "good," however, the data does not indicate a trend. These streams have stable banks and the stream beds were only slightly degraded by some silt and sediment deposition. The stream channels do not appear to have been straightened or otherwise altered.

The habitat at Pennsylvania Run is rated as "fair" and showing improvement. The stream banks have some stability problems and the stream lacks shallow, rocky riffles. None of the stream channels appear to have been straightened or otherwise altered.

Dissolved Oxygen and Temperature

MSD and the USGS continuously monitor streamflow, dissolved oxygen, and water temperature at both sites. Streamflow has been monitored on Cedar Creek at Thixton Road (USGS gage number 03298250) since 2007 and on Pennsylvania Run (USGS gage number 03298300) since 1998. Dissolved oxygen conditions were "good" (criteria met more than 97 percent of the time) and declining at Thixton Lane and "fair" and declining on Pennsylvania Run from 2018-2020. Water temperature criteria at both sites were met 100 percent of the time.

Bacteria

MSD collected fecal coliform data until 2016. Based on the last analysis of fecal coliform bacteria, concentrations along both Cedar Creek and Pennsylvania Run were moderate.

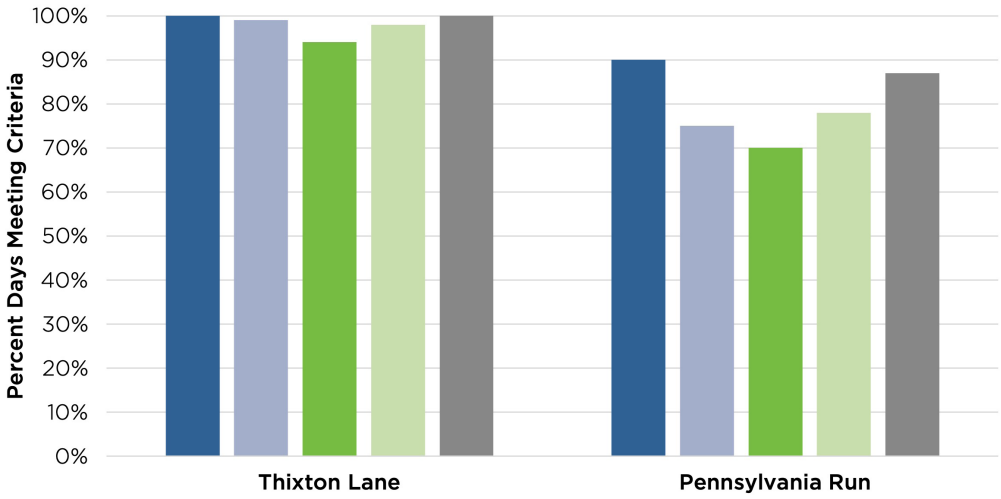
Conditions were improving for Cedar Creek and stable on Pennsylvania Run. Based on the analysis of *E. coli* bacteria for the past five years of data collection along Cedar Creek, the median concentrations were above the instantaneous recreational standard of 240 colonies/100ml and the 2020 median values were above the recreational standard. For Pennsylvania Run, the five-year median concentration was below the recreational standard, however, the 2020 median value was above the standard. The geometric means are shown in the chart on the following page.

CEDAR CREEK / PENNSYLVANIA RUN WATERSHED (CONTINUED)

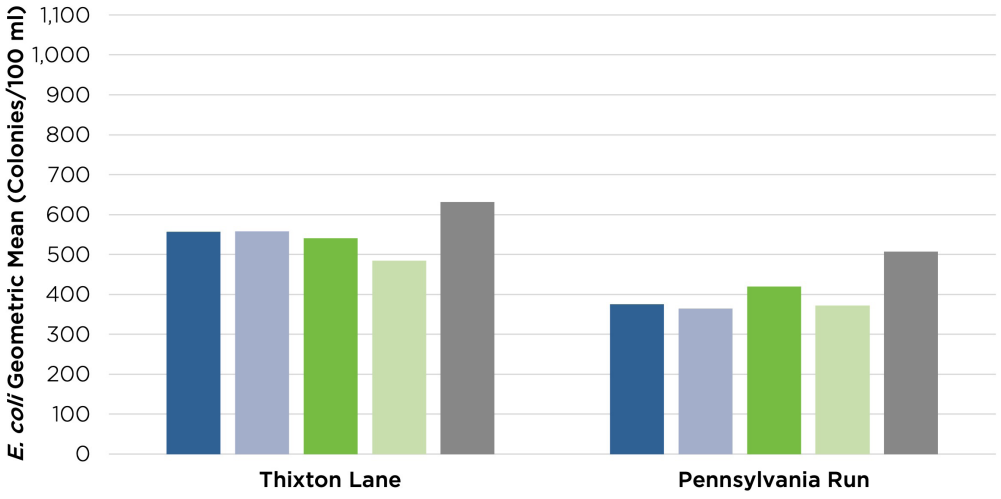
Nutrients

MSD monitored the concentrations of nutrients and total suspended solids in streams periodically from 2000 to 2005 and on a quarterly basis since 2005 at both sites. Levels of all nutrients at Pennsylvania Run were "good" and improving or showing no trend. Cedar Creek at Thixton Lane, total suspended solids were "good," however, there were "fair" levels of total Kjeldahl nitrogen and "poor" levels of nitrate. Trends for nitrates and total suspended parameters were demonstrating improvements, however, total Kjeldahl were declining.

Dissolved Oxygen in Cedar Creek / Pennsylvania Run Watershed
Water Years (October 1 to September 30)



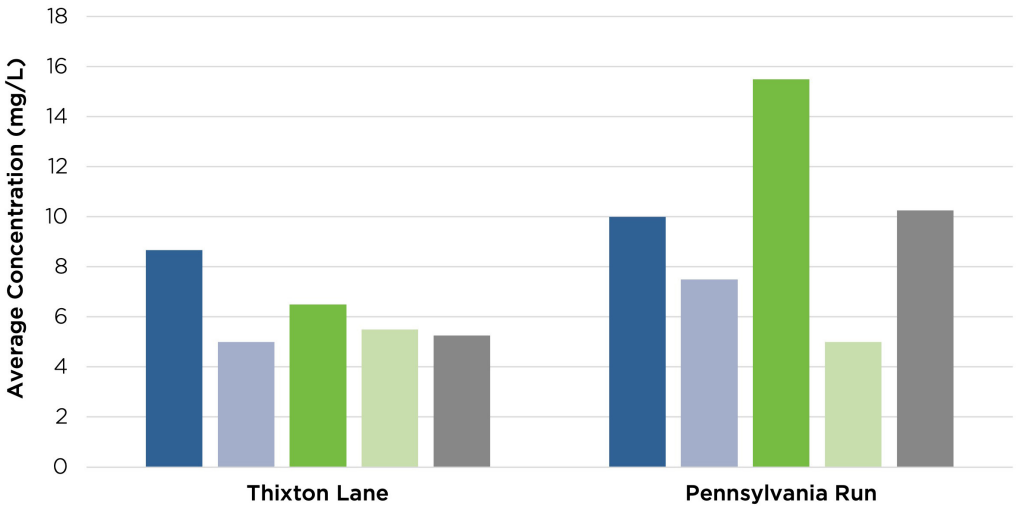
***E. coli* in Cedar Creek / Pennsylvania Run Watershed**
Recreational Seasons (May 1 to October 31)



2016 2017 2018 2019 2020

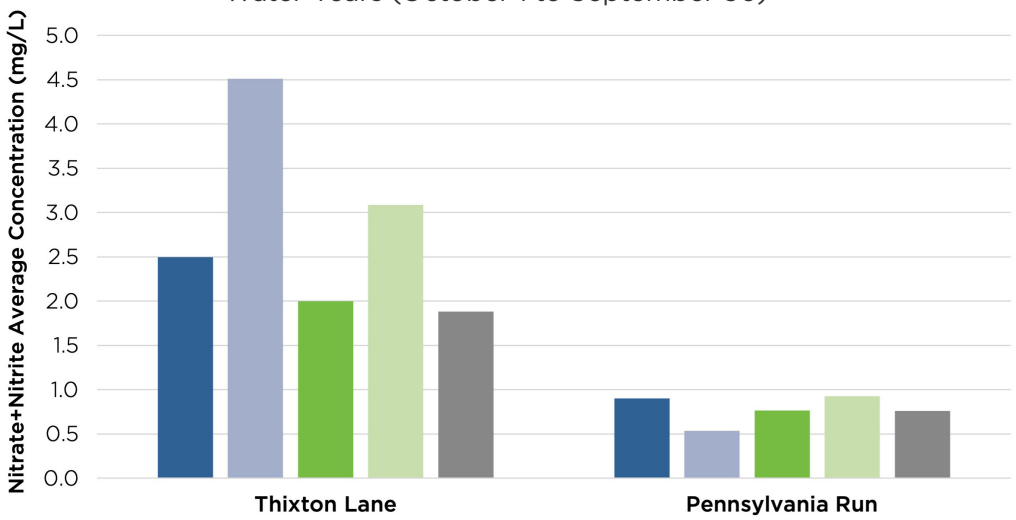
Total Suspended Solids in Cedar Creek / Pennsylvania Run Watershed

Water Years (October 1 to September 30)



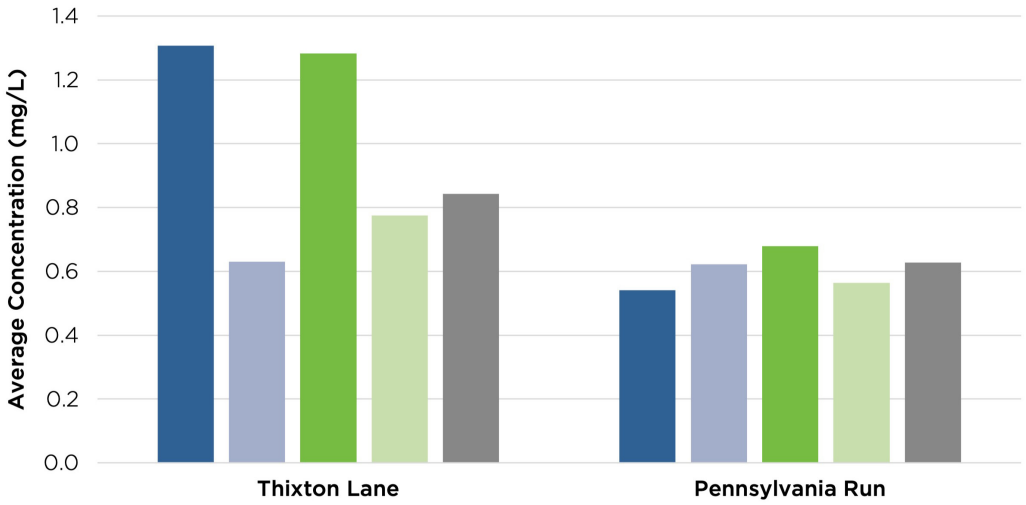
Nitrate + Nitrite in Cedar Creek / Pennsylvania Run Watershed

Water Years (October 1 to September 30)



2016 2017 2018 2019 2020

Total Kjeldahl Nitrogen in Cedar Creek / Pennsylvania Run Watershed
Water Years (October 1 to September 30)

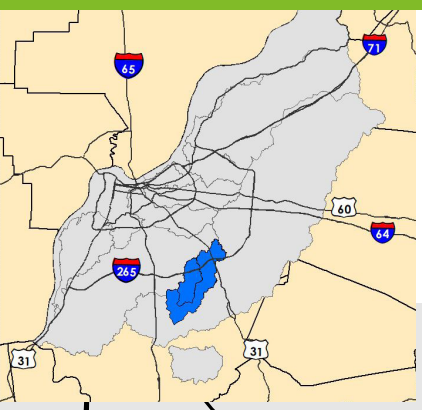


WATERSHED PROJECT SPOTLIGHT

BARTLEY DRIVE RIPARIAN RESTORATION

In 2016, MSD initiated the Bartley Stream Restoration Project. The project restored the riparian stream buffer along an MSD flood mitigation property on Bartley Drive. The improvements included planting trees, shrubs and grasses along the stream buffer to improve the stream health by adding shade and habitat along Cedar Creek.

Bartley Drive Riparian restoration project



Watershed area shown in blue

WATER QUALITY STATUS AND TRENDS

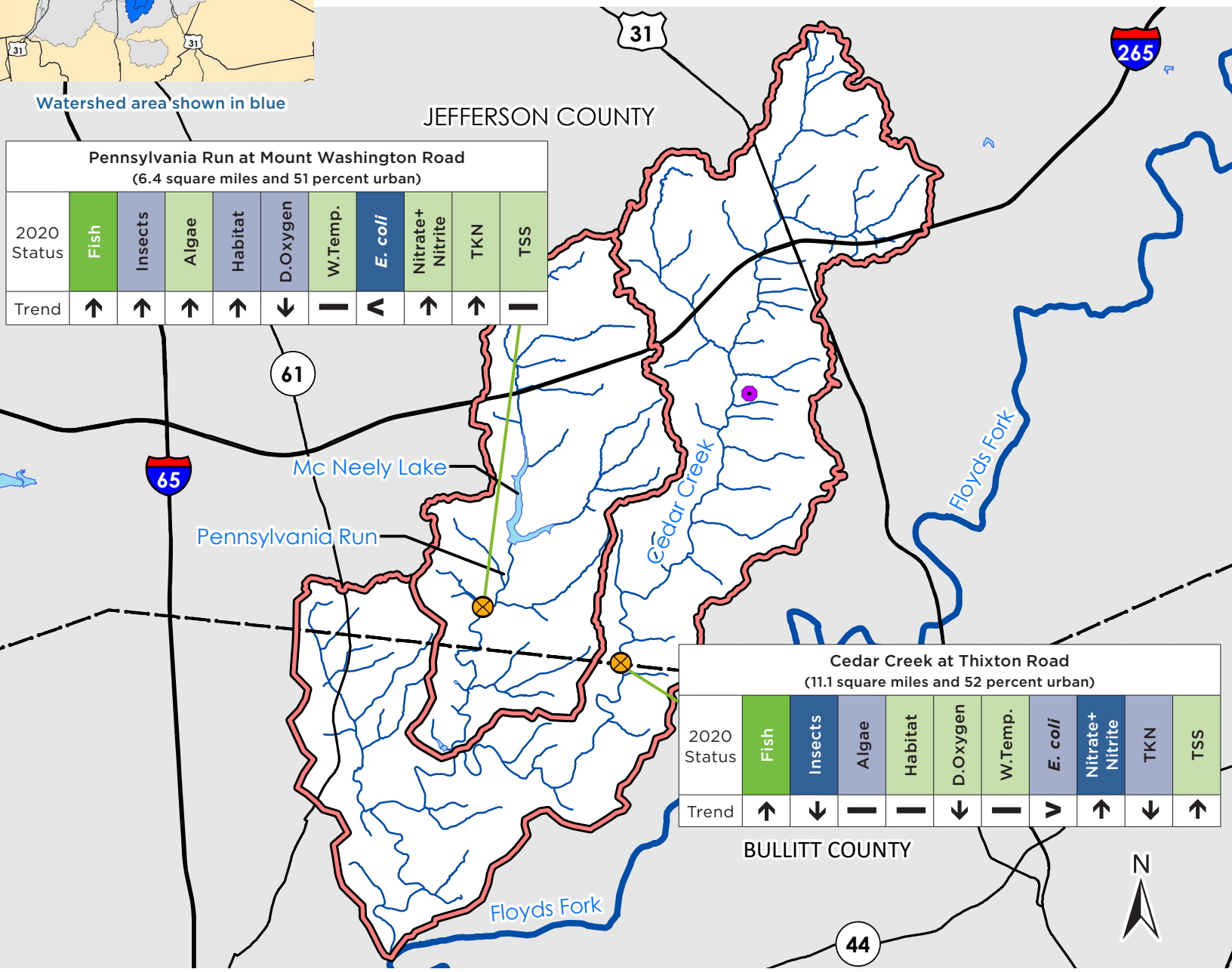
CEDAR CREEK / PENNSYLVANIA RUN WATERSHEDS

Pennsylvania Run at Mount Washington Road
(6.4 square miles and 51 percent urban)

	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	E. coli	Nitrate+ Nitrite	TKN	TSS
2020 Status										
Trend	↑	↑	↑	↑	↓	—	<	↑	↑	—

Cedar Creek at Thixton Road
(11.1 square miles and 52 percent urban)

	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	E. coli	Nitrate+ Nitrite	TKN	TSS
2020 Status										
Trend	↑	↓	—	—	↓	—	>	↑	↓	↑



Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

POND CREEK WATERSHED

Fern Creek Tributary

The Pond Creek Watershed drains about 126 square miles in southern and southwestern Louisville Metro area. Approximately 89 square miles are located in Jefferson County and 37 square miles are in Bullitt County. The Louisville International Airport and its associated large industrial complex, and Jefferson Memorial Forest are prominent features in this watershed.

BACKGROUND AND LAND USE

The relatively flat portion of the Pond Creek Watershed was once a shallow lake, which gradually filled with silt and debris to form a flat plain with standing water and dense swamp vegetation. Parts of this area were known as the "wet woods." Starting in the 1850s, a system of man-made ditches was developed to reduce flooding and to increase the amount of land suitable for development, which continued to expand before and after World War II. Many of the streams in the Pond Creek Watershed have been extensively channelized, and large flat areas are now drained by Northern Ditch and Southern Ditch. Excessive development within wetlands contributed to some of the most severe flooding during the March 1997 Flood. Due to intense industrial and commercial development, this area is considered an urban watershed.

The 94 square mile Pond Creek Watershed is located in south central and southwest Jefferson County. It is primarily drained

by a series of natural and improved channels called Fern Creek, Northern Ditch, Southern Ditch, and Pond Creek. The headwaters of Fern Creek originate in the west side of Jeffersontown and flow southwest to Shepherdsville Road. At this point, the flow turns to the west and the improved channel is called Northern Ditch. This westerly flow continues into the vicinity of the Louisville and Nashville Railroad's Osborn Yard, where it turns southwest and finally outlets into Southern Ditch at the Outer Loop. The flow in Southern Ditch, an improved channel, originates in the Smyrna area and moves west, generally paralleling the Outer Loop. From this point, Southern Ditch flows to the west about three-quarters of a mile, then turns to the southwest and flows about one mile to Manslick Road. Downstream from Manslick Road, the natural channel is called Pond Creek. It flows in a generally southwesterly direction to its eventual outlet into the Salt River. Numerous tributaries enter these four main channels, including Fishpool Creek, Mud Creek, Wilson Creek, Bee Lick Creek, Greasy Ditch, Duck Spring Branch, Salt Block Creek, Slate Run, Bearcamp Run, Crane Run, Brier Run, and Weaver Run.

As a part of MSD's Stormwater Quality Management Plan, stream restoration inspection and maintenance is a key component of ensuring and improving stormwater quality.

MSD has been monitoring water quality and stream flow in this watershed since 1999 at five locations listed here from upstream to downstream: Fern Creek at Old Bardstown Road, Northern Ditch at Preston Highway, Pond Creek at Manslick Road, Pond Creek at Pendleton Road, and Brier Creek at Bear Camp Road.

Communities situated in this watershed include parts of Jeffersontown, Fern Creek, Highview, Newburg, Smyrna, Okolona, Lynnview, Auburndale, Fairdale, Prairie Village, Medora, Orell, and part of Valley Station. Notable landmarks include the Louisville International Airport, General Electric's Appliance Park, Jefferson Mall, part of Iroquois Park, Komosdale Cement Plant, and much of the Jefferson County Memorial Forest. Roberson Run Park is located along Roberson Run, a tributary of Pond Creek, and provides preserved open space along that tributary. A conservation easement has been created near the Outer Loop by the Trinity High School Foundation to protect existing wetlands in the Pond Creek watershed. Three floodplain compensation/ wetlands mitigation banks are also located in this watershed. In addition, a Woodland Protection Area has been established in the Brookhurst Subdivision. The majority of the land use in the Pond Creek Watershed is residential.

Oxygen depletion from high nutrient levels has decreased fish populations in the watershed. Biological communities are severely impacted. Habitat quality is low due to the removal of trees and plants along the stream banks. Many of the streams in the Pond Creek area have been extensively channelized and offer little or no habitat for the macroinvertebrate and fish communities.

MONITORING FINDINGS

Fish Communities

MSD has monitored fish communities in the Pond Creek Watershed since 1999. In 2017, the fish communities at all sites rated "fair" with the exception of Manslick Road which rated "very poor." Fish communities of the Pond Creek Watershed ranged from "poor" to "good" in 2020. Sites within Pond Creek Watershed had relatively low population of native species, darter, madtom, and sculpin. Tolerant fish species were common in the Pond Creek Watershed. It should be noted that the upper limit of electrofishing seconds for headwater streams was exceeded at Brier Creek at Bear Camp Road. This was because of the presence of limbs and junk metal debris within pools, as well as an unusual stream morphology at the site. Pools were unusually deep for a stream that size, most likely due to scouring, and resulted in additional electroshocking effort to adequately survey the pool habitats. Fish communities are improving at all sites.

Aquatic Insect Communities

MSD has monitored the aquatic insect communities in the Pond Creek Watershed since 2000. At the Fern Creek and Northern Ditch sites, aquatic insect communities rated "poor" in 2017 and 2019 with relatively little change over time. In 2017, conditions were "poor" at both sites along the Pond Creek main stem. They remained "poor" in 2019 at Pendleton Road and "fair" at Manslick Road. Both sites are showing improvement. Along Brier Creek, the aquatic insect communities rated "fair" in 2017 and "good" in 2019, with an overall improvement over time.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in the watershed since 2001. Using a Diatom Bioassessment Index (DBI), the Pond Creek Watershed has varied results. Conditions were "good" and "excellent" in 2017 with the exception of Brier Creek which was rated as "poor."

In 2020, conditions ranged from "poor" to "excellent" for the sites. Trends over time showed improvement along Northern Ditch and at Manslick, relatively little change along Fern Creek and at Pendleton Road, and declining conditions along Brier Creek.

Stream Habitat

MSD has assessed stream habitat when fish and aquatic insects were sampled since 2005. The habitat in all of the sites in the watershed rated as "poor" in 2017, 2019, and 2020. The trends vary across the sites.

There was an overall improvement in the habitat along Fern Creek while the data at Northern Ditch does not indicate a trend. Good stream bed habitat is limited at the Fern Creek site by bedrock, but both growth of stream bank vegetation and development of a rocky substrate at the Northern Ditch site have improved habitat in the past.

The sites along Pond Creek and Brier Creek are declining. Both of the Pond Creek sites have been channelized and have unstable, sediment laden stream beds and a general lack of rocky riffles, which provide important habitat for fish and aquatic insects. In Brier Creek, habitat quality improved from "poor" in 2005 to "good" in 2009 but has declined to "fair" since then. The stream in this location generally has unstable banks as well as shifting sediment deposits in the stream bed. This site has a very small drainage area and is affected by longer periods of low to zero stream flow.

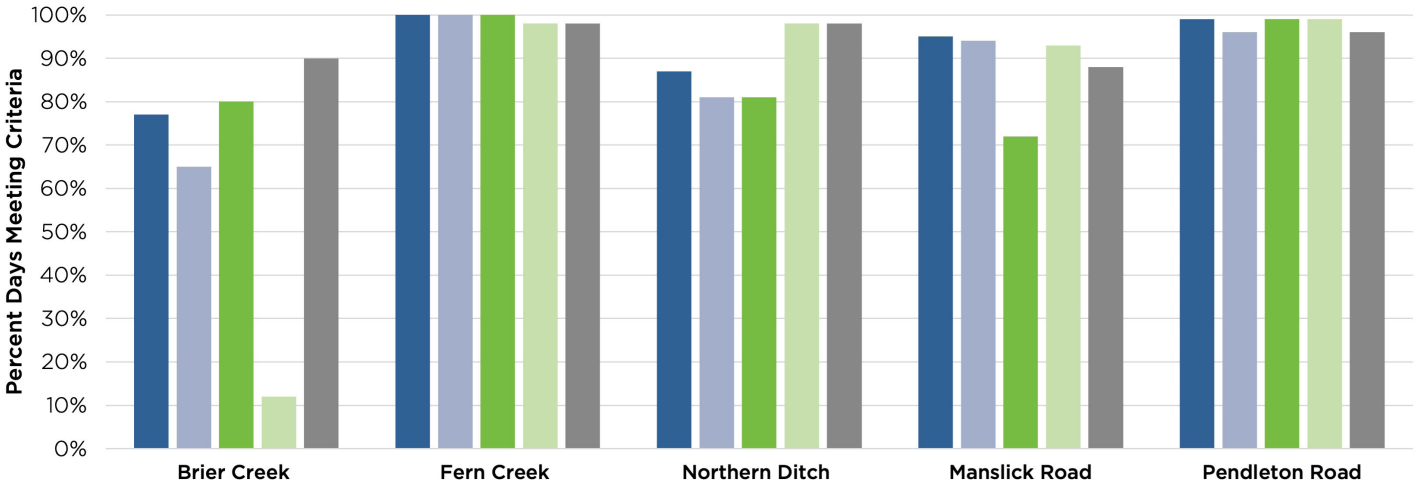
Dissolved Oxygen and Temperature

MSD and the USGS continuously monitor streamflow, dissolved oxygen, and water temperature at the five sites in the Pond Creek Watershed; Brier Creek (USGS Gage 03302050), Fern Creek (USGS Gage 03301900), Northern Ditch (USGS Gage 03301940), Manslick Road (USGS Gage 03302000), and Pendleton Road (USGS Gage 03302030).

Along Pond Creek, dissolved oxygen conditions were "fair" and declining at the Manslick Road site and conditions were "good" and steady at the Pendleton Road site from 2018-2020. Water temperature criteria at Manslick Road were met 98 percent of the time.

At Pendleton Road, water temperature criteria were met 100 percent of the time. Along Brier Creek, dissolved oxygen conditions were "fair" (criteria met more than 76 percent of the time) and improving. In 2019, the dissolved oxygen readings at this site met criteria only 12% of the time and data were limited to January through June and October through December. This

Dissolved Oxygen in Pond Creek Watershed
Water Years (October 1 to September 30)



was a very dry year with very little rainfall and low stream flow at this site. Water temperature criteria were met 100 percent of the time. Along Fern Creek, dissolved oxygen conditions were "good" (criteria met more than 99 percent of the time) and declining. Water temperature criteria were met 100 percent of the time. Along Northern Ditch, dissolved oxygen conditions were "good" (criteria met more than 93 percent of the time) and improving. Water temperature criteria were met 94 percent of the time.

Bacteria

MSD collected fecal coliform data until 2016. Based on the last analysis of fecal coliform bacteria, concentrations were moderate and stable along Fern Creek and along Pond Creek at Manslick Road. Concentrations were low and improving along Northern Ditch, Brier Creek, and at the Pendleton Road LTMN site on Pond Creek.

Based on the analysis of *E. coli* bacteria for the past five years of data collection, both the median concentrations and the 2020 median values on Fern Creek were above the instantaneous recreational standard of 240 colonies/100ml. For Northern Ditch, both the five-year median concentration and the 2020 median value was below the standard.

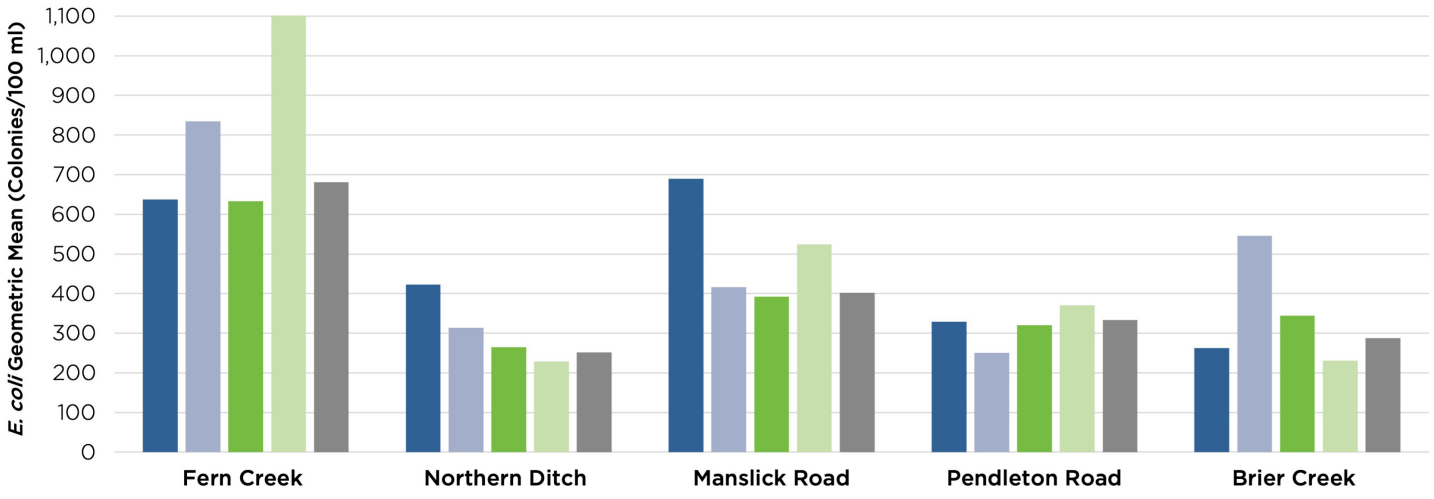
The median concentrations on Brier Creek were above the instantaneous recreational standard of 240 colonies/100ml; however, the 2020 median values were below the recreational standard. Along Pond Creek, the five-year median concentrations at Manslick Road were above the instantaneous recreational standard; however, they were below the standard at Pendleton Road. The 2020 median values at both sites were below the recreational standard. The geometric means are shown in the adjacent chart.

Nutrients

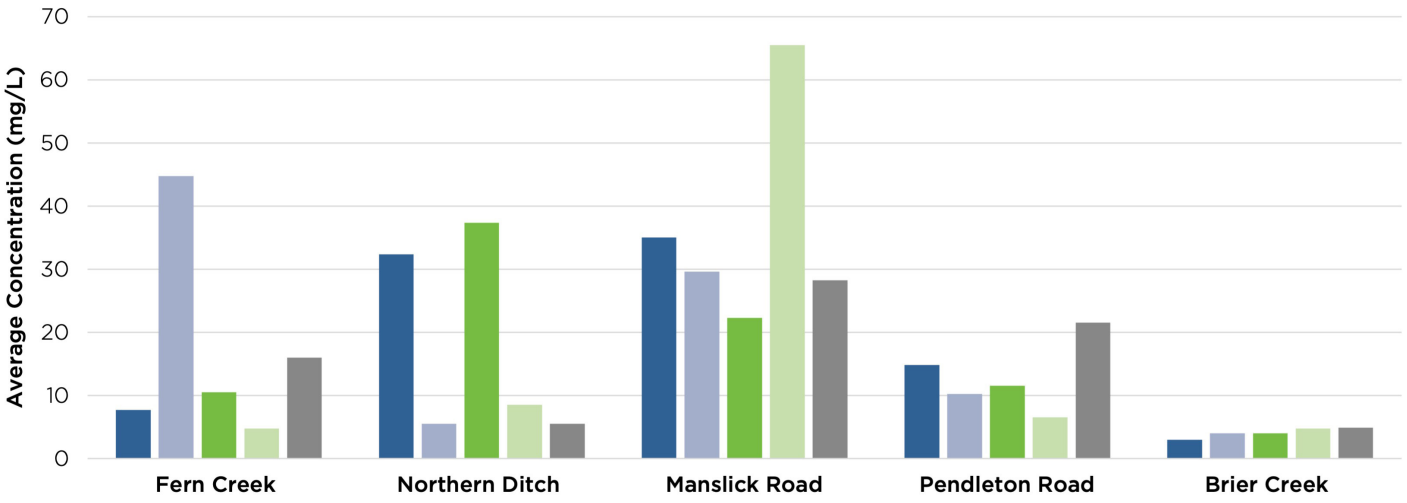
MSD monitored the concentrations of nutrients and total suspended solids in streams periodically from 2000 to 2005 and on a quarterly basis since 2005 at five sites in the Pond Creek Watershed. The sites along Pond Creek indicated "good" nitrate and total Kjeldahl nitrogen levels with "fair" to "poor" total suspended solids levels. Total suspended solids and total Kjeldahl nitrogen levels at these sites were improving while nitrates were declining or did not exhibit a trend. Northern Ditch and Brier Creek resulted in "good" levels for all nutrient values that were improving with the exception of the nitrate levels, which were declining. Nutrient levels at Fern Creek were all improving; however, the nitrate levels were "poor," and the total suspended solids were "fair."

E. coli in Pond Creek Watershed

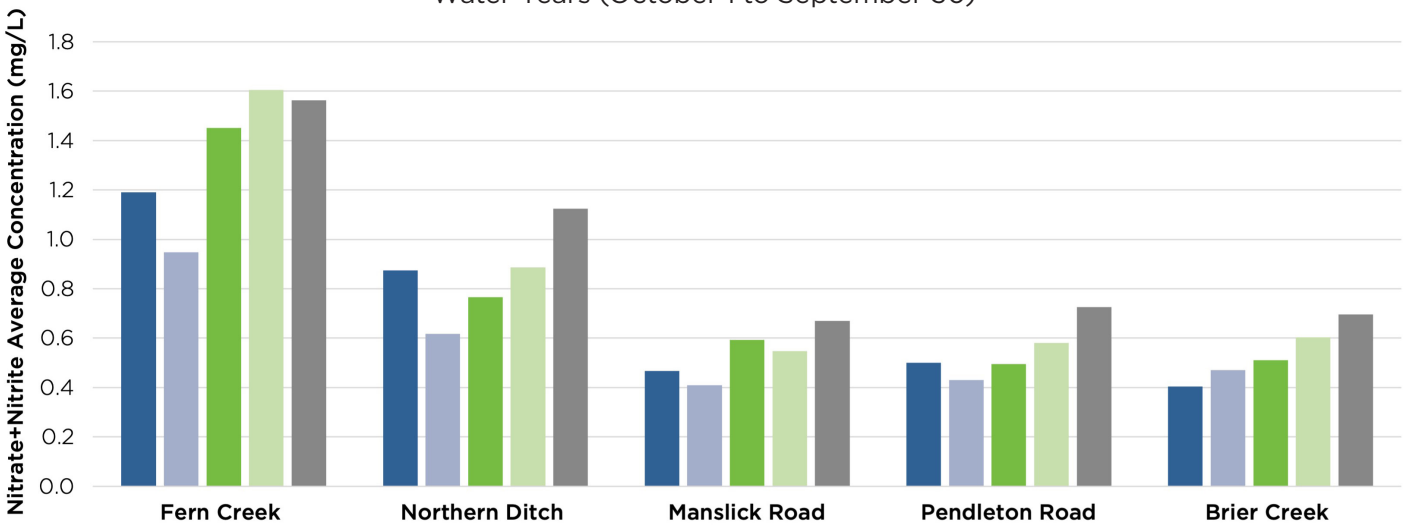
Recreational Seasons (May 1 to October 31)



Total Suspended Solids in Pond Creek Watershed
Water Years (October 1 to September 30)

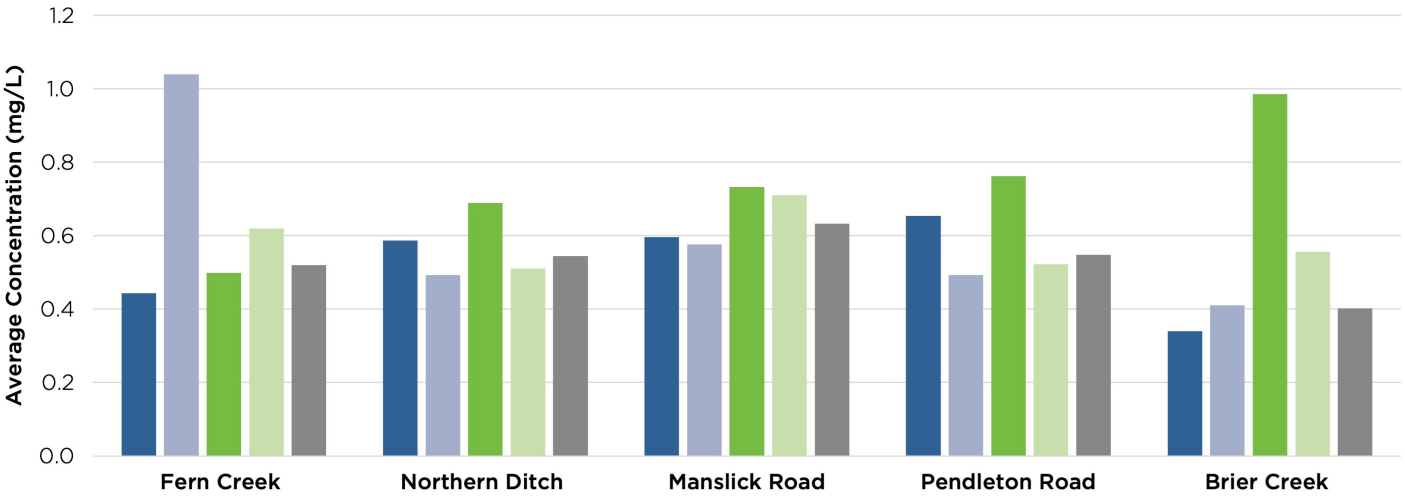


Nitrate + Nitrite in Pond Creek Watershed
Water Years (October 1 to September 30)



2016 2017 2018 2019 2020

Total Kjeldahl Nitrogen in Pond Creek Watershed
Water Years (October 1 to September 30)



WATERSHED PROJECT SPOTLIGHT

STREAM BANK STABILIZATION PROJECTS

As a part of MSD's Stormwater Quality Management Plan, stream restoration inspection and maintenance is a key component of ensuring and improving stormwater quality. The stabilization of the bank improves water quality through reducing erosion and increasing drainage efficiency. These improvements will help to decrease the amount of sediment that is picked up by stormwater and deposited into the creek.

Mount Holly bank stabilization

2016 2017 2018 2019 2020

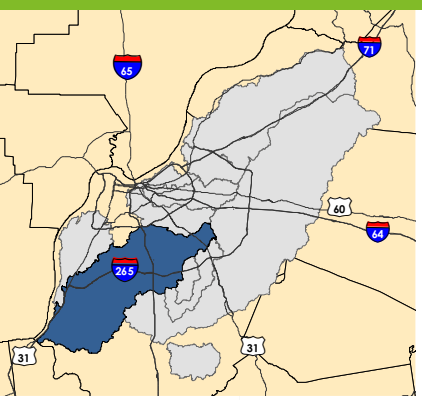
Northern Ditch at Preston Highway

NORTHERN DITCH

Northern Ditch is an example of a stream that has been severely altered as a result of urban development. As the city was developed, the stream was rerouted and straightened in order to convey stormwater out of the area more quickly and to reduce flooding. Trees and vegetation along the stream were removed as part of the construction effort, and while the project did improve drainage in the area, the health of the stream suffered. Since the MSD Long Term Monitoring Network program was initiated, the biological monitoring results have indicated a general increase in stream health for Northern Ditch.

Since the MSD Long Term Monitoring Network program was initiated, the biological monitoring results have indicated a general increase in stream health for Northern Ditch.

Over the years, the stream has evolved within its existing straightened channel to form riffle/run/pool complexes. Woody vegetation is developing along the once treeless, steep sides of the channel. The trees are providing shade, which decreases water temperatures in the stream, and the habitat is more varied both allowing colonization of less tolerant fish and insects. These factors, along with improved stormwater and pollution management, have most likely played an integral role in improving the overall integrity of Northern Ditch.



Watershed area shown in blue

WATER QUALITY STATUS AND TRENDS

POND CREEK WATERSHED

Fern Creek at Old Bardstown Road
(3.5 square miles and 80 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	—	—	↑	↓	—	>	↑	↑	↑

Northern Ditch at Preston Highway
(11.1 square miles and 78 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	—	↑	—	↑	—	<	↓	↑	—

Pond Creek at Manslick Road
(64 square miles and 72 percent urban)

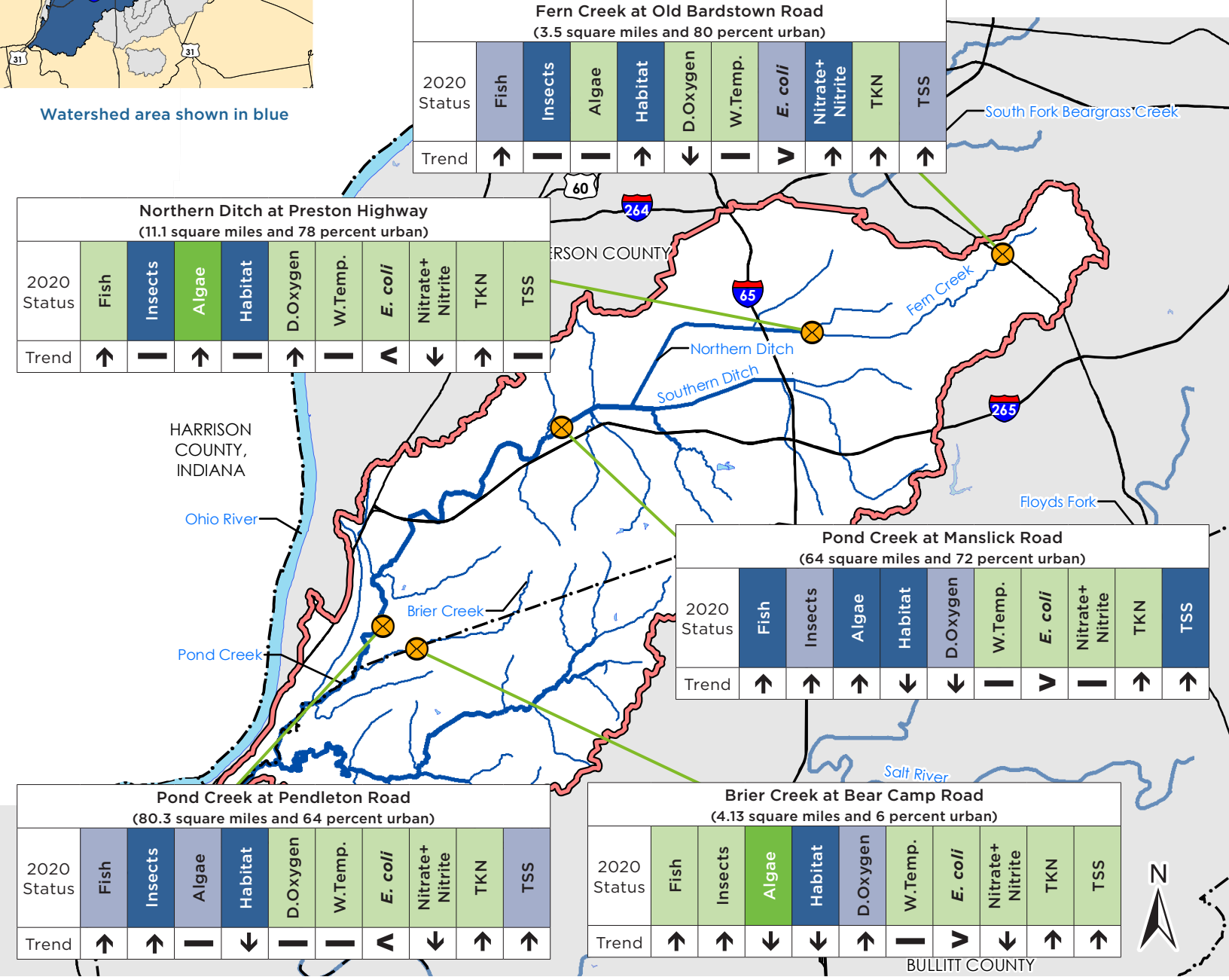
2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↑	↑	↓	↓	—	>	—	↑	↑

Pond Creek at Pendleton Road
(80.3 square miles and 64 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↑	—	↓	—	—	<	↓	↑	↑

Brier Creek at Bear Camp Road
(4.13 square miles and 6 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↑	↓	↓	↑	—	>	↓	↑	↑



Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

MILL CREEK WATERSHED

Mill Creek

The Mill Creek Watershed drains about 34 square miles in western Louisville, near the Ohio River. The northern part of the watershed includes streams that drain to the Mill Creek Cutoff, which directly flows into the Ohio River near Shively. The southern part of the watershed flows south through Pleasure Ridge Park and then into the Ohio River near Watson Lane. Many of the streams in this watershed were straightened or channelized in the past to reduce flooding.

BACKGROUND AND LAND USE

Due to the diversion of the upstream reaches of Mill Creek into a "cut-off" channel, this watershed is divided into two entirely separate sections. These are referred to as Upper Mill Creek and Lower Mill Creek. Major streams included in Upper Mill Creek include Big Run, Cane Run, and Mill Creek Cutoff. Major streams included in Lower Mill Creek include Mill Creek and Black Pond Creek.

The 19 square mile Upper Mill Creek's headwaters originate in the area of Manslick Road and I-264. From here, they flow in a westerly direction to the western side of Shively, where several tributaries including Cane Run, Boxwood Ditch, Lynnview Ditch, and Big Run join the flow. From this point, the flow direction is to the northwest, via the cutoff channel. The stream outlets into the Ohio River just south of Riverside Gardens.

Communities lying in the Upper Mill Creek section include Shively, Heatherfield, Hunters Trace, Parkwood, St. Denis,

and Riverside Gardens. Notable landmarks include Louisville Gas & Electric's Mill Creek Power Station, Western High School, Doss High School, Shively Park, Dixie Manor, and a part of Iroquois Park. Sun Valley Park is located on Mill Creek near Lower River Road. This park provides preserved open space along Mill Creek.

The 15 square mile Lower Mill Creek's headwaters originate in the area of Lower Hunters Trace and Terry Road. From here, the flow is generally to the south, paralleling the Ohio River. Several tributaries, including Black Pond Creek and Valley Creek, join this flow in the Valley Downs area. The stream eventually outlets into the Ohio River west of Valley Village.

Communities lying in the Lower Mill Creek section include Valley Village, Meadow Lawn, Valley Downs, parts of Valley Station and Pleasure Ridge Park, Sylvania, Greenwood, and Waverly Hills. Notable landmarks include Sun Valley Community Park, Valley High School, Waverly Park, and the Louisville and Jefferson County Riverport Authority.

The majority of the land use in the Mill Creek Watershed is residential, with commercial areas located along Dixie Highway and a combination of commercial and industrial uses near the river. MSD has monitored water quality and flow in Mill Creek Cutoff at two sites in this watershed since 1999; on Mill Creek Cutoff at Old Cane Run Road and on Mill Creek at Orell Road.

Nutrient levels in Mill Creek are generally moderate to high. Algae are a particular problem in the Mill Creek Cutoff, due to high levels of nutrients, discharge from septic tanks, and seepage pits. Trees have been removed along the stream banks in most of the watershed area. Without trees along the banks, full sun causes water temperatures to rise sharply, making it difficult for plant and animal communities within the stream to survive. Instream habitat is seriously impacted by extremely low flows in the summer and heavy levels of siltation.

Stream monitoring parameters indicate this watershed area contains moderate to severe impacts. Solutions include the elimination of septic systems and seepage pits, which are the primary means of wastewater treatment in the lower portion of the watershed. Revegetation of the stream banks would also aid to lessen the impacts on area streams.

MONITORING FINDINGS

Fish Communities

MSD has monitored fish communities at the two sites since 1999. The fish communities of Mill Creek Watershed rated "poor" at Old Cane Run Road and "very poor" at Orell Road in 2017 and "poor" and "fair" in 2020 respectively. Darter, madtom and sculpins were absent from the Mill Creek Watershed sites. Fish communities are improving at Orell Road and declining at Old Cane Run Road.

Sun Valley Park is located on Mill Creek near Lower River Road. This park provides preserved open space along Mill Creek.

Aquatic Insect Communities

MSD has monitored aquatic insect communities at the two sites since 2000. The aquatic insect communities improved slightly from "very poor" to "poor" at the Mill Creek Cutoff site. At Orell Road, aquatic insect communities were classified in "poor" condition in 2017 and 2019 and declining.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in the watershed since 2001. Using a Diatom Bioassessment Index (DBI), both sites rated as "good" in 2017. In 2020, conditions at the Mill Creek Cutoff rated as "good" with relatively little change over time while Orell Road rated as "poor" and declining. The man-made channels that lack rocky riffles and tree-lined banks could favor algal growth.

Stream Habitat

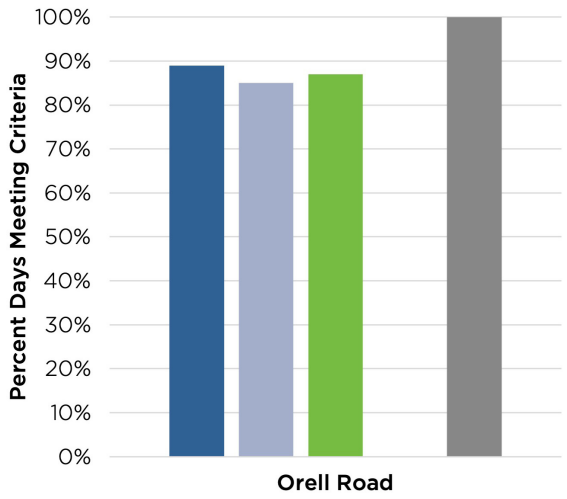
MSD has assessed stream habitat when fish and aquatic insects were sampled since 2005. The habitat ratings for both sites were "poor" in both 2017, 2019, and 2020. While the overall trend at the Mill Creek Cutoff is an improvement over time, the conditions have declined at Orell Road. These sites are located in straight man-made channels that lack rocky riffles and tree lined banks. These features provide important habitat for fish and aquatic insects. The less than optimal stream habitat and the natural effects of low stream flow may have stressed aquatic communities at the two sites.

Dissolved Oxygen and Temperature

MSD and the USGS continuously monitor streamflow, dissolved oxygen, and water temperature on Mill Creek at Orell Road. Streamflow has been monitored at the Orell Road site (USGS gage number 03294570) since 1999 and at the Mill Creek Cutoff site (USGS gage number 03294550) since 1988; however, dissolved oxygen and temperature data are not available at the Mill Creek Cutoff site. The gage at Orell Road did not record dissolved oxygen date between July 2018 through March 2020 and from May 2020 through October 2020. For the remainder of the record, conditions were "fair" at the Orell Road site from 2018-2020, which is a slight improvement since 2016. Water temperature criteria were met 100 percent of the time.

Dissolved Oxygen in Mill Creek Watershed

Water Years (October 1 to September 30)



No data was collected for 2019.

Bacteria

MSD collected fecal coliform data until 2016. Based on the last analysis of fecal coliform bacteria, concentrations were moderate and getting worse along Mill Creek Cutoff with concentrations higher during wet weather events. Concentrations at Mill Creek at Orell Road were low and stable.

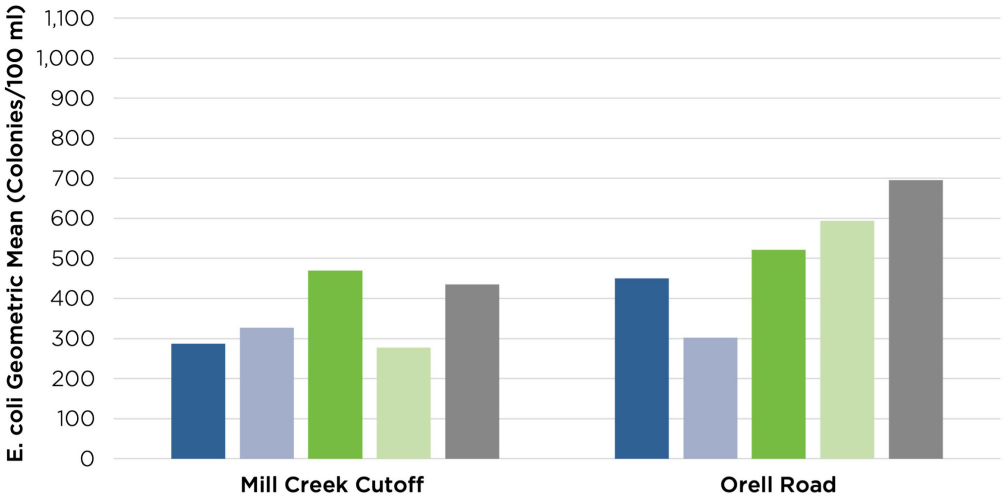
Based on the analysis of *E. coli* bacteria for the past five years of data collection, the median concentrations for both sites on Mill Creek were below the instantaneous recreational standard of 240 colonies/100ml. The 2020 median values were below the recreational standard along Mill Creek Cutoff and above the recreational standard at Orell Road. The geometric means are shown in the adjacent chart.

Nutrients

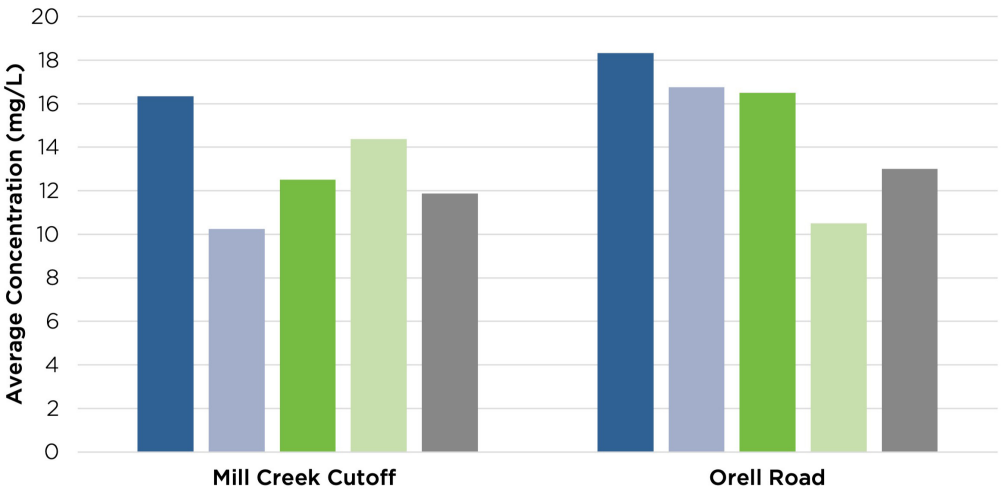
MSD monitored the concentrations of nutrients and total suspended solids in streams periodically from 2000 to 2005 and on a quarterly basis since 2005 at two sites in the Mill Creek Watershed. Nitrate results at both sites were below the threshold of 1.32 mg/L, however the trend indicates declining conditions. At Mill Creek Cutoff, samples had "good" total Kjeldahl nitrogen levels and "fair" total suspended solids with both parameters indicating improvement. Orell Road indicated "fair" and declining total Kjeldahl nitrogen levels and "poor" but improving total suspended solids.

E. coli in Mill Creek Watershed

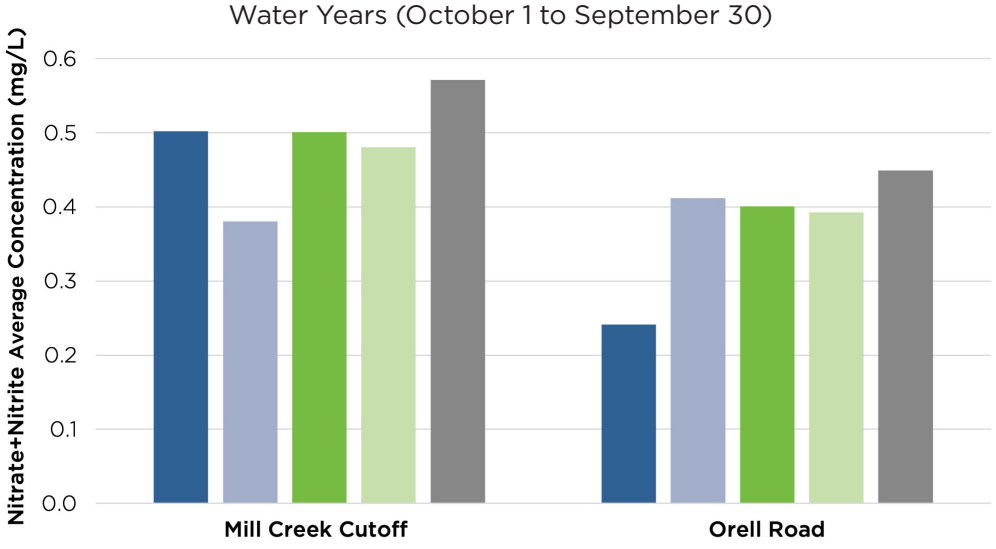
Recreational Seasons (May 1 to October 31)



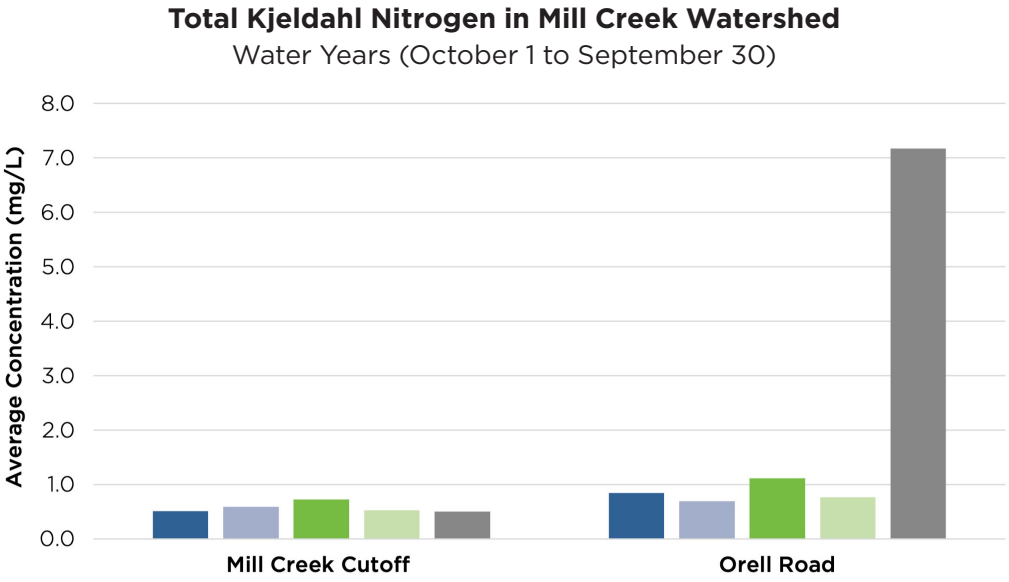
Total Suspended Solids in Mill Creek Watershed
Water Years (October 1 to September 30)



Nitrate + Nitrite in Mill Creek Watershed
Water Years (October 1 to September 30)



2016 2017 2018 2019 2020



WATERSHED PROJECT SPOTLIGHT

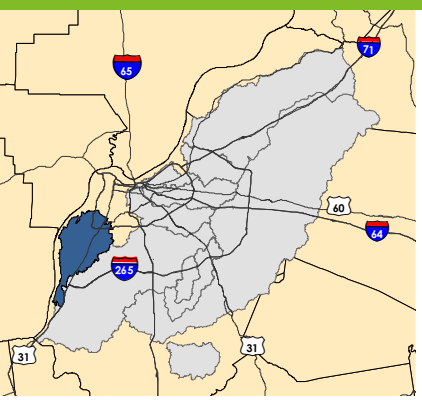
WATERSHED PLANNING

MSD, along with community stakeholders and partners, continue to utilize watershed planning, following the Kentucky Watershed Planning Guidebook, to address non-point source pollution challenges throughout Jefferson County.

MSD completed the first urban watershed plan in 2022 for the State of Kentucky in Middle Fork Beargrass Creek, and will begin a second effort in Mill Creek watershed in 2022. Through these watershed planning efforts, the importance of community activism is becoming more apparent; therefore, education and engagement will help to better understand the unique needs of each watershed and its community.

Additional collection of watershed data will occur to analyze and compare the data to regulatory benchmarks, as well as to Kentucky ecoregional averages, to set goals for reduction levels. All these efforts are utilized to develop a plan that includes solutions that address the non-point source pollution concerns.

Trash pick-up event organized as part of the watershed planning efforts



Watershed area shown in blue

WATER QUALITY STATUS AND TRENDS

MILL CREEK WATERSHED

FLOYD COUNTY, INDIANA

HARRISON COUNTY, INDIANA

JEFFERSON COUNTY

BULLITT COUNTY

Ohio

Mill Creek Cutoff

Mill Creek

Mill Creek

Mill Creek Cutoff at Old Cane Run Road
(24.4 square miles and 89 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↓	↑	—	↑	ND	ND	<	↓	↑	↑

Mill Creek at Orell Road
(13.5 square miles and 50 percent urban)

2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↓	↓	↓	↑	—	<	↓	↓	↑

N

Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

CEDAR CREEK (BULLITT COUNTY) REFERENCE REACH

Cedar Creek in Bullitt County originates in the Cedar Grove area, flows north and empties into the Salt River east of Shepherdsville.

BACKGROUND AND LAND USE

The small streams that eventually form the reference reach, Cedar Creek, originate in the Cedar Grove area of Bullitt County. Cedar Creek flows north and empties into the Salt River east of Shepherdsville. This site is located outside of the urban influences of Louisville and provides a basis for comparison of water quality conditions in a less urbanized watershed to the more urbanized sites in the Louisville Metro area.

There are 12.1 square miles of land draining to the Cedar Creek in Bullitt County site. A relatively small percentage of the watershed has been developed for urban and suburban uses. Much of the land is forested with areas of agriculture and grasslands. MSD has been monitoring water quality and stream flow in Cedar Creek at Cedar Creek at State Highway 1442 (Bullitt County) since 2002.

MONITORING FINDINGS

Fish Communities

MSD monitored fish communities at the State Road 1442 site in Bullitt County since 2002. The fish communities of this watershed rated "excellent" in both 2017 and 2020. Like other sites that scored "good" or "excellent," insectivores comprised greater than 50% of the fish community and tolerant species were infrequent. Fish communities are improving at the site.

Aquatic Insect Communities

The aquatic insect communities in Cedar Creek at State Road 1442 were classified as "good" in 2017 and 2019 and are improving.

Algae Communities

MSD has monitored benthic algal communities, largely diatoms, in the watershed since 2002. Using a Diatom Bioassessment Index (DBI), the site rated "good" in 2017 and "excellent" in 2020 showing an overall improvement over time.

Stream Habitat

MSD has assessed stream habitat when fish and aquatic insects were sampled since 2005. The habitat along the reference reach was rated as "good" in both 2017, 2019, and 2020; however, overall the habitat conditions are declining over time. Stream reaches at Cedar Creek sites have stable banks, and the stream beds were only slightly degraded by some silt and sediment deposition. The stream channels do not appear to have been straightened or otherwise altered.

Dissolved Oxygen and Temperature

MSD and the USGS have continuously monitored streamflow, dissolved oxygen, and water temperature on Cedar Creek in Bullitt County (USGS gage number 03297800) since 2002. Dissolved oxygen conditions were "good" (criteria met more than 94 percent of the time) from 2018-2020, which is an improvement since 2016. Water temperature criteria at the Cedar Creek site were met 100 percent of the time.

Bacteria

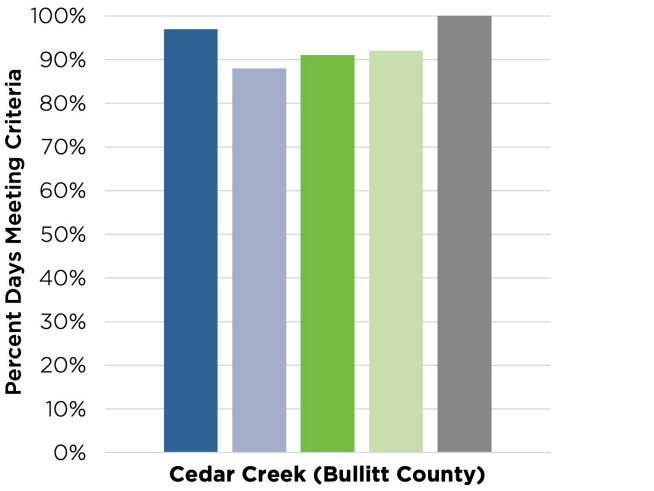
MSD collected fecal coliform data until 2016. Based on the last analysis of fecal coliform, bacteria concentrations were moderate and improving. Based on the current analysis of *E. coli* bacteria for the past five years of data collection, the median concentrations for both sites were above the instantaneous recreational standard of 240 colonies/100ml and the 2020 median values were above the recreational standard. The geometric means are shown in the adjacent chart.

Nutrients

MSD monitored the concentrations of nutrients and total suspended solids in streams periodically from 2000 to 2005 and on a quarterly basis since 2005 at Cedar Creek. The Cedar Creek site in Bullitt County had relatively low numbers of samples in the upper third for nutrients and total suspended solids. Compared to previous years, the level of total suspended solids appears to be declining.

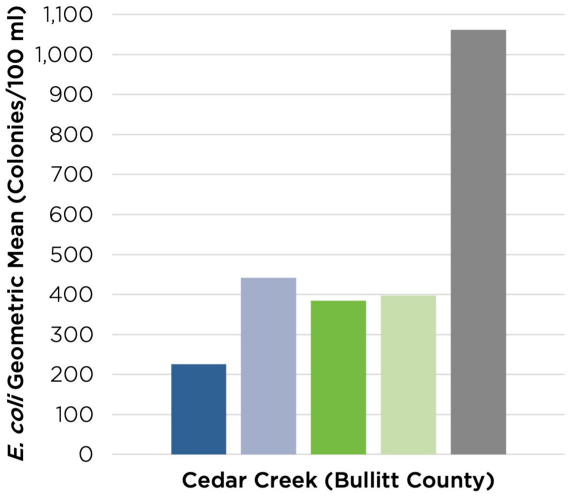
Dissolved Oxygen in the Reference Reach Watershed

Water Years (October 1 to September 30)



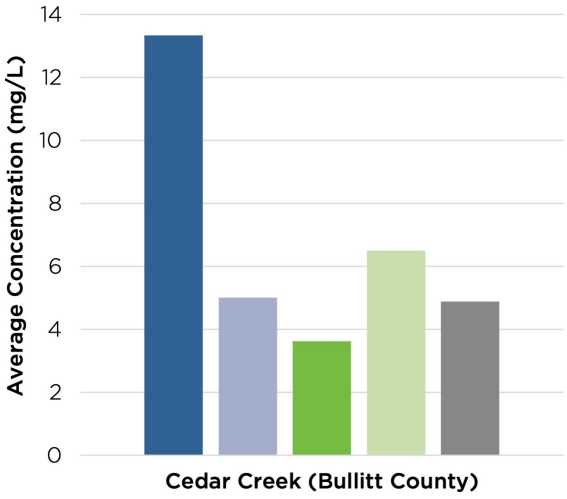
***E. coli* in the Reference Reach Watershed**

Recreational Seasons (May 1 to October 31)



Total Suspended Solids in the Reference Reach Watershed

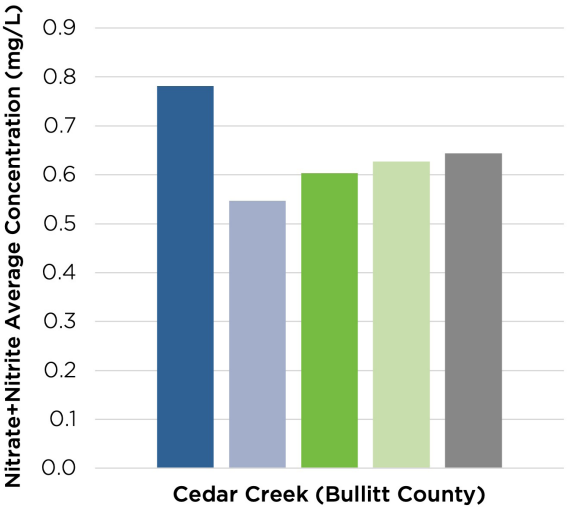
Water Years (October 1 to September 30)



2016 2017 2018 2019 2020

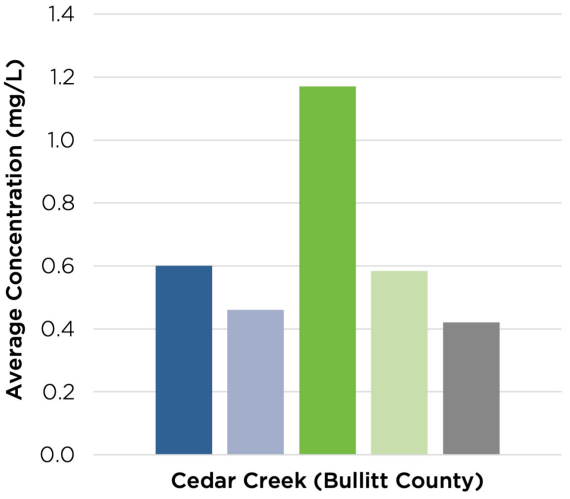
Nitrate + Nitrite in the Reference Reach Watershed

Water Years (October 1 to September 30)



Total Kjeldahl Nitrogen in the Reference Reach Watershed

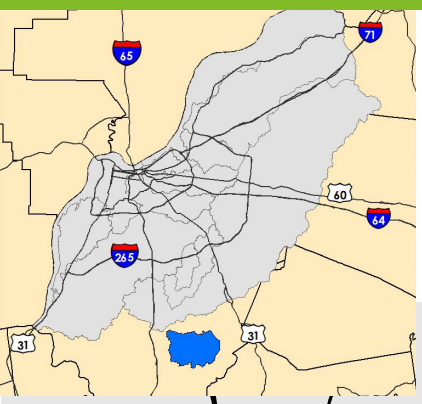
Water Years (October 1 to September 30)



2016 2017 2018 2019 2020

WATER QUALITY STATUS AND TRENDS

CEDAR CREEK (BULLITT COUNTY) REFERENCE REACH



Watershed area shown in blue

BULLITT COUNTY

Floyds Fork

44

Salt River

Cedar Creek

RIDGE RD

CEDAR GROVE RD

61

65

N

Cedar Creek at State Road 1442 (12.1 square miles and 10 percent urban)										
2020 Status	Fish	Insects	Algae	Habitat	D.Oxygen	W.Temp.	*E. coli*	Nitrate+ Nitrite	TKN	TSS
Trend	↑	↑	↑	↓	↑	—	>	↑	—	↓

Legend

- Completed Project
- Monitoring Site
- Water Quality Treatment Center (Operated by MSD)
- Stream
- Road
- County Boundary
- Watershed Boundary
- Lake

Ratings Key

STATUS

- Excellent
- Good
- Fair
- Poor

TREND

- ↑ Improving
- ↓ Declining
- ~ Varies
- — No Change
- ND No Data
- < Median Concentration Below 240 CFU/100 ml
- > Median Concentration Above 240 CFU/100 ml

OHIO RIVER WATERSHED

Beargrass Creek at the Mouth of the Ohio

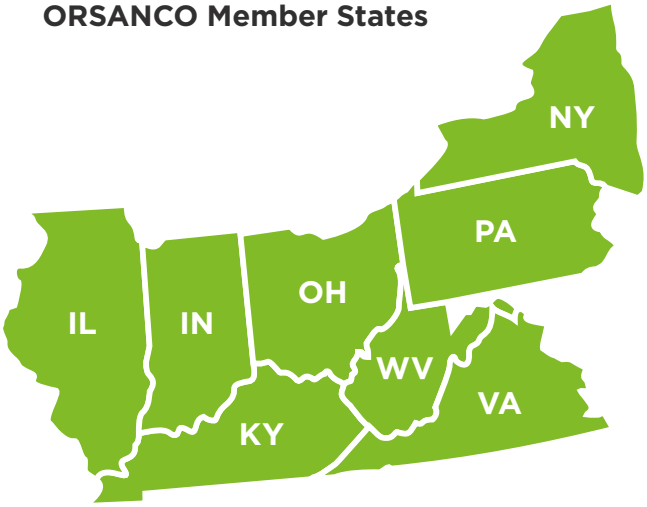
The Ohio River is one of the nation's great natural resources. The river not only provides drinking water for over five million people but serves as a warm water habitat for aquatic life, provides numerous recreational opportunities, is used as a major transportation route, and is a source of water for the manufacturing and power industries. The Ohio River begins in Pittsburgh, Pennsylvania at the confluence of the Allegheny and Monongahela Rivers and flows southwesterly for 981 miles, joining the Mississippi River near Cairo, Illinois. For the stretch of river near Louisville, it forms the state boundaries between Indiana to the north and Kentucky to the south.

The Ohio River Valley Water Sanitation Commission (ORSANCO) is an interstate agency charged with abating existing pollution in the Ohio River basin and preventing future degradation of its waters. ORSANCO was created in 1948 with the signing of the Ohio River Valley Water Sanitation Compact among the bordering states (orsanco.org).

ORSANCO's Bimonthly Monitoring Program, in existence since 1975, is comprised of 31 monitoring sites, which includes 17 locations on the main stem of the Ohio River and 14 locations near the mouth of major tributaries. The Bimonthly Sampling Program currently collects six samples per year, every other month. This was reduced from a monthly frequency in 1992.

ORSANCO completes an assessment and report of Ohio River water quality conditions every two years, otherwise known as the "305b Report." Water quality data are compared to water quality criteria (or goals) over a two-year period to determine

ORSANCO Member States



ORSANCO Bimonthly Sampling Program Sites

if the Ohio River meets each of its four designated uses; warm water aquatic life, public water supply, contact recreation, and fish consumption. The entire 981 miles of the Ohio River is designated as impaired for the fish consumption use, caused by PCBs and dioxin. Approximately two-thirds of the river is designated as impaired for contact recreation caused by *E. coli* or fecal coliform bacteria. The entire river is fully supporting the public water supply use. The entire Ohio River is assessed in this report as fully supporting the aquatic life use. https://www.orsanco.org/programs/water-quality-assessment/.

For the 2014-2018 monitoring period, ORSANCO reported that the entirety of the Ohio River fully supported aquatic life and public water supply.

The Kentucky Division of Water's Water Health Portal (watermaps.ky.gov/waterhealthportal) shows that aquatic life, primary contact recreation, and domestic water supply designated uses were fully supported in the Ohio River between Harrods Creek and the Kennedy Bridge (I-65) as of 2014. The reaches above and below this segment in Jefferson County partially support the four designated uses. A plan for reducing bacteria in the river is in the process of being developed by the US Environmental Protection Agency with participation from ORSANCO and member states. orsanco.org/programs/bacteria-tmdl.

For the 2014-2018 monitoring period, ORSANCO reported that the entirety of the Ohio River fully supported aquatic life and public water supply.

At times, elevated nutrients and warm, slow moving water conditions can contribute to blooms of potentially harmful blue-green algae in the river. The algae can cause skin irritation and affect breathing of children and sensitive individuals. ORSANCO's role regarding Harmful Algal Blooms (HABs) is to monitor the Ohio River and coordinate response to reported HABs. In September 2015, Kentucky Division of Water issued a recreational advisory due to a harmful algal bloom affecting the entire Ohio River including Louisville. People were advised to avoid direct contact with water that had an unusual color. This bloom was quickly identified as the cyanobacteria Microcystis aeruginosa. The bloom produced instream levels of the cyanotoxin microcystin as high as 3,000 ug/L.

Contact recreation advisories were also issued by Ohio, West Virginia, and Indiana. In September 2019, an algae bloom was identified near Russell, Kentucky. This bloom was identified as Microcystis wessenbergii and later included M. aeruginosa and M. flos-aquoe. Ohio, Kentucky, and Indiana issued recreation advisories which were in place for over a month. ORSANCO, Kentucky Division of Water and many other agencies are working to reduce the level of nutrients in the river. Over time, these efforts are anticipated to minimize harmful algal blooms. https://www.orsanco.org/programs/harmful-algae-blooms/.

ORSANCO has conducted fish surveys to evaluate the Ohio River since 1957, including surveys of the McAlpine Lock and Dam adjacent to and upriver of Louisville (https://www.orsanco.org/programs/fish-population/). Improvements to Ohio River water quality have provided a cleaner environment for aquatic life. Increases in various measures of the fish communities over time indicate an overall improvement in the fish community health. Population data collected during ORSANCO's yearly fish population studies evidences this progress. For example, the percentage of pollution tolerant fish species in the river has declined and pollution intolerant and native species have increased since 1957. In the 2014 McAlpine Lock and Dam pool survey, ORSANCO rated the overall biological condition of this area as very good. 216.68.102.178/data/pool/2014McAlpineAssessmentSummary.pdf.

ORSANCO has analyzed the trends in various water quality measures at Ohio River sampling sites from 1990 to 2007. At three Ohio River sites near Louisville, concentrations of nitrogen compounds, total suspended solids, iron, and zinc in the river are declining or staying the same. Concentrations of total phosphorus and chloride, however, are increasing over time. orsanco.org/images/stories/files/publications/trendsreport/2008trendsanalysis.pdf.

2020 COVID-19 Compliant Ohio River Mini-Sweep

WATERSHED PROJECT SPOTLIGHT

GREEN INCENTIVE PROGRAM

MSD has partnered with many businesses through the Green Incentive Program to improve water quality by decreasing combined sewer overflows to the Ohio River and Beargrass Creek. This program provides funding to partners to construct green infrastructure that creates stormwater storage and infiltration, as well as sewer separation projects.

Recent projects have included infiltration basins at the University of Louisville, Churchill Downs, and the Louisville Urban League Sports and Learning Campus and a sewer separation project at the Lynn Family Soccer Stadium. MSD has invested over $42 million on green infrastructure projects that remove over 400,000 gallons of stormwater on an average annual basis.

Green Incentive Infiltration Basin at Churchill Downs

SUMMARY AND CONCLUSIONS

Beargrass Creek at the Ohio River

MSD, in cooperation with the United States Geological Survey (USGS), operates a Long-Term Monitoring Network (LTMN) to collect physical, chemical and biological data about streams in the Louisville Metro Area.

This State of the Streams Report is focused on the conditions of fish, aquatic insects, algae, stream habitat, bacteria, nutrients, total suspended solids, copper, stream flow, dissolved oxygen and water temperature of the streams in our community, and whether or not measures of these components are improving.

The data collected at the 27 LTMN sites since 1999 helps MSD prioritize investments and better understand water quality conditions. The better the data is understood, the more informed MSD's decisions are for investments and programming that contribute to the mission of improving water quality in MSD's jurisdiction. This report is produced as part of the MS4 program (prior reports are available in the Project WIN library section at msdprojectwin.org).

The health of aquatic communities in streams of the Louisville Metro area can be compromised by one or more factors that commonly affect urban and suburban streams. Significant and rapid runoff from impervious areas often leads to stream bank erosion due to increases in the percentage of rainfall that becomes runoff. More rapid runoff can also cause scouring of stream beds and banks in higher velocity areas, with downstream deposition of some of that sediment often partially covering habitat needed by fish and other aquatic organisms. Channel modifications such as straightening and shoring up the stream bank with concrete or large stones leads to limited amounts of rock riffle habitat and usually insufficient protective tree cover along the banks, both of which are needed to support healthy aquatic communities. Occasional periods of very low flow, high temperatures, or low dissolved oxygen infrequently contribute to lower than desired observed health of aquatic communities.

In addition to the typical urban effects, a major impact on stream quality in the older urban areas of Louisville is related to the presence of combined sewer systems that release sewage and stormwater during larger rainfall events. The lower parts of the South and Middle Forks of Beargrass Creek are affected by combined and sanitary sewer overflows, and their aquatic insect communities are generally rated as poor condition. Higher concentrations of bacteria also were observed in these watersheds. These are being mitigated by extensive projects to eliminate or reduce the frequency and volume of overflows.

MSD continues to pursue projects and opportunities to improve water quality. Initiatives ranging from educating the community to the $200M Waterway Protection Tunnel are all components of MSD's mission.

The aquatic communities in watersheds with impervious area greater than 20 percent have shown variable responses to the effects of development depending, in part, on the presence of healthy stream habitat. Parts of the South Fork Beargrass Creek watershed have poor habitat and fair to poor conditions of their aquatic communities. Some watersheds, like Pond Creek and Mill Creek, have considerable amounts of man-made channels without the healthy mix of rocky riffles and tree covered banks. As a result, the aquatic communities generally are in poor to fair condition but they are improving at most sites. Northern Ditch in the Pond Creek watershed is an exception in that the conditions of the fish communities are good showing improvement, perhaps in part, due to channel stabilization projects.

Streams that run on bedrock, like Cedar Creek, Fern Creek, and Pennsylvania Run, to some extent lack the variety of in-stream habitat types such as deep pools and rocky riffles that provide good habitat for fish and aquatic insect communities.

The predominance of forested and agricultural land in less developed watersheds, like Harrods Creek, Floyds Fork, Brier Creek, and Cedar Creek (Bullitt County), helps slow down and absorb runoff during rain events. As such, healthier stream habitat conditions in these systems were found to be supporting healthier aquatic communities.

Measures of aquatic community health in 2020 indicate that for algae and fish communities, over half of the sites were in good to excellent condition, whereas, for stream habitat and aquatic insects, most sites were in poor to fair status. Trends in fish, aquatic insect, algal and stream habitat health indicate that majority of the sites were improving or had no trend. The fair to poor habitat conditions of about half of the streams can be attributed to historic stream channelization and straightening along with the loss of rocky riffles, bends, vegetative bank protection, and the now less stable banks and narrow to nonexistent riparian corridors. MSD is currently implementing stream restoration techniques and riparian tree plantings which may improve conditions for fish and insects in streams with poorer habitat conditions. In order to protect existing stream buffers, MSD also enforces a 25' stream buffer requirement for all perennial and intermittent streams through the Louisville Metro Floodplain Ordinance.

Previous State of the Streams reports have reported on fecal coliform trends. For this Synthesis Report and future reports, MSD will be reporting on *E. coli*. The median *E. coli* concentrations for over half the sites were above the instantaneous recreational standard of 240 colonies/100ml in both 2020 and for the five-year period (2016-2020).

The lower parts of the South and Middle Forks of Beargrass Creek had the highest concentrations of bacteria and most frequent exceedances of the recreational criteria. These impacts are being mitigated by extensive projects to eliminate or reduce the frequency and volume of sewer system overflows

during larger rainfall events. Studies during higher flow periods also indicate that non-point sources of bacteria can still be high, even in the more rural streams.

During and shortly after rainfall events, bacteria concentrations tend to be higher and likely are from a broader range of sources, including wild animals, pets, and birds as well as collection system issues that have not yet been addressed. Bacterial conditions at most sites, especially during higher flow conditions, will remain a concern.

This State of the Streams report helps to better understand the water quality data and the potential sources to address to achieve MSD's vision of being the innovative regional utility for safe, clean waterways.

Dissolved oxygen data in 2018-2020 indicate that 15 sites were in good status and eight were fair. Trends in the historical data did not indicate a trend in dissolved oxygen conditions at any of the sites. Water temperature conditions in 2016-20 indicate that all 23 sites met the criteria (not greater than 31.7 °C or 89.1 °F) at least 90 percent of the time. Four of the sites do not have a gage to collect temperature data. Periodic hot days and low stream flows occasionally can cause an exceedance of dissolved oxygen or temperature criteria.

The levels of nutrients (nitrate and total Kjeldahl nitrogen) in 2020 at each site were compared to all samples at 27 LTMN sites collected. Using a natural break in the data, the Beargrass watersheds (Middle Fork, South Fork, and Muddy Fork) had some of the highest numbers of all LTMN samples for these nutrients. The mid-range sites were largely urban.

The picture of total suspended solids is a little different. Pond Creek at Manslick Road is very dominant with 90 percent of its samples in the upper third of all LTMN total suspended solids samples. It is suspected that the banks and sediment-laden stream bed in this channelized system are highly erodible and that even small rises in flow can lead to higher suspended solids. Sites on Little Goose Creek, Mill Creek, and Floyds Fork follow next, but were well behind in percent of samples in the upper third of all samples.

Of more than 430 total samples collected for copper at 27 monitoring sites since 2017, there were nine exceedances at five sites. In summary, four of the copper exceedances were at sites in the Mill Creek watershed, two were in the Goose Creek watershed, two were along Brier Creek, and one was along South Fork Beargrass Creek. The relatively few exceedances of the acute and chronic Aquatic Life Criteria (together about 2% of the total number of analyses) since 2017 would indicate that trace copper currently is not a large issue of concern in LTMN streams.

This State of the Streams report helps to better understand the water quality data and the potential sources to address to achieve MSD's vision of being the innovative regional utility for safe, clean waterways. Water quality is impacted by many factors. Some of these factors are not able to be controlled, however, MSD continues to pursue projects and opportunities to improve water quality. Initiatives ranging from educating the community to the $201 million Waterway Protection Tunnel are all components of MSD's mission. The tunnel project is now underway and planned to be operational in 2022. It is one part of MSD's $1.15 billion Consent Decree to reduce sewer overflows.

The 2021 State of the Streams Report tells the story of how streams in our community are doing and whether they are improving or not. The monitoring data highlights the importance of wastewater projects, stormwater management and green infrastructure. These investments have helped to improve and protect our waterways.

SUMMARY AND CONCLUSIONS

SUMMARY OF THE STATUS AND TRENDS IN STREAM WATER QUALITY

Watershed	MSD Site Name	Characteristics of the Watershed			Fish KIBI Status and Trend		Aquatic Insect MBI Status and Trend		Algal DBI Status and Trend	
		Drainage Area (square miles)	Percent that is Urban	Percent that is Impervious	Fish Status (2020)	Trend as Percent Change (oldest to 2020)	Aquatic Insect Status (2019)	Trend as Percent Change (oldest to 2019)	Algal Status (2020)	Trend as Percent Change (oldest to 2020)
Harrods Creek	Harrods Creek at Covered Bridge Road	70.3	13%	3%	Good	5%	Fair	-29%	Good	6%
	Wolf Pen Branch at 8200 Wolf Pen Branch Road	2.1	60%	29%	Fair	-32%	Poor	-39%	Good	12%
Goose Creek	Goose Creek at Old Westport Road	6.0	62%	17%	Excellent	57%	Fair	-14%	Good	2%
	Goose Creek at US 42	10.1	61%	17%	Excellent	39%	Poor	-26%	Excellent	0%
	Little Goose Creek at US 42	5.8	75%	30%	Excellent	108%	Fair	5%	Good	-17%
Muddy Fork of Beargrass Creek	Muddy Fork of Beargrass Creek at Mockingbird Valley Road	6.2	67%	16%	Excellent	47%	Poor	4%	Good	-13%
Middle Fork of Beargrass Creek	Middle Fork of Beargrass Creek at Browns Lane	15.2	83%	33%	Fair	27%	Poor	-22%	Excellent	-6%
	Middle Fork of Beargrass Creek at Old Cannons Lane	18.9	0%	0%	Good	34%	Poor	-43%	Good	-10%
	Middle Fork of Beargrass Creek at Lexington Road	24.8	0%	0%	Excellent	83%	Poor	-16%	Excellent	4%
South Fork of Beargrass Creek	South Fork Beargrass Creek at Trevilian Way	17.2	91%	40%	Fair	31%	Poor	5%	Good	-11%
	South Fork Beargrass Creek at East Breckinridge Street	22.8	90%	39%	Fair	80%	Poor	17%	Good	4%
	South Fork Beargrass Creek at Brownsboro Road	51.5	88%	36%	Fair	161%	Poor	18%	Good	-16%
Floyds Fork	Floyds Fork at Ash Avenue	80.0	16%	3%	Excellent	38%	Fair	43%	Excellent	9%
	Floyds Fork at Old Taylorsville Road	138.0	21%	6%	Excellent	26%	Fair	12%	Fair	-4%
	Floyds Fork at Bardstown Road	213	23%	7%	Fair	38%	Good	18%	Good	2%
	Chenoweth Run at Ruckriegel Parkway	5.5	86%	46%	Good	61%	Poor	-67%	Excellent	12%
	Chenoweth Run at Gelhaus Lane	11.6	67%	31%	Excellent	79%	Poor	-48%	Excellent	22%
Cedar Creek / Pennsylvania Run	Cedar Creek at Thixton Lane	11.1	52%	18%	Excellent	72%	Poor	-19%	Fair	0%
	Pennsylvania Run at Mount Washington Road	6.4	51%	15%	Excellent	67%	Fair	80%	Good	14%
Pond Creek	Fern Creek at Old Bardstown Road	3.5	80%	25%	Fair	51%	Poor	-7%	Good	2%
	Northern Ditch at Preston Highway	11.1	78%	27%	Good	41%	Poor	-4%	Excellent	37%
	Pond Creek at Manslick Road	64.0	72%	34%	Poor	28%	Fair	17%	Poor	20%
	Pond Creek at Pendleton Road	80.3	64%	29%	Fair	67%	Poor	12%	Fair	-5%
	Brier Creek at Bear Camp Road	4.1	6%	0%	Good	44%	Good	39%	Excellent	-32%
Mill Creek	Mill Creek Cutoff at Old Cane Run Road	24.4	89%	45%	Poor	-10%	Poor	20%	Good	4%
	Mill Creek at Orell Road	13.5	50%	19%	Fair	92%	Poor	-39%	Poor	-15%
Reference Reach	Cedar Creek at State Road 1442 Bullitt County	12.1	10%	1%	Excellent	29%	Good	29%	Excellent	37%

**USGS Gage 03292500 is missing 2016 and 2017, 03292550 is missing 2015-2020 and 03292500 was used to estimate 2015, 2018, 2019, and 2020

Excellent Good Fair Poor

Stream Habitat Status and Trend		Dissolved Oxygen Status and Trend		Water Temperature	*E. coli* Status and Trend		Nutrients and Suspended Solids Status			MSD Site Number
Habitat Status (2020)	Trend as Percent Change (oldest to 2020)	Status as Percent of Days Meeting Criteria (2018 to 2020)	Trend as Percent Change (2016 to 2020)	Average No. of Days Criterion Exceeded Per Year (2016 to 2020)	2020 Median Concentration (colonies/ 100mL)	Median Concentration (2016 to 2020)	Nitrate + Nitrite > 1.32 mg/l	Total Kjeldahl Nitrogen > 0.9 mg/l	Total Suspended Solids > 12 mg/l	
Good	-9%	99%	1%	0	349	172	15%	30%	25%	EHCHC001
Poor	-1%	No Gage	No Gage	No Gage	281	169	20%	20%	20%	EHCWP002
Fair	9%	93%	1%	0	1035	426	50%	5%	10%	EGCGC001
Good	-1%	97%	-1%	0	738	304	45%	20%	30%	EGCGC002
Good	2%	100%	2%	0	490	226	55%	25%	55%	EGCLG001
Poor	-8%	95%	1%	0	472	294	55%	10%	20%	EMUMU001
Poor	30%	No Gage	No Gage	No Gage	736	561	70%	15%	15%	EMIMI009
Fair	-9%	98%	-1%	0	297	276	55%	5%	11%	EMIMI002
Poor	-46%	74%	3%	0	577	766	40%	10%	25%	EMIMI010
Poor	25%	78%	8%	0	1359	3126	30%	25%	20%	ESFSF001
Poor	-6%	83%	3%	0	867	1315	60%	30%	35%	ESFSF012
Poor	-5%	No Gage	No Gage	No Gage	959	910	75%	10%	20%	ESFSF006
Fair	-20%	89%	1%	0	688	593	20%	45%	40%	EFFFF001
Good	-12%	98%	-1%	0.1	89	142	40%	15%	45%	EFFFF003
Fair	-29%	94%	-4%	0.2	348	171	15%	30%	50%	EFFFF002
Fair	-1%	98%	0%	0	177	319	15%	0%	20%	EFFCR002
Fair	-4%	98%	-1%	1.7	193	252	5%	5%	15%	EFFCR001
Good	-3%	97%	-3%	0	287	275	70%	30%	0%	ECCCC001
Fair	25%	77%	-5%	0	732	192	15%	10%	10%	EPRPR001
Poor	16%	99%	-1%	0	326	432	50%	10%	30%	EPCFC001
Poor	-2%	93%	7%	5.6	211	129	15%	5%	15%	EPCND001
Poor	-42%	86%	-8%	2.2	233	272	0%	10%	90%	EPCPC001
Poor	-13%	98%	0%	0	158	139	0%	10%	35%	EPCPC002
Poor	-37%	76%	5%	0	149	291	0%	5%	0%	EPCBC001
Poor	11%	No Gage	No Gage	No Gage	176	152	0%	5%	40%	EMCMX001
Poor	-25%	88%	1%	0	397	219	0%	39%	50%	EMCMC001
Good	-15%	94%	2%	0	226	274	0%	10%	15%	ECBCB001

Excellent Good Fair Poor

IMPORTANT TERMS

Algae

Small simple, nonflowering, and typically aquatic plant-like organisms that include the seaweeds, many single-celled forms, and benthic which live on rocks and other materials. Benthic algae have limited mobility, growing in areas suitable for their survival for weeks to months and they are particularly responsive to stream nutrient concentrations, sunlight, and the effects of sedimentation. Many algae types (especially diatoms, green algae, and blue-green algae) are an important food source for many fish and aquatic insects.

Aquatic Insects

Aquatic insects, also known as benthic macroinvertebrates, are small animals (bugs) that can be seen with the naked eye, live on the bottom of streams and lakes, and don't have a backbone. They are often the immature aquatic forms of insects that live on land as adults, and they are an important food source for fish and other aquatic organisms.

Aquatic Life Criteria

Aquatic life criteria are estimates of concentrations of pollutants in ambient water that—if not exceeded—are expected to protect fish, invertebrates, and other aquatic life from adverse effects associated with exposure.

Biological Indices

Various methods used in this report to assess water quality by applying measures (metrics) of biological communities to derive a narrative rating of good, fair or poor condition of the aquatic communities in a stream. A number of metrics are used, including the total number and diversity of species, tolerance to pollution, and other assessments. This report used data on the fish, aquatic insect, algae, and stream habitat communities to rate each stream.

Dissolved Oxygen

Dissolved oxygen is the oxygen that is freely available in water, and that is vital to fish and other aquatic life and for the prevention of odors. Dissolved oxygen levels are considered an important indicator of a water body's ability to support desirable aquatic life. Dissolved oxygen levels fluctuate seasonally and over a 24- hour period. They also vary with water temperature and altitude (elevation). Water at the same temperature holds less oxygen at higher altitudes and cold water holds more oxygen than warm water.

Erosion

Erosion is when soil, silt, sand, rock and other particles are removed from unprotected land surfaces or stream banks usually by flowing water (runoff and stream flow) and are

deposited downstream as sediment (mud, silt, sand, and gravel). Sediment becomes problematic when it covers rocks and other stream habitat needed by fish and other aquatic life.

Floodplain

A floodplain, or flood plain, is the flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding.

Geometric Mean

The geometric mean is a way of averaging a set of numbers by using the product of their values, as opposed to the arithmetic mean, which uses their sum. The geometric mean is defined as the nth root of the product of n numbers. It is used in this report to compute a value of multiple samples of bacteria for comparison with a standard value or criteria.

Impervious Surface

An impervious surface is any surface that is covered by materials that block the infiltration of water into the ground or soil. Impervious surfaces include roads, sidewalks, driveways, parking lots, and rooftops. Compacted soils (including some lawns) can also behave like impervious surfaces.

Indicator Bacteria

Bacteria that live in the water and on the bottom of streams are both natural and beneficial conditions in healthy streams. Bacteria in wastewater inflows and runoff from urban surfaces can lead to less healthy conditions, especially if they contain untreated animal or human waste. There are two types of bacteria that are used to indicate whether streams are clean or polluted, getting better or worse. Fecal coliform bacteria are one type more generally indicative of the presence of some kind of fecal material. The other type, *E. coli* bacteria, is more indicative of the presence of fecal material from the gut of warm blooded animals, including humans. Both types have established criteria mainly related to body contact recreation by humans.

Nutrients

The primary nutrients in streams are nitrogen and phosphorus compounds carried in runoff and other inflows. They are important for the growth and health of aquatic organisms. In excess, however, they can lead to nuisance growths of algae and low dissolved oxygen. Nitrate nitrogen is largely in a dissolved form, derived from fertilizers and wastewater. The other compounds are both in dissolved and particulate forms. Total Kjeldahl is a measure of both ammonia and organic nitrogen carried with sediment runoff and wastewater inflows. Total phosphorus is particularly important for algal growth and also is delivered to the stream with sediment runoff and wastewater inflows.

Riffle

A riffle is a short, steeper, relatively shallow and coarse-bedded length of stream over which the stream flows at a faster velocity and higher turbulence than in a pooled reach of a stream. Riffles are usually caused by an increase in a stream bed's slope or an obstruction (rocks, logs, etc.) in the flow. Riffles typically increase dissolved oxygen and provide high quality aquatic habitat.

Riparian Zone or Area

A riparian zone is the area of land at and near the stream interface. Riparian zones, when well vegetated, have a significant role in stream bank stabilization, soil conservation, filtration of chemicals and sediment in runoff, and in providing shade and food (organic material).

Runoff

Runoff is the portion of rain, snow melt, or irrigation water that arrives in streams, rivers, lakes, ponds, drains or sewers.

Stream Flow

Stream flow is the volume of water flowing past a point in a fixed unit of time. Stream flow is often expressed in cubic feet per second (ft3/ sec).

Stream Habitat

Stream habitat is the underwater environment that is used as a living space by fish, aquatic insects, other plants and animals. Vegetation near the channel also is important for quality habitat. Streams that have a variety of habitats, with shallow and deep areas, fast and slow water, and places with rocks, gravel, woody debris, tree covered banks, and shade are characteristics of good habitats.

Total Suspended Solids

Total suspended solids in streams are indicative of the amount of sediment washing off watershed surfaces and from erosion of stream banks. Sediment carried in higher flows, when deposited downstream, can reduce the quality of aquatic habitat and negatively affect aquatic communities.

Trace Metals

Various metals carried in trace amounts in runoff and other inflows. They are both in dissolved and particulate forms and in higher concentrations can affect the health of aquatic organisms. Criteria exist for the more important metals.

Watershed

The area of land where all the water drains to a particular stream or location along a stream. The boundary of a watershed is formed by the highest elevations surrounding the stream. A rain drop of water falling outside the watershed boundary will drain to another watershed. Small watersheds join together to form larger watersheds. A major river, such as the Ohio River, will encompass many smaller watersheds.

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This 2021 State of the Streams Report was prepared by MSD, Stantec Consulting Services Inc. and The Cubero Group.